

China Council for International
Cooperation on Environment and
Development (CCICED) Secretariat

Building an Inclusive, Green and Low-Carbon Economy

CCICED Annual Policy Report 2022



中国环境与发展国际合作委员会
China Council for International Cooperation
on Environment and Development

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Preface

Now, the COVID-19 pandemic is eroding decades of gains in global development, the implementation of the UN's 2030 Agenda for Sustainable Development is encountering difficulties, the North-South gap keeps widening, and crises are emerging in food and energy security. We have embarked on a new journey toward building a modern socialist country and entered a new phase of quality development.

The year 2022 is an important landmark that marks the 30th anniversary of the China Council for International Cooperation on Environment and Development (CCICED) and the first year for CCICED Phase VII. In the face of evolving international situation and the impact of pandemic, CCICED continues aiming to develop into an innovative platform for international cooperation on the environment and development that embraces global inclusiveness, open cooperation, and mutual benefits and development. CCICED has carried out the plan as approved by the executive members under the annual theme of "Building an Inclusive, Green and Low-Carbon Economy." It has also provided advice and recommendations on the environment and development that embraces open cooperation, mutual benefits and development, the 14th Five-year Plan (14th FYP), and the guard against all risks and hidden dangers of medium and long-term structural transformation. The aim of this period is to provide suggestions for promoting China's environment and development undertakings and contribute wisdom and strength to building a community with a shared future for mankind and a clean and beautiful world.

The CCICED Secretariat publishes CCICED Annual Policy Report every year, in order to better reach a consensus on green development and promote green transition and transformation. The Annual Policy Report is a flagship publication that presents research outputs, papers, and reports by Chinese and international CCICED teams, as well as outlining policy recommendations, the CCICED has proposed to the Chinese government. It shares the observations and thinking of the Chinese and international members, special advisors, and experts on hot issues in the environment and development, for the reference of decision-makers at all levels, scholars, and the public.

The 2022 CCICED Annual Policy Report incorporates the policy recommendation proposed to the Chinese government "Maintaining the Strategic Determination and

Stabilizing Expectations Towards a Low-Carbon Green Transition: Opening a New Green Chapter for High-Quality Development”; the 2022 issues paper “Stability, Resilience and the Green Transition,” which is written by CCICED’s chief advisors; research reports from 6 Special Policy Studies, including “Carbon Dioxide Emissions Peak and Carbon Neutrality Policy Measures and Implementation Pathways,” “Value Assessment of Nature-based Solution (NbS),” “Ecosystem-based Integrated Ocean Management under the Vision of Carbon Neutrality,” “Low-carbon and Resilient Urban Development and Adaptation to Climate Change,” “Sustainable Food Supply Chain,” and “The Key Pathways on a Green and Low-Carbon BRI”; 4 Scoping study reports on “Digitalization to Advance Sustainability,” “Risk Prevention of Carbon Neutrality under the New Development Concept,” “Sustainable Trade and Investment,” “Innovative Green Finance,” and Report on Gender Mainstreaming in SPS Research for the Period 2021–2022.

Beijing, China

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Introduction: Stability, Resilience and the Green Transition

Stability and the Green Transition: Risks, uncertainties, and shocks have risen dramatically in 2022. China’s Two Sessions Conference in the first quarter of 2022—the National People’s Congress and People’s Political Consultative Conference—warned of the “triple pressures of shrinking demand, disrupted supply and weakening expectations.” China’s key strategic goals—economic growth, innovation, common prosperity, and climate mitigation—are now all seen from the single lens of ensuring stability and security in the face of turbulence and volatility.

The most pressing challenge of 2022 and for the foreseeable future is therefore aligning low-carbon, high-quality, green development with this focus on stability and security goals by highlighting two points: (i) that delaying ambitious climate and ecological protection and pollution action will magnify economic, human, and ecological insecurity and (ii) that supporting the transition to green development can enhance energy, food, human well-being, and other key security goals.

The key conclusion of CCICED’s 2022 research work is that green development complements and reinforces key stability and security goals. Stability does not mean relying on business-as-usual approaches to energy, food, or other security goals. Instead, enhancing stability and security in the face of global ecological and other shocks means deploying smart, innovative, and adaptive policies that bolster resilience. Four areas of CCICED’s work—energy security, food security, climate security, and financial stability—are explored briefly below.

Energy Security: Energy is on the front lines of security and stability objectives. Since the second quarter of 2021, global oil and gas prices have surged, driven by chaotic swings in energy markets.¹ Global coal markets, valued at over USD 1 trillion in early 2021, have risen sharply. In turn, this price volatility contributed to interim supply shortages in China in late 2021.

¹ First-quarter energy prices were described as bedlam. Newcastle coal future prices rose from roughly USD 82 per ton in mid-2021, to more than USD 400/ton in early March 2022, before declining to USD 350/ton in the early spring. Crude oil future price indexes, which remained roughly stable throughout much of 2021, have more than doubled by late March 2022. In many countries, gasoline prices passed a 10-year high during the same period.

At the 2022 Two Sessions Conference, President XI reiterated China's commitment to reaching carbon peaking and carbon neutrality goals. At the same time, he underscored the strategic importance of an orderly and predictable energy supply transition, stating that China "cannot throw away our means of living first, only to find that our new livelihood has yet to arrive." Like other countries, China is simultaneously expanding older energy sources with which it has significant endowments, notably coal, while increasing investments in clean, renewable energy. In the case of coal, researchers at China's State Grid Corporation estimate that up to 150 GW of new coal-fired power capacity will be built in the 2021–2025 period, bringing the total to 1230 GW. China's fleet of coal-fired electricity stations is the largest in the world, at over 1000 power plants. Other countries have similarly responded to energy supply shocks by reverting to fossil fuels. In 2021, global demand for oil and gas rebounded sharply. By the first quarter of 2022, oil and gas majors posted record earnings.

This increased reliance on fossil fuels comes as the Intergovernmental Panel on Climate Change released its *Sixth Assessment Report*, warning of the escalating human, ecological, and economic impacts of climate change and warning that the window to meet the Paris Agreement target of 1.5 °C is closing: ambitious action is needed by 2030.

The challenge is therefore to leverage the current energy crisis as a means to meet the twin objectives of energy security and climate security. The European Union's (EU's) response to greater energy self-reliance takes exactly that track: in March 2022, it laid out measures to further accelerate its shift away from imported oil and gas and toward greater energy independence by rapidly scaling up renewable energy.²

The economics of this link between energy security and renewable energy is clear: the International Renewable Energy Agency estimates again that renewable energy is cheaper than most of the fossil fuel alternatives. Markets are responding, although, as noted, inconsistently. The International Energy Agency estimates that investments in renewable energy dominated new power generation, accounting for an estimated 70% of the USD 530 billion spent in 2021 in new energy-generation capacity. China remains the world's leader in renewable energy and has updated targets both at home and through the ongoing greening of the Belt and Road Initiative (BRI) to expand installed renewable energy further. Increased renewable energy can support key current accounts and balances of payment, particularly given that 75% of China's oil use is imported.

Off-the-shelf renewable energy systems like wind, solar, geothermal, and others are meeting critical energy security criteria, particularly related to affordability, reliability, and accessibility. Mid-term solutions like long-term battery storage, smart grids, and green hydrogen are becoming increasingly viable and cost-effective. In

² EU Executive Vice President Frans Timmermans issued this challenge: "Let's dash into renewable energy at lightning speed. Renewables are a cheap, clean, and potentially endless source of energy and instead of funding the fossil fuel industry elsewhere, they create jobs here."

turn, clean energy investments are a growing source of employment in high-skilled manufacturing and services.³

Another pillar of clean energy entails energy efficiency and conservation. The most effective energy security policy entails avoiding consumption in the first place. Energy efficiency is a critical pillar of productivity: the smart application of green technologies can boost the innovation-led productivity, thereby lowering per-unit energy costs while increasing outputs. The evidence shows that the energy efficiency can contribute from 25% to as much as 40% of global climate mitigation targets.

Clean energy also complements trade security. Market forecasts expect a steadily rising proportion of traded green goods and services, from low-carbon industrial goods like iron, steel, aluminum, and chemicals to consumption-based items like green tourism and zero deforestation—sustainable soft commodities. These markets are likely to grow, especially among younger consumers. Underscoring the importance of consumption-based models, the 2022 report on China by the International Monetary Fund concludes that China's structural shift from an investment-led to a consumption-based economy would bolster economic stability while reducing its greenhouse gas (GHG) emissions by 15%, based on the current basket of consumer goods. That reduction could be greater as China expands items like electric vehicles and other green choices.

Food Security: Recent supply and price volatility have hammered global food security objectives that lie at the heart of the Sustainable Development Goals. The April 2022 Food and Agriculture Organization of the United Nations (FAO) Food Index shows that the global food price index reached a record high, with cereal prices jumping 17% in one month and vegetable oils rising 23%. The cost of fertilizers in some countries has increased by 170%. In response, a growing number of countries as diverse as Sri Lanka, Chile, and South Sudan have all issued domestic food price warnings. Many more are expected.

Compounding these acute shocks are longer-term, chronic food security risks linked to climate change and the loss of biodiversity. At the 26th Conference of the Parties (COP 26), the UN Special Envoy for the Food Systems Summit warned that without urgent action to increase the resilience of agriculture to climate shocks, an additional 100 million people in Africa alone will face hunger by 2030. The most recent 5-year global UN assessment of land degradation⁴ shows rising losses in soil health and soil fertility vital to food security. Land degradation, in turn, creates a vicious cycle in which the combined effects of climate change and

³ Renewable energy contributes to common prosperity: in 2021, renewable energy continued to create new, skilled green jobs: of the roughly 12 million green jobs created globally through renewable energy, the largest proportion of that by a large margin was 4.7 million jobs created in China. As noted, the spinoff-job effects of renewable energy investments are typically higher than for conventional energy sources.

⁴ Among the findings of the April 28, 2022, global assessment by the UN Convention to Combat Desertification is that modern and traditional regenerative agricultural practices deliver multiple and interconnected benefits, including rural income and poverty alleviation, cost-effective climate change mitigation, and biodiversity conservation.

ecosystem degradation amplify extreme flooding and drought, further exacerbating food insecurity.

Yet there are proven solutions to counter land degradation. The economic case for investing in sustainable, regenerative land systems suggests that every dollar spent on soil conservation and regeneration yields between \$7 and \$30 in benefits. Rather than being a single point of intervention, regenerative land system approaches entail comprehensive, systemic bottom-up and top-down approaches that involve production, consumption, protection, and restoration practices working in tandem. Science continues to show the vital importance of working with nature. For example, ongoing research on complex underground fungi networks shows how nature is connecting what had previously been assumed to be competing trees and other species, with underground systems exchanging water, nutrients, and carbon among species across landscapes. Emerging carbon markets create an additional incentive to protect these underground networks, which have been dubbed the carbon currency for above-ground forests and other carbon banks. Moreover, China's croplands comprise an estimated 19% of all carbon stocks. In addition to these vital terrestrial carbon stocks, there are similar ecosystem functions in oceans and the marine environment.

Emerging nature-based solutions are demonstrating concrete ways to support regenerative landscapes, deliver sustainable food systems, bolster climate resilience, and support sustainable rural livelihoods.⁵ Project-based nature-based solutions complement wider climate adaptation measures needed to bolster food security in the face of rising drought and flooding affecting large river basin areas. Given that food production in the Yangtze River basin accounts for nearly half of China's total output of rice, oil crops, vegetables, and pork, integrating climate adaptation is vital to food security goals.

Building sustainable food systems, scaling up nature-based solutions, and integrating climate resilience within integrated water management systems are the focus of three 2022 CCICED Special Policy Studies. Each underscores the critical importance of building food security as part of wider human security and well-being, by which common prosperity goals like advancing equality for women and girls—including through rural green finance, gender-based trade finance, access to public health, education, entrepreneurship, and other opportunities—lead to more durable, inclusive, and adaptive outcomes.

Climate Security: In 2021, the number of record-breaking extreme climate events once again increased. In its *State of the Climate 2021* annual report, the UN World Meteorological Organization estimated that over 4 days in July 2021, Henan Province recorded record rainfall: more than 200 mm of rain occurred in just one hour, smashing previous national records. The city of Zhengzhou experienced extreme flash flooding that led to more than 300 deaths. The flooding of buildings, roads, and subways resulted in economic losses totaling USD 17.7 billion.

Deadly heat waves also increased in 2021: a recent study published in *The Lancet* estimates that heat-wave exposures in China measured per person increased by 4.5

⁵ The 2022 UNEA-5 meeting marks a key step forward by adopting, for the first time, a multilateral definition of nature-based solutions.

days compared with the 1986–2005 average, leading to an estimated 92% increase in heat-wave-related deaths, USD 176 million in direct economic losses, and lost work hours estimated at 1.4% of China’s annual gross domestic product.

Financial Stability: CCICED’s 2022 work underscores the critical role of green finance as an enabler in implementing high-quality, green development. Growth in environmental, social, and governance (ESG) financial products continues, backstopped by the further elaboration of green taxonomies, green bond eligibility, innovative private–public partnerships, and new pilots to finance the transition of companies to meet green financing eligibility. With more green claims, China, like other jurisdictions, has flagged the importance of transparency, verification, and accountability.⁶ China joins others in mandating climate risk disclosure in the future.

Carbon markets in 2021 reached an estimated USD 851 billion globally, with the biggest contributions coming from compliance markets like the EU’s Emissions Trading Scheme, China’s national carbon market trading, and other carbon pricing in roughly 60 other jurisdictions. In addition to compliance markets, companies and others are investing in voluntary carbon markets, which surpassed USD 1 billion in 2021. With the completion of Article 6 of the Paris Rulebook, expectations are that both public sector compliance carbon markets and voluntary carbon markets will continue growing.⁷

The other side of the financial market coin is the growing uncertainty and longer-term instability associated with carbon investments. In 2020, the Bank for International Settlements warned of the growing risk that climate change could trigger a global financial crisis. The Basel Bank warned that due to escalating and unpredictable or nonlinear climate risks—what is called Green Swan or fat tail risks linked to physical and transition risks—the current approach of financial actors in anticipating risk based on quantitative models and other tools is ill-suited to warn when risks like stranded assets would occur. Initiatives like the Glasgow Financial Alliance for Net Zero (GFANZ), in which different subsectors of the financial sector have pledged net-zero targets, are promising. The focus is on implementing these and scores of other private sector pledges.

An additional and urgent dimension of financial security involves sovereign debt. Also, 2022 has seen dangerous debt levels, with an alarming number of both developing and emerging economies experiencing or facing debt distress or default. Climate change and the loss of ecosystems are magnifying this debt turbulence:

⁶ Like other jurisdictions, China has signaled the growing risk of greenwashing—and with good reason: for example, a recent EU review or “sweep” to weed out greenwashing claims found 37% of company claims they investigated included vague and misleading statements, while an astonishing 59% of claims were not sufficiently backed up by evidence to support them. In response, the EU ESMA Securities is proposing new regulations against ESG greenwashing. Other regulators are considering similar actions. Similarly, MEE has brought to light standard bodies like Sinocarbon that had unverified carbon claims.

⁷ The newly established Integrity Council for Voluntary Carbon Markets is a welcome step to ensure that voluntary carbon market investments in carbon offset credits are of high integrity, meeting for example the International Union for Conservation of Nature Gold Standards for nature-based solutions.

for example, 40% of the world's most indebted countries are also the most exposed to climate change impacts. In 2022, CCICED continued to identify options to align sovereign debt with climate, nature, the Sustainable Development Goals, and other goals.

The Implementation Challenge: Policy: CCICED's 2022 work has focused on opportunities to align carbon-neutral, nature-positive, and equitable options for energy, food, and other security and stability priorities. Realizing win-win results is neither automatic nor simple. Instead, win-win outcomes require a high degree of governance, institutional and administration coordination, competence, and innovation.

The Glasgow climate and Kunming biodiversity COPs present unique opportunities for international collaboration. Virtually, all governments have agreed on common targets, timetables, policy priorities, and sequencing to meet common goals set out in nationally determined contributions and updated National Biodiversity Strategies and Action Plans (NBSAPs).

At the same time, the same governments advance contradictory policies, largely through incoherent policy goals in complex administrative systems. For example, while making new pledges at Glasgow and Kunming, governments allocated roughly USD 350 billion in fossil fuel subsidies and roughly USD 500 billion in harmful agricultural subsidies in 2021 alone.⁸

It is a complex task to ensure policy coherence within and between public ministries across different jurisdictions and between market-oriented and regulatory approaches, especially when drawing on the evidence of science and the advice of civil society organizations to meet key climate, nature, and other goals. Whole-of-government models will become indispensable. In 2021, China established the Climate Leaders Group, which is chaired by Vice Premier Han Zheng and comprised of other senior members, including the ministers of construction, industry, natural resources, ecology and environment, transportation, commerce, and others. In February 2022, the Group reaffirmed the need to meet China's carbon peaking and carbon neutrality goals while acknowledging the important role of coal and the need to maintain energy security, food security, supply chain security, and living standards.

Other countries are implementing government-wide coordination to advance climate implementation. The United Kingdom's Climate Action Strategy Cabinet Committee is chaired by the Prime Minister and other senior-level bodies. British implementation targets and timetables are measured against a national climate budget.⁹ In March 2022, Canada released its updated climate plan, which is

⁸ Such measures are part of broader government spending, estimated by Business for Nature at US\$ 1.8 trillion in 2021, involving subsidies to pollution-intensive industries like coal, oil, gas as well as agriculture and other sectors.

⁹ The UK carbon budget (December 2020) calculates the emissions reductions needed to meet net-zero targets, recommending a 78% reduction in UK territorial emissions between 1990 and 2035, as well as the specific climate actions needed to meet that target. These include mandating that all new cars and vans and all boiler replacements in homes and other buildings be low carbon by 2030, largely based on electricity, which should be zero carbon by 2035, with offshore wind becoming

comprised of 79 distinct implementation plans across multiple federal ministries that will need to partner with provinces, Indigenous communities, the private sector, and civil society. Other jurisdictions, such as the EU, the U.S. federal government, France, Germany, Denmark, and others, have all set out whole-of-government climate plans.

While each jurisdiction has its own distinct administrative design, common elements related to a new generation of green industrial policy explored in the CCICED Special Policy Study on green trade emphasize the success of innovation- and technology-based partnerships between the private sector and government. Phase VII of CCICED will be among the most important of its impressive 30-year history, in particular, for identifying through evidence, research, case studies, and perhaps most importantly—through international cooperation, the exchange of views, and the building of trust—how to design and implement high-quality, green development.

the backbone of the national energy system. Low-carbon hydrogen is recommended to expand in the same scale that electricity supply is today, by 2050. Other recommendations from the carbon budget include increased energy efficiency for buildings, a shift in favor of low-carbon diets, a sharp reduction in waste, increased productivity of farms, and increased forest cover to help remove CO₂.

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Chapter 1

Carbon Dioxide Emissions Peak and Carbon Neutrality Policy Measures and Implementation Pathways



1 Review of COP26 Negotiation Processes and Trend Outlook

The importance of global climate change in the international agenda is constantly increasing. All the countries have reached a basic consensus on actively implementing international conventions, strengthening climate targets and practical actions, despite the impact of the pandemic and short-term recovery. Under this background, the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26) was held in Glasgow, UK after a one-year delay, and achieved the expected results. Through observation, discussion and analysis, this paper conducts a systematic evaluation on the effectiveness of the COP26, and predicts the trend of climate negotiations after the COP26. Generally, the COP26 has achieved a balanced and inclusive package of results thanks to joint efforts of all parties. The conference marked an end to the six-year negotiation on the implementation rules of the *Paris Agreement*. It can be said that the COP26 is another major milestone regarding global climate governance after the implementation of the *Paris Agreement*. Meanwhile, the *Glasgow Climate Pact* consolidated the global consensus on accelerating climate actions in the next decade, and reached certain breakthrough consensus on coal reduction, methane control, and halting deforestation. In the post-COP26 era, we still need to take concrete actions to implement the outcomes of the *Paris Agreement* and the *Glasgow Climate Pact*, create paths to accelerate CO₂ emission reduction, and continue to strive for breakthroughs in important issues such as funding, technology, adaptation, and cooperation, avoid intensifying international conflicts, work together to properly handle the relationship between energy security, carbon reduction and development, and promote all the countries to achieve sustainable development goals including climate. China will continue to maintain the existing multilateral mechanisms and processes of climate governance, continue to take concrete actions

to respond climate change, promote its own comprehensive green transition and global carbon neutrality cooperation, and contribute constructively to global climate governance.

1.1 COP26 Was Initiated in the Context of New Development

Due to the impact of the COVID-19 pandemic, the COP26 originally scheduled in 2020 was postponed to be held in 2021 in Glasgow, UK. The outbreak of the pandemic has triggered a profound reflection in the international community, which has deepened people's understanding of non-traditional security issues. On August 9, 2021, the IPCC released the report from the first working group for the sixth assessment report (AR6). The observation data showed that the average temperature rise during the period from 2011 to 2020 was 1.09 °C higher than that before industrialization (1850–1900). In the coming decades, climate change in all regions will further intensify [1]. Although the pandemic has reduced carbon emissions in multiple countries in the short term, the trend is unsustainable in the long run, and carbon emissions may rebound after the end of the pandemic [2]. A new global energy crisis is also hindering a green recovery of post-pandemic economy [3]. In this context, the COP26 was postponed for one year, which overcame many difficulties and is of special significance, reflecting the basic consensus among countries in actively implementing international conventions, reinforcing climate targets and practical actions.

As the first conference of the signatory parties held after the United States returned to the *Paris Agreement*, the COP26 attracted great attention from various parties. It sought to achieve climate targets in four directions, i.e. mitigation, adaptation, funding and cooperation, specifically: First, the global response to climate change is still insufficient, and the current total NDCs of all countries are still difficult to achieve the 2 °C target, not to mention that there is still a gap in performance [4]; Second, the issue of adaptation has attracted more and more attention. Developing countries are very concerned about the construction of adaptation infrastructure. It is also very important to improve the collaborative governance of biodiversity and climate change proposed in the Kunming Declaration; Third, the climate governance capacity building is still insufficient, especially the widely criticized climate funding commitment still faces a large gap; and Fourth, the negotiation on the implementation rules of the *Paris Agreement* has not yet been completed, and it needs to be advanced as soon as possible so that the *Paris Agreement* can be fully implemented. At this conference, the organizer conducted a lot of pre-conference communication, and set the core goals and agenda of the negotiation around the above four issues. It can be said that the COP26 has properly set topics for discussion in key areas of global climate governance, and promoted significant progress in various fields during the conference.

1.2 *Progresses and Outcomes at the COP26*

The conference of the signatory parties under the United Nations Framework Convention on Climate Change is an important link in the global climate governance mechanism. Before the COP26, the host country made great efforts to promote relevant subjects to reach a consensus on key issues of global climate governance through a lot of communication, laying the foundation for the effective convening of the conference.¹ During the process of the COP26, the organizer actively created opportunities and built a platform by setting topics for discussion, etc., so that multiple stakeholders could fully discuss specific topics, and finally achieved a series of results on the issues like coal exit, deforestation reduction, and methane emission reduction. As stated in the COP26 WORLD LEADERS SUMMIT—PRESIDENCY SUMMARY, COP26 launched a decade of accelerated climate action to ensure that the *Paris Agreement* works, and progress is made in key areas.

1.2.1 **The COP26 Developed Issues Through a Lot of Pre-conference Communication, and Drew on the Experience of the *Paris Agreement* in Promoting International Cooperation, Laying the Foundation for the Formation of a Consensus**

Before the COP26 was held, all stakeholders had conducted close consultations on a number of issues of their own concern. For example, China, the United States, and the EU had close bilateral climate consultations before and during the COP26 to enhance their respective positions and understandings on the key issues of global climate governance, which facilitated the formation of a consensus. Based on the extensive pre-conference communication, the host country finally set a series of ambitious goals in four major aspects, including: To ensure the global net zero by 2050 is achieved and the global temperature rise is controlled within 1.5 °C during this century by means of coal exit, deforestation reduction, accelerating the development of electric vehicles, and promoting investment in renewable energy, etc.; to adapt to protective communities and natural habitats, by means of ecosystem protection and restoration, adaptation investments, etc.; to fully mobilize funds to ensure that developed countries realize the \$100 billion commitment in climate finance, and promote the active participation of international financial institutions in the global climate process; and to make efforts together for the climate governance targets, including the co-preparation and finalization of the Paris Rules, as well as multi-agency action and cooperation.

¹ COP26 President concludes constructive discussions with China on climate action, <https://www.gov.uk/government/news/cop26-president-concludes-constructive-discussions-with-china-on-climate-action>.

1.2.2 The COP26 Adhered to the Goals, Principles and Policy Orientation of the Paris Agreement, and Achieved a Balance Between Ambitious Goals and Practical Actions, Laying a System and Capacity Foundation for Subsequent Global Climate Governance

The COP26 is another important milestone in global climate governance after the implementation of the *Paris Agreement*. In the conference, certain consensus and progresses were achieved in all aspects including mitigation, adaptation, funding, technology transfer and capacity building. Before the COP26, 156 countries proposed or updated NDC goals based on their national conditions, of which 93 countries proposed more ambitious emission reduction goals. During the COP26, Thailand, Israel, Vietnam, Nigeria, India and other countries proposed carbon neutrality goals. The *Glasgow Climate Pact* reiterated that the global temperature rise should be controlled within 2 °C, with 1.5 °C as a striving goal, emphasizing that the realization of the 1.5 °C target requires intensified efforts to reduce emissions. All countries have joined hands to initiate a decade of accelerated climate actions, and “actions speak louder than words” has become a major trend, which involves boosting ambition, expanding funding, strengthening public–private cooperation, and conducting a global inventory. **The COP26 marked an end to the six-year negotiation on the implementation rules of the *Paris Agreement***, and the issues including Articles 6 and 13 of the Implementation Rules have formed pragmatic and balanced results. Specifically, the construction framework of the global carbon market was established; it was determined that 5% revenue share would be levied in the transactions under Article 6.4 and transferred to the adaptation fund, and repeated counting should be avoided; the transition mechanism for the clean development mechanism was confirmed, and the system frame to enhance the transparency under Article 13 was determined.

1.2.3 COP26 Finally Reached a Breakthrough Consensus on Key Issues of Concern to Several Parties, and Determined a Series of New Orientations for the Global Response to Climate Change, Such as Emission Reduction Goals, Coal Exit, Stop of Deforestation, Methane, Climate Finance, Etc.

The *Glasgow Climate Pact* emphasized that the realization of the 1.5 °C target requires the global CO₂ emission is reduced by 45% by 2030 compared with the 2010 level; confirmed the global inventory starts in 2022; proposed that the unabated coal-fired power should be gradually reduced for the first time; required the coal-fired power plants without carbon reduction facilities should be reduced, and the inefficient fossil fuel subsidies should be eliminated. Although there is a risk of failure again, it still proposed a more ambitious climate funding target, requiring that the deliberation on the new quantitative funding targets after 2025 should be completed in 2024 and urging the doubling of the adaptation funds provided to

developing countries in 2025 on the basis of that in 2019; decided to establish and immediately initiate the Glasgow–Sharm el-Sheikh Two-year Work Program on the Global Goal on Adaptation; decided to start the San Diego Network as early as possible, to provide developing countries with technical assistance in their response to and mitigation of loss and damage; and also decided to carry out the Glasgow Dialogue on the financial mechanism of loss and damage. In addition to the *Glasgow Climate Pact*, 23 countries pledged to stop using coal for the first time in the *Global Coal to Clean Power Transition Statement*. More than 120 countries signed the *Glasgow Leaders' Declaration on Forests and Land Use*, with the goal of halting and reversing forest loss and land degradation by 2030, providing funding and making 75% of forest commodity supply chains sustainable. More than 100 countries signed the *Global Methane Pledge*, committing to reduce methane emissions by 30% by 2030. China did not sign the pledge but it proposed to carry out methane emission reduction work in the U.S.-China Joint Glasgow Declaration on Enhancing Climate Action in the 2020s.

1.2.4 The Conference Created Opportunities for Multiple Relevant Subjects to Actively Participate in Relevant Issues, and Effectively Promoted the Participation of Stakeholders and Actors in Global Governance

Before and during the COP26, a large number of business entities, industry associations, banking institutions and other non-governmental subjects and actors actively participated in the discussions on carbon reduction governance in relevant industries, and finally created conditions for the formation of a consensus on carbon reduction goals in the industry. Through the COP26, a consensus was finally reached on carbon reduction in several key industries, including that it proposed the net zero will be achieved in the cars and vans that are sold in the leading markets by 2035 and newly-sold across the world by 2040, in the Declaration on Accelerating the Transition to 100% Zero Emission Cars and Vans. A similar memorandum of understanding was signed for medium and heavy-duty vehicles, which proposed the proportion of sold net-zero emissions vehicles should reach 30% by 2030 and reach 100% by 2040. At the COP26, the International Aviation Climate Ambition Coalition composed of 23 countries including the United Kingdom, the United States, and France proposed in the *International Aviation Climate Declaration* in which they committed that the aviation industry will achieve net-zero carbon dioxide emissions by 2050. In a joint statement on the Nature, People and Planet, the multilateral development banks committed to achieve mainstreaming of nature issues in terms of policy, analysis, assessment, advice, investment and business.

As we see, the COP26 set a series of governance issues to respond to the concerns of multiple subjects, and progresses have been made in addressing key issues such as mitigation, adaptation, funding, technology, and capacity building involved in the *Paris Agreement*. Before and during the conference, it created conditions and opportunities for relevant subjects under different issues to participate in climate

governance, and promoted full discussion and the formation of a consensus on the issues, by means of the theme day, leaders summit, ministerial meeting, negotiation and consultation, etc. Ultimately, a series of climate governance mechanisms were formed through the conference, including: the negotiation on the implementation rules of the *Paris Agreement* which was completed before the COP26 was completed; the coal reduction was mentioned for the first time, ensuring that it is still possible to achieve the 1.5 °C temperature rise target. It further clarified the guarantee mechanisms such as global inventory and transparency, and strengthened the scope and degree of existing climate governance [5]. It can be said that the COP26 has successfully maintained and implemented the basic principles and goals of the *Paris Agreement*, continued the effectiveness of the UNFCCC-based multilateral governance system to tackle climate change, and promoted the process of global climate governance. Therefore, we can say that the COP26 is another major milestone in the global climate governance after the *Paris Agreement* was signed.

1.3 Post-COP26 Trends and Prospects

The COVID-19 pandemic is still raging, and the international geopolitical environment gets more complex and even deteriorating, but climate change gradually affects the entire socio-economic system, and our climate governance requires more tenacious global system thinking and transformation [6]. The COP26 effectively promoted the formation of a consensus among all countries, but there are still a lot of differences and problems that need concerted efforts of all countries. For example, there is lack of full implementation of specific actions, the cooperation on the “hardest nut” is still insufficient, addressing climate change may even exacerbate conflicts, all countries have not yet gotten rid of their dependence on fossil energy, the energy security and energy poverty coexist, and the collaboration between addressing climate change and actions in other areas is still insufficient. Therefore, all countries should adopt a practical attitude to reach a constructive consensus and take concrete actions on the issues mentioned above.

1.3.1 Taking Concrete Actions to Actively Respond to the Climate Crisis Should Become the Mainstream, and It Is an Urgent for Multiple Subjects to Actively and Systematically Participate in Climate Governance

Boosting climate ambitions is important, but actions are far more valuable than goals [7]. All countries should have an open attitude to extensively discuss diverse issues such as boosting global climate ambitions, non-CO₂ gas governance and climate collaborative governance. However, actions speak louder than words, it is urgent for all countries to take concrete actions to achieve the goals of the *Paris Agreement* [8]. Especially, developed countries need to realize climate action goals and

implement climate finance commitments to avoid failure again [9]. At the same time, they should also avoid uncertainty about the rule of law to address climate change. Concrete actions are inseparable from the active participation of all sectors of society and diverse subjects. All countries need to mobilize the enthusiasm of multiple subjects to participate in climate governance based on their national conditions to establish a green production and consumption system, actively explore the best practices for promoting the active participation of multiple subjects in economic and social transition, and provide experience and reference for developing countries to address climate change.

1.3.2 Global Climate Cooperation Should Strive to Make Positive Progresses in the Implementation Pathway for Addressing Climate Change and Core Emission Reduction Issues

The agenda in future climate cooperation should not bypass any difficulty, and the cooperation should focus on key issues and critical links. Firstly, in the current climate cooperation, two pairs of ease and difficulty relationships have appeared: **Firstly**, it is difficult for all interested parties to reach a consensus on the implementation path and specific actions to address climate change, including funding, technology, etc., while they intend more to reach a consensus on ambitions to address climate change; **Secondly**, it is difficult to form a consensus on the core CO₂ emission reduction in addressing climate change, and all the parties prefer to reach a consensus on non-CO₂ reduction such as methane emission reduction and curbing deforestation; and, **Thirdly**, if the manufacturing powers represented by China restrict the development of energy-intensive industries and their products in order to reduce emissions, then a huge challenge that the world will face is how to meet the demand for relevant products, as well as how and who to invest in the production utilizing more advanced, energy-saving and low-cost technologies. It must be acknowledged that all relevant issues will make great contributions to addressing climate change. However, it will be difficult to form effective climate governance by only boosting ambition without clear implementation path, and only promoting the non-CO₂ emission reduction issues without actually tackling CO₂ emission reduction. Therefore, all parties should strengthen communication and cooperation on the “hardest nut” issues.

1.3.3 The International Cooperation and Competition Should Not Jeopardize the Response to Climate Change, and the Specific Implementation of Carbon Pricing and Funding Mechanisms Should Avoid Exacerbating International Conflicts

Climate change has always been a major threat to human survival, and the confrontation in the international political and economic situation is intensifying. Promoting international political and economic cooperation is indeed beneficial to combating climate change [10]. All countries should take responsible actions, strengthen

communication and cooperation to avoid misjudgment, and ensure that both competition and cooperation can benefit rather than harm response to climate change. During the process of building a global carbon pricing mechanism, the differences in national conditions of different countries should be fully respected, and carbon pricing and funding mechanisms should be set up with the goal of driving the green and low-carbon structural transformation of the trade and financial systems, rather than setting up green barriers. A one-size-fits-all approach to carbon pricing, financial mechanisms, and product standards is prone to harm the interests of developing countries and their willingness and ability to engage in addressing climate change [11]. All countries should work together to strengthen the connection of carbon pricing and financial mechanism changes, and carry out the mechanism design. We should take into account the differences between countries in transition, avoid more conflicts and uncertainties, and avoid undermining international cooperation on climate change.

1.3.4 Although Different Countries Are at Different Energy Transition Stages, All Countries Should Make Joint Efforts to Properly Handle the Relationship Between Energy Security, Carbon Reduction and Development

The schedules and paths of low-carbon energy transition in different countries are not exactly the same due to their different development stages and resource endowments [12]. What's doubtless is that the process of low-carbon energy transition will not be a smooth sailing no matter for developed countries or for developing countries. The new round of global energy crisis that began in the first half of 2021, and the soaring prices of fossil energies represented by natural gas and coal, may significantly affect the policy path selection of governments in terms of energy security and addressing climate change [13, 14], which has brought new uncertainties to the global low-carbon energy transition and fully demonstrated the arduousness and complexity of the low-carbon energy transition. There may be national conditions-based differences in the transition stages and paths of different countries, but taking into account energy security, carbon reduction and development is the common challenge faced by them, so their solutions and technical routes may be used for mutual reference. Successful coal exit needs new development models and policy measures in addition to a lot of efforts [15, 16], and European and American countries need to synchronously solve the problems of oil and gas exit. Developed countries have the responsibility to work with developing countries to explore the energy decarbonization of coal and gas exit, so as to create space for global response to climate change and in-depth climate cooperation [17].

1.3.5 Enhance the Capacity to Adapt to Climate Change and Strengthen Synergistic Governance in Multiple Areas Including Climate Change and Biodiversity

With the increase of the risks from climate change, the necessity for all countries to work together to strengthen the adaptive ability is increasing as well. They should try to achieve a balance between mitigation and adaptation. A problem which is certainly encountered during the improvement of the adaptive ability is funds. At the COP26, the developed countries enhanced their ambitions in terms of fund support, but which are most likely to fail once more and affect the overall situation of global climate governance. On the issue of climate funding, developing countries are increasingly demanding to increase the proportion of adaptation in climate funds [18]. At the COP26, discussions on the related topics such as curbing deforestation, sustainable supply chain, and biodiversity protection were added, which promoted the collaboration of topics in multiple fields. An important direction of the multilateral process of climate and environment in the future is to promote positive progress in sustainable development goals including climate, and we look forward to strengthening the discussion on the collaborative governance of climate change in the second session of CBD COP15. The COP27 will be held by Egypt, a developing country. Then, the issues such as adaptation to climate change and reduction of losses and damage will become the focus of discussion. Sharm El Sheikh is also the host of CBD COP14, and it may be a meeting place for the collaborative governance of biodiversity and response to climate change. Therefore, a greater progress on this aspect is expected during the COP27.

1.4 China Will Actively Maintain and Participate in Global Climate Governance Through Concrete Actions

As President Xi Jinping stressed in his written address to the COP26 World Leaders Summit, “successful governance relies on solid action”. China believes that the global response to climate change requires actions rather than words. China has incorporated the dual-carbon goal into the Five-Sphere Integrated Plan, and will make unswerving efforts to achieve the dual-carbon goal and promote its own comprehensive green transition. Before the COP26, China successively issued the *Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy*,² the *Action Plan for Carbon Dioxide Peak Before 2030*,³ and the white paper with the title of *China’s Policies and Actions for*

² Full Text: Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy, http://english.www.gov.cn/policies/latestreleases/202110/25/content_WS61760047c6d0df57f98e3c21.html.

³ Full Text: Action Plan for Carbon Dioxide Peaking Before 2030, http://english.www.gov.cn/policies/latestreleases/202110/27/content_WS6178a47ec6d0df57f98e3dfb.html.

Addressing Climate Change, and submitted the *China's Achievements, New Goals and New Measures for Nationally Determined Contributions and the China's Mid-Century Long-Term Low Greenhouse Gas Emission Development Strategy*, which clarified the general idea and roadmap for achieving carbon emission peak by 2030 and achieving carbon neutrality by 2060 [19]. At present, China is stepping up the improvement of the 1 + N policy system involving carbon emission peaking and carbon neutrality, so that it will finally become a two-stage policy and measure system for various fields and industries, covering the whole country and local areas. The 1 + N policy system will provide all-round support for realization of China's dual carbon goals, paths and policies, and ultimately form China's carbon peak and carbon neutral solutions [20, 21].

China firmly supports and maintains multilateral mechanisms and processes of climate governance, attaches great importance to working with the international community to address the global climate crisis, and promotes global carbon neutrality cooperation. It carried out close consultations with the UNFCCC secretariat, the UK (presidency), the United States and Europe and other parties before and during the conference. China, as always, supports and maintains the UNFCCC and the *Paris Agreement*, adheres to the goals, principles and policy orientation of the *Paris Agreement*, achieves a balance between ambitious goals and practical actions, and is willing to play an active role and adopt a systematic approach in coping with climate change. Besides, China has committed not to build any new overseas coal-fired power project, and vigorously supports the green and low-carbon development of energies in developing countries. In the future, China will actively carry out green BRI and South-South cooperation to help developing countries respond to climate change.

China attaches great importance to inheriting the successful experience of the *Paris Agreement*, and promotes the process of multilateral governance through bilateral cooperation. The bilateral climate cooperation between China and the United States has made a breakthrough in Glasgow. China and the United States conducted intensive climate talks and communication in 2021, which laid the foundation for the release of the U.S.-China Joint Glasgow Declaration on Enhancing Climate Action in the 2020s during the COP26. On the basis of the *Joint Statement Addressing the Climate Crisis of April 17th, 2021*, China and the United States reached a major consensus in four aspects: strengthening actions, cooperating to promote the success of the COP26, actively implementing the joint statement, and establishing "a working group on enhancing climate action". The two sides signed the *U.S.-China Joint Glasgow Declaration on Enhancing Climate Action in the 2020s*, which will accelerate the implementation of China-US climate cooperation and facilitate the formation of a consensus on the *Glasgow Climate Pact*. China will continue to actively carry out climate cooperation dialogues with Europe, the United States and other economies through bilateral mechanisms and achieve a series of positive results.

China will continue to develop the benefits of collaborative climate governance and promote the combination of climate governance with other issues. China attaches great importance to the combination of climate change and economic and social system transition, accelerates the formation of industrial structures, production

methods, lifestyles, and spatial patterns that are conducive to resource conservation and environmental protection, and promotes a comprehensive green transition of economic and social development while adhering to the collaborative promotion of carbon reduction, pollution decreasing, green expansion, and growth. The collaborative governance of climate and environment is also a key task, and we will continue to promote the synergy of pollution decreasing and carbon reduction. Meanwhile, we will also focus on the combination of climate and biodiversity governance, and support the promotion of the second session of COP15 to achieve collaborative benefits in addressing climate change.

2 Path and Policy Security for Green and Low-Carbon-Oriented Energy Transition Under the New Situation

The success of the COP26 has boosted global confidence in climate governance. The energy transition to green and low-carbon should have heated up rapidly in 2021, but it is facing severe challenges instead, due to the impact of a new round of global energy crisis. In 2021, the global energy market fluctuated violently, and the sharp rise in traditional energy prices triggered a new round of global energy crisis, which is further intensified by the geopolitical conflict between Russia and Ukraine in 2022. As the result, the energy security of multiple countries has been seriously threatened, and the process of global economic recovery and green transition of energy are also facing huge obstacles. Under the new situation with coexistence of crisis and transition, how can the global green and low-carbon-oriented energy transition continue to advance in an orderly manner on the premise that the energy security is ensured? This chapter will analyze the causes of this round of global energy crisis, analyze the trend of energy transition in the future, and put forward suggestions for China to orderly promote green and low-carbon energy transition in the next step.

2.1 Analysis on the Causes of the New Round of Energy Crisis and Judgment on the Development Situation

2.1.1 The Energy Crisis Started in Europe, and the Economic Development and Social Security of Multiple Countries Have Been Adversely Affected Greatly

In 2021, the prices of the world's three major traditional energies i.e. natural gas, coal and oil rose rapidly, and the energy crisis started in Europe and eventually spread across the world. Since the beginning of 2021, the price of natural gas in

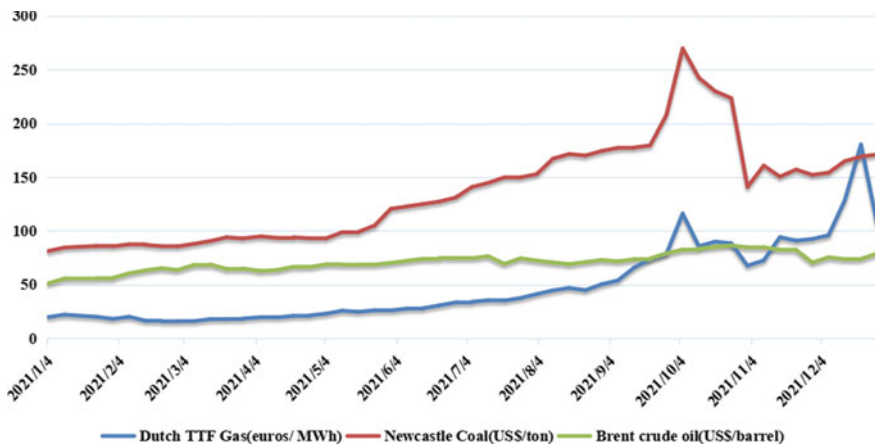


Fig. 1 Global representative prices of natural gas, coal and oil in 2021. *Source of Data* [investing.com](https://www.investing.com)

Europe has shown a trend of rapid rise, and continued to break through record highs, triggering the European energy crisis. With the future price of Dutch TTF natural gas as an example, the lowest and highest prices of TTF futures during the whole year of 2021 were 15.485 euros/MWh on March 3rd and 187.785 euros/MWh on December 21st, respectively, and the difference between the two was about 12.13 times (see Fig. 1). The sharp rise in the price of natural gas stimulated the demands for its substitutes i.e. coal and oil, which was also reflected in the form of a sharp rise in prices. During the full year of 2021, there was a difference of about 3.4 times between the highest and lowest prices for Newcastle coal futures, and 1.715 times for Brent crude oil futures (see Fig. 1). The sharp rise in the prices of the three major traditional energies spread across the world along with the global trade chain, eventually triggering a global energy crisis.

The global energy crisis has had a serious adverse impact on the economic development and social security of multiple countries. In **Europe**, since the beginning of 2021, electricity prices in multiple countries has been rising rapidly due to the impact of natural gas prices, and electricity costs had risen by about 500% by the end of the year (see Fig. 2). In the industries like metals, fertilizers and foods, enterprises had to reduce their production significantly, and even got bankrupt due to severe hit by high electricity costs. The energy commodities are facing an inflation rate of 23%, nearly 35 million people are involved in energy poverty and their basic demands for power supply and heating cannot be met; In **China**, during September 2021, coal-fired power plants suffered serious operating losses due to high domestic and foreign coal prices, and the sharp decline in thermal coal stock eventually led to the occurrence of the national “electricity shortage” event, and power rationing has been implemented in about 20 provinces across the country (see Table 1). According to statistics, the coal procurement cost of coal-fired power enterprises across the country increased by about 600 billion yuan in 2021, and the cumulative loss for the

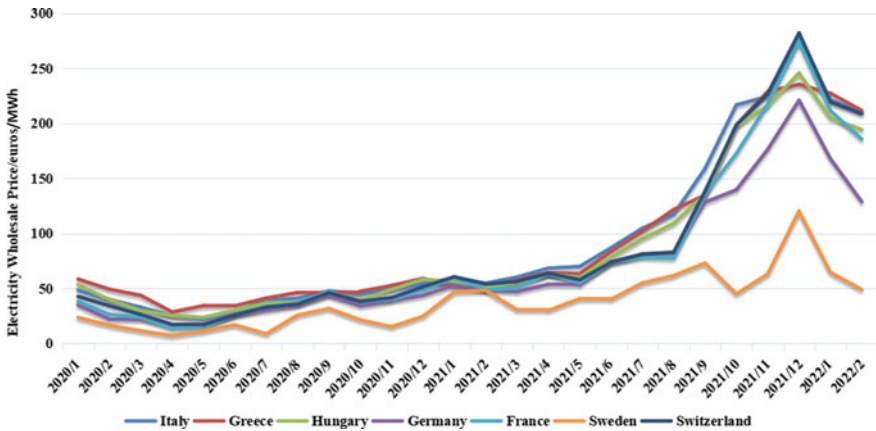


Fig. 2 Average monthly electricity wholesale prices of major European countries from 2020 to 2022. *Source of Data* Statista

whole year reached about 80% [22]; In **India**, influenced by the sharp rise in prices, the coal stock of domestic coal-fired power plants dropped sharply in October 2021, and power outages occurred in many areas. According to data from the Central Electricity Authority of India, 16 of India's 135 coal-fired power plants had zero coal data. In addition, more than half of the power plants have the stock for less than 3 days of operation, and more than 80% of the power plants have a stock for less than a week's operation. According to the Global Times, in the first 12 days of October 2021, India's electricity supply shortage reached about 750 million kW-h, and the electricity supply gaps in northern regions such as Rajasthan, Punjab and Uttar Pradesh, as well as the eastern regions like Jharkhand and Bihar ranged from 2.3 to 14.7%.

2.1.2 Analysis on the Causes of a New Round of Energy Crisis

The Factors Like the COVID-19 Pandemic and Monopoly Have Caused the Shortage of Traditional Energy Supply, and It Is Difficult to Meet the Increasing Energy Demands

Affected by factors such as the COVID-19 pandemic and monopoly, the global traditional energy supply has been limited and continued to tighten. On the one hand, the COVID-19 pandemic continues its adverse impact on the resumption of work and production across the world. The traditional energy production is much lower than the pre-pandemic level although it showed a rebound, and the coal and oil yields increased by 4.5% and 1.3% year-on-year respectively in 2021

Table 1 Power rationing in various provinces of China in 2021

Province	Time	Power rationing policies
Jiangsu	September 15	Electricity rationing was implemented in part of areas, which was tentatively scheduled for 15 days. Power was cut for industrial use, but available for domestic use. Air conditioners in offices were not allowed to operate, and street lights were halved to be on at night
	September 19	Enterprises were subject to power cuts and production limits by levels. 1096 companies followed the “two days enabled and two days disabled in a week” policy and 143 companies were completely closed down
Guangdong	September 16	The five-level orderly electricity consumption based on the “two days enabled and five days disabled in a week” was implemented, and the security load on off-peak days was kept below 15% of the total load
	September 26	It was recommended that the air-conditioning cooling temperature should not be lower than 26 °C, and the elevators should not be used for the floors below the 3rd floor in the office buildings
Shandong	September 15	Rizhao City issued an emergency warning of a large power supply gap that could last until the end of September
	September 13	Zaozhuang City issued a notice, with priority to demand response, meeting the basic requirement for orderly power supply
	September 12–18	The power rationing policy of the Zibo plant was continuously upgraded, and the power rationing schedule was finally adjusted to be the periods of 16:00–20:00 and 7:30–24:00
Shanxi	September 13	The “two-height” projects that were put into production in the year was subject to production limit by 60% of the previous month’s output. Other “two-height” enterprises were required to reduce the operating load of the production line, shut down the submerged arc furnace, and ensure that the production limit would reach 50% in September, and the covered period was from September to December
Guangxi	September	From September, the monthly electricity load of electrolytic aluminum enterprises was reduced by 35% for the whole period on the basis of the average monthly electricity load from January to June. Industrial and commercial enterprises were required to use electricity in an orderly manner and take the initiative to stagger the electricity consumption and avoid peaks

(continued)

Table 1 (continued)

Province	Time	Power rationing policies
Yunnan	September 11	The production control on key industries was strengthened, and the production limits involved the industries like steel, cement, electrolytic aluminum, and coal-fired power generation, and it was ensured that the average monthly output of green aluminum enterprises from September to December was not higher than the output in August
Guizhou	September 10	According to the power gap scale of the province, the early warning was made by 4 levels, and the corresponding level of response was activated. Unlike the power rationing and production limits implemented by other provinces due to the dual control of energy consumption, Guizhou Province took an early warning measure based on the possible shortage of power resources
Inner Mongolia	August 31	It was recommended to limit the electricity load by implementing an orderly electricity consumption plan in the period from August to December
Xinjiang	August 25	Changji State strictly controls the production capacity and outputs of electrolytic aluminum enterprises. From August, the total monthly output of the five enterprises in the region should not exceed 238,000 tons
Qinghai	August 20	Part of the electrolytic aluminum enterprises received a power cut warning notice from the State Grid Xining Branch, which mentioned that the enterprises should get ready for orderly power consumption in advance, but the notice didn't involve the specific power rationing schedule and plan
Ningxia	July 12	The production of high energy consuming industries such as cement, calcium carbide and titanium alloy were suspended for one month
Sichuan	August 5	Non-essential production, lighting, office electricity loads were suspended
Henan	August 9	Part of the processing enterprises were implemented with power rationing for more than three weeks. Some aluminum processing enterprises in Zhengzhou and Luoyang were notified of power cuts. Large industrial enterprises were subject to power rationing by 50%, depending on actual situations, and all industrial enterprises with the capacity below 10 kV stopped production
Chongqing	September 26	The plan of orderly power consumption was implemented across the city to respond to the reduction of power load
Liaoning	September 10–22	A total of 6 rounds of Level III (load gap: 5–10%) and 3 rounds of level IV (load gap: 5% and below) orderly electricity consumption measures were implemented, and the coverage was limited to part of industrial enterprises

(continued)

Table 1 (continued)

Province	Time	Power rationing policies
	September 23–25	The power supply gap was increased to a serious level. To prevent the entire grid from collapsing, the “power rationing to avoid accident shutdown of the power grid” was implemented, and the coverage was extended to residents and enterprises that are not subject to orderly electricity consumption measures
	September 26	The Provincial Department of Industry and Information Technology held a meeting on the power security work of the province, requiring minimizing the possibility of power cuts
Heilongjiang	September 24	Since September 10, the orderly electricity consumption would be implemented simultaneously in Liaoning, Jilin and Eastern Mongolia. Some enterprises’ failure to follow the above electricity consumption policy caused the urgent power rationing on September 23. The relevant authority made explicit requirements, and any individual or enterprise’s refusal to follow the policy would be held accountable
	September 26	Except for the Central Street business district, Qiulin business district and all fresh food supermarkets, all commercial enterprises in the city should subject to the off-peak power consumption policy and close their stores from 16:00 every day
Jilin	September 23	According to the order of the Northeast Power Grid, power rationing was implemented at 16:37, which covered nine urban areas in the province, and part of the users in Yanbian Area were subject to power cuts
	September 26	Jilin Xinbei Water Affairs Co., Ltd. issued an announcement that power rationing would be implemented in the irregular and unscheduled form, without prior notice; this situation would continue until March 2022, and power and water outages would become normal. On September 27, the company made an apology and said that there was “improper wording and inaccurate content” in the announcement
Hunan	September 22	An orange warning was issued for the security of Hunan Power Grid, and the electricity load was controlled below 26 million kW
Anhui	September 22	The orderly electricity consumption plan was implemented across the province, high-energy-consuming and high-emission enterprises were first arranged to follow the off-peak power consumption policy, and the landscape lighting and lighting projects were taken the initiative to shut down

(continued)

Table 1 (continued)

Province	Time	Power rationing policies
Zhejiang	September 21	High-energy-consuming enterprises such as printing and dyeing plants, sewage treatment plants, and chemical plants would be closed down from September 21 to 30, and related enterprises in Keqiao District, Shaoxing City, where printing and textile enterprises gather, would halt production

Source of Data Provincial development and reform commissions, energy bureaus, power grid companies and other government and enterprise institutions

[23]⁴; **On the other hand, monopoly organizations strictly control the supply of traditional energies in order to protect their own monopoly interests.** With oil as an example, OPEC+, the world's largest oil monopoly, has maintained a prudent production increase plan of 400,000 barrels per day under the situation that the global oil supply is in shortage of 2021, which is to control the international oil price within a reasonable price range that can maintain common interests of the entire alliance.

The limited supply of traditional energies and the continuous growth of demands form a stark contradiction, and the global energy supply and demand is significantly unbalanced. In 2021, the global demands for natural gas, coal, and oil increased by 3.2%, 4.5%, and 6% year-on-year, respectively [3]. Except for oil, the demands for coal and natural gas were higher than the pre-COVID-19 level. There was a sharp contradiction between the rising demand of traditional energy and the continuous tightening of traditional energy supply. The gap of traditional energy supply was gradually widening, the balance of energy supply and demand was broken, and the energy situation in short supply was presented by the rapid rise in prices, which eventually led to a new round of global energy crisis.

The Economic Stimulus Policies Implemented by Major Economies Have Triggered Global Inflation and Exacerbated Sharp Rises in Energy Prices

The United States and other major economies implemented economic stimulus policies, which prompted a large amount of currency to enter the market, causing domestic inflation. In 2021, the world's major economies led by the United States promulgated a series of economic stimulus policies in order to counteract the downward pressure on the economy and achieve post-pandemic economic recovery. Of such policies, the Federal Reserve's unlimited quantitative easing monetary policy, and Biden's various economic stimulus acts are the most representative, the total expenditure of which reached trillions of dollars. This directly led to the over-issue of the dollar currency, and a large number of dollars entered the domestic market of the United States, driving up consumer demand. However, due to the limited

⁴ OGJ: The global oil production rose 1.3% in 2021. <https://new.qq.com/omn/20220216/20220216A0965W00.html>.

recovery of the domestic industrial chain and the shortage of labor in the United States, its productivity could not meet the rising consumer demands, thus resulting in the intensified contradiction between supply and demand in the market, pushing up the terminal consumer price, and ultimately causing domestic inflation.

The domestic inflation of the United States spreads globally due to its global currency characteristic, fueling further sharp rise in energy prices. Because of the dominance of the US dollar in the international currency, a large amount of funds in the US domestic market would flow to the world market in search of investment returns, resulting in the flood of US dollar liquidity. Similarly, the entry of a large number of U.S. dollars into the international market has pushed up global consumer demands, and due to the continued adverse impact of the COVID-19 pandemic, the repair progress of the global industrial chain was significantly lagged behind the growth rate of demands, and the mismatch between supply and demand caused global inflation, which was manifested in the rise of prices of terminal products, and energy prices would naturally face a sharp rise due to its commodity attributes.

The Renewable Energy Power Generation Failed to Reach the Expected Level Due to Extreme Weather, and It Is Difficult to Meet the Rapidly Increasing Power Demand

Extreme weather may have certain adverse impacts on renewable energy generation, resulting in a lower-than-expected generation capacity. In 2021, as the occurrence frequency of extreme weather such as ultra-high pressure weather and drought was significantly higher than that in previous years, the output of renewable energy power generation declined and failed to reach the expected level, with hydropower and wind power being the most representative ones. In 2021, the global hydropower generation capacity remained at 2020 levels, ending the growth since 2001, which was mainly due to significant declines in countries such as Brazil, the United States, China and Turkey caused by drought. Affected by ultra-high pressure weather in Europe, the overall wind force was obviously insufficient in 2021, and the EU's annual wind power generation fell by 3% year-on-year, which was the first decline in the past three decades. According to the International Energy Agency (IEA), if there were no extreme weather in 2021, the global renewable energy generation capacity will increase by nearly 9% year-on-year [24].

Under the impact of extreme weather, the supply of renewable energy maintains a relatively high growth rate, but the global power demand grows more rapidly, and the contradiction between power supply and demand is sharp. In 2021, the global renewable energy generation capacity increased by 6% year-on-year, 500 TWh higher than that in 2020, creating a record high [24, 25]. However, the global electricity demand was growing at an even higher rate, with an increase of 1538 TWh compared to that in 2020, more than three times the increase in renewable energy generation capacity [3]. Therefore, the renewable energy power generation capacity was difficult to meet the rapidly-rising demand for electricity, which resulted in the gradual intensification of the contradiction between global power supply and

demand. The existence of power supply gap stimulated the demand for substitutes of power generated with traditional energy in various countries. In the context of the continuous tightening of traditional energy production capacity, the situation with traditional energy in short supply and prices sharply rising gradually emerged, and the pressure on energy use in countries around the world has gradually intensified, eventually triggering a global energy crisis.

2.1.3 The Impact of the Russia-Ukraine Conflict on the Future Global Energy Pattern

On February 24, 2022, Russian President Vladimir Putin announced the launch of a “special military operation” against the Donbas region of Ukraine. The military conflict between Russia and Ukraine officially broke out. European and American countries successively imposed sanctions on Russia in terms of energy and finance. As an important energy exporter, Russia plays a pivotal role in global energy supply, especially for Europe. For a long time, about 35% and 25% of Europe’s natural gas and oil imports respectively are from Russia (see Figs. 3 and 4). Therefore, the outbreak of the Russia-Ukraine conflict will trigger turmoil in the global energy market, which will have a considerable impact on the global energy supply situation and the future global energy pattern.

In the short term, the Russia-Ukraine conflict has further pushed up energy prices, especially oil and gas prices. However, it is a matter of caution whether they will continue to rise, thus exacerbating the global energy crisis. The prices of Brent and New York crude futures both broke through the US\$100/barrel mark on

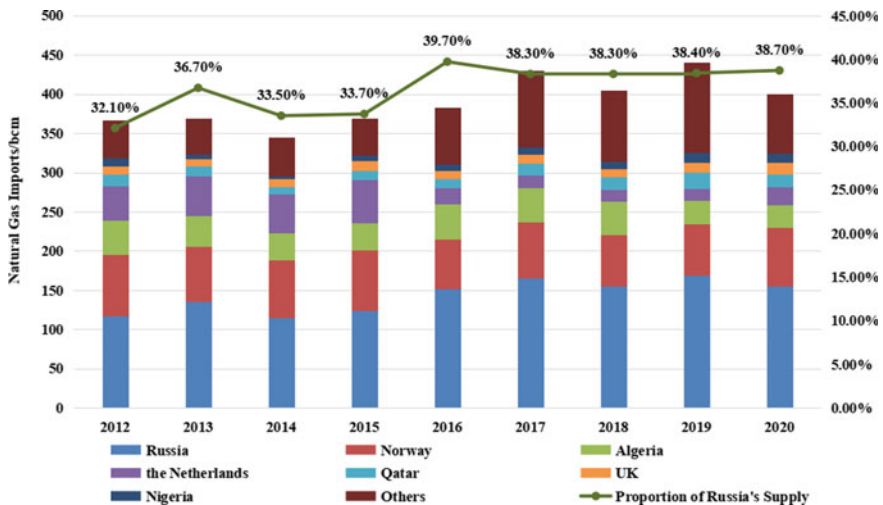


Fig. 3 Distribution of natural gas imports and importing countries of Europe from 2012 to 2020. *Source of Data* Eurostat

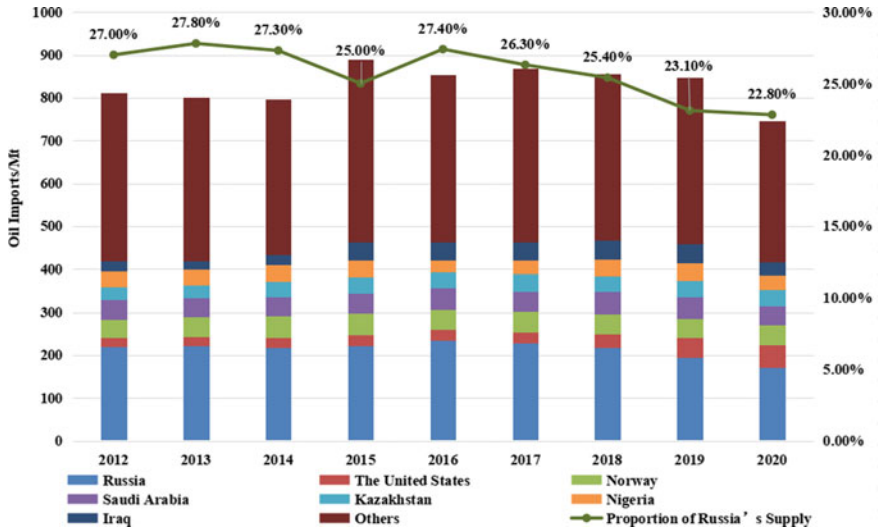


Fig. 4 Distribution of oil imports and importing countries of Europe from 2012 to 2020. Source of Data Eurostat

February 24, the day the conflict erupted, creating a record high and further rising on that basis. There are two reasons for the sharp rise in energy prices triggered by the Russia-Ukraine conflict: Firstly, Russia is an important exporter in the global energy market. Sanctions against Russia by the United States, Europe and other countries have directly or indirectly affected Russia's supply of global energy, which led to tight global energy supply and push up prices. Secondly, oil and gas are special commodities with strategic attributes, closely related to geopolitics. The outbreak of geopolitical conflict increased the market's concerns about the production and supply of oil and gas, which in turn caused a rapid rise in oil and gas prices. However, the high energy prices caused by the Russia-Ukraine conflict was mainly driven by the market risk aversion and has limited impact on the output and transportation supply of energy exporting countries, especially Russia. Therefore, the future trend of energy prices will be determined by the situation of the Russia-Ukraine conflict. If the situation continues to ferment, energy prices may continue to go higher; otherwise, energy prices are likely to peak and fall steadily.

In the long run, the Russia-Ukraine conflict may affect the global climate process and the energy pattern. Firstly, the Russia-Ukraine conflict may reconstruct the traditional energy trade pattern. On the one hand, due to the substantial restrictions imposed by European and American countries on oil and gas imports from Russia, Russia will look for other export sources for its redundant oil and gas to replace Europe, and China will be the main potential incremental direction of Russia's natural gas exports in the future; on the other hand, in light of the rigid demand for oil and gas imports in the short term, Europe will look for other import sources to replace Russia, the oil and gas supply from the Gulf region as well as the

liquefied natural gas export from the United States, Qatar, etc. will be its stable energy sources. **Secondly, the Russia-Ukraine conflict may accelerate the formation of a renewable energy pattern.** The European Commission's Energy Independence Plan, entitled Joint European Action for More affordable, Secure and Sustainable Energy released on March 8, 2022, fully demonstrated Europe's determination to get rid of energy dependence on Russia by accelerating the development of renewable energy. The Russia-Ukraine conflict is likely to become a catalyst for Europe to accelerate the green transition of energy, prompting Europe to accelerate its investment in renewable energy technologies and enterprises in its own territory, and to accelerate the formation of an energy industry chain based on new energy technologies in Europe, thereby securing its energy future. At that time, the global renewable energy pattern will be formed in an accelerated way, and the global energy industry chain structure based on new energy technologies will undergo major changes, and the core of energy may gradually shift to Europe, making Europe in the leading position during the process of energy transition.

2.1.4 Judgment on the Future Trend of Energy Transition

Properly Deal with the Medium and Long-Term Energy Low-Carbon Transition and the Medium-Term Energy Supply Security

The energy crisis is only a short-term fluctuation in the transition process. Countries should maintain strategic focus and continue to adhere to the mainstream trend of green and low-carbon energy transition. At present, the growth rate and investment level in renewable energy are still not enough to support the achievement of global climate targets as expected. To promote the realization of the global net-zero goal by 2050, the renewable electricity generation capacity needs to grow at an average rate of nearly 12% between 2021 and 2030, which is almost double the rate during the period from 2011 to 2020; meanwhile, the global investment in clean energy remains well below what is required to avoid severe impacts of climate change, the amount of which should be doubled during the 2020s to keep the temperature rise is far below 2 °C. The amount of investment would need to be increased by more than double if the 1.5 °C temperature rise target under the *Paris Agreement* is achieved [26]. Therefore, all countries should still maintain their willpower for the transition, make greater efforts to promote the rapid development of renewable energy and make it gradually replace traditional fossil energy, so that a diversified, clean and low-carbon energy structure is established.

The energy transition is not accomplished overnight. The moderate investment in traditional energy is needed to ensure energy security in the near and medium term. Currently, the fossil energy meets more than 80% of the world's energy demand,⁵ and even in the global net-zero situation in 2050, the oil and gas

⁵ The data is from U.S. Energy Information Administration. <https://www.eia.gov/international/data/world>.

demand will account for about 35% of global energy demand [27]. In some industries, such as heating, and petrochemical industries, it is difficult to find clean industrial raw materials that can effectively replace traditional fossil energy in the short term, and the contribution of renewable energy to the entire process of these industries is quite limited. Therefore, during the process of short- and medium-term energy transition, it is necessary to invest in traditional energy moderately to meet the short-term demand for traditional energy and ensure the security of energy supply.

The Short-Term Fluctuation During the Process of Long-Term Energy Transition Should Be Treated Properly to Avoid Global Inflation Risks

The rise in short-term energy demand is in contradiction with the goal of energy green transition, and a short-term fluctuation upon an energy supply and demand imbalance are prone to occur in the transition process. In the long run, the trend of global green transition of energy requires the gradual reduction of fossil energy and replacing it with fast-growing renewable energy. However, in the short term, the renewable energy production capacity is insufficient, and to meet the rising energy demand still depends on fossil energy to a certain extent. The contradiction between the two is prone to cause a short-term imbalance of energy supply and demand in the transition process. Besides, external adverse factors such as the COVID-19 pandemic, monopoly, and geopolitical conflicts will have a certain impact on the stability of global energy supply, further triggering the occurrence of a short-term energy supply and demand imbalance.

The imbalance between energy supply and demand has led to a sharp rise in energy prices, which is prone to affect the finance sector and may trigger global inflation. At present, most of the energy is circulated in the global trade market in the form of commodities, and the imbalance between energy supply and demand will lead to a sharp rise in energy prices, and the sharp rise in its price will be transmitted from industrial production to various sectors of the global economy, which will significantly inhibit the total output and consumption of terminal products [28]. In addition, global energy commodities are generally capitalized and closely related to the financial sector. The sharp rise in energy prices will lead to excessive speculation and malicious speculation in the financial sector, resulting in the generation of energy commodity price bubbles, and cause energy prices to deviate far from the ones corresponding to their intrinsic values, thereby increasing the fluctuation risk in the financial market, impacting the real economy, and further triggering inflations.

In the Future, Extreme Weather Will Become an Important Consideration for Energy Security in the Transition Process

Extreme weather events will occur frequently in the future, which will adversely affect the balance of energy supply and demand. Affected by human activities and greenhouse gas emissions, extreme weather events will occur more frequently

in the future [1], both energy supply and demand will be affected by this. On the one hand, the current renewable energy technology is intermittent and fluctuant to a large degree due to limits of natural conditions. Besides, the related energy storage technology has not been well developed, and the occurrence of extreme weather such as sudden decrease of wind force and drought will cause a sharp reduction in the level of the renewable energy output. For example, the European Union and the United Kingdom were affected by the decrease of the overall wind force in the North Sea during the summer and autumn of 2021. From January to September, the wind power generation capacity fell by 17% and 25% year-on-year, respectively. Brazil was affected by a severe drought in 2021, with about 30 hydropower plants unable to generate electricity efficiently due to insufficient water storage. On the other hand, the occurrence of extreme weather will push up energy demand and increase the pressure on energy supply. In 2021, in addition to the rapid economic recovery, more extreme weather than that in 2020, such as a colder winter [29] were also the main factors driving global electricity demand to soar to a record high. Besides, **the global energy infrastructures have not shown sufficient climate resilience and adaptability, and the frequent occurrence of extreme weather will significantly affect its energy supply efficiency.**

The Supply Chain System with New Energy Technologies as the Core Will Become the Focus of Attention of All Countries in the Future Energy Transition

New energy technologies have become the strategic support for the global energy transition. The construction of supply chain with new energy technology as the core will accelerate the process of green energy transition. In recent years, with the vigorous development of new energy technologies, global energy has been brought into a new journey from resource dependence to technology dependence, and the key core role of new energy technologies has become increasingly prominent during the process of green transition of energy. Therefore, accelerating the construction of a supply chain system centered on new energy technology will be an important direction in the energy transition of various countries in the future. On the one hand, the formation of a complete supply chain system with new energy technologies as the core can improve the green energy supply capacity, reduce the dependence on traditional fossil energy, and accelerate the process of energy transition to build a green, low-carbon and efficient energy system earlier, so as to achieve the climate targets of various countries; on the other hand, new energy technologies have become the commanding height of the new round of technological revolution and industrial transformation competition. Some countries have issued or are issuing relevant policies and acts in order to guide their overseas new energy industries to return to their own countries, thereby stepping up the construction of a supply chain system with new energy technologies as the core in their own countries.

2.2 Present Challenges and Recommendations for China's Energy Green and Low-Carbon Transition

2.2.1 China's Primary Energy Structure Is Dominated by Coal, and the High Dependence on Coal Indicates the Necessity of Coal Reduction

China is rich in coal resources, and coal takes a dominant position in its primary energy production and consumption for a long time. Although the proportion is decreasing year by year, it still exceeds half. In 2020, the raw coal accounted for 67.6% of total primary energy production and coal accounted for 56.8% of total energy consumption in China (see Figs. 5 and 6). The balance and stability between coal supply and demand is directly related to China's energy security and economic development. China's power structure is also dominated by coal-fired power, and the power generation capacity is closely related to the supply of thermal coal. In the first half of 2021, the growth rate of China's raw coal production was 8.7 percentage points lower than the growth rate of coal-fired power during the same period, and the coal imports also fell by 19.7% year-on-year due to the rapid rise in global coal prices [30]. The serious imbalance between domestic coal supply and demand led to a sharp rise in coal prices, resulting in a rapid increase in fuel costs borne by the coal-fired power companies. However, the increased fuel costs could not be transmitted to the demand side through an effective price transmission mechanism, which caused the insufficient power supply of the coal-fired power industry as a whole, while the gas electricity and renewable energy power generation, etc. are difficult to make up for the coal-fired power output shortage of power gap, which eventually led to the occurrence of nationwide power rationing.

Currently, the high dependence on coal exposed in China's coal-dominated energy structure shows the lack of energy resilience in China, and it was affected by the sharp rise in coal prices during the global energy crisis, triggering the occurrence of nationwide power rationing. Therefore, based on the basic national conditions with the coal-dominated energy structure, China should effectively promote the green and low-carbon transition of the energy system, and build a diversified, clean and efficient energy structure, so as to present sufficient energy resilience and effectively ensure energy security, fundamentally avoiding the occurrence of similar domestic energy crises like the nationwide power rationing event.

2.2.2 China Has Made Clear Its Commitment to Coal Control and Coal Reduction and Issued Relevant Policies

On the basis of the dual carbon goal, the Chinese government has made clear coal control commitments, rooting in the basic national conditions of coal-dominated energy structure. It will build a carbon-peaking and carbon-neutrality "1 + N"

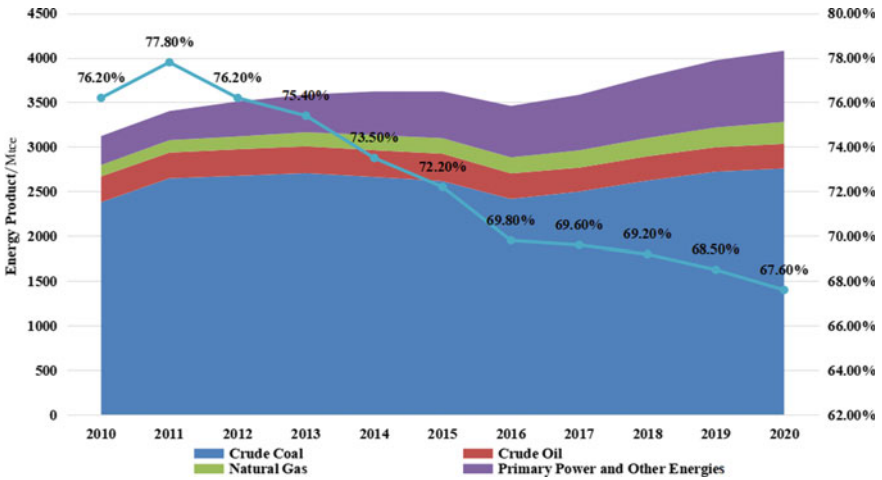


Fig. 5 Total primary energy production and composition in China. *Source of Data* National Bureau of Statistics

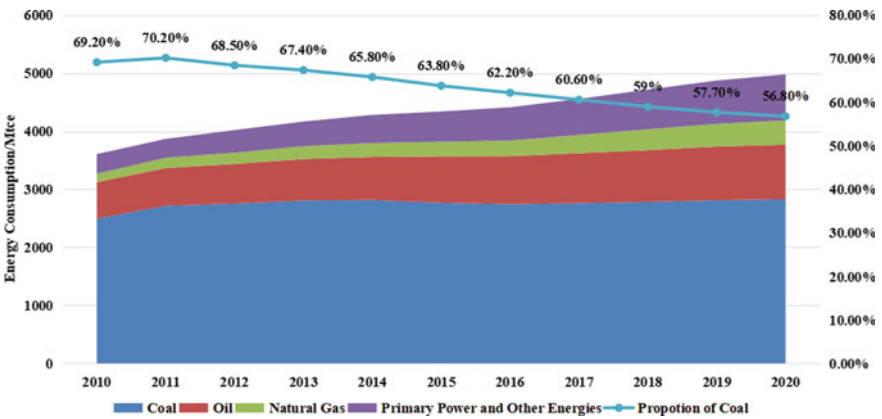


Fig. 6 Total primary energy consumption and composition in China. *Source of Data* National Bureau of Statistics

policy system to improve the top-level design and implement the new situation energy production and consumption revolution strategy. Besides, China has also issued relevant coal control policies to clarify the development direction in coal-fired power, key coal-consumption industries, bulk coal and other fields, so as to promote the effective implementation and advancing of coal control and reduction work under the general trend of energy transition advance (see Boxes 1 and 2).

Box 1 China's coal control and reduction commitments made at international conferences are as follows:

- On April 22, 2021, at the Leaders' Climate Summit, Chinese President Xi Jinping stated that China commits to strictly control coal power projects, and limit the growth of coal consumption during the 14th Five-Year Plan period, and make it gradually reduced during the 15th Five-Year Plan period.

- On September 21, 2021, at the 76th United Nations General Assembly, China further expanded its coal reduction commitments that it will no longer build new overseas coal power project to support the green and low-carbon development of energy in developing countries.

- On October 26, 2021, the State Council issued the Action Plan for Carbon Peaking before 2030. This is the core document on "N" in the carbon dioxide peaking and carbon neutrality and the "1 + N" policy system. It pointed out that China will promote the substitution, transformation and upgrading of coal consumption, and make additional supplements to the content of coal reduction in the Guidance. In terms of coal-fired power, it has added some contents to eliminate backward production capacity in an orderly manner, actively promote the transformation of heating supply, and advance the transition of coal-fired power to both basic security and system-regulating power sources; for the bulk coal, the government has increased efforts to promote the clean utilization of coal, taken multiple measures to actively promote the substitution of bulk coal in an orderly manner.

Box 2 China's relevant policy documents issued on the basis of coal control and reduction commitments are as follows:

- On October 24, 2021, the State Council issued the *Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy* (hereinafter referred to as the "Guidance"). This is the core document on "1" in the carbon dioxide peaking and carbon neutrality and the "1 + N" policy system. It pointed out that China will speed up the pace of coal reduction, strictly control the installed capacity in terms of coal-fired power, accelerate the energy-saving upgrade and flexibility transformation of existing coal-fired power units; and gradually reduce the use of bulk coal until it is completely prohibited.

- On October 26, 2021, the State Council issued the *Action Plan for Carbon Peaking before 2030*. This is the core document on "N" in the carbon dioxide peaking and carbon neutrality and the "1 + N" policy system. It pointed out that China will promote the substitution, transformation and upgrading of coal consumption, and make additional supplements to the content of coal reduction in the Guidance. In terms of coal-fired power, it has added some contents to

eliminate backward production capacity in an orderly manner, actively promote the transformation of heating supply, and advance the transition of coal-fired power to both basic security and system-regulating power sources; for the bulk coal, the government has increased efforts to promote the clean utilization of coal, taken multiple measures to actively promote the substitution of bulk coal in an orderly manner.

- On January 24, 2022, the State Council issued the *Comprehensive Work Plan for Energy Conservation and Emission Reduction during the 14th Five-year Plan Period*, and made further instructions on how to achieve coal exit and reduction in the coal power industry. The document pointed out that it is necessary to promote the transformation of cogeneration of large coal-fired power plants, and to carry out the “three-transformation linkage” of coal saving and consumption reduction transformation, heating transformation and flexibility transformation for the existing coal-fired power units.

- On February 24, 2022, the National Energy Administration released a summary of the reply to the CPPCC members’ Proposal on the High-Quality Development of the Coal-fired Power Industry under the Carbon Neutrality Goal, which clearly detailed the functional positioning, optimization direction and system value of the coal-fired power industry.

- On March 22, 2022, Vice Premier Han Zheng chaired a symposium on clean and efficient utilization of coal. Han Zheng pointed out that it is necessary to promote the clean and efficient utilization of coal from the actual situation of China, make the coal effectively play its role as a bottom-line guarantee and ensure the national energy security. For the clean and efficient production and washing of coal, the energy-saving and consumption-reducing transformation of key coal-using industries, and the governance of bulk coal, it is necessary to make overall planning, integrate resources, and exert the collaborative effect.

- On March 22, 2022, the National Energy Administration released the *14th Five-Year Plan for Modern Energy System*. The document elaborates and deploys multiple aspects including energy production, green transition and development pattern, and mentions other content about coal exit and carbon reduction, involving vigorous development as well as clean and efficient utilization of coal, strengthening of cutting-edge technologies such as intelligent green mining of coal, and improvement of the governance level of coal consumption areas.

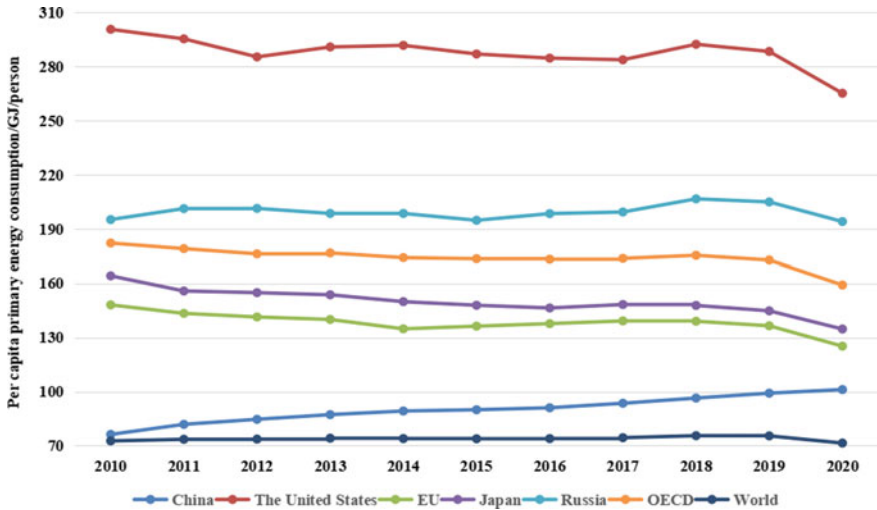


Fig. 7 Global per capita primary energy consumption from 2010 to 2020. *Source of Data* BP's Statistical Review of World Energy 2021

2.2.3 The Present Challenges of China's Short-Term and Medium-Term Low-Carbon Transition of Energy

Rapid Economic Development Needs Energy Security

In the short- and medium-term, the rising energy demand brought about by China's rapid economic development still needs to be met by coal. In recent years, with the rapid growth of China's economy, China's per capita primary energy consumption has gradually increased (see Fig. 7). Currently, China's economic development has entered a new normal, and the energy demand has entered a period of medium and low-speed growth, the rigid energy demand will exist for a long time even and the level of per capita energy consumption will continue to increase and move closer to developed countries [31]. Based on China's national conditions with the coal-dominated energy structure, even if the proportion of coal in the primary energy consumption structure gradually declines, it will still occupy a dominant position at present and in the future [32].

Under the background of the dual carbon goal, the green and low-carbon transition of China's energy structure has become an established trend, which objectively requires China to vigorously control and reduce the total coal consumption in the future, so as to promote the gradual transition of coal from the main energy status to the basic, and security status, which constitutes a serious contradiction with the objective reality that China's increasing energy demand will still be met by the use of coal in the future. China's energy supply and demand balance will be impacted, and energy security will face severe challenges. How to implement both breakthroughs, maintain the rhythmic coordination between the reliable replacement of clean energy

and the gradual exit of coal, and ensure the security of China's energy supply, this will be a major challenge during the process of China's coal reduction.

China's Coal-Fired Power Units Are Generally New and Early Decommissioning Faces a High Risk of Stranded Assets

China's power sector consumes a large amount of coal, and the decommissioning of coal-fired power units is its main direction for coal reduction. The power industry is an industry with the largest proportion of coal consumption in China. By the end of 2021, China's full-caliber coal-fired power generation capacity was 5.03 trillion kWh, accounting for 60.0% of the total power generation capacity [22]. Due to the high carbon lock-in effect of coal-fired power, the locked-in emissions of China's coal-fired power after 2018 are 102.3 (43.9–147.3) Gt CO₂, which will accumulate a large amount of carbon emissions in the future [33]. Therefore, the gradual decommissioning of coal-fired power units will become the main planning direction for coal exit and carbon reduction in China's power sector.

However, China's current coal-fired power units generally have a relatively short service duration and are far from reaching the decommissioning age. Early decommissioning will result in huge stranded assets, which will be prone to lead to conflicts of interest and financial risks. In 2020, the average service Duration of China's active coal-fired power units was only 11 years, of which more than 75% of the coal-fired power units had been in service for less than 15 years (see Fig. 8) [34], which is much lower than the average design life of 30 years. Under the scenario of early decommissioning of coal-fired power units, the assets with the remaining life will become to huge stranded assets, with a value of several trillion yuan, which will make coal-fired power companies face huge investment losses and cause disputes between companies and the government, and stimulate strong opposition from coal-fired power investors to coal reduction measures. At the same time, since coal-fired power plants require a relatively high level of upfront capital investment, which usually requires the participation of financial institutions, the huge amount of stranded assets will also have an adverse impact on the asset quality of relevant financial institutions, resulting in credit default risks, and may even cause a macroeconomic crisis, affecting financial stability [35].

The High Correlation Between Coal and the Industry in China Increases the Difficulty of the Coal Reduction

The coal industry is an important basic industry in China and has a high correlation with heavy industries such as electric power, steel, building materials, and chemicals. In 2020, the cumulative coal consumptions of the above four industries in China were 2.19 billion tons, 730 million tons, 490 million tons and 290 million

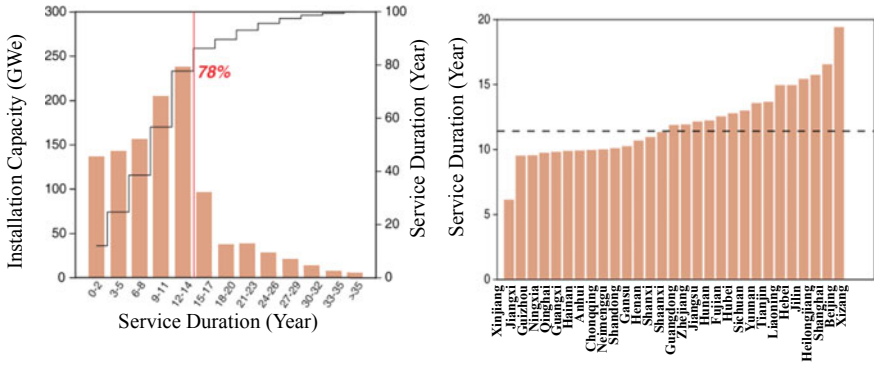


Fig. 8 Distribution of installed capacities and service durations of China’s active coal-fired power units and average service durations by province (autonomous regions and municipalities directly under the Central Government) in 2020 (the black dotted line on the right represents the national average service duration). *Source of Data* Global Energy Infrastructure Emissions Database

tons, respectively.⁶ In view of the high correlation between coal and the industry, the China’s coal reduction process means not only a strict control on the coal production capacity and consumption, but also a systematic project closely related to the transformation of the industrial structure. The production reduction of the coal industry shall not only meet the objective requirements in the coal reduction process, but also ensure the coordination with the reduction of coal consumption of its main downstream users to a certain degree. While maintaining the economic competitiveness of the downstream industry, it is also necessary to promote the green transition and upgrading of the industrial structure. At present, although some green manufacturing technologies in the industrial field have developed significantly, such as hydrogen energy steelmaking, electrolysis hydrogen production, etc., a series of green industrial products have been derived. However, these technologies face problems such as high costs and immature technologies, so they are impossible to replace the coal consumption in the industry to a large extent, and the derived green products have not yet developed enough market shares to bring enough market profits for industrial enterprises to maintain their competitiveness. Therefore, the high correlation between China’s coal and the industrial sector has increased the difficulty of China’s short- and medium-term coal reduction, and posed higher requirements for China’s coal reduction process. It is necessary to achieve the coordinated development of the coal and related industries.

⁶ Energy bureau: The proportion of coal consumption will fall below 56% this year. http://fjlib.net/zl/fjstsgjcx/jjzd/202104/t20210425_451104.htm.

The Coal Reduction Process May Bring About Social Justice Issues

The issues of re-employment and corporate subsidies will arise in coal and related industries, following the implementation of the coal exit policy. During the 13th Five-Year Plan period, China's coal industry withdrew 1 billion tons of outdated production capacity and had to re-employ about 1 million workers [36]. Those labors generally had relatively single skills, weak competitiveness, and poor adaptability to the transformation. They were less attractive to the enterprises in other industries, and had less space to be absorbed and re-employed through the job transfer training. Under the background of the dual carbon goal, the number of coal mines in China will constantly decrease, if such a traditional method is adopted, namely the redundant labors are to be arranged to continuous mines or contracting projects for re-employment, the difficulty is continuously increasing. Meanwhile, the coal exit process will inevitably have an impact on the coal production and coal-fired power companies, which may result in their early exit.

Coal resources and related industries in China are unevenly distributed. The regional difference caused by coal exit needs to be attached importance. China's coal resources are unevenly distributed. In the regions with rich coal resources, such as Inner Mongolia and Shanxi, the coal industry is usually an important pillar for economic development, and is crucial to local fiscal revenue, employment and social stability. Under normal circumstances, the coal-substituting industries in these regions emerged relatively late as their excessive reliance on the coal industry, so they have no advantages in terms of technological level and costs, as the results, no scaled substituting industries have formed there. In this case, the coal-based regions will be more affected and have larger fluctuations than other regions in terms of the economic development. Furthermore, these regions will face higher pressure from the adjustment in the industrial structure, local finance and employment structure [37].

2.2.4 Suggestions on China's Green and Low-Carbon Energy Transition

In general, China should, based on the basic national conditions with the coal-dominated energy structure, carry out the green and low-carbon energy policies in a reasonable and orderly manner on the premise of ensuring the energy security. To achieve the goals, we should follow the principles of exercising nationwide planning, prioritizing conservation, leveraging the strengths of the government and the market, coordinating efforts on the domestic and international fronts, and guarding against risk, while adhering to the concept of establishing the new in advance before abolishing the old, to seek progresses in stability. The gradual exit of traditional

energy should be established on the basis of the new energy's security and reliability.⁷ On the one hand, we will effectively promote the substitution, transition and upgrading of coal consumption, appropriately speed up the pace of coal reduction [38], to successfully achieve the transformation of coal from its main status in China's energy structure to a basic and security status. On the other hand, we should vigorously develop renewable energy, effectively increase the proportion of renewable energy in the primary energy structure, and rapidly achieve transition and development to a clean, reliable and efficient green modern energy system.

It is necessary to properly handle the energy demand during the process of low-carbon energy transition in the future, and to realize that the new energy demand is mainly met by renewable energy. China's medium-high economic growth will face rising energy demand, which will bring a lot of investment opportunities. Renewable energy investment projects should be prioritized among investment projects with potential stable growth, and capital flows should be actively guided to the field of renewable energy through policy means, to promote technological innovation in renewable energy, and to accelerate the construction of the integrated energy system covering "source, network, load, and storage and use", thereby improving the supply capacity of renewable energy to mainly meet the rising energy demand brought about by economic development. Traditional fossil energy as backup energy like coal, only plays a role in making up for a small amount of energy demand gap. Through these measures, the benign synergy between China's economic development and energy transition will be realized.

Effectively strengthen the coal-fired power flexibility transition process by means of technology, market and so on, and gradually promote the coal-fired power to be replaced by renewable energy power generation and achieve its transition from its dominant status to the basic and security status. On the one hand, technical innovation should be actively used to effectively enhance the peak shaving capability of coal-fired power units and improve the flexibility and regulation of thermal power, which can not only promote the orderly reduction of coal power generation based on the rapid growth of renewable energy generation, but also is expected to ensure the stable exit of most coal power units after their operation to a reasonable life (20 or 30 years), thereby effectively avoiding the risk of asset stranding caused by early retirement of coal power units. On the other hand, it is necessary to fully reflect the capacity value and adjustment service value of coal-fired power units through policies such as compensation and transaction of auxiliary services in the power market, so that coal-fired power enterprises can obtain the same value of income, thereby guiding more coal-fired power units to be involved in the flexibility transformation, making the coal-fired power units give full play to the capacity effect, effectively making up for the intermittent and fluctuating problems of renewable energy power generation, and exactly improving the consumption capacity of renewable energy.

⁷ An important speech delivered by Xi Jinping and Li Keqiang at the Central Economic Working Conference. http://www.gov.cn/xinwen/2021-12/10/content_5659796.htm.

The energy transition process along the entire industrial chain should be planned systematically to avoid the disconnecting of the upstream and downstream industries. The energy transition is a systematic project involving all industries in the entire industrial chain. The coal reduction of the coal industry should be coordinated and consistent with the coal saving and consumption reduction, energy efficiency improvement, green fuel substitution and green process innovation, as well as production capacity expansion of the renewable energy industry in the downstream high-coal-consuming industries. The transition process between various industries should complement and promote each other, so as to avoid the negative impact on the entire industry chain due to the inconsistent pace of transition. Under the condition of maintaining the continuous development of the core competitiveness of each industry, we should effectively promote and realize the high-quality green transition of all industries.

To achieve fairness and equity in the green and low-carbon energy transition, the following measures should be taken. Firstly, multiple strategies should be adopted to promote economic diversification in coal-producing areas and improve the “hematopoietic function” of affected areas. Consideration should be given to the reuse of coal assets, for example, the abandoned mines are used for CCUS, energy and hydrogen storage, cold chain refrigeration, etc.; the infrastructure advantages of coal production areas should be fully utilized, combined with specific location factors and business environment background, to achieve local economic diversification, such as developing warehousing and logistics centers, new industrial parks, tourism services and other industries. The combination of the coal industry and emerging strategic industries should be promoted, especially those related to new energy and energy efficiency, to minimize sunk assets in the coal industry, and identify opportunities for value transfer; **Secondly, the re-employment and re-settlement mechanism for coal workers should be improved.** The re-employment and re-settlement should be solved according to the factors like the education level, age, and local economic development situation, which are helpful to more accurately identify the different needs of the people facing re-employment problems. For the regions with difficulties in local re-employment, it is necessary to strengthen the construction of re-employment training institutions, especially the construction of cross-regional re-employment service platforms; for the employees with special economic difficulties, or the weak and disabled employees, they should be supported with priority to ensure they enjoy the social security, medical care, pension and other security mechanisms; for the personnel with low education levels or difficulties in changing jobs, they shall be given priority to have employment opportunities such as e-commerce and community services; it should be considered to use the taxes and profits of the coal industry, along with the central transfer payments to establish a special assistance fund for the people who are seeking re-employment and resettlement; and **thirdly**, we should provide financial assistance to coal and related enterprises that are negatively impacted in the transition process to make up for their economic losses through policy guidance.

The low-carbon energy transition has the risk of exacerbating gender inequalities, but may also bring an opportunity to enhance gender equality. In the coal industry,

decision makers and the majority of the workforce are dominated by men. The implementation of coal exit as well as the development of alternative energy and its related emerging industries, will provide females with more employment opportunities and make it possible to reduce the male-dominated lock-in effect in the energy industry. However, ignoring gender equality considerations in the transition process may further exacerbating inequalities between men and women in the job market and the provision of free domestic work.

3 Strengthening the International Cooperation to Promote the Low-Carbon Energy Transition Under the Belt and Road Initiative

3.1 *Current Situation of Low-Carbon Energy Transition in the Belt and Road Countries*

3.1.1 **Current Situation of Economy, Energy and Emissions in the Belt and Road Countries**

The Belt and Road countries have huge population bases and relatively low levels of economic development. In 2018, the population of the Belt and Road countries accounted for 64% of the world's total population, while the GDP accounted for only 39% of the world's total GDP, which formed a large contrast with the huge population base of more than 60% (see Fig. 9). The IMF data clearly shows that the economic growth prospects of the Belt and Road regions far exceed that of North America or Europe. Even if the predicted growth rate of the Belt and Road regions is halved, it will not be lower than that of North America or Europe, which means that for a period of time in the future, the Belt and Road regions will become an important engine driving the world's economic growth.⁸

The total energy consumption of the Belt and Road countries is relatively high, and the fossil energy remains the dominant energy source, so the low-carbon energy transition is imminent. In 2018, the energy consumption of the Belt and Road countries accounted for 58% of the global total, and the fossil energy was the main source (see Fig. 9). It should be noted that coal has a high weight in the energy consumption structure of the Belt and Road countries. In 2018, the coal consumption of the Belt and Road countries accounted for 73.6% of the world's coal consumption, and the consumption of natural gas, oil and renewable energy basically was the same as that of the non-Belt and Road countries (accounting for 56.6%, 50.5% and 46.7% of the world's total energy consumption, respectively). Except for China, the energy consumption structure of the Belt and Road countries

⁸ Sina Finance, 2017. The Belt and Road will become a major engine driving the world's economic growth. <http://finance.sina.cn/zl/2017-05-15/zl-ifyfeivp5713360.d.html?from=wap>.

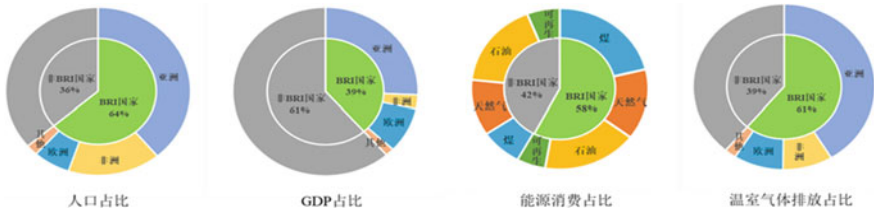


Fig. 9 Current situation of economic, social and energy emissions in the belt and road countries. *Source of Data* United Nations, World Bank, Energy Information Administration, Our World in Data

in Asia mainly consists of natural gas and oil, which account for 24% and 20% of the world’s total, respectively; the annual energy consumption of the Belt and Road countries in Africa is not high, but it is nearly about the same in these different countries. The averaged consumption of various energies accounts for about 3% of the world’s energy consumption, and that of oil accounts for the highest proportion, at 4.2%. The main energy consumed in the Belt and Road countries in Europe is natural gas, accounting for about 19% of the world’s total natural gas consumption. Renewable energy in the Belt and Road countries only accounts for 9% of total energy consumption. In 2018, the GHG emissions of the Belt and Road countries accounted for 61% of the global carbon emissions (see Fig. 9). If the Belt and Road countries do not change the traditional economic growth path highly depending on fossil energy, under the current rapid economic growth, they will become potential high-carbon lock-in areas in the future.

3.1.2 Current Situation of Energy Investment Cooperation of the Belt and Road Countries

China is the largest trading partner of the Belt and Road countries, and energy is the most important area for China to participate in the investment and construction of the Belt and Road. Data from the General Administration of Customs shows that in 2021, China’s total trade in goods with the Belt and Road countries was 11.6 trillion yuan, increasing by 23.6% compared to the previous year and creating a new high.⁹ It should be noted that in 2020, the import and export amount between China and ASEAN was 4.74 trillion yuan, with a year-on-year increase of 7%. For the first time, the two parties became each other’s largest trading partners.¹⁰ In 2021, China participated in the construction of projects in 144 Belt and Road countries, totaling about US\$59.5 billion (about US\$13.9 billion in investment and

⁹ People’s Daily Overseas Edition, 2022. Building the Belt and Road, following the Trend of Economic Globalization (hotspot dialogue). http://paper.people.com.cn/rmrhwb/html/2022-02/26/content_25905068.htm.

¹⁰ Foreign Economy, 2021. For the first time, China and ASEAN are each other’s largest trading partners. http://shanghaibiz.sh-ic.net/article/dwjywjw/202101/1508062_1.html.

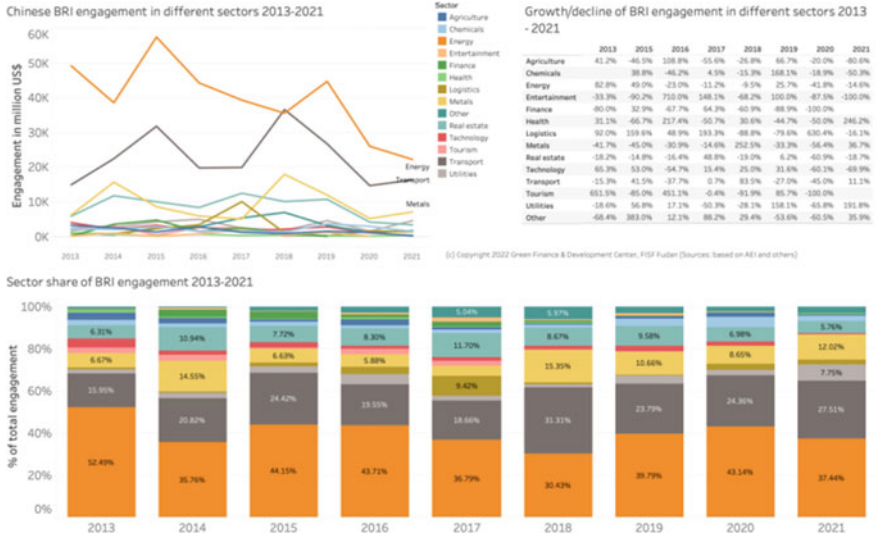


Fig. 10 Proportion of sectors in which China participated in the investment and construction of the belt and road regions from 2013 to 2021. *Source of Data* China’s Investments in the Belt and Road Initiative (BRI) in 2021

US\$45.6 billion in contracts) through financial investment and contractual cooperation. Among them, energy cooperation was the most important part of China’s investment and construction for the Belt and Road, accounting for 37.44% of the total investment and construction in 2021 (see Fig. 10) [39].

China’s participation in the investment and construction of the energy sector under the Belt and Road Initiative has gradually become cleaner, and renewable energy investment has become the main part. Since 2017, China’s renewable energy investment in the Belt and Road has gradually increased. In 2020, the proportion of renewable energy investment from China has reached 56%, becoming the main body of China’s energy investment in the “Belt and Road” countries. In 2021, Chinese President Xi Jinping promised in the general debate of the 76th United Nations General Assembly that China will no longer build new overseas coal-fired power projects. In the same year, China invested about US\$10 billion in renewable energy construction in the Belt and Road countries, which was mainly concentrated in solar and wind energy (31%) and hydropower (17%) (see Fig. 11).

3.1.3 Cooperation Mechanism for Energy Investment and Construction Between China and the Belt and Road Countries

Reach a consensus on development, cooperation and governance in the energy sector by virtue of dialogue mechanisms and platforms such as the Belt and

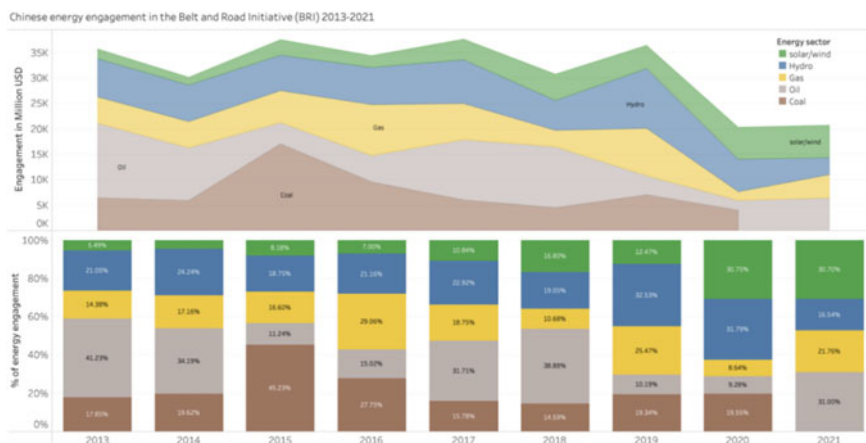


Fig. 11 China's energy cooperation in the belt and road regions by types from 2013 to 2021. *Source of Data* China's Investments in the Belt and Road Initiative (BRI) in 2021

Road Energy Ministerial Conference and the Energy Partnership. Energy cooperation is a key area in the joint construction of the Belt and Road. At the first Belt and Road Energy Ministerial Conference on October 18, 2018, China and other 17 countries jointly issued the *Joint Declaration on the Establishment of the Belt and Road Energy Partnership*. In March and April 2019, China and the member states under the partnership held two fruitful consultations, and reached a consensus on the establishment of the partnership, cooperation principles and practical actions. On April 25, 2019, during the 2nd Belt and Road Forum, 30 countries jointly established a partnership in Beijing. The partnership has become the first intergovernmental multilateral energy mechanism initiated by the Chinese government, providing a new platform for member states to solve problems faced by energy development and promote pragmatic cooperation in the field of higher quality, higher level and more sustainable energy. In December 2019, the first Belt and Road Energy Partnership Forum was held in Beijing, focusing on clean energy cooperation, aiming to promote the Belt and Road energy cooperation to deepen and solidify, achieve green development, and promote the implementation of energy cooperation demonstration projects. In December 2020, the 2nd Belt and Road Energy Partnership Forum was held in Beijing. With the theme of Green Energy Investment Promotes Inclusive Economic Recovery, the forum focused on global energy transition and green development after the outbreak of the pandemic, and promoted the inclusive economic recovery of the Belt and Road countries to achieve sustainable development goals.¹¹ On October 18, 2021, the 2nd Belt and Road Energy Ministerial Conference included an expansion ceremony and a cooperation network establishment ceremony, at which the *Charter on the Belt and Road Energy Partnership* was adopted, and the *Qingdao Initiative*

¹¹ Belt and Road Energy Cooperation, 2021. Special Report on the 2nd Anniversary of the Belt and Road Energy Partnership. <http://obor.nea.gov.cn/pictureDetails.html?id=2957>.

on Green Energy Cooperation for the Belt and Road and Best Practices in Energy International Cooperation was released.

Take pragmatic actions to promote the construction of energy infrastructure in the Belt and Road countries through project investment, engineering construction and other means, and gradually realize low-carbon transition.

Energy projects are the top priority of the China-Pakistan Economic Corridor, and it is also the field with the fastest progress and the most significant achievements. As of February 2020, 12 energy projects in the corridor have been in commercial operation or under construction, with a total installed capacity of 7.24 million kW, with a total investment of about US\$12.4 billion. The actual power generation of the corridor project in the 2018–2019 fiscal year was 17.728 billion kWh, accounting for 14.5% of the total power generation of the National Grid of Pakistan (NTDC), which can supply power for about 33 million people and provide more than 10,000 jobs.¹² The focus of energy cooperation between China and ASEAN is also shifting from traditional fossil energy to the investment and construction of renewable energy. In 2017, the *Vision and Actions for Promoting the Belt and Road Energy Cooperation* formulated by the National Development and Reform Commission of China and the Energy Administration pointed out that China will actively implement the China-ASEAN clean energy capacity building, and the new energy investment projects have gradually increased, and cooperation in renewable energy has become a key area [40]. China is a firm supporter of sustainable development in Africa, and the two parties have implemented hundreds of clean energy and green development projects within the framework of the Forum on China-Africa Cooperation.

Under the guidance of the concept of Urban Diplomacy, local governments in China have actively formed sister city cooperation agreements with important energy cities along the Belt and Road, and strengthened high-level visits and dialogues at the provincial level. Provinces and cities such as Xinjiang, Shaanxi, Ningxia and Gansu have concluded sister city cooperation agreements with many important energy cities along the Belt and Road. For example, Xinjiang has studied and formulated an implementation plan for participating in China-Kazakhstan, China-Tajikistan cooperation and the construction of the China-Mongolia-Russia Economic Corridor, and a total of 45 pairs of international sister cities have been established, including 7 pairs of sister cities with which Xinjiang has established the cooperation relationship with local governments at various levels in Pakistan, and it is the province with the largest number of sister city relations between China and Pakistan. Xinjiang Goldwind Science Technology Co., Ltd. has also become one of the first batch of Chinese wind power manufacturers entering Pakistan. Up to now, Goldwind has put 7 wind power projects in Pakistan into operation, which can provide more than 1.5 billion kWh of green power to the local area every year.

A number of capital financing projects have provided a solid financing platform for energy cooperation between China and the Belt and Road countries. Key financial institutions such as the Asian Infrastructure Investment Bank and the

¹² Belt and Road Energy Cooperation Network, 2020. China–Pakistan Energy Cooperation. <https://obor.nea.gov.cn/pictureDetails.html?id=2567>.

Silk Road Fund can provide long-term, stable and risk-controlled financial support for the Belt and Road regions. By the end of 2020, the AIIB had 47 climate-related investment projects, with a total investment and financing amount of US\$8.89 billion, accounting for 40% of the total scale, mainly in the energy sector. It also proposed that by July 1, 2023, all AIIB investment projects will be fully consistent with the relevant goals of the *Paris Agreement*, and will continue to increase the proportion of financing for addressing climate change. It is planned to achieve the goal that the proportion of climate financing reaches 50% by 2025. Its total cumulative climate financing is expected to reach US\$50 billion by 2030. Besides, China supports and encourages policy and development financial institutions to participate in the financial cooperation under the Belt and Road Initiative. The China Development Bank gradually assists the development of clean energy industry in partner countries by providing large and long-term financing services. According to statistics, by the end of 2018, it had released a total loan of US\$6.4 billion for the clean energy projects under the Belt and Road Initiative, of which the loans for renewable energy covered wind power, solar energy and other new energy utilization fields [41]. The Minas San Francisco Hydropower Station project in Ecuador supported by the Export–Import Bank of China has completed the final acceptance and handover in April 2021. According to the plan, it can provide 1.291 billion kWh of clean electricity every year, which will create more than 2000 jobs, meet the domestic electricity demand of about 1.2 million residents and the commercial electricity demand of 2000 production-oriented enterprises, and provide an important green energy guarantee for the social and economic recovery of Ecuador.

3.2 Low-Carbon Energy Transition Planning of the Belt and Road Countries

The Belt and Road countries are striving to improve their nationally determined contributions to achieve climate goals, and promote the global green and low-carbon energy by formulating relevant coal reduction and renewable energy development goals. With the continuous advancement of the global climate process, the Belt and Road countries headed by China are actively improving and striving to enhance their own Nationally Determined Contributions (NDCs), in order to achieve the goals of keeping global temperature rise within 1.5 °C and 2 °C by the middle of this century set in the *Paris Agreement* by driving their own active emission reductions. Meanwhile, along with the wave of global green and low-carbon energy transition, the Belt and Road countries have also accelerated the pace of coal exit and decarbonization of the energy system by establishing and formulating relevant energy strategic goals and plans, and vigorously developing renewable energy to improve and strengthen their proportion and position in the energy structure, and, are making efforts to promote the orderly construction and formation of a clean, low-carbon and efficient green energy system.

3.2.1 Nationally Determined Contributions (NDCs) of the Belt and Road countries

Most of the Belt and Road countries have set clear and quantitative emission intensity reduction goals in their Nationally Determined Contributions (NDCs), and most countries have proposed carbon neutrality or net zero emission goal. So far, except for Yemen and Libya, the other 147 Belt and Road countries have submitted their Nationally Determined Contributions (NDC) documents to the UNFCCC Secretariat. Table 2 shows the climate change mitigation goals proposed by the Belt and Road countries in their respective Nationally Determined Contributions (NDCs), which mainly include five types. Among the Belt and Road countries, the ones that proposed emission reduction goals relative to the baseline situation and the quantitative emission intensity goal relative to the baseline occupied the largest proportion, accounting for 69% of the Belt and Road countries. Only 5 countries have proposed absolute emission reductions, and another 6 countries have energy intensity reduction as their emission reduction goals. In addition, 21% of countries proposed a series of emission reduction actions instead of quantitative mitigation goals. Besides, so far, 128 countries in the world have proposed the carbon neutrality or net zero emission goals,¹³ including 93 Belt and Road countries which account for 73% of all. This fully shows that the Belt and Road countries are making efforts to actively improve its own emission reduction contribution.

3.2.2 Coal Reduction or Exit Plans and Goals in the Belt and Road Countries

The *Glasgow Climate Pact* was formulated at the COP26, which for the first time put forward clear requirements for countries to gradually reduce coal-fired power plants without installation of emission reduction facilities. In addition, more than 70 countries and organizations signed the *Global Coal to Clean Power Transition Statement*. Of the 70 countries, there were 32 Belt and Road countries, which fully demonstrates that the Belt and Road countries are actively participating and improving their own contributions to promote the global transition from coal to renewable energy. However, due to their own energy and economic development needs, most of the Belt and Road countries cannot completely get rid of their dependence on coal within a short period, and their coal reduction process still needs to be advanced steadily and orderly.

By mid-2021, 21 countries around the world have pledged to fully phase out coal within a fixed time frame, but they are mainly developed countries that are G20 and EU member states [42]. Schedule 1 lists the coal exit, coal reduction plans, goals and related policy documents of some Belt and Road countries. Among them, only European countries such as Italy, Portugal, Greece, Hungary and Slovenia have clearly set the target time for complete coal reduction (phasing out coal-fired power),

¹³ Net Zero Tracker. <https://zerotracker.net/>.

Table 2 Types of emission reduction goals in the Nationally Determined Contributions (NDC) of belt and road countries

Type of emission reduction goals	Countries
Emission reduction relative to baseline situation	Brunei, Cambodia, Kiribati, Philippines, Solomon Islands, Thailand, Vietnam, Indonesia , Iran, Iraq, Lebanon , Georgia, Salvador, Jordan, Palestine, Kyrgyzstan, Mongolia, Afghanistan , Bangladesh, Sri Lanka, Maldives, South Korea, Burundi, Comoros , Djibouti, Ethiopia , Kenya, Madagascar, Uganda, Benin , Côte d'Ivoire, Cameroon, Congo (Brazzaville), Ghana, Mali, Guinea-Bissau, Central Africa, Niger, Nigeria, Senegal, Sierra Leone, Chad, Togo , Angola, Lesotho, Tanzania , Zimbabwe, Algeria, Morocco, Albania, Bosnia and Herzegovina, North Macedonia, Turkey , Venezuela, Peru, Barbados, Costa Rica, Grenada, Jamaica, Panama, Trinidad and Tobago (61 countries)
Emission reduction relative to baseline year	Cook Islands, Federated States of Micronesia, Seychelles , Azerbaijan, Kazakhstan , Tajikistan, Gabon, Gambia , Equatorial Guinea, Mauritania, Zambia , Tunisia, Bulgaria, Cyprus , Czech Republic, Estonia, Hungary, Lithuania, Latvia, Malta , Poland, Romania, Slovakia, Slovenia, Austria, Greece, Italy, Luxembourg, Portugal , Belarus, Moldova, Ukraine, Croatia, Montenegro , Serbia, Russia , Dominica, Israel , Turkmenistan, Eritrea, Dominican Republic, New Zealand and Botswana (43 countries)
Energy intensity reduction	China, Malaysia, Singapore , Uzbekistan, Chile and Uruguay (6 countries)
Absolute emission reduction	Oman, Armenia, Guinea, Namibia and South Africa (5 countries)
Policy action	Fiji, Laos, Myanmar, Niue, Papua New Guinea, Timor-Leste, Tonga, Vanuatu, Samoa, United Arab Emirates, Bahrain , Kuwait, Qatar, Saudi Arabia, Nepal, Pakistan, Rwanda, Sudan, Somalia, Cape Verde, Liberia, Mozambique , Egypt, Guyana, Suriname , Bolivia, Ecuador , Syria, Antigua and Barbuda , Cuba, Democratic Republic of Congo and South Sudan (32 countries)
Non-NDC	Yemen and Libya (2 countries)
Carbon neutrality goal achieved	Bhutan (1 country)

Note Countries marked in bold are those that have proposed carbon neutrality or net zero emission goals

while most of the remaining countries set their coal reduction goals through policy documents, conference commitments, etc. Besides, such goals are all concentrated in the field of coal-fired power, and few countries have formulated clear goals and plans for comprehensive coal exit.

3.2.3 Renewable Energy Development Goals and Plans in the Belt and Road Countries

The Belt and Road countries generally begin to attach importance to the renewable energy development, and establish clear and quantified renewable energy development goals in national plans and policies, but they still face many problems and challenges. With the continuous innovation and popularization of renewable energy technologies and the continuous decrease of costs, the Belt and Road countries have gradually attached importance to the deployment and planning of renewable energy development, which have been reflected in relevant plans, policies and even legal documents. Schedule 2 lists the renewable energy development goals or plans of some Belt and Road countries. It can be seen that most countries have set clear and quantified renewable energy development goals. However, most of the Belt and Road countries are developing countries, and their renewable energy development faces many problems and challenges. All the countries still need to pay sufficient attention to these problems and challenges to ensure the healthy development of renewable energy. With ASEAN as an example, the high-speed growth demand brought about by economic development has led ASEAN countries to generally still rely heavily on traditional fossil energy, and the short- and long-term systematic plans for gradual reduction and exit of traditional energy are still unclear. Meanwhile, even though the cost of renewable energy in ASEAN is decreasing significantly, it still does not have a cost competitive advantage over traditional fossil energy. Except for Singapore, Brunei, Malaysia, and Thailand, other ASEAN countries generally have a low level of economic development, and will face a relatively large financial pressure to meet renewable energy growth by investment and financing in the future, so they need strong international financial support. In addition, the weak grid infrastructure of ASEAN countries also poses a lot of difficulties for the consumption and integration of renewable energy.

3.3 Risks and Challenges the Belt and Road Countries Face in the Low-Carbon Energy Transition

3.3.1 The Belt and Road Countries Face Many Challenges Such as Energy Security Risks, Asset Stranding, and Just Transition During the Process of Reducing the Use of Fossil Energy Such as Coal and Realizing Low-Carbon Energy Transition

Coal phase-out in the Belt and Road countries is the general trend, and more and more countries have given the schedule in terms of stopping the construction of coal-fired power projects. China, Japan, and South Korea are the top three financing countries for overseas coal-fired projects in the world, and they have all pledged not to build overseas coal-fired power plants anymore. In the face of changes in the macro

environment such as coal-fired power financing, fewer and fewer new coal-fired power projects are planned to be started. The Belt and Road countries, especially those countries with huge electricity demand and high dependence on traditional fossil energy such as coal-fired power, are facing many risks and challenges brought about by the transition.

Generally speaking, the Belt and Road countries are highly dependent on coal-fired power. If the green and low-carbon transition cannot be advanced in an orderly and stable manner, it may lead to energy security risks in these countries. According to data from the BP World Energy Statistical Yearbook, as of the end of 2020, the coal-fired power plants in 79 countries around the world were still in operation, and among them, there were 37 the Belt and Road countries.¹⁴ The regions with a large proportion of coal-fired power in the Belt and Road countries are mainly concentrated in Asia, and the proportion of coal-fired power in the countries like Indonesia, Malaysia, Vietnam and Kazakhstan is more than 50%. The coal-fired power generation in South Africa accounts for more than 85% of the total electricity supply. Besides, from the perspective of final power consumption, the electrification level will be greatly improved after the energy transition. Even under the same conditions of the whole society's energy consumption, the whole society's electricity consumption will also increase significantly, forcing the power supply side to provide more electricity, as the result, both the installed capacity and power generation capacity of the power system in China will increase significantly, and the accelerated exit of coal-fired power will further increase the mismatch between energy supply and demand and aggravate the risk of energy supply security.

The high cost in asset stranding following the exit of fossil energy may affect macroeconomic development. The gradual reduction of traditional fossil energy will break the original pattern of energy investment, production, and consumption, and reshape the industrial chain and supply chain in the green and low-carbon energy transition. Which will cause that the market supply and demand are mismatched or misaligned, resulting in risks of asset stranding and probably further leading to economic system risks. The global market value of fossil energy and related companies is about US\$18 trillion, accounting for 1/4 of the total market size; the relevant tradable bonds are about US\$8 trillion, accounting for 1/2 of the total market size [43]. It is estimated that about 59% of the global coal reserves under the 2 °C target will become stranded assets, while the proportion will rise to 84% under the 1.5 °C target [44]. A report released by the financial think tank Carbon Tracker pointed out that the global coal-fired power projects currently under construction or in the planning stage reached 499 GW, which may lead to stranded assets with a value of US\$638 billion, of which the value of the coal-fired power plants planned or under construction in Southeast Asia reaches a total of 78 GW, and the coal-fired power investment at risk is up to US\$124 billion [45]. China's current coal-fired power equipment is generally "young", with an average age of only 12 years. It is estimated that China's coal stranded assets may reach 3–7 trillion yuan [46]. In

¹⁴ Challenges from coal-fired power projects under the Belt and Road Initiative.

addition, the sharp falling in the profitability of traditional fossil energy companies will cause asset prices to collapse, which will potentially lead to huge debt defaults.

The exit of fossil energy will have an impact on traditional industries and trigger the challenge of just transition. The gradual reduction and exit of the fossil energy industry will have an impact on coal and other traditional fossil energy companies and workers, and cause social unemployment. Although energy creates more new jobs with the rapid development of the renewable energy industry, there is a mismatch in time, space and skills between job creation and job loss. When the traditional fossil energy industry is affected, and it is difficult for employment populations to fully find suitable positions in the newly created jobs. At present, the employment scale in China's coal industry is about 2.6 million people. According to estimates, under different scenarios, including policy and environmental factors, the employment scale in the entire coal industry will be halved by 2030, and may even be reduced to about 1 million people. In the long run, the number of employees in the entire coal industry may drop to 200,000 by 2050.¹⁵ South Africa has been extremely dependent on coal for a long time. Coal-fired power generation accounts for over 85% of South Africa's total electricity supply, and the employment of about 400,000 people is directly related to the coal industry [47]. In addition, due to the gap between energy supply and demand and the increase in energy costs, the increase in energy prices will lead to inflation when it is transmitted to the downstream, which will bring greater economic pressure to low-income populations and cause more social problems.

3.3.2 Challenges Faced by the Belt and Road Countries During the Process of Developing Renewable Energy

Most Belt and Road countries have abundant solar, wind, hydro, geothermal and biomass resources but their renewable energy development and utilization levels are relatively low. As the result, they will face many development obstacles such as policy, capital, technology, and environment during the process of promoting renewable energy.

Ambition is lack in the renewable energy development goals. The renewable energy development goals set by many Belt and Road countries are not enough to support the green and low-carbon energy transition. In the 2016–2025 cooperation action plan, ASEAN proposed that by 2025, the proportion of renewable energy in the primary energy supply structure will reach 23%, while Vietnam only plans that the proportion of renewable energy reach 21% of the total installed capacity by 2030. Lai plans that the proportion of renewable energy will be only 10% of the total installed capacity by 2035, which is lower than ASEAN's overall goal. Nigeria, Africa's largest economy, has set a target that its energy consumption from renewables will account for 10% of the total energy consumption by 2025, while South Africa, Africa's second-largest economy, has yet to set a clear goal. In addition, in the face

¹⁵ CNEnergyNews, 2020. Impacts of Coal Power and Coal Transition on Employment.

of economic recovery pressure, many countries will support fossil energy, which is set as the main content of the recovery plan.

Policy support to renewable energy is insufficient. The development of renewable energy requires support of relevant policies, such as price subsidies and power grid construction commitments. However, many Belt and Road countries lack support of relevant policies, which limits the development of renewable energy. The market consumption and pricing policy framework for renewable energy are not sound, affecting the “financeability” of renewable energy projects along the Belt and Road. Insufficient or frequent changes in feed-in tariff policy incentives make renewable energy development uncompetitive, while high feed-in tariffs in other countries have led to a surge in applications for specific types of power supply construction, and over-allocation has led to the termination of relevant incentive policies. In addition, most ASEAN countries still lack fully transparent land licensing procedures for renewable energy development. The procedures for acquiring, retaining and transferring land use rights are complicated. Long land acquisition periods and expensive acquisition fees also lead to project development delays and cost overruns [48]. The cumbersome and lengthy project permitting process, changing policies in the short term and unclear guidelines for grid-connected renewable energy generation have resulted in low investment efficiency in the industry, and the cost of solar and wind energy development in Southeast Asia is still higher than that in many other regions.

Insufficient funding restricts the development of renewable energy in the Belt and Road countries. According to the World Energy Outlook 2020 report released by the International Energy Agency, in 2021, the investment needs of the solar energy industry in Africa region in the south of Saharan alone will reach US\$ 6 billion, and there is a large funding gap. Vietnam has planned and approved a number of renewable energy projects, but the conversion rate is very low due to insufficient funding. Most projects are funded through international banks, and local banks only participate in project investment by providing guarantees. At present, Vietnam can only provide funds for renewable energy projects with an installed capacity of 1000–2000 MW, and there is still an urgent need to solve the financing of renewable energy projects with an installed capacity of 10 GW [49]. Due to financial constraints, there is no funding to replace existing thermal power plants, forcing these countries to maintain the current situation of energy development. In addition, investment and financing difficulties also restrict the development of renewable energy in the Belt and Road countries. Some Belt and Road countries have huge debts or weak power purchasers, and it is often difficult for renewable energy projects to obtain sovereign guarantees from host countries, which increases financing costs [34].

Insufficient renewable energy technologies and weak R&D capabilities for key core technologies cannot yet support the green and low-carbon energy transition. Renewable energy technology constraints are one of the main obstacles to the development of renewable energy in the Belt and Road region. ASEAN has certain deficiencies in innovation of renewable energy technologies, and the related photovoltaic technology and wind power technology capabilities are still weak, which restricts the development of renewable energy in ASEAN countries. Meanwhile, the current national grid foundation along the Belt and Road is not strong, the grid

structure of the countries along the route is weak, there are few high-voltage lines, and the power interconnection between countries is limited, which makes it difficult to achieve power grid connection and transmission of large-scale renewable energy [41]. For example, a unified power grid has not been formed among the islands of Indonesia, and areas with abundant resources but limited consumption capacity cannot transmit clean renewable energy power to areas with large power demand, which limits the development of renewable energy.

Inconsistent standards hinder international cooperation in renewable energy under the Belt and Road Initiative. Standardization is one of the main obstacles restricting Chinese companies to participate in renewable energy investments in the Belt and Road countries. Most the Belt and Road countries have mandatory requirements for equipment and products made in China to be imported only after certification, and only international standards are recognized as the construction standards. Therefore, wind power and photovoltaic enterprises have to pass the international certification for their products to be used in the overseas investment. In addition, they also have to pass different certifications due to different requirements of various countries. For example, the standards of African French-speaking regions, English-speaking regions and Portuguese-speaking regions are different, which has greatly hindered international cooperation in renewable energy [50].

3.4 Suggestions for Cooperation in Low-Carbon Energy Transition Under the Belt and Road Initiative

The Belt and Road countries should adopt a gradual low-carbon energy transition strategy based on their national conditions. **Firstly**, explore and formulate a schedule for the exit of fossil energy and specific goals in terms of the development of renewable energy according to local conditions, so as to provide macro guidance for the orderly exit of fossil energy and the reasonable substitution of renewable energy. **Secondly**, strengthen the clean and efficient utilization of fossil energy for a large number of existing fossil energy infrastructures, such as promoting the popularization and application of technologies such as the efficient coal combustion power generation technology, clean coal combustion technology, biological carbon sequestration and chemical carbon sequestration. **Thirdly**, design a package of policy systems with the systemic and synergistic policies considered, including the overall financial and technical guarantee policies, as well as the electricity market price stabilization policies, and the renewable energy subsidy support policies.

Carry out international cooperation in clean energy technology under the Belt and Road Initiative. **Firstly**, clarify the clean energy technology needs of different Belt and Road countries. **Secondly**, provide targeted technical cooperation programs according to the resource conditions and development conditions of different countries. In this process, we should attach great importance to providing

“small but beautiful” clean energy project solutions, and promote “big cooperation” with “small projects”. **Thirdly**, strengthen the capacity building through joint research and development, joint training of talents, etc., and effectively improve the technical level of international renewable energy development in the Belt and Road regions. **Fourthly**, strengthen the summary of China’s clean energy technology development experience, provide technical practice with reference significance, and deepen international cooperation in clean energy technology.

Deepen the promotion of green investment and financing cooperation under the Belt and Road Initiative. Improve the negative list system for overseas investment, and further strengthen the climate and environmental factors in overseas investment and financing policies. According to local conditions, develop green investment and financing tools suitable for developing countries participating in the Belt and Road Initiative, encourage innovation in green investment and financing products and services, and promote the establishment of green investment and financing standards applicable to the Belt and Road Initiative. Attach importance to ensuring fairness and justice in the green upgrade and transition process of traditional industries in the Belt and Road countries through emerging concepts and tools such as transformational finance. Explore debt conversion methods such as “debt-to-nature”, provide funds for vulnerable countries that are deeply troubled by climate change and environmental degradation, and support a green recovery in the post-pandemic era. In addition, support the construction of carbon markets of the Belt and Road countries, explore the Belt and Road carbon market linkage mechanism, and promote green and low-carbon transition with lower emission reduction costs.

Strengthen the awareness of fairness and inclusiveness in the transition process, and actively promote the just energy transition in the Belt and Road countries. **Firstly**, the Belt and Road countries should formulate their overall strategic plan for just energy transition from the overall strategic system layout, systematically plan the transition goals, technological innovation, talent training and other aspects of each region and industry, and ensure that all citizens share the benefits and costs brought about in the transition process. **Secondly**, for fossil energy and related enterprises that have been negatively impacted during the transition process, a just transition fund should be established, and corresponding subsidies should be given to help them alleviate the economic losses caused by the transition. At the same time, additional technical and talent support should be given to enterprises with transition potential. For the redundant unemployed labor force generated in the transition process, it should be properly resettled and retrained to the sustainable development industry, and they should actively guide alternative industries and emerging industries to create new employment opportunities to fully accommodate and accept this part of populations.

Strengthen the in-depth integration between the Belt and Road Initiative and relevant international cooperation initiatives, to jointly promote the process of low-carbon energy transition in the Belt and Road countries. We should actively promote the in-depth integration between the Belt and Road initiative and the European Union’s “Global Gateway” program and the US’ Build Back Better World initiative and other regional cooperation initiatives, to achieve open cooperation and

exchange in energy transition to a wider and larger field and deeper level. China, the United States, Europe and other parties should increase discussions on energy transition issues in their climate cooperation with the Belt and Road countries, actively share successful experiences and best practices during the process of energy transition, and give full play to their respective strengths in technology, capital, and talent. and other aspects, form a multi-party synergy effect, give full play to multi-party synergy, effectively enhance the capacity building of the Belt and Road countries in energy infrastructure, renewable energy technology, etc., and jointly promote the green and efficient transition of the Belt and Road countries in the energy field, to achieve multi-party mutual benefit and win-win situation.

4 Analysis of Gender Mainstreaming

Gender equality is a fundamental human right, so male and female alike should be treated equally in politics, economy, society, and family, as well as in mitigating and adapting to climate change. Failure to take gender equality into account in tackling climate change and a lack of supporting measures will limit women's full participation and contribution in this regard. What's more, if the perspectives and demands of women are not fully expressed or reflected, the corresponding solutions will not be gender-responsive, which may result in further gender inequality. In climate-related policy-making, not only do we need female leadership and perspectives, but also consider the situations bothering women, such as violence, demands for medical service, weak economic resilience, unpaid housework, etc., so that their predicament wouldn't be neglected because of single perspective. A synergy between gender equality and sustainable development is necessary.

At the 23rd session of the Conference of the Parties (COP23) to the UN Framework Convention on Climate Change in 2017, Parties adopted the Gender Action Plan and asked the Parties, subsidiary bodies, the UN organizations, observers, and other stakeholders to participate in the implementation of the Plan in order to incorporate gender-related issues into each and every aspect of climate action. In February 2020, at the 52nd Plenary Session of Intergovernmental Panel on Climate Change (IPCC), the expert panel adopted Gender Policy and Implementation Plan which aimed to improve gender equality and promote gender-inclusive environment. The Paris Agreement also mentioned gender equality and regarded it as one of the many issues that needed to be considered while taking actions on climate change. In NDCs in 2016, 64 Parties mentioned women or gender. When countries submitted new or updated NDCs, most included a reference to women and gender, indicating improved recognition and willingness to deal with the issue of gender equality in climate action.¹⁶

¹⁶ Quick Analysis—Gender Climate Tracker. <https://genderclimatetracker.org/gender-ndc/quick-analysis>.

Gender equality is part of China's basic national policy. In order to improve women's position and promote gender equality, China attaches great importance to ensuring equal opportunities for women and their equal participation in economic activities, employment, and starting business.¹⁷ In Outline for the Development of Chinese Women (2021–2030), Women and Environment was identified as one of the eight themes. However, China's gender awareness in environment and climate is not prominent enough, and there's still a gap between China and the international community which is experiencing neck to neck development in both gender and environment. Strengthening gender equality considerations and measures in environment and climate will, on the one hand, promote China's progress in realizing gender equality and provide multiplication effect for sustainable development, on the other hand, significantly improve China's international image. In this section, we propose three specific aspects which are major and practical to integrate gender equality and climate action in China.

4.1 Give Full Play to Women's Role as Participants and Facilitators in Climate Work and Enhance Women's Climate Leadership

At the Glasgow Climate Change Conference (COP26) in 2021, Glasgow Women's Leadership Statement¹⁸ was jointly released by the Scottish Government and UN Women, calling for the role of women and girls to be advanced in addressing climate change. Only ten of the 140 heads of delegations at COP 26 were women. Women are underrepresented in global governance systems for climate and environment. In 2020, just 15% of environmental ministers globally were women,¹⁹ and female employees only took up an average of 1/3 in public administration.²⁰ None of the seven leaders of Ministry of Ecology and Environment of the People's Republic of China is female.²¹

¹⁷ Women, U. N. "Gender Dimensions of Vulnerability to Climate Change in China." (2016).

¹⁸ Gender equality and climate change: Glasgow Women's Leadership statement. <https://www.gov.scot/publications/glasgow-womens-leadership-statement-gender-equality-climate-change/>.

¹⁹ Gender Equality Today for a Better Tomorrow. <https://www.cn.undp.org/content/china/zh/home/ourperspective/ourperspectivearticles/2022/gender-equality-today-for-a-better-tomorrow.html>.

²⁰ Gender Equality in Public Administration. <https://www.undp.org/publications/global-report-gender-equality-public-administration>.

²¹ Organization of the Ministry of Ecology and Environment of the People's Republic of China. <https://www.mee.gov.cn/zjhb/>.

Giving full play to women's leadership is vital in alleviating and addressing climate change. Rural areas are highly dependent on natural resources, therefore the impact of climate change bears on the livelihood of local people. Women, as a major part in agricultural production and household labor, are relatively more vulnerable to climate change. And actions on mitigating and tackling climate change will also exert more impact on them. As a group most significantly influenced by climate change, women should be fully represented in decision making of alleviating and addressing climate change. Only by empowering women can we better realize sustainable development and poverty alleviation.

UNFCCC encourages Parties to appoint and provide support for a National Gender and Climate Change Focal Point (NGCCFP) for climate negotiations, implementation, and monitoring. With the support of UNFCCC, NGCCFPs can achieve gender mainstreaming in climate work by the following effort²²:

- Awareness-raising and capacity-building within the delegation and/or at a national level on gender and climate change issues
- Point-of-contact within the delegation for questions on thematic issues e.g., climate finance and gender
- Coordination of the delegation's positions on gender within the gender and climate change agenda item and other thematic areas
- Coordination at the national level for climate planning e.g., between ministries on climate change and those dealing with gender, and to better connect the UNFCCC process to national process
- Participation in networking and capacity-building events organized by other entities in support of the UNFCCC progress e.g., WEDO, UN Women, IUCN etc.
- Point-of-contact for the secretariat (and others) to communicate about relevant events, information, training etc.
- Raising awareness and tracking progress on gender-responsive climate plans and communication (NDCs, NAPs, national communications etc.)
- Tracking progress on the delegation's goals on gender balance at UNFCCC and other meetings
- Advocating for gender balance in the delegation's or Group's nominations to constituted bodies and Bureaux.

NGCCFPs can effectively enhance their nations' capacity building in gender and climate change and help to incorporate gender into climate work. Up to now, 94 Parties have nominated their respective NGCCFP, excluding China. China's nomination of its NGCCFP will be a simple but effective and meaningful step in promoting gender mainstreaming in climate work.

²² Capacity Building and Training Needs of National Gender and Climate Change Focal Points. https://unfccc.int/sites/default/files/resource/NGCCFP_WebinarPPT_ChineseSim.pdf.

4.2 Promote Just Transition, Ensure Women's Equal Participation in Job Market, Achieve Win-Win Results in Low-Carbon Energy Transition and Promotion of Gender Equality

Just Transition is a framework to encompass a range of social interventions needed to secure workers' rights and livelihoods when economies are shifting to sustainable production, primarily combating climate change, and protecting biodiversity,²³ and it has been highlighted in the discussion on energy transition policies. In green transition, Just Transition aims to share the interests of transition and to support those participants who suffer economic loss, be it nations, regions, industries, communities, workers, or consumers. It should be noted that women, as a vulnerable group, are likely to suffer in the transition. In just transition, not only should we pay attention to laid-off workers in phased out industries, but also focus on female group affected by the transition.

Systematic transformation of economic structure is required to realize carbon neutrality, which will in return change the job market in a fundamental way, resulting in both risks of gender inequality and opportunities to promote gender equality. Take conventional industries with high carbon intensity like coal industry as an example. Originally, they are male-dominated industries with men as the major decision makers and labor force. However, the trend to withdraw coal and to develop alternative energy and relevant emerging industries brings about opportunities to reshape women's position in the job market and eliminate the lock-in effect in male-dominated energy sectors. According to the statistics from International Labour Organization (ILO), measures taken by energy sectors to limit global warming to 2 °C by the end of this century will create some 24 million jobs which will to a large extent offset job losses.²⁴ Men and women should have equal access to new jobs in emerging green industries, especially those that haven't been regarded as male arenas, including many technical positions and work related to climate change mitigation and adaptation policies and initiatives.²⁵ We have to make sure that gender inequality in traditional energy and industry sectors will not be shifted to the emerging green economy. Neglecting of gender equality in transition may lead to exacerbated inequality between men and women in job markets and unpaid housework.

To ensure equal job opportunities for women in emerging industries, there should be equal coverage of trainings for both male and female groups in the jobs. Reemployment trainings for former employees from phased out high-carbon industries are of great importance. However, if the reemployment is still male dominated, there will still be risks for male-dominated lock-in effect in the emerging industries. Therefore,

²³ Wikipedia: Just Transition. https://en.wikipedia.org/wiki/Just_transition.

²⁴ Bureau international du travail. World Employment Social Outlook 2018: Greening with Jobs. International labour office, 2018.

²⁵ Pearl-Martinez, R. "Women at the forefront of the clean energy future." Washington, DC: United States Agency for International Development (2014).

unemployed female groups should be equally covered in the trainings. Moreover, we need to promote gender equality education, carry out women's capacity-building programs, and improve the awareness and recognition of women in positions for green transition, especially their leadership positions. Policy and decision makers should make sure there's no gender discrimination whatsoever in policies for employment and capacity development in green positions. Meanwhile, businesses and other organizations should ensure high inclusiveness in recruitment.

Those who lost their jobs because of transition should be settled appropriately. Unemployment and poverty will squeeze space for women to survive and thrive, and a lack of resources and skills will not only force them to take more unpaid household service but also may exacerbate such issues as domestic violence. Just Transition will have positive influence on promoting gender equality from all perspectives, and special attention to female group during the transition will further enhance gender equality construction.

4.3 Take More Account of Social Impact in Overseas Green Investment and Aids, Conduct International Cooperation on Gender Equality, and Give Play to China's Leading Role in Global Climate Governance

Overseas investment and aids have not only an economic impact on the host country, but also significant social and environmental influence. Currently, China's overseas investment and aid projects, especially the green ones, have already had comprehensive consideration and recognition of the environmental impact; however, its understanding and management of the social impact is still at preliminary stage. When it comes to gender, we should focus on preventing harms to women and protecting the basic rights and interests of female workers in the construction of overseas investment and aid projects. Besides, contributions of the projects to bridging income gaps between genders and alleviating unequal social positions should be considered. Taking gender into account in those projects will promote the host country's social development, avoid project risks caused by harm to the vulnerable groups, and is conducive to improving China's international reputation as a responsible power.

So far, climate finance has taken little account of gender. Only 1.5% of climate-related ODA identified gender equality as a primary objective, while 2/3 of the projects and plans failed to consider gender equality in design, budget, and implementation. And only 0.2% of the ODA realized women's leadership and established women's organizations.²⁶ In China, however, there hasn't been any official policies or guidance in this regard.

In China's overseas green investment and aid projects, gender mainstreaming should be integrated into project objectives or evaluation indicators. At early stage,

²⁶ CLIMATE FINANCE SHADOW REPORT 2020. <https://oxfamilibrary.openrepository.com/bitstream/handle/10546/621066/bp-climate-finance-shadow-report-2020-201020-en.pdf>.

we should at least adhere to the principle of “do-no-harm”, i.e., to identify and avoid negative impact related to gender caused by the projects, and compensate for unavoidable impact; for example, we should avoid employment discrimination and unequal payment, avoid exacerbated inequality in men’s and women’s positions as well as gender-based violence. At later stage, we should take account of the projects’ contribution to promoting gender equality (do-good), for example, promoting equal employment, equal pay for equal work, equal right of speech and decision-making, as well as equal possibilities for individual development, etc.

5 Policy Recommendations

5.1 Synergistically Promote Steady Growth and Green Development, Inject New Drivers into China’s Economic Growth

First, remain committed to the overall strategy of green development, especially under the complicated and evolving international and domestic situations. Jointly pursue the goals of economic growth, energy security, environmental quality, climate protection, etc. A new Industrial Revolution based on low-carbon energy technology will be a breakthrough to jointly achieve green development and stabilized growth. The conventional tools to boost the economy based on projects with high energy consumption and high emission should come to an end. Instead, we should give full play to China’s advantages from its systems and institutions, market scale and economic resilience, as well as in new energy equipment manufacturing. Concrete efforts should be made in expanding green investment and consumption in such areas as the digital upgrading and green transformation of traditional industries, green and low-carbon urbanization and consumption, renewable energy, new power system construction and so on, so that investment related to carbon neutrality can be stimulated and provide significant momentum for economic growth by the middle of this century (direct investment in China’s carbon neutrality will reach at least 140 trillion RMB by 2050).

Second, remove the barriers to green growth investment and make them the new economic drivers for development in the short, mid, and long run. In the short term, we should prevent and control the epidemic in a well-targeted and scientific way, and actively expand green consumption through measures like financial support and consumption policy reform. Infrastructure investment in such areas as new energy can be made in advance in a moderate manner to drive economic growth. In the mid and long term, we should clarify emission reduction goals in different phases, set up stable expectations for investors and technology developers, accelerate the establishment of carbon pricing system, and guide investment towards emission reduction.

5.2 Accelerate Low Carbon Energy Transition Under the Premise of Energy Security

First, accelerate the investment in the construction of the new energy system (especially new power systems) with renewable energy as the key. Pilot projects and application of integrated energy systems should be sped up in different regions, which focus on renewable energy and integrate “power supply, power grid, power load, energy storage and utilization”. Further research in pilot projects and solutions “integrating wind, solar, hydro energy, and storage” should be explored to solve problems such as insufficient consumption within the province and uneven power transmission to surrounding regions, lacking coordinated power grid development in different regions, poor price transmission mechanism. Policies should be formulated to further reduce the cost for renewable energy sector, and enhance support for renewable energy development in terms of land assignment, IPO fast-tracking, targeted lending and reduction of the required rate of return. When it comes to investing in projects contribution to a stable growth in 2022, the priority should be given to renewable energy investment.

Second, guide the gradual and orderly phase out of coal power whose role in power system should shift from base-load power generation to peak-management power generation. Based on eliminating outdated production capacity, the existing coal power should be flexibly transformed so that most of the coal-fired power plants can withdraw in a stable way after operating for a reasonable period (20 or 30 years). Lessons learnt can be drawn from the international community (e.g., Germany and the UK) and guide the orderly withdrawal of coal power through market-oriented mechanisms. A bidding mechanism for power supply to the grid can be established to break the system of guaranteed of power generation hours and fixed power price for coal power units. And a spot market for power can be set up to provide economic returns for its flexibility service. We should also improve the construction of carbon market in China and guide the phase out of coal power by higher carbon price. In a nutshell, we should stabilize the stock of coal power and strictly control its increase.

Third, improve the green electrification degree of end-users. We should at least align our electrification goals with those of Europe and the U.S. or set even higher targets so that some Chinese industries (e.g., EV and renewable energy) which have overtaken the West can maintain their competitive edge. As the price of raw materials has soared (the price of lithium carbonate, the main material for battery, jumped ten times within a year), extending the industrial chain (e.g., car manufacturers and battery plants can set up joint ventures in the upstream) and enhancing battery recycling and reuse will ensure supply and help stabilize price.

5.3 Resort to Legal, Economic, and Administrative Measures to Establish Efficient and Coordinated Policy Systems and Institutional Mechanisms for Carbon Peaking and Carbon Neutrality

First, system development should adhere to the principle of “construction before destruction”, and the system for “dual control” of aggregate energy consumption and energy consumption intensity should be more carbon-reduction oriented. Schedules and roadmaps of “dual control” system for carbon emission are required. According to goals set for carbon peaking and carbon neutrality, absolute carbon emission objectives for each stage of the path towards carbon neutrality are needed, and a dynamic regulatory mechanism should be set up. The decomposition of carbon emission targets should take into consideration the development gaps among regions and industries, the flow of products among different regions, and the security of industrial supply chain. The “dual control” system for carbon emission should be incorporated into the provincial, municipal, and industrial action plans for carbon peaking and carbon neutrality. Carbon emission “dual control” pilot projects should be conducted as soon as possible in key areas and key industries before they are gradually promoted to the whole industry and the whole country.

Second, accelerate the establishment of legal and institutional systems centered on the absolute control of carbon emissions; built upon supporting systems such as carbon emission permits, carbon emission allowance trading, carbon emission information disclosure, carbon emission accounting report, carbon emission supervision and inspection, and carbon emission dispute settlement; and covering flexible execution mechanisms like clean development mechanism and voluntary emission reduction. Meanwhile, the formulation and revision of relevant laws should be put in place coordinately so as to achieve a systematic management of absolute carbon emission.

Third, coordinate the promotion of pollution reduction and carbon reduction, and make sure that the measures for pollution reduction and carbon reduction are highly aligned. We should focus on “dual high” regions and industries with high air pollutants emission and carbon dioxide emission, and strive for collaborative governance.

Fourth, establish a cohesive mechanism for absolute carbon emission control system and carbon trading market system, and improve the mechanism for carbon pricing. Accelerate the coordination and unification of carbon market, energy consumption rights market and green power market.

Fifth, strengthen the organizational leadership of the central leading group for carbon peaking and carbon neutrality, and improve its institutionalization and mainstreaming level in execution capacity as well as the overall planning and coordination ability. The intricate relation between carbon peaking and carbon neutrality and the social and economic development, should be made fully aware by enhancing communication and coordination among different departments, as well as coordinating international and domestic affairs in order to ensure alignment and coherence in policy directions and processes.

5.4 Lead Overseas Green Investment, Enhance International Cooperation and Trade in Low-Carbon Technologies, and Maintain a Resilient Supply Chain

First, actively support the Belt and Road Initiative countries in their low-carbon infrastructure construction, and strive to coordinate and connect with other international initiatives such as the Global Gateway by the EU and Build Back Better World by the U.S. in order to form synergies and jointly facilitate the low-carbon energy transition in BRI countries.

Second, make full use of the existing regional, multilateral, and bilateral cooperation mechanisms, enhance dialogues and exchanges among countries and regions, improve negative list system for overseas investment, and highlight climate and environment factors in policies for overseas investment and financing. By adopting such emerging concepts and tools as transition finance, we can help ensure the BRI countries to upgrade their conventional industries while ensuring a just and fair transition. Debt reconversion like “Debt for Nature Swap” should be explored so that vulnerable countries struggling with climate change and environmental deterioration can be funded to support green recovery in the post-pandemic era.

Third, summarize China’s successful experience and best practice in climate change and low-carbon transition, analyze its applicability in the BRI countries, and provide those countries with low-carbon transition experience and targeted guidance in accordance with their own conditions.

Fourth, pay attention to the progress in setting up a new round of green standards and trade systems in developed economies like the EU and the U.S., speed up the formulation of mid and long-term development strategies and policies for green supply chain in China, accelerate the development and improvement of green and low-carbon standard systems for key products in China, and explore mutual recognition and unification with global green and low-carbon standard systems in order to safeguard the stability and security of supply chains in China, and contribute Chinese Wisdom to the establishment of global green supply chain systems.

5.5 Enhance International Cooperation on Climate, and Promote Pragmatic and Balanced Progress in International Climate Governance

First, maintain the global climate governance framework based on the UN Framework Convention on Climate Change and the Paris Agreement, and promote pragmatic international cooperation on climate. Facilitate the implementation of the Paris Agreement, promote the execution of the COP 26 decision, and strive for breakthrough in such key issues as climate finance, technology, etc. We should take continuous and concrete actions to tackle climate change, promote comprehensive

green transition and global cooperation on carbon neutrality so that we can make constructive contributions to global climate governance.

Second, facilitate synergy between climate change tackling and relevant multi-field governance, and promote implementation of the UN 2030 Agenda for Sustainable Development. Make joint efforts to strike a balance between energy security, carbon reduction, and development, and focus on the impact of various crises such as energy, food, and supply chains on global climate governance. Promote the integration of global climate governance with overall global development initiatives, and drive the world to respond to the multiple global goods crises in a systematic manner that prevents systemic risks.

Third, continue to promote bilateral and multilateral dialogues and cooperation on climate. Actively move forward with the establishment of Sino-US Working Group for Enhancing Climate Action in the 2020s and the relevant work, strengthen climate cooperation and communication with the EU. Actively conduct Track II dialogues and exchange on climate, and create opportunities for Track 1.5 dialogue so as to enhance mutual trust, avoid miscalculation, and boost the establishment of policy linkage mechanisms.

Appendix

Schedule 1: Goal or Plans for Coal Exit and Reduction in Part of the Belt and Road Countries

Region	Country	Policy/Meeting/Event/Report	Coal exit and reduction goals/Plans
Asia	China	Leaders Summit on Climate	Strictly control coal-fired power projects; control the growth of coal consumption during the 14th Five-Year Plan period; and achieve gradual decrease of coal consumption during the 15th Five-Year Plan period
		The 76th Session of the UNGA	No new overseas coal-fired power projects will be built to support green and low-carbon energy development in developing countries
		The Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy	Promote coal consumption substitution, transformation and upgrading, and accelerate the pace of coal reduction

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Region	Country	Policy/Meeting/Event/Report	Coal exit and reduction goals/Plans
		The Action Plan for Carbon Dioxide Peak before 2030	
	Korea	Leaders Summit on Climate	Stop funding coal-fired power plants overseas
		The 9th Basic Plan for Power Supply and Demand (BPPE) (2020–2034)	Close all coal-fired power plants by 2034
		Global Coal to Clean Power Transition Statement	Stop building and licensing coal-fired power plants in domestic and phase out coal gradually
	Singapore	The Powering Past Coal Alliance	Phase out coal-fired power plants with no emission reduction by 2050 and limit direct financing to coal-fired power projects with no emission reduction
	Indonesia	PLN's 2021–2030 Electricity Supply Business Plan (RUPTL)	Cancel or delay the construction of the planned new plants with capacity of up to 15.5 GW, of which only about 2.3 GW are from renewable energy projects
		Global Coal to Clean Power Transition Statement	Stop building and licensing coal-fired power plants in domestic and phase out coal gradually
		China Policies and Regulations on Energy No. 79/2014	In 2025, coal supply will account for a minimum of 30% of primary energy supply, and a minimum of 25% in 2050
	Bangladesh	South and Southeast Asia's Last Coal Plants	In November 2020, Bangladesh's Ministry of Energy formulated a plan to cancel all coal-fired power plant projects not under construction, which will effectively cancel the 22.9 GW planned coal-fired power; however, Bangladesh has not committed to abandoning the use of coal as renewable energy is currently unable to meet the electricity demands of its large population

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Region	Country	Policy/Meeting/Event/Report	Coal exit and reduction goals/Plans
	Vietnam	Power Development Plan 8 (PDP8)	The proportion of coal-fired power will drop to 40% in 2030 and further to 30% in 2045
		Global Coal to Clean Power Transition Statement	Stop building and licensing coal-fired power plants in domestic and phase out coal gradually
	Philippines	Boom and Decline 2021—Global Coal Plant Tracker	In October 2020, the Philippine Department of Energy announced a moratorium on new coal-fired power plants that have not yet entered the approval process
	Pakistan	Climate Ambition Summit	No more new coal-based power projects will be built
Europe %	Italy	Global Status of Coal-fired power—Pre-Covid19 Baseline Analysis	Phase out all coal-fired power plants by 2025
	Portugal		Phase out all coal-fired power plants by 2023
	Greece		Phase out all coal-fired power plants by 2030
	Hungary		
	Slovenia		
	Poland	Global Coal to Clean Power Transition Statement	Stop building and licensing coal-fired power plants in domestic and phase out coal gradually
Energy Policy of Poland until 2040 (EPP2040)		The proportion of coal-fired power will account for no more than 56% by 2030	
Ukraine	Global Coal to Clean Power Transition Statement	Stop building and licensing coal-fired power plants in domestic and phase out coal gradually	
South America	Chile	No New Coal-fired power Compact	No more new coal-fired power plants will be built
		Phasing out Unabated Coal	Phase out all coal-fired power plants by 2040
Africa	South Africa	Boom and Decline 2021—Global Coal Plant Tracker	South Africa cancelled coal-fired power projects with capacity of 3.8 GW in 2020

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Region	Country	Policy/Meeting/Event/Report	Coal exit and reduction goals/Plans
	Egypt	Boom and Decline 2021—Global Coal Plant Tracker	Egypt had shelved or cancelled a total of 15.2 GW of planned new coal-fired power projects by 2021

Schedule 2 Renewable Energy Development goals or Plans in Part of the Belt and Road Countries

Region	Country	Policy/Meeting/Event/Report
China	The Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy	The proportion of non-fossil energy consumption will reach about 20% by 2025; about 25% by 2030; and above 80% by 2060
	The Action Plan for Carbon Peaking before 2030	
	Guidance on Energy Work in 2022	In 2022, the proportion of non-fossil energy in total energy consumption will increase to about 17.3%, and the proportion of wind power and photovoltaic power in the total electricity consumption will reach about 12.2%
	The 14th Five-Year Plan for Modern Energy System	By 2025, the proportion of non-fossil energy consumption will increase to about 20%, and the proportion of non-fossil energy power generation will reach about 39%; the installed capacity of conventional hydropower will reach about 380 million kW
Korea	The 9th Basic Plan for Power Supply and Demand (BPLE) (2020–2034)	It is planned that by 2034, the installed capacity of renewable energy power generation will reach 40%
Indonesia	PLN's 2021–2030 Electricity Supply Business Plan (RUPTL)	By 2030, 40.6 GW of new power generation capacity will be added, which will include 20.9 GW of renewable energy projects accounting for 51.6%. Among them, renewable energy will account for at least 23% and at least 31% of the overall energy structure of the industry in 2025 and 2050, respectively, and at least 23% and 28% of the power energy structure in 2025 and 2050, respectively

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Region	Country	Policy/Meeting/Event/Report
	China Policies and Regulations on Energy No. 79/2014	New and renewable energy will account for at least 23% of the primary energy supply in 2025 and at least 31% in 2050
Malaysia	Peninsular Malaysia Generation Development Plan 2019 (2020–2030)	The proportion of renewable energy generation will reach 20% by 2025
Philippines	Philippine Energy Plan Towards a Sustainable and Clean Energy Future (2020–2040)	Renewable energy will account for at least 35.0% of the total power generation mix by 2030, and further achieve a proportion of more than 50% by 2040
	PHILIPPINES: National Climate Change Action Plan (NCCAP) 2011–2028	Increase hydropower capacity from 3478 MW in 2010 to 7534 MW in 2030, wind power capacity from 33 MW in 2010 to 1018 MW in 2030, and solar power capacity from 6.74 MW in 2010 W to 85 MW in 2030, biomass power generation capacity from 75.5 MW in 2010 to 93.9 MW in 2030
Thailand	Power Development Plan of Thailand 2018–2037	Raise the share of renewable power generation to a goal of 30% by 2037, which will require an additional 56,431 MW of renewable power generation capacity
	Alternative Energy Development Plan 2018–2037 (AEDP 2018–2037)	Increase the proportion of renewable and alternative energy sources (in the form of electricity, heat and biofuels) by 30% by 2037
Vietnam	Power Development Plan 8 (PDP8)	Renewable energy will account for 32% of the power generation mix in 2030, 40.3% in 2040, and 43% in 2050
	National Energy Development Strategy to 2030 with vision to 2045	Renewable energy will account for 15–20% of the energy mix by 2030 and 25–30% by 2045
Italy	Integrated National Energy and Climate Plan	By 2030, renewable energy will account for 30% of the total terminal energy consumption; and the proportion of renewable energy is 55% in the power sector, 33.9% in the heating sector (heating and cooling), and 22% in the transportation sector
Poland	Energy Policy of Poland until 2040 (EPP2040)	Renewable energy will account for at least 23% of the terminal energy consumption, of which its proportion in the power industry will be at least 32% by 2030

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Region	Country	Policy/Meeting/Event/Report
Portugal	National Energy and Climate Plan of Portugal for 2021–2030	Renewable energy will account for 47% of the overall energy consumption, and about 80% of the electricity comes from renewable energy, of which 20% of the energy consumption in the transportation sector comes from renewable energy
Greece	National Energy and Climate Plan of Greece for 2021–2030	By 2030, renewable energy will account for at least 35% of the end energy consumption and account for at least 60% of the final power consumption
Panama	Panama First NDC (Updated submission)	30% of electricity will be produced with renewable energy sources such as wind and solar by 2050
Cuba	Cuba First NDC (Updated submission)	Renewable energy (RES)-based power generation in Cuba's electricity matrix will reach 24% by 2030
Morocco	Morocco First NDC (Updated submission)	By 2030, 52% of installed power generation capacity will come from renewable energy, of which 20% will come from solar, 20% from wind and 12% from hydro
Zimbabwe	System Development Plan 2017	By 2025, the scale of solar power generation will be expanded to 300 MW
Chile	Energy Compact	The participation rate of renewable energy in national power generation by 2030 will be 40% and it will become one of the largest exporters of green hydrogen in the world with cheapest green hydrogen by 2030
Uruguay	Uruguay First NDC (Updated submission)	If conditions are limited, the installed capacity of wind, solar and biomass power generation will reach 1450 MW, 220 MW and 160 MW, respectively by 2025, accounting for 32%, 5% and 4% of the installed capacity of the national grid system, respectively. If conditions allow, the electricity storage technology will be introduced, including electricity storage and pumping systems. Specifically, the installation capacity will be 300 MW by 2025, and the water source technology for power generation (small hydropower plants) will be popularized and the installed capacity will be 10 MW by 2025

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Chapter 2

Value Assessment of Nature-Based Solution (NbS)



1 Introduction

1.1 Background to the Special Policy Study

In September 2021, CCICED published a Special Policy Report on Nature-based Solutions (NbS) in response to guidance issued earlier that year by the Ministry of Ecology and Environmental Protection and growing international, national, and subnational interest in holistic NbS approaches, such as agro-ecological food systems, ecosystem-based adaptation to climate change, climate mitigation etc. The report concluded that NbS should be a topic of future CCICED studies and that research should be coordinated with other programs of work, including the Green Belt and Road Initiative (BRI), green supply chains, climate adaptation and mitigation, among others.

The report specifically recommended that future work should (1) identify objectives and opportunities to advance NbS based on a clear and coherent definition; (2) identify opportunities for international NbS cooperation; (3) establish a database portal of NbS case studies; (4) apply innovative measurement to NbS outcomes; (5) identify policies and partnerships needed to implement NbS.

Since the report was issued, NbS have continued to increase in profile, most notably through the adoption of a United Nations Environment Assembly Resolution (UNEA) 5.2 on Nature-based Solutions for Supporting Sustainable Development [1]. NbS also increasingly featured in the climate negotiations at COP 26 in Glasgow, where several parties spoke strongly in support of NbS, while others expressed interest but called for more information about the ways in which NbS would be operationalized. A related development was the adoption of the System of Environmental-Economic Accounting–Ecosystem Accounting (SEEA EA) as an international standard by the UN Statistical Commission to identify and measure

linkages between economy and nature using approaches consistent with the System of National Accounts.

In this respect, this current Special Policy Study was undertaken at a time of high global interest. The study sought to answer two overarching questions:

- How closely do NbS align with established Chinese approaches and frameworks for environmental protection and sustainable development?
- How can the contribution that NbS make to green economic development, ecosystem management, climate change, and other societally desirable outcomes be guided and effectively measured?

1.2 Research Objectives

These overarching research questions were explored by pursuing three research objectives that built upon and expanded on the conclusions of the earlier CCICED SPS on Nature-based Solutions. These objectives were:

- To develop a framework for the design and implementation of NbS that is compatible with established Chinese environmental protection and sustainable development concepts.
- To establish a prototype database of national and international NbS case studies, described and documented using a consistent and common assessment framework.
- To propose an outline framework that enables the benefits and societal contributions of NbS outcomes to be consistently and comprehensively measured according to internationally adopted natural capital and national accounting principles.

1.3 Research Methodology

The three research objectives used the IUCN Global Standard for Nature-based Solutions (the most in-depth and widely recognized outline to guide NbS operational approaches that is currently available) as a consistent framework of enquiry. Specifically:

Objective 1: Design and implementation features: A systematic literature review was undertaken, including both published peer-reviewed literature and grey literature such as policy documents, to map key elements of Chinese environmental protection and sustainable development concepts (as manifested in NbS in China), against the eight criteria of the IUCN Global Standard for Nature-based Solutions. The results were used to establish a typology of NbS in China and identify gaps.

Objective 2: A prototype database of NbS case studies: The eight criteria and current Chinese eco-protection policies were used as a framework to classify NbS cases. Both Chinese case studies and international case studies were included. In order to ensure a balanced range of NbS applications, a range of different case studies was selected, drawing from urban, rural, and coastal examples.

Objective 3: A proposed framework to measure NbS outcomes: A practical framework for measuring NbS outcomes was developed, drawing from natural capital accounting principles and guided by SEEA EA. The framework was tested with a subsample of the NbS case studies where sufficient data was available and its suitability to support or enhance the calculation of gross ecosystem product (GEP) and SEEA EA assessed. Both Chinese case studies and international case studies were included.

2 Background to Nature-Based Solutions in China

2.1 *Nature-Based Solutions for Different Ecosystems in China: Policies and Frameworks*

In recent years, NbS have gradually become a crucial approach to dealing with a series of societal challenges, such as climate change, disaster prevention and mitigation as well as economic and social development, which is widely recognized by the international community. Under the guidance of President Xi Jinping's Thought on Ecological Civilization, China has paid more attention to the power of nature, adhered to the concepts of respecting nature, conforming to nature and protecting nature, and successively issued a series of policy documents related to climate change and biodiversity protection. Meanwhile, China has carried out a variety of coordinated practices of ecological protection and climate mitigation, such as the "red line of ecological protection" system. However, China still lacks an assessment of specific practice projects against the criteria of the IUCN Global Standard for Nature-based Solutions™, as well as comprehensive and systematic technical methods and sharing platforms that could translate experiences into local practical operation guidance and restoration approaches for different ecosystems. In this study, according to the key issues and policy requirements of ecosystem restoration identified in China, entry points of NbS for various issues are presented. On the basis of summarizing the policies and cases of China's ecological environment protection and climate change response, the NbS implementation framework is explored; it is of guiding practical significance in accordance with China's national conditions.

2.2 Problems and Challenges

2.2.1 Forest Ecosystems

China has a vast territory, with extremely rich and diverse forest plants and forest types. The national forest area is 208 million ha, and the forest coverage rate is 21.63%. Nevertheless, China's forest ecosystem is still facing severe problems. First, China's forest coverage rate is far lower than the global average of 31%. Therefore, the total amount of forest resources is relatively insufficient, the quality is not high, the distribution is uneven, and the quality of forest ecological construction needs to be improved. Second, with the acceleration of urbanization and industrialization, spaces for ecological construction will be further squeezed, and pressures on strictly observing the forestry ecological red line and maintaining the national ecological security bottom line will increase. Third, China's forest land suffers from low productivity and unreasonable age group structure. There is still great potential for further increasing investment, strengthening forest management, boosting forest productivity, increasing forest stock, and enhancing ecological service function. Fourth, there is a prominent contradiction between effective forest supply and increasing social demand.

2.2.2 Grassland Ecosystems

China's grassland ecosystems cover 2.7767 million km², accounting for 28.92% of the national land area. Grassland ecosystems, compared with other types of ecosystems, are more fragile and sensitive to environmental impacts. From the last century to the present, influenced by climate change, overgrazing, irrational utilization, lack of management, and other factors, grassland ecosystems have suffered more serious pressure from many aspects and are facing great threats and challenges. These threats and challenges are mainly manifested in the following ways: (1) grassland degradation and ecosystem damage; (2) loss of biodiversity and aggravation of pests and diseases; and (3) decline of social and economic benefits.

2.2.3 Wetland Ecosystems

Wetland ecosystems cover 353,800 km², accounting for 3.69% of China's land area. Economic development and population growth have become the indirect driving forces for the loss and degradation of wetlands. Furthermore, there is a widespread lack of awareness of the importance of wetlands in society, which has resulted in overutilization, neglect of protection, and difficulty in effectively carrying out wetland protection. Further, it has caused a decline in ecosystem services, such as a shortage of freshwater resources and a decline of biodiversity.

2.2.4 Farmland Ecosystems

Farmland ecosystems cover 1.7929 million km², accounting for 18.68% of the country's land area. At present, the problems and challenges faced by the farmland ecosystem mainly include: (1) farmland degradation, desertification, alkalization, and land-quality decline, resulting in crop yield reduction; (2) meteorological disasters, such as droughts, floods, gales, hail, and frost, as well as major diseases and insect pests, have a large area, high frequency, extensive and far-reaching impact, and lack of efficient means of control; (3) waste gas, heavy metals, garbage, and other serious pollution that threaten the production, life, and ecology of farmland systems; (4) inappropriate modes of operation, including predatory modes of operation, such as extensive planting but poor harvest, land use and output, in many areas; and (5) farmland ecosystems that have been damaged to varying degrees in internal and surrounding biodiversity and have not been restored or improved.

2.2.5 Urban Ecosystems

From the perspective of landscape ecology, the process of urbanization is a process of mutual transformation of the underlying land properties in urban areas and expansion areas. Natural elements such as waterbodies, woodlands, scrubs, and grasslands are continuously encroached and fragmented by the artificial landscapes brought about by urbanization. As a result, the natural ecological space is continuously swallowed up, leading to a number of problems and challenges. These problems mainly include many urban ecological problems such as the heat island effect, urban flooding, air pollution, water pollution, frequent extreme weather, reduced biodiversity, environmental noise, surface exposure, and a series of social problems such as traffic, housing, epidemics, psychological stress, resource waste, and energy shortages.

2.2.6 Marine Ecosystems

Marine ecosystems provide abundant natural resources for human beings. However, under the influence of human activities, such as large-scale reclamation projects, a massive discharge of pollutants into the sea, overfishing, exploitation, and intensive transportation of offshore oil and gas mineral resources, as well as the combined action of natural factors including global climate change and natural disasters, a series of ecosystem degradation issues, such as habitat loss, resource attenuation, eutrophication, disturbance of hydrodynamic conditions, and decline of biodiversity have arisen in marine ecosystems.

2.3 Policies

2.3.1 Forest Ecosystems

Particular priority was given to analyzing NbS-related content in China's forest ecosystem protection policies, which mainly include: (1) laws and regulations related to the forest ecosystem, such as the *Forest Law*, amended in 2019; (2) strategic plans, action plans, and schemes to deal with climate change and ecological environment protection. For example, in 2019, the General Office of the CPC Central Committee and the General Office of the State Council issued the *Natural Forest Protection and Restoration System Plan*, and in 2022, the National Forestry and Grassland Bureau, the National Development and Reform Commission, the Ministry of Natural Resources and the Ministry of Water Resources jointly issued the *Plan for the Construction of Major Projects for Ecological Protection and Restoration of the Northeast Forest Belt (2021–2035)*; and (3) guiding opinions on forest carbon sink trading. For example, in 2014, the State Forestry Administration issued the *Guiding Opinions on Promoting Forestry Carbon Sequestration Trading*.

2.3.2 Grassland Ecosystems

To promote grassland ecological management, relevant state departments have successively issued a number of policies and regulations, including among others, the *Outline of Forestry Grassland Protection and Development Plan in the 14th Five-Year Plan*, several opinions on strengthening grassland protection and restoration, and the *13th Five-Year Plan for National Grassland Protection, Construction and Utilization*. These policy documents include the following measures: (1) speed up grassland ecological restoration; (2) promote the introduction of regulations and systems for grassland protection; and (3) strengthen the supervision system of grassland ecological protection and restoration.

2.3.3 Wetland Ecosystems

At present, there are different levels of wetland ecosystem policy documents involved, such as the *Wetland Protection Law of the People's Republic of China*, the *Yangtze River Protection Law*, and the *Kunming Dianchi Wetland Construction Management Measures (for Trial Implementation)*. These policy documents clarify the ecological management and ecological restoration of wetlands, strengthen wetland protection, and maintain wetland ecological functions and biodiversity.

2.3.4 Farmland Ecosystems

In 2008, the Third Plenary Session of the Seventeenth Central Committee of the Communist Party of China put forward the concept of “permanent basic farmland.” This shows that the Party Central Committee and the State Council attach great importance to basic farmland and its quality, quantity, and ecology, and protect it in all aspects. The state has also put forward the idea of farmland ecological restoration and management via a series of other policies, including the *National Agricultural Green Development Plan in the 14th Five-Year Plan*, the *Cultivated Land, Grassland, Rivers and Lakes Rehabilitation Plan (2016–2030)*, the *Agricultural Resources and Ecological Environment Protection Project Plan (2016–2020)* and other master plans, as well as the *Guidelines for the Treatment and Restoration of Contaminated Cultivated Land*.

2.3.5 Urban Ecosystems

In response to a series of problems in the process of urban development, in October 2015, the General Office of the State Council issued the *Guiding Opinions on Promoting Sponge City Construction, proposing to promote green park space construction and natural ecological restoration* in view of urban waterlogging. The *Guiding Opinions on Strengthening Ecological Restoration of Urban Remediation*, issued by the Ministry of Housing and Urban–Rural Development in March 2017, proposes respecting the laws of the natural ecological environment, including by implementing the concept of sponge city construction. In the *Opinions on Promoting the Green Development of Urban and Rural Construction* issued by the General Office of the CPC Central Committee and the State Council in October 2021, it is proposed to promote the green development of regional and urban agglomerations through spatial planning, housing construction, ecological space construction, and public infrastructure construction.

2.3.6 Marine Ecosystems

Based on the reality of marine ecological restoration in China and a focus on the types and natural characteristics of the marine ecosystem, starting from the integrity of the ecosystem, the *Technical Guide for Marine Ecological Restoration (for Trial Implementation)* issued in July 2021 implements the requirements of overall protection, system restoration, and comprehensive management, and defines the objectives, principles, general requirements, and technical processes of marine ecological restoration. In March 2017, the State Oceanic Administration announced the *Measures for the Administration of Coastal Protection and Utilization*, which strengthened the hard measures for coastal protection. According to the *National Marine Main Functional Area Plan* issued by the State Council in August 2015, classified management is implemented to improve marine environmental quality and enhance marine

ecological service function. In August 2020, the Ministry of Natural Resources and the State Forestry and Grassland Administration issued the *Special Action Plan for Mangrove Protection and Restoration (2020–2025)* to comprehensively protect the existing mangroves.

2.4 Development of a Nature-Based Solutions Implementation Framework Consistent with China’s Policies

Actively responding to climate change is the inherent requirement of China’s sustainable development, while biodiversity is considered the foundation of human survival and development. To strengthen the overall integration of climate change response and biodiversity protection and to enhance the overall joint force of climate change response, NbS has become an effective pathway that promotes interlinkages and creates synergies. China boasts a vast territory and rich ecosystem types. However, the ecological problems in different ecosystems are representative, and in the process of ecosystem restoration and utilization, they usually involve different departments (such as the land department, ecological environment department, forestry and grass department, housing and construction department). Therefore, by analyzing the relevant policies of China, coordinating the ecological restoration problems and governance schemes of each ecosystem, and considering the interests and needs of all parties, the following NbS design and implementation framework consistent with Chinese policies has been constructed. In particular, the implementation framework listed in this study covers only NbS directly supported by relevant policies. Many elements of NbS are still not covered by policies and are not listed in the following table.

Box 1 An NbS implementation framework consistent with China’s policies

<p>Criterion 1: NbS effectively address societal challenges</p>	<p>Carbon peaking and carbon neutrality goals/climate change Biodiversity loss Food security Sand erosion Soil erosion Urban waterlogging Soil functional degradation Marine ecological environment degradation</p>
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<p>Criterion 2: Design of NbS is informed by scale</p>	<p>Policy guidance (overall) Large-scale afforestation and returning farmland to forests (overall) Permanent farmland (overall) Urban green space system planning (overall) Construction of biodiversity reserve and ecological corridor (biodiversity loss) Wind-sand shelter forest construction (wind-sand erosion) Restoration of barren hills/mines/bare land (soil function degradation) Carbon sink trading market (carbon peaking and carbon neutrality goals) Urban sponge project construction (urban waterlogging) Strengthen the integration and exchange between urban and rural areas (food supply security) Coordinate upstream and downstream, land and ocean (marine ecological environment degradation)</p>
<p>Criterion 3: NbS should bring about biodiversity net gain and ecosystem integrity</p>	<p>Alien species control Corridor construction/communication of isolated grassland patches Control means and intensity Constructing ecological chain Improve the diversity of urban green space vegetation community</p>
<p>Criterion 4: NbS are economically viable</p>	<p>Ecological compensation Carbon sink trading Corporate social responsibility (Ant Forest) Franchise mode, PPP mode, EOD mode</p>
<p>Criterion 5: NbS are based on inclusive, transparent, and empowering governance processes</p>	<p>Consider stakeholders for ecological compensation (forest rangers) Publicity of development project planning period Rural production and management cooperative/village-enterprise cooperation (Wuyuan) Set up a telephone number for protection, supervision, and complaints, and solicit opinions from the society</p>

(continued)

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<p>Criterion 6: NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits</p>	<p>Returning farmland to forest and permanent basic farmland management Marine tourism development with controllable ecological impact Forest-thinning fire belt Rotation fallow and strip tillage</p>
<p>Criterion 7: NbS are managed adaptively, based on evidence</p>	<p>Remote sensing monitoring of ecosystem/once a year Ecological system disaster monitoring/real-time Continuous dynamic monitoring of pollutants/real-time Investigation of land use status/once every 10 years Ecosystem investigation and assessment/once every 5 years Zoning construction guidance/industry access restriction Regular animal and plant surveys/long-term</p>
<p>Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context</p>	<p>Set up the red line system of nature reserves/ecological protection Demarcate permanent basic farmland Set the system of urban sponge city construction and urban greenway construction The ecological management effect enters the assessment Construction of Forest and Wetland Parks</p>

2.5 Summary

First, China has formulated and implemented NbS-related policies and measures in various ecosystems, but has not yet formed a policy system with NbS as the starting point.

Second, relevant policies and measures of NbS are scattered in different departments, and the lack of communication and coordination mechanism between different departments makes it difficult to form an efficient and overall management mechanism.

Third, not many policy documents clearly address Criterion 4: “NbS economically viable”. Currently, the main source of funds is still financial investment, and no diversified fund investment mechanism has been formed.



Fig. 1 Societal challenges addressed by Nature-Based Solutions as defined at the IUCN World Conservation Congress in 2016 (Resolution 069) (©IUCN)²

3 Prototype Database of Nature-Based Solution Case Studies

Human well-being and livelihoods are deeply connected to and depend on nature. Understanding the multiple benefits that ecosystems provide to diverse beneficiaries while ensuring the protection of ecosystem integrity, functions, and services, is at the heart of NbS.¹

Case studies can be an effective tool to illustrate the value of NbS in real terms. Furthermore, they provide an opportunity for learning as they exemplify key components, approaches, and safeguards that are characteristic of true NbS interventions and accordingly prevent mislabelling. While each case has to be considered in its unique context, there are a number of overarching parameters with which projects and interventions should comply in order to qualify as NbS. Such parameters ensure that societal challenges (see Fig. 1) are addressed adequately and that human well-being and biodiversity benefits are simultaneously generated.

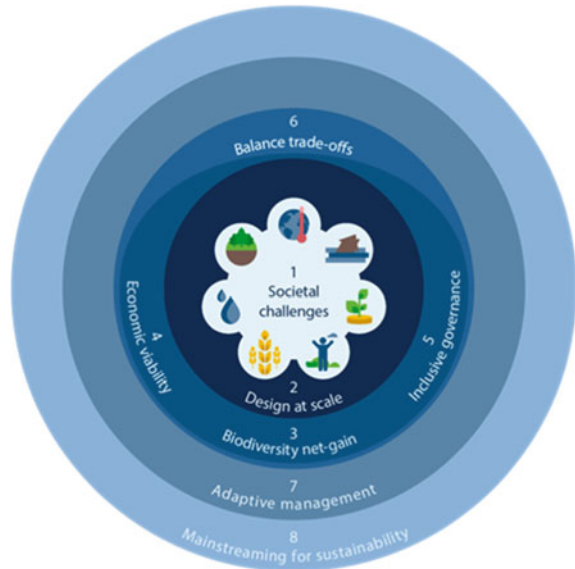
The IUCN Global Standard for Nature-based Solutions™, with its eight criteria (see Fig. 2) and 28 indicators, is particularly suited for the documentation of NbS as it provides clear, science-based and widely consulted parameters for benchmarking NbS interventions.² One important feature of the Standard is the interdependent and non-hierarchical nature of its eight criteria. As a result, inadequacy in just one criterion means that the intervention in question is not in adherence with the Standard and therefore cannot be verified as an NbS.

The prototype database of NbS case studies presented here constitutes an effort to draw on a range of national and international experiences relevant in the context of Chinese eco-protection policies. The national and international case studies help identify policy measures that enhance the uptake, implementation, and financing of

¹ IUCN defines Nature-based Solutions (NbS) as “actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (endorsed by IUCN’s 1400 members at the 2016 World Conservation Congress in Resolution 069).

² IUCN (2020a). Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS. First edition. Gland, Switzerland: IUCN; IUCN (2020b). Guidance for using the IUCN Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of Nature-based Solutions. First edition. Gland, Switzerland: IUCN.

Fig. 2 The eight criteria of the IUCN Global Standard for Nature-Based Solutions™ (©IUCN)²



NbS. It was established in three steps: (1) development of a common and agreed-upon documentation framework; (2) selection of relevant and illustrative national and international case studies; and (3) documentation of selected case studies applying said documentation framework. Additionally, it was noted that gender-responsive and inclusive approaches should be specifically highlighted whenever possible, especially in relation to criteria 5, 6, and 7 of the Standard.

To ensure comparability and to increase the impact of case studies, they were documented using a coherent and consistent manner through a documentation framework that was based on the IUCN Global Standard for Nature-based Solutions™ as well as the information required by the *PANORAMA: Solutions for a Healthy Planet*³ case study database. *PANORAMA* was recognized as a strategic database to make the five Chinese and the five international case studies widely accessible.

The agreed documentation framework that helped extract key information and lessons learned for successful NbS design and implementation is represented in Fig. 3.⁴ Quantitative information on the key features and benefits under the eight criteria of the Standard was captured wherever possible.

³ <https://panorama.solutions/en>.

⁴ A more detailed elaboration of the methodology applied can be found in a supplementary report: Meyer, K. and Hessenberger, D. (2022). Prototype database of international Nature-based Solutions case studies. China: CCICED and IUCN.

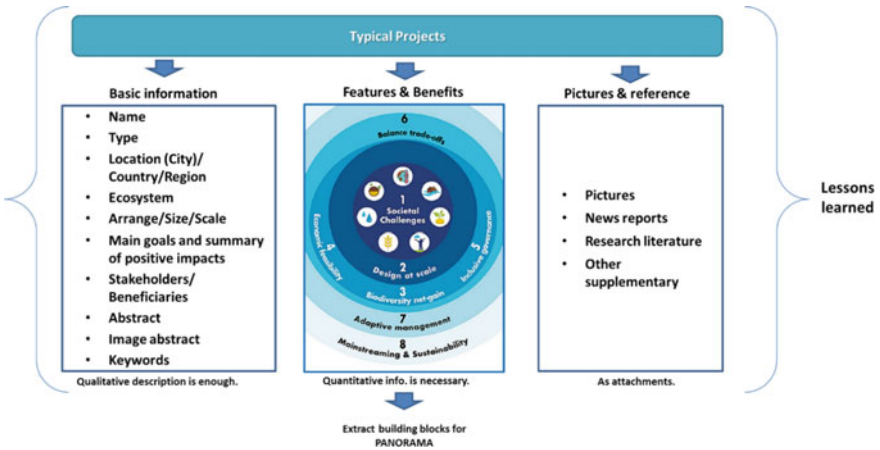


Fig. 3 Documentation framework developed to capture relevant information and lessons learned from case studies

3.1 China Case Studies

In this part, five typical NbS Chinese cases implemented in five different ecosystems are presented. Those case studies are (1) Ganjia grassland ecological management in Gansu province, (2) Shenzhen sponge city construction case in Guangdong province, (3) overall ecological restoration of land and sea in Beihai, Guangxi, (4) “Three north” shelterbelt project in Northwest, North and Northeast China, and (5) Dongying wetland city project in Shandong province. All those cases are described following the IUCN Global Standard for Nature-based Solutions™ mentioned above. Here, the Ganjia grassland case is described in detail.

Location: Ganjia Township, Xiahe County, Gannan Tibetan Autonomous Prefecture, Gansu Province.

Main implementing agency: Local tribal villages.

Type of NbS interventions [1]: Type 1 (solutions that involve making better use of existing natural or protected ecosystems).

Case overview: Ganjia Grasslands, located in Ganjia Township, Xiahe County, Gannan Tibetan Autonomous Prefecture, Gansu Province, with an area of around 80,900 ha and an average elevation exceeding 3000 m, are mostly mountainous and alpine meadows with a typical semi-arid highland continental climate. The grasslands are found in the transitional region between the Tibetan Plateau and the Loess Plateau in geographical terms and on the border between Gansu and Qinghai provinces in terms of administrative division. Generating income primarily from livestock feeding, most residents in Ganjia are pastoralists and have retained four-season rotational grazing and pasture sharing typical for nomadism. In recent years, however, as a result of environmental changes and the implementation of grassland governance policies, there have been only a few shared pastures left on the plateau,

and most pastures that have been contracted or prohibited from grazing have to deal with severe ecological problems, such as grassland degradation. In light of the situation, all villages in Ganjia have markedly adjusted grassland governance rules, including those on four-season rotational grazing. In addition, local pastoralists have drawn on external policies to figure out pasture leasing methods that are conducive to the sustainable use of local grasslands, and even created the “livestock-free” option. At present, Ganjia Grasslands have made progress in ecosystem governance, with relatively high average vegetation cover and average hay yield, and in terms of biodiversity, a variety of endangered wild animals have been recorded. Meanwhile, as local pastoralists take the initiative to seek new grazing methods or new ways to support their livelihood, income has increased, and people’s awareness has changed to some extent, generating greater socio-economic benefits.

Box 2 Characteristics and benefits based on the criteria of the IUCN Global Standard for Nature-based Solutions™

Overall assessment	Strong adherence to the IUCN Global Standard for Nature-based Solutions™
Intervention status	All main NbS restoration activities have been completed and are subject to monitoring and feedback. The current focus is on sustainable management of the implementation area
Criterion 1: NbS effectively address societal challenges	<div style="text-align: center;"> </div> <p>Through continuous practice and exploration, local pastoralists and village collectives have explicitly identified the key societal challenges they face and the impact on human well-being. Of the major issues facing grassland ecosystems around the world today, climate change remains one that cannot be ignored. It has led to environmental problems, such as grassland degradation and desertification, and resulted in enormous economic losses. Subsequently, damaged habitat gives rise to a loss in local biodiversity to some extent. Pastoralists in Ganjia, a group that has spontaneously initiated grassland management and directly benefited therefrom, have established a coupled system featuring the symbiosis among human, grasslands, and animals, which is closely related to the most pressing societal challenges in pastoral areas, including climate change adaptation and mitigation, economic and social development, and ecosystem degradation and biodiversity loss</p>

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<p>Criterion 2: Design of NbS is informed by scale</p>	<p>Based on the relatively large climate variability and spatial heterogeneity in local natural conditions, pastoralists in Ganjia have chosen the governance method of combining pasture sharing with four-season rotational grazing while taking villages as the basic governance unit. They decide on the use and management of pastures in different time and space based on a consideration of interactions among the economy, society, and ecosystems. The process requires both the spontaneous actions of local pastoralists and the management and coordination by tribal villages, so as to explore methods that fit local conditions. In addition to the most directly related department of agriculture, the departments of ecology and environment, civil affairs, and cultural tourism are also closely related to grassland governance</p>
<p>Criterion 3: NbS result in a net gain to biodiversity and ecosystem integrity</p>	<p>Despite the lack of in-depth research to examine the ecological benefits generated by the Ganjia Grasslands, both the intuitions of local pastoralists and scientific monitoring data have indicated a recovery of wildlife species diversity in recent years. The fenceless land use on the shared pastures and the openness of saline-alkali soils and other natural resources have increased the integrity and connectivity of the grassland ecosystem</p> <p>Main ecological benefits:</p> <ul style="list-style-type: none"> • Despite the hot and dry climate in Ganjia Grasslands, in 2018, during the maximum grass growth period from July to August, local average vegetation cover exceeded 70%, and the growth of grass exceeded that of neighbouring towns with similar climate conditions, such as Wangge'ertang • In 2020, the average hay yield in Ganjia Grasslands reached 1975.67 kg/ha • In terms of biodiversity, endangered wildlife species, such as snow leopards, sand cats, alpine musk deer, black storks, and black-necked cranes, have been recorded in the area
<p>Criterion 4: NbS are economically viable</p>	<p>Grassland is one of the main sites for agricultural activities in China, and it generates considerable economic benefits. Based on local conditions, pastoralists in Ganjia have adopted multiple grazing strategies such as renting pastures and adjusting the livestock structure to improve the returns from grazing while ensuring the sustainable use of pastures. Meanwhile, measures, such as trade quotas have made pasture governance diversely funded in a sustainable way. The short-term livestock-free strategy created by local pastoralists not only serves as a flexible adaptation to market changes but also brings forth new business opportunities, namely, "Tibetainment" with idle pastures. Furthermore, local pastoralists can increase income by working away from home or others. This case has provided a reliable basis and a viable reference for other places to bolster their practice and governance in grassland agricultural production</p>

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<p>Criterion 5: NbS are based on inclusive, transparent, and empowering governance processes</p>	<p>Throughout the case, governance is based on negotiations among local pastoralists and between pastoralists and communities, which is the key for the area to implement NbS. Villages in Ganjia have established a complete decision-making process and an open negotiation platform. The main decision-maker, i.e., the pasture management group, and the actor, i.e., the patrol group, are elected by village collectives under election rules formulated based on their individual situations and through voting by representatives from each household, which reflects inclusiveness and fairness to all pastoralists. In addition, as a group distinctly formed through blood and geographical ties among the tribes, local villages perform activities that cannot be accomplished by individual pastoralists, such as traditional identity-related rituals, and group-based essential activities like sheep shearing and house building, creating an influential atmosphere that bonds pastoralists from different backgrounds more closely</p>
<p>Criterion 6: NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits</p>	<p>Villages in Ganjia treat collective and long-term interests as the primary goal in pasture management, and make decisions based on the majority rule. The pasture sharing and four-season rotational grazing are the basis and most important features of the current ecosystem governance in Ganjia Grasslands. Such methods have been retained after continuous practice, which is obviously in consideration of collective interests, and only by doing so can the interests of the majority pastoralists can stay intact. In cases where any individual pastoralist disrupts collective harmony and stability, the village may consider his/her reasonable requests, e.g., demanding a separate pasture, but at the same time excluding them from group activities, thus reducing unstable factors and realizing multiple benefits</p>
<p>Criterion 7: NbS are managed adaptively, based on evidence</p>	<p>Villages in Ganjia mainly rely on long-accumulated trials and adaptive local ecological knowledge to set rules for hire pasture, short-term without livestock, etc. According to local conditions, which is conducive to rapid ecosystem recovery. The management and patrol groups spontaneously organized by local village collectives can track problems encountered in implementing NbS more swiftly and solve them in time. In the face of unpredictable changes in nature, policies, and markets, local pastoralists have made adjustments accordingly by spontaneously designing flexible solutions, such as pasture leasing and the short-term livestock-free strategy, with feedback provided on the local NbS system</p>

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<p>Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context</p>	<p>Within the pastoralist community in Ganjia, villages are bonded together through long-term reciprocal relationships, which is essential to local grassland governance. They share experience, for instance, in warding off wolves, and create knowledge together, thus ensuring the sustainability of these measures. The experience of Ganjia Grasslands in NbS practices has produced ecological, environmental, economic, and social benefits, which serves as a reference point for other regions and may be incorporated into national or regional strategies as a policy that can be summarized and normalized for long-term implementation and efficiently applied to practice in other regions</p>
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Lessons Learned

Although the core characteristics and value of the solutions lie in using the power of science to understand nature and replacing certain manual techniques with the forces of nature, more emphasis should be placed on the role of local ecological knowledge in acquiring comprehensive ecosystem information. Designers of ecosystem governance solutions should stay open minded in communicating and sharing information with local pastoralists, governments, and other stakeholders, so as to gain a deeper understanding of local natural, social, and cultural contexts and to make designs that accommodate local conditions.

At present, most NbS are implemented by enterprises and governments, whereas communities, one of the stakeholders, are somewhat ignored and should get more involved in governance. First, communities should be given sufficient knowledge about the project. Second, an open platform that allows negotiation with communities should be established, and the design should be adjusted accordingly. Finally, authorities and responsibilities should be fairly distributed among different stakeholders within each community, so as to extend the depth and breadth of participation by different groups and improve the nature conservation capacity of communities.

It is important to bypass the “one-size-fits-all” approach and give sufficient flexibility to the governance rules when designing the solutions. Meanwhile, efforts are needed to continuously optimize the prototype based on the initial design and monitor the project’s impact on an ongoing basis during the implementation process. With these efforts, we would be able to better tackle the multi-scale and complex societal challenges.

3.2 *International Case Studies*

To complement the five Chinese case studies, five international cases were analyzed. Each of the international cases had already undergone a full assessment with the IUCN Global Standard for NbS. They include examples applied in marine, forest, farmland, coastal, and wetland ecosystems.⁵ A detailed account of agroforestry systems for sustainable cocoa farming in the Lachuá Ecoregion, Guatemala, is provided here as an illustrative example. The full set of international case studies can be found in a supplementary report to this CCICED Special Policy Study [2].

Location: Lachuá Ecoregion (municipalities of Ixcán, Quiché, and Chisec), Guatemala

Main implementing organization: IUCN

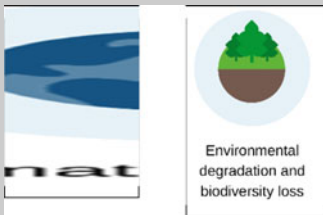
Other implementing organization: Fundalachuá (Laguna of Lachuá Foundation), Ministry of Agriculture of Guatemala

Type of NbS intervention [1]: Type 2 (solution for sustainable management of restored and managed ecosystems, including innovative land-use planning protocols)

Case overview: An estimated 30–40% of annual household income in Guatemala is derived from forest products. Cocoa production was recognized as an economically viable alternative for job creation and increased local income, underscoring its economic, social, environmental, and cultural value. The NbS intervention carried out in the Lachuá Ecoregion supported 170 cocoa producers in an area of 303 ha and aimed to intensify cocoa production based on sustainable agroforestry management approaches that would not only contribute to local livelihoods but also improve conservation and biodiversity outcomes through forest landscape restoration. One of the key success factors of this intervention was the long-term support from IUCN and other initiatives (including the Food and Agriculture Organization of the United Nations and other organizations), leading to good governance of local communities at several levels (e.g., the creation of Fundalachuá, an IUCN Member, as a second-level organization). In addition, the close coordination with public and investment programs, as well as the reliance on good agricultural and manufacturing practices with a focus on building human capital and capacities rather than requiring large monetary inputs, infrastructure, equipment or supplies, ensured sustainability over time. The intervention helped reduce poverty and strengthened the livelihoods of local communities, mostly belonging to the Indigenous Q’eqchi’ ethnic group. It contributed significantly to restoring degraded areas outside the protected areas (in the ecoregion) and reduced threats to the Laguna Lachuá National Park.

⁵ The following five international case studies were analyzed in accordance with the agreed documentation framework: (1) Agroforestry systems for sustainable cocoa farming in the Lachuá Ecoregion, Guatemala, (2) Medmerry managed coastal realignment, (3) Flood-based agriculture in the upper Mekong delta floodplain, (4) Maristanis integrated coastal and wetlands management, and (5) Sustainable aquaculture and innovative seaweed farming in Zanzibar.

Box 3 Characteristics and benefits based on the criteria of the IUCN Global Standard for Nature-based Solutions™

Overall assessment	Strong adherence with the IUCN Global Standard for Nature-based Solutions™
Intervention status	All major NbS restoration activities have been completed and monitored. Continuous sustainable management of the intervention area is ongoing
Criterion 1: NbS effectively address societal challenges	 <p>Key societal challenges and impacts on human well-being were identified in consultation with local communities and stakeholders. In addition, IUCN had a good understanding of the societal challenges, having worked in the region for over 20 years. The Lachuá Ecoregion is primarily inhabited by communities of the Indigenous Q'eqchi' ethnic group. Poverty is a major challenge in the region, and land-use changes have affected biodiversity and caused degradation. An assessment of livelihood options that provide economic, social, and environmental benefits identified cocoa agroforestry systems as the most desirable option, also due to cocoa's cultural value for Q'eqchi' Mayans. Through the intervention, income from cocoa agroforestry systems and access to international markets and value chains positively affected the livelihoods of producers</p>
Criterion 2: Design of NbS is informed by scale	While the NbS intervention focused on changing land uses toward good agricultural and manufacturing practices for cocoa agroforestry systems, the project placed great emphasis on developing strategies that covered the full value chain, including production, processing, marketing, organizational capacities of local farmers and associations, provision of technical assistance and services from key organizations, as well as increased access to public and private funding mechanisms and investments. Besides the agricultural sector, tourism and private sectors were involved throughout the project to facilitate the mainstreaming of good practices into business models. Actions at the local level ensured tailored approaches in local contexts, while actions at the national level contributed to the mainstreaming of organizational and technical capacities across the region

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<p>Criterion 3: NbS result in a net gain in biodiversity and ecosystem integrity</p>	<p>Due to the longstanding presence of IUCN in the region, various studies on the status of ecosystems already existed. These served as a baseline to understand the positive outcomes for biodiversity of the NbS intervention. In particular, the Restoration Opportunities Assessment Methodology (ROAM) and the InVEST tool were used to provide evidence of direct and co-benefits. Additionally, a manual of good practices for cocoa cultivation was prepared to build the capacities of the local community</p> <p>Key biodiversity outcomes [3]:</p> <ul style="list-style-type: none"> • 303 ha restored from traditional monocrops to cocoa agroforestry systems in areas of high value for conservation; • land-use change to agroforestry systems contributed to: GHG emissions reductions of 9320 tons of CO₂e (1864 tons of CO₂e per year; 80% increase in CO₂e storage in terrestrial biomass, such as trees and roots, and 20% in soils), erosion reduction between 33.8 and 107.7 tons per ha and sedimentation reduction between 0.03 and 4.6 tons per ha depending on the land-use prior to cocoa agroforestry; • other observed outcomes include improved forest connectivity, increased plant cover, new sightings of birds and other species absent in traditional crops and absence of chemical contamination from the use of industrial agricultural inputs
<p>Criterion 4: NbS are economically viable</p>	<p>A financial and economic analysis was carried out as part of the project to develop a comprehensive business model for cocoa cultivation by community associations and Fundalachuá. This provided a framework for agricultural and manufacturing practices, good governance and access to financing, innovation and the market (including international markets). In addition, it served as a source of guidance on what, how, and when to produce, how to sell the product and how to finance activities. The cocoa value chain and main activities of each actor were also agreed. Commercial contracts were established with 36 businesses from the United States, Belgium, South Korea, and others, opening the international market to Guatemalan cocoa products. Due to the improved quality of the cocoa, it was possible to increase the price from USD 2.28 to USD 4.50 per kg</p> <p>Key economic benefits [3]:</p> <ul style="list-style-type: none"> • farm production yields improved by 152% (293 kg per ha per year); • sales of export-quality products increased from 0 to 47 tons per year with average annual sales above USD 170,000; • at least 315 permanent jobs created (289% increase in comparison to the 2015 baseline); • the National Strategy for the Cocoa Value Chain positioned the cocoa produced in the international market value chain; • average family income reached USD 1411 per year (an increase of 342% of the average daily income per capita); • 180 ha of sustainable cocoa agroforestry systems incorporated into the national incentive program

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<p>Criterion 5: NbS are based on inclusive, transparent, and empowering governance processes</p>	<p>Throughout the project, consultations, participatory approaches and free, prior and informed consent (FPIC) were applied. In particular, local community associations were created and strengthened in close coordination with formal organizational structures (community councils for development). New employment opportunities were generated, especially for Q'eqchi' Maya youth and women, covering the value chain of production. An Institutional Technical Team was established at national level, which was responsible for coordinating and promoting actions in accordance with the National Strategy for the Cocoa Value Chain. The technical team included the government of Guatemala, local NGOs and actors involved in the cocoa value chain. A total of 898 producers and technicians developed technical skills for sustainable agricultural and manufacturing practices (20% women) [3]. Particularly young women and men profited and became recognized leaders as they got involved in technical, managerial and administrative activities. As part of the intervention, producer associations for the collection, processing, and transport of cocoa as well as the marketing and technical assistance services for producers were promoted. The established plantation management system and strengthened organizational and administrative capacities of associations and producers contributed to the success of the project</p> <p>In 2018, the initiative won the IUCN-Impact Award in the category of Social Inclusion, celebrating the engagement strategy of women and youth</p>
<p>Criterion 6: NbS equitably balance trade-offs between the achievement of their primary goal(s) and the continued provision of multiple benefits</p>	<p>The formalization of land tenure rights in the 1990s, which involved local cocoa producers in the Lachuá Ecoregion, was a key enabling condition for the NbS intervention. An analysis of the environmental and economic benefits of different land uses was conducted and informed the choice of agroforestry options. Local and Traditional Knowledge from the local Indigenous Q'eqchi' community was particularly valuable in agreeing the limits of trade-offs. Specifically, the approaches and intended benefits were agreed with nine producer associations, Fundalachuá and a number of service providers. The development of an agricultural calendar for cocoa cultivation in northern Guatemala contributed to increased accountability and transparency of production chain processes. Besides business plans to increase market access for cocoa products, the project also supported the identification of other sources of income, including through tourism</p>

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Criterion 7: NbS are managed adaptively, based on evidence	The NbS intervention contributed to the strategic priorities that were defined in the 1990s, which identified key drivers of poverty and triggers for nature. Further, it identified cacao as an alternative solution. For the NbS intervention, a monitoring and evaluation framework was put in place that provided feedback loops throughout the project intervention cycle, so that approaches could be adapted accordingly. In a survey conducted with 31 households in the Lachuá Ecoregion on the positive impacts of increases in income on their livelihoods, the majority considered their living conditions to have improved. The lessons learned from experiences in the Lachuá Ecoregion resulted in a follow-up project with activities in a number of sites in Guatemala, involving 1000 producers and achieving the restoration of 776 ha of land. In addition, the government defined a national goal of 15,000 ha of land to be dedicated to cocoa agroforestry systems
Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context	Lessons learned from the NbS intervention in Lachuá, especially the generation of financial, economic, and environmental benefits as key criteria to prioritize landscape restoration at the national level, contributed directly to the inclusion of cocoa agroforestry in the National Strategy for the Cocoa Value Chain. The government of Guatemala established an incentive program to finance investments in and maintenance of cocoa agroforestry systems based on clear technical parameters for management plans of such systems [3]. The business model developed for cocoa cultivation in the Lachuá Ecoregion ensured the sustainability and continuity of the intervention as well as the recognition of Indigenous People and the inclusion of women

Lessons Learned

Long-term engagement. The understanding and information generated over 20 years of working in the region were key to identifying the relevant societal challenges and associated impacts on biodiversity and human well-being. This supported the proposal of options that are acceptable in the specific social, economic, and cultural context.

Inclusive governance with a focus on women and youth. The inclusion of Traditional Knowledge and involvement of Indigenous communities, and especially women and youth, increased equity and contributed to the success of the NbS intervention in terms of improved livelihoods and poverty reduction.

A strong business case. The development of a robust and agreed business model in partnership with relevant actors not only secured the sustainability of the intervention but also created new opportunities to enter national and international markets.

3.3 Summary

First, the IUCN Global Standard for Nature-based Solutions™ offers robust criteria and indicators for benchmarking NbS interventions. A documentation framework based on the Standard enables coherent assessments of NbS project design, implementation, and monitoring and facilitates convergence and comparability of practices between Chinese and international NbS interventions. Moreover, a detailed self-assessment provides insights into the strengths, weaknesses, opportunities, and challenges of an intervention and enables the identification of concrete corrective actions and improvements.

Second, aligning the NbS case study documentation framework with and uploading the cases to well-known databases, such as *PANORAMA: Solutions for a healthy planet* or *NetworkNature*,⁶ increases accessibility. By utilizing existing platforms, lessons learned can be shared more widely, and information about the design, implementation, and evaluation of NbS interventions from China and internationally disseminated to different interested audiences.

Third, apart from taking advantage of existing case study databases, other, tailored means of communication and dissemination of NbS case studies appropriate for the Chinese context could be explored to further increase impact and uptake of experiences and lessons learned as well as to support greater understanding of NbS and the application of relevant national and international standards, including the IUCN Global Standard for Nature-based Solutions™.

4 Develop a Proposed Framework to Measure Nature-Based Solution Outcomes

NbS are increasingly being adopted to help support biodiversity, secure ecosystem services, and mitigate climate change impacts while slowing further warming. To understand the benefits intended by NbS, it is important to measure their outcomes consistently across scales and locations, as well as to follow internationally recognized standards and recommendations. However, a framework to measure NbS outcomes has not yet been developed.

This chapter describes two complementary frameworks to measure NbS outcomes, including (i) GEP [4] applied to the China case studies and (ii) a new framework developed here to assess the international case studies on the basis of the System of Environmental-Economic Accounting–Ecosystem Accounting (SEEA EA), an international statistical standard recently adopted by the United Nations Statistical Commission [5]. The chapter is structured so that Sect. 4.2 first explains the GEP indicator and applies it to the China case studies. Section 4.3 then develops an NbS outcomes measurement framework consistent with the SEEA EA and applies

⁶ <https://networknature.eu/network-nature-case-study-finder>.

it to the international case studies. The two measurement frameworks are closely linked, as GEP is an indicator that can be derived from one of the main accounts in SEEA EA. The linkages between the two approaches presented are discussed in Sect. 4.3.

4.1 GEP and China Cases Studies

4.1.1 Comparison of Different Assessment Methods of Ecosystem Services

Currently, international academia is still actively exploring nature's contribution to humankind through valuation. A related accounting framework was put forward and will play a positive role in protecting ecological environment. In 1992, the UN Conference on Environment and Development passed Agenda 21, which explicitly mentioned conducting an evaluation study of natural capital and ecosystems. Relevant research has since emerged. Costanza [6] and Daily [7] then subsequently put forward their respective research paradigm and made natural capital accounting a hot topic for study. Ouyang et al. [4, 8, 9] conducted a series of accounting and application of ecosystem services valuation (ESV) in China, eventually promoting the establishment of the first official ESV system in China and the world.

Usually, ESV comprises two stages: product amount accounting and monetary value accounting. The similarities and differences between scholars in China and those abroad can be concluded into the following three typical methods:

- (1) Landcover coefficient method based on ecosystem types, represented by Costanza and Xie [10]. The method has its advantage as it needs little data for calculation. Its disadvantage lies in the lack of accuracy in results due to two factors. First, the qualities of ecosystems are not taken into account. Second, although a few scholars added weight coefficient of quality to amend the disadvantage of this method, they still could not see distinct geospatial disparities.
- (2) Biophysical modeling method based on localized parameters, represented by Daily and Ouyang [8]. Based on localized data and parameters, this method uses various biophysical models to carry out targeted assessments of ecosystem service product amount for each study area. On the basis of product amount assessment, the method uses local alternative project costs to carry out monetary value assessment. To achieve this purpose, Daily initiated a Natural Capital program which developed a free assessment software called InVEST (Integrated Valuation of Ecosystem Services and Trade-offs). Moreover, considering the characteristics of monitoring data in China's ecosystems, Ouyang Zhiyun's team developed a free online analysis platform called IUEMS (Intelligent Urban Ecosystem Management System), which can assess a few ecosystem service types. This method's downside lies in its high requirement for data. It is safe

to say this method has obvious advantages. First, it provides high accuracy in assessment and analysis, thus being able to reflect characteristics of the local ecological environment. Second, the requirement of rich data means that, when managing ecosystems, people can have more ways of analyzing and improving the capability of ecosystem services.

- (3) Equivalent replacement method based on non-monetary accounting, represented by Liu [11]. In general, this method is still being studied and used by only a few people, who are mostly Chinese scholars with notably different research directions. Compared with the previous two methods, this method is advantageous in its calculation of ecological product value without considering human economic activities and can reduce the influence of human economic activities (such as pricing) on the value of ecological products. Yet this method has its apparent downsides as well. First, the parameters of energy conversion rate are for general use and cannot meet the need for localized accurate calculation. Second, this method adopts energy-currency conversion rates of different countries to calculate monetary values. The conversion rates are neither universal nor updated regularly; therefore, the method cannot satisfy management demand. Third, although solar energy value or “ecological unit” substituted conventional currencies and unified the units of various ecological products, they do not conform to the connotation of “value” in a general sense (i.e., monetary value). Therefore, users must change their mindset drastically (Table 1).

Table 1 Comparison of typical assessment methods of ecosystem services

	I. Landcover coefficient method based on ecosystem types	II. Biophysical modeling method based on localized parameters	III. Equivalent replacement method based on non-monetary accounting
Scale (Accuracy)	National (Average)	Localized (High)	National (Average)
Calculation of product amount	Simple (with the table of landcover coefficient method based on ecosystem types)	Complex (various ecosystem service process models)	Same as Method I and II
Calculation of product value	Simple (alternative project cost)	Simple (alternative project cost)	Simple (equivalent replacement coefficient table)
Users	Wide	Ecological environment area	Few
Management practice	Limited tools	Many tools	Relatively difficult to comprehend

4.1.2 Methodology

Physical Quantity Assessment Method

In NbS benefit assessment based on ESV, we provide 14 typical and practice-proved ESV methods. In different NbS cases, users can choose different indicators and methods according to their needs (Table 2).

Value Quantity Assessment Method

Please browse the supplementary material for more explanation of specialized words and the mathematical method (Table 3).

4.1.3 Marine Ecosystems: The Case of Futian Mangrove Park, Shenzhen

Case Background

Shenzhen Mangrove Ecological Park is located in Futian District, Shenzhen city. Covering an area of about 38 ha, it is a municipal park open to the public for free. As an ecological park that addresses both ecological conservation and wetland education, it plays an important role in providing ecological, cultural, sports, and recreational functions for the city. The park is managed by the Mangrove Foundation (MCF), entrusted by the Futian District government, and is the first ecological park in China to have adopted the social governance model of “government + professional institutions + public participation.” Geographically, to the west the park is adjacent to Futian Mangrove National Nature Reserve, the smallest and only national nature reserve located in the hinterland of a city. To the south, it is close to Hong Kong Mai Po Nature Reserve, an important wetland of international importance. Futian Mangrove Ecological Park is located in the middle of the two reserves, serving as a significant buffer zone. The three constitute the Shenzhen Bay Wetland with their precious native mangroves and other wetland organisms and have important values in both ecology and landscape culture (Fig. 4).

Evaluation System of This Case

In the NbS case evaluation of Shenzhen Mangrove Ecological Park, due to the lack of local agricultural production or water resources supply service, its benefits to human beings are classified into two categories for evaluation: regulation service products (eight sub-items) and cultural service products (two sub-items). See Table 4 for the detailed indicator system.

Table 2 Overview of quantitative valuation methods of ecosystem services

Categories	Accounting indicators	Accounting methods
Substance provisioning	Biomass provisioning	For agriculture, forestry, animal and fishery products, refer to local statistical yearbooks or agricultural department's data. For water supply, refer to local water reports or water department's data, or calculate the amount of local natural water supply in total water supply
Regulation services	Water conservation	Local rainfall minus runoff minus evapotranspiration
	Soil retention	Under the condition of runoff and rainfall, soil retention is calculated by the Universal Soil Loss Equation (RUSLE), and then multiplied by the sediment formation coefficient to obtain the amount of sediment reduction. Soil retention is multiplied by the content of non-point source pollutants in the soil to obtain the amount of non-point source pollution reduction
	Wind prevention and sand fixation	Use the Revised Wind Erosion Equation (RWEQ) to calculate the actual and potential erosion in the research area. The gap between the two numbers is the amount of wind prevention and sand fixation in the ecosystem
	Coastal zone protection	Use the natural shoreline method to calculate the total length of protective natural shoreline in the area
	Flood mitigation	Use the SCS model to calculate the runoff reduced by vegetation; use monitoring data to calculate water retention in lakes, marshes, and reservoirs
	Air purification	Follow the standard level of local air pollutants, and select pollutant discharge amount or purification amount (purification amount per unit area multiplied by the area of each ecosystem) as the quantity

(continued)

Table 2 (continued)

Categories	Accounting indicators	Accounting methods
	Water purification	Follow the local water quality standard level and select water pollutant discharge amount or purification amount (purification amount multiplied by area per unit area of each ecosystem) as the physical quantity
	Carbon sequestration	Use net primary productivity data and NPP/NEP conversion coefficient to calculate the amount of carbon sequestration; or based on the gap of two years' biomass and the coefficient of converting C to CO ₂ to calculate the amount of carbon sequestration; or use the rates of carbon sequestration in different ecosystems, multiplied by time to obtain yearly carbon sequestration amount
	Climate regulation	When the temperature is higher than the optimum, the transpiration and evaporation heat consumption per unit area of various local ecosystems is multiplied by the area and summed up
	Noise attenuation	By monitoring data in typical sections of different roads, assess the average noise reduction amount of roadside green space (at both sides and inside)
Cultural services	Ecotourism	Through sampling survey statistics, obtain the number of tourists and their average stay time at a tourist site
	Recreation	Through sampling, obtain total leisure hours and number of tourists of public recreation green space (parks, green trails, waterfront space, etc.) in the research area
	Landscape added-value	Obtain landscape premium of housing transactions and hotel transactions from the sampling statistics of the year

Table 3 Overview of product valuation methods of ecosystem services

Categories	Accounting indicators	Accounting method
Substance provisioning	Biomass provisioning	Land rental method, market price method, and residual method
Regulation services	Water retention	Surrogate market method, to calculate the ecosystem's water retention value by calculating the cost needed to construct water conservancy facilities which can conserve the same amount of water
	Soil retention	Surrogate market method, to use the cost of clearing and removing earth to calculate the value of reducing sediments, to use the cost of cleaning pollutants to calculate the value of reducing non-point pollution
	Wind prevention and sand fixation	Surrogate market method, to use per unit area cost of treating desertification land, or per unit cost of vegetation restoration, to calculate the forest ecosystem's value in preventing wind and fixing sand
	Coastal zone protection	Surrogate market method, to use the cost of constructing and maintaining sea wave protection works to assess the ecosystem's value in preventing wind and protecting dikes through marine salina, mangroves, and coral reefs
	Flood mitigation	Surrogate market method, to use the cost of constructing and maintaining a reservoir to calculate the ecosystem's value in flood mitigation
	Air purification	Surrogate market method, to use the cost of treating industrial atmospheric pollutants to calculate the ecosystem's value in air purification. Mainly needs to calculate the value of cleaning pollutants such as sulfur dioxide, NO _x s, smoke, and dust, etc

(continued)

Table 3 (continued)

Categories	Accounting indicators	Accounting method
	Water purification	Surrogate market method, to use the cost of treating industrial water pollutants to assess the ecosystem’s water purification value. Mainly needs to calculate the value of cleaning pollutants such as COD, total nitrogen treatment, total phosphorus treatment
	Carbon sequestration	Market price method, to calculate ecosystem’s carbon sequestration value by using carbon-trading price in the market
	Local climate regulation	Surrogate market method, to calculate ecosystem’s local climate regulation value by calculating power consumption required by manual temperature and humidity regulation
	Noise attenuation	Surrogate market method, to assess ecosystem’s noise attenuation value by calculating the cost of constructing and maintaining sound insulation walls
Cultural services	Ecotourism	Use travel cost method to calculate value of landscape recreation
	Recreation	Use surrogate market method to calculate ecosystem’s leisure service value
	Landscape added-value	Use hedonic price method or market price method to assess ecosystem’s value in providing aesthetic and joyful experience for surrounding communities

Case Evaluation Outcome

The accounting outcome shows that Futian Mangrove Ecological Park is an important ecological corridor and habitat for the ocelot (a genre of wildcats existing in Shenzhen and Hong Kong) and more than 300 black-faced spoonbills living in the surrounding areas. Moreover, it conserves about 723,000 m³ of water every year, reduces cooling energy consumption by 3009 kWh, and reduces urban storm runoff by 140,000 m³. In addition, the park plays a crucial role in reducing non-point source pollution, absorbing carbon dioxide, and purifying air and waterbodies. Ecological-regulation products are worth 31.07 million Yuan per year.



Fig. 4 Shenzhen mangrove ecological park

Futian Mangrove Ecological Park also plays an important role in providing cultural services, hosting on average 1.3 million visitors and holding popular science education sessions that benefit 11,000 people each year. It provides various value-added landscape services for about 1.5 million square metres of building space within a radius of 2 km. These cultural ecological projects are worth 161 million Yuan/year on average.

Futian Mangrove Ecological Park is an important ecological product supply area in Shenzhen. The supply capacity of regulated ecological products per unit area is 2.28 times that of the city's average, and the total supply capacity of ecological products per unit area is 7.43 times that of the city's average (Table 5).

4.1.4 Urban Ecosystems: The Case of the Shenzhen Traffic Green Belt

The researchers used the Shenzhen transport green belt as a case study to assess the ecosystem service provisioning capacity of green linear spaces in megacities. The traffic greenbelt in Shenzhen can play a significant role in flood regulation and noise reduction with its roadside subsided green space design and complex community structure design. Thus flood mitigation and noise attenuation became the evaluation indicators of traffic green belts in Shenzhen. The results showed that in terms of the city's roadside green belts, the functional capacity of their noise reduction service stood at 154,090.91 dB/km, and the value quantity 1.156 billion Yuan. The average functional capacity of noise reduction stood at 9.87 dB, with the average value quantity of noise reduction 73.99 Yuan/m. The results showed that in the city, roadside stripe-shape sunken green space and roadside point-shape sunken green space would reduce runoff by 2212 mm and 2966 mm respectively each year.

Table 4 The indicator system of Futian mangrove ecological park’s ecosystem services

First level indicators	Second level indicators	Definitions of indicators
Regulation services	Sediment reduction	The local ecosystem protects the soil, reduces rainfall erosivity, increases soil erosion resistance and reduces silt in river channels through various layers, such as forest canopy, litters, and roots
	Pollution reduction from non-point sources	Non-point source pollution (nitrogen and phosphorus) in related streams is reduced thanks to less sedimentation in the local ecosystem
	Climate regulation	Heat removed by evaporation from the local terrestrial ecosystem
	Carbon sequestration	Local ecosystem absorbs carbon dioxide from the atmosphere, synthesizes it as organic matter, and then sequesters carbon in plants or soil
	Flood mitigation	Precipitation, conserved runoff, and transit water are absorbed by the local ecosystem
	Water conservation	The net increase in local water resources through local ecosystem’s interception of conserved precipitation, which is made possible through enhanced soil infiltration, conservation, and groundwater replenishment
	Air purification	The local ecosystem absorbs, filters, blocks and decomposes air pollutants to improve the atmospheric environment (sulfur dioxide, oxynitride, and industrial dust)
	Water purification	Wetland ecosystems such as lakes, rivers, and marshes absorb, decompose and transform water pollutants (COD, ammonia nitrogen, and total phosphorus)
Cultural services	Tourism and recreation	Local ecosystem provides recreational and leisure services which enrich people’s knowledge and make them joyful
	Natural landscape premium	Beautiful landscape of the local ecosystem leads to premium in property use

Table 5 Accounting results of ecosystem services

Types of ecosystem services		Functional capacity	Unit	Value quantity	Unit
Sediment reduction		613	m ³	7719	Yuan
Non-point source pollution reduction	Total phosphorus	3.24	ton	36,288	Yuan
	Total nitrogen	1.89	ton	6615	Yuan
Carbon sequestration		658	ton	28,116	Yuan
Water conservation		722,901	m ³	4,417,433	Yuan
Flood reduction		140,753	m ³	4,691,294	Yuan
Climate regulation		3009	10,000 kW-h	21,577,183	Yuan
Air purification	Sulfur dioxide	5	ton	8654	Yuan
	NO _x	138	ton	262	Yuan
	Dust	615	ton	276,812	Yuan
Self-purification of water body	Chemical Oxygen Demand (COD)	6	ton	15,777	Yuan
	Total nitrogen	0.44	ton	1529	Yuan
	Total phosphorus	0.44	ton	4892	Yuan
Recreational services		130	10,000 people	10,400	10,000 Yuan
Landscape premium		150	10,000 m ³	5783	10,000 Yuan
Total		–	–	19,290	10,000 Yuan

If all potential sunken green space in Shenzhen was created, then altogether it could potentially reduce runoff by $214.65 \times 10^6 \text{ m}^3$ and storm runoff by $7.10 \times 10^6 \text{ m}^3$ each year.

4.1.5 Desert Ecosystems: The Case of the Ant Forest Afforestation Project

“Ant Forest” is a charity initiative by Alibaba. Users could grow virtual trees on their mobile phones with “green energy.” When the trees grew up, Ant Forest and its partners would plant real trees on earth. Since 2016, the total number of real

trees planted has exceeded 223 million. The researchers evaluated the results of the reforestation projects of Ant Forest for the period 2016–2020, and the system of evaluation indicators is shown in Table 6.

Table 6 Ant forest ecosystem service accounting indicators

Service categories	Accounting subjects	Definitions of indicators
Material products	Forest products	Timber products, forest products, and primary products related to forest resources, such as tricholoma matsutake and sea-buck thorns
Regulation services	Water conservation	Through its structure and process, the ecosystem intercepts stagnant precipitation, enhances soil infiltration, conserves water in the soil, replenishes underground water, regulates river flow, and increases available water resources
	Soil retention	Through its structure and process, the ecosystem protects the soil, reduces the erosion ability of rainwater and reduces soil loss
	Wind prevention and sand fixation	By enhancing soil's wind resistance, the ecosystem reduces wind erosion and sand hazard
	Carbon sequestration	The ecosystem absorbs carbon dioxide and synthesizes organic materials, sequesters carbon in plants and soil, and reduces carbon dioxide concentrations in the atmosphere
	Oxygen generation	The ecosystem releases oxygen through photosynthesis and maintains stable oxygen concentrations in the atmosphere
	Air purification	The ecosystem absorbs, blocks, and filters pollutants in the atmosphere, such as SO ₂ , NO _x , and dust, reduces the concentration of air pollution, and improves air quality
	Climate regulation	The ecosystem regulates the temperature and makes the living environment more comfortable through vegetation transpiration and water surface evaporation
Cultural services	Recreation and tourism	The intangible benefits that human beings get from the ecosystem through tourism, such as feelings, knowledge obtaining, recreation, and aesthetic experience

In 2020, the GEP of Ant Forest's Forestation Projects between 2016 and 2020 stood at 2.088 billion Yuan. Among the 56 banners and counties covered by Ant Forest's projects, the plots with the highest GEP were located in Zuo Banner of Alxa, Inner Mongolia, with its GEP reaching 633 million Yuan in 2020. In 2020, Ant Forest's GEP per unit area stood at 1.0803 million Yuan/km², and the plot with the highest GEP per unit area was located in Longhua County, Chengde, Hebei Province, reaching 11.3052 million Yuan/km². In addition, the assessment predicted the GEP of Ant Forest 2016–2000 forestation projects when all plots' vegetation reached a mature state in their respective areas.

4.2 SEEA EA for NbS Outcomes and Illustration for International Case Studies

This section develops and illustrates an integrated environmental-economic measurement framework for NbS outcomes. The measurement framework developed allows to consistently and comprehensively measure each of these dimensions by using the same principles as the SEEA EA, an international statistical standard adopted by the United Nations Statistical Commission in 2021, after a global development in 2018–2020 that involved more than 100 authors and global reviews and public consultations by more than 600 experts [5].

SEEA EA comprises a scientifically robust and comprehensive framework for measuring ecosystems and their linkages to the economy and human well-being, including ecosystem services and their economic value. The System of National Accounts (SNA) is a well-established framework to measure the status of the economy by producing aggregate indicators like the GDP. The SEEA EA complements the SNA by providing a complete framework for describing the relationship between the environment and the economy using the same accounting principles.

Conceptually, SEEA EA views ecosystems as natural capital assets, characterizing them by their extent and condition and linking them to society through the provision of ecosystem services (Fig. 5). SEEA EA constitutes a set of standards, principles, and recommendations to measure ecosystems extent, condition, and ecosystem services in physical and monetary terms.

As such, the measurement framework developed here for NbS enables linking the estimates to national economic aggregate variables, including GDP; to understanding the absolute and relative contribution of NbS to national economy; and to assessing the relative significance of different ecosystem assets and ecosystem types; as well as comparisons with other conservation policy options or even with other economic policies and assets, such as infrastructure. In addition, the framework allows to compute aggregate indicators, including GEP.

When developing the measurement framework, we note that NbS outcomes can go beyond the scope of SEEA EA. For example, SEEA EA measures the contribution of ecosystems to crop production, but does not measure total crop production and its

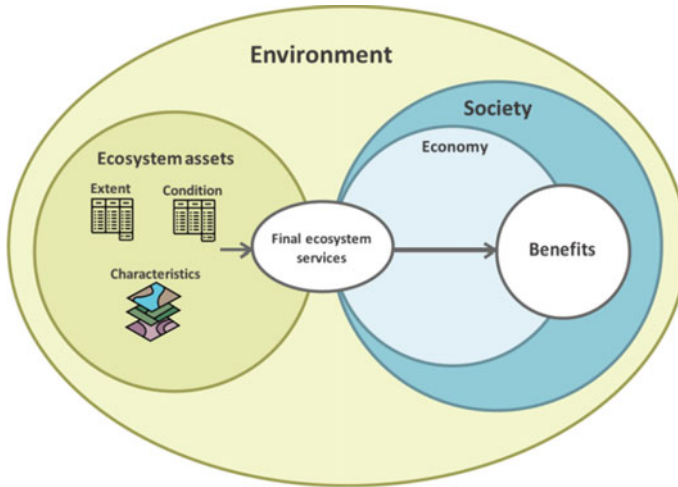


Fig. 5 The SEEA EA general ecosystem accounting framework. *Source* United Nations [5]

linkages in the value chain. These sectoral and economy-wide impacts are important to be considered and we show how they can be considered.

In the rest of Sect. 4, Sect. 4.2.1 develops a general framework for measuring NbS outcomes consistent with SEEA EA, showing general examples from the set of international case studies assessed by IUCN and a more in-depth assessment of the case of sustainable cocoa farming in Guatemala. Thereafter, Sect. 4.2.2 describes how to go beyond SEEA EA by measuring economy-wide impacts consistent with SNA. Finally, Sect. 4.2.3 presents conclusions and discusses areas of essential future work.

4.2.1 A Framework to Measure NbS Outcomes Consistently with SEEA EA and Illustration of an International Case Study

NbS can help to conserve and/or protect ecosystems to assure the continuous flow of ecosystem services that benefit society by addressing key societal challenges. SEEA EA allows measuring and tracking benefits from NbS in a comprehensive and consistent way. The SEEA EA is built on five interlinked accounts: (1) Ecosystem extent (physical); (2) Ecosystem condition (physical); (3) Ecosystem services flow (physical), (4) Ecosystem services flow (monetary); and (5) Monetary ecosystem asset account.

The above five accounts constitute a system where the accounts are strongly interconnected and provide a comprehensive and coherent view of ecosystems. Physical and monetary accounts as a system allow to assess synergies and trade-offs on the changes in ecosystems and their benefits to people (Fig. 5).

The variables chosen to measure NbS outcomes for each of the five accounts depend on which intervention is implemented, at which scale, and which societal challenges are addressed. Table 7 summarizes the main features of the five international cases assessed by IUCN.

Below, we develop ecosystem accounts for measuring NbS outcomes. For each account, we first explain the SEEA definition, then elucidate its application to measuring NbS outcomes, and finally develop an illustrative application for the case of sustainable cocoa farming in Guatemala.

Extent Accounts

Ecosystem extent accounts construct and organize data on the physical extent or area of different ecosystem types in the ecosystem accounting area. An ecosystem accounting area is the geographical territory for which ecosystem accounts are compiled; for example, a country or the area of NbS intervention.

When measuring NbS outcomes, the first step is to define the ecosystem accounting area of the NbS intervention. For example, the case of sustainable cocoa agroforestry in Guatemala is implemented in agricultural plots. In this case, the relevant scale might be the agricultural plots and the broader landscape they are part of. SEEA EA provides a detailed discussion on spatial unit delineation. Table 8 describes ecosystem accounting areas relevant for each NbS from Table 7.

The second step is to measure the extent of different ecosystem types in ecosystem accounting area before and after the NbS intervention is implemented. The SEEA EA uses the IUCN Global Ecosystems Typology (GET) [12] as a reference classification system for ecosystem types. The IUCN GET applies an ecosystem process-based approach to a hierarchical, multi-level ecosystem classification for all ecosystems around the world, including terrestrial, subterranean, freshwater, marine, and atmospheric environments [13].

We illustrate an ecosystem extent account to measure the NbS outcomes in the case of cocoa agroforestry in Lachuá, Guatemala (Table 8). Prior to the NbS implementation, the area was mostly used for agricultural activities (annual agriculture, including maize and beans); plantations (cardamom), semi-natural pastures for livestock grazing, and fallow lands that are mostly land in rest from cardamom production. The plots also include small urban areas (mostly buildings in the farm plot) and wetlands. The extent of different land uses was first reclassified to correspond to IUCN GET Ecosystem Functional Groups (Level 3) and then recorded in the first row in Table 8 (opening extent).

Next, the closing extent is recorded as the extent of ecosystems after the implementation of NbS. Ecosystem extent can be recorded annually or after a certain period that is relevant for the outcomes of the intervention. All of the area of the intervention in the Lachuá case has been converted to cocoa agroforestry, except urban and wetland areas. This is recorded as a managed expansion of ecosystem type T7.3

Table 7 Summary of international cases reviewed

	Mekong delta flood-friendly farming	Sustainable cocoa in Guatemala	Medmerry coastal realignment in England	Sustainable aquaculture in Zanzibar	Integrated coastal and wetland management in Italy
Intervention	Flood-based agriculture as an NbS to conserve and restore flood plain ecosystem functions	300 ha of agriculture, semi-natural pastures, and old fields transformed into cocoa agroforestry	Coastal habitat creation and flood alleviation scheme on the West Sussex coast (184 ha of intertidal habitat)	Marine protected areas co-management for sustainable seaweed aquaculture	Integrated coastal and wetlands management, by protecting, sustainably managing, and restoring a large portion of the Gulf of Oristano
Societal challenge	Disaster risk reduction/economic and social development	Economic and social development/Env. degradation and biodiversity loss	Disaster risk reduction	Economic and social development/food security	Climate change adaptation and mitigation/Economic and social development/Env. degradation and biodiversity loss
Ecosystem context	Water basin	Terrestrial (agriculture)	Coastal	Coastal	Wetlands

Table 8 Ecosystem extent account for agroforestry cocoa farming in Lachuá

Realm	Terrestrial				Total
	T7 Intensive land-use systems				
Biome	Annual croplands	Plantations	Urban and industrial ecosystems	Derived semi-natural pastures and oldfields	Terrestrial-freshwater TFI Palustrine wetlands
Selected Ecosystem Functional Group (EFG)					
Opening extent	79.1	85.5	0.4	139.5	0.9
Other type of management	79.1	85.5	0.4	139.5	0.9
Additions in extent	0	304.1	0	0	0
Managed expansion					
Agroforestry		304.1			
Other type of management					
Unmanaged expansion					
Reductions in extent	79.1	85.5	0	139.5	0
Managed reduction					
Agroforestry					
Other type of management	79.1	85.5	0	139.5	0
Unmanaged reduction					
Net change in extent					
Agroforestry	0	304.1	0	0	0
Other type of management	-79.1	-85.5	0	-139.5	0

(continued)

Table 8 (continued)

Realm	Terrestrial				Terrestrial-freshwater	Total
Biome	T7 Intensive land-use systems					
Selected Ecosystem Functional Group (EFG)	Annual croplands	Plantations	Urban and industrial ecosystems	Derived semi-natural pastures and oldfields	TF1 Palustrine wetlands	
					Seasonal floodplain marshes	
	0	304.1	0.4	0	0.9	305.4
Closing extent						

Plantations.⁷ Reductions in the extent of different ecosystem types by management type are also recorded. The net change by ecosystem and management type and the closing extent after the NbS implementation are recorded in Table 8.

In addition, we categorize the expansions or reductions of ecosystem types by the type of NbS intervention; in this case, this concerns only agroforestry practices. Additional rows can be added to describe additions/reductions in agro-forested areas, protected areas, or areas with coastal protection interventions. The opening and closing extent can also be listed by management type if needed. This is relevant for understanding NbS outcomes from different interventions but different from standard practice in ecosystem accounting, which only records the additions and reductions to the extent of the different ecosystem types, and considers whether they are managed or unmanaged.⁸

Ecosystem Condition Accounts

Ecosystem condition accounts construct data on selected ecosystem characteristics and their distance from a reference condition to help assess the integrity of ecosystems. Jointly with the ecosystem extent, the ecosystem condition determines the flow of ecosystem services to benefit society. For example, soil characteristics in part determine the yield of agricultural crops, and water clarity will similarly determine the need for chemicals in water purification for human consumption.

When measuring NbS outcomes, the structure of ecosystem condition accounts will depend on the ecosystem targeted by NbS, the type of NbS implemented, and data availability. Appendix 1 shows potential variables to measure ecosystem conditions for NbS interventions in Table 8.

Table 9 shows a stylized ecosystem condition account for one variable for plantations in the case of cocoa agroforestry plantations in Lachuá, Guatemala. Ecosystem condition accounts are commonly compiled by ecosystem type because each type

⁷ Plantations are generally long-rotation perennial woody crops established and maintained for a variety of food and materials. The harvested products include wood, various fruits, tea, coffee, palm oil and other food additives, materials such as rubber, ornamental materials (cut flowers), etc. The vegetation of most plantations comprises at least two vertical strata (the managed woody species and a ruderal ground layer), although mixed plantings may be more complex and host a relatively diverse flora and fauna if managed to promote habitat features. Fertilizers and water subsidies are applied, and harvesting occurs at intervals depending on the crop.

⁸ Managed area change of an ecosystem is due to direct human activity, including unplanned effects of such activity. Unmanaged area change corresponds to changes resulting from natural processes, including seeding, sprouting, suckering, or layering. Unmanaged expansion can be influenced by human activity, for example, the expansion of deserts due to the effects of climate change, or result from abandonment of land by people.

has distinct characteristics.⁹ In this case, the percentage of agroforestry is a characteristic of the ecosystem structural state; a potential condition indicator derived directly from NbS implementation (Table 9).

As with other accounts, ecosystem condition accounts record the condition variable value before and after the NbS intervention. Table 9 shows that the closing value for the percentage of agroforestry is 100, measured as the percentage of the agricultural plots converted to cocoa agroforestry plantations. The opening value is recorded as non-applicable because there was zero extent of cocoa agroforestry plantations before the NbS intervention. The condition account also records the reference values for each variable. For the case of the percentage of agroforestry in plantations, the reference values are between zero and 100. Including the reference value is important because the boundaries could be less obvious for other variables, like the gross primary production. Finally, the ecosystem account also includes an indicator value for each condition variable that is useful to compare the condition across different variables.

Ecosystem Services (Physical)

The ecosystem services account connects ecosystem assets and their beneficial contributions to society. Although no globally accepted classification of ecosystem services exists, SEEA EA offers a general typology using 27 relatively high-level ecosystem service category classes that form a robust basis for a more or less detailed classification as needed by the application.

Ecosystem services flow account in physical terms records direct ecosystem services, e.g., the contribution of ecosystem assets for growing crops, or wood provision, as well as indirect ecosystem services like carbon sequestration services that help with global climate regulation services. The ecosystem services account also allows for the recording of intermediate service flows between ecosystem assets, e.g., pollination services from grasslands and forests supplied to croplands, increasing the yield of crops.

Most times, NbS affect and contribute through more than one ecosystem service. Implementing cocoa agroforestry farming in Guatemala is important as a means of generating income for households in a sustainable way over time; by reducing soil erosion and the need for fertilizers, it increases the lifespan of soil as well as capturing carbon to mitigate GHG emissions.

Table 10 summarizes annual ecosystem service flows for selected ecosystem services; based on data availability; before and after the NbS implementation in Lachuá, Guatemala. Annual flows in physical terms are recorded units that match

⁹ The SEEA ecosystem condition typology (ECT) is a hierarchical typology for organizing data on ecosystem characteristics and its major abiotic and biotic components (water, soil, topography, vegetation, biomass, habitat, and species). The ECT has six classes of characteristics organized in three groups of ecosystem characteristics: A. Abiotic (A1. physical state and A2. chemical state), B. Biotic (B1. compositional state, B2. structural state, and B3. functional state), and C. Landscape level (C1 landscape/seascape).

Table 9 Stylized ecosystem conditions account for plantations in the case of agroforestry cocoa farming in Lachuá, Guatemala

SEEA ecosystem condition typology class	Variables		Terrestrial							
	Descriptor	Measurement unit	T7 Intensive land-use systems			Indicator values (rescaled)				
			T7.3 Plantations		Reference-level values		Opening value	Closing value	Change	
			Opening value	Closing value	Change	Upper level	Lower level	Opening value	Closing value	Change
B1. Structural state	% Agroforestry	% of total land plot	NA	100		0	100	NA	1	

Note NA = Non-Applicable

Table 10 Summary of ecosystem services annual flows by ecosystem type before and after agroforestry cocoa NbS implementation in Lachuá, Guatemala

	Ecosystem service	Physical		Monetary (in quetzales year 2016)	User	
		Units	Volume			
Before NbS implementation	Annual croplands	Crop provisioning: Beans	kg	6024	26,979	Agriculture
		Crop provisioning: Corn	kg	37,567	37,022	Agriculture
		Global climate regulation	tons CO _{2e}	-100	-3501	Global society
		Soil erosion control	tons	49,728	NA	Croplands (int.)
	Plantations	Crop provisioning: Cardamom	kg	17,803	907,956	Agriculture
		Global climate regulation	tons CO _{2e}	474	16,581	Global society
		Soil erosion control	tons	1067	NA	Croplands (int.)
	Derived semi-natural pastures and oldfields	Global climate regulation	tons CO _{2e}	-372	-3501	Global society
		Soil erosion control	tons	1,262,940	NA	Croplands (int.)
	After NbS implementation	Plantations	Crop provisioning: Cocoa pods	kg	270,953	1,788,290
Global climate regulation			tons CO _{2e}	1864	65,195	Global society
Soil erosion control			tons	1,332,002	NA	Croplands (int.)

different ecosystem services. For example, crop provisioning is measured in weight measurements such as kilograms or tons. Soil erosion control is measured in tons of soil erosion retained (usually relative to no soil cover; bare lands).

As a convention, avoided soil loss is recorded using positive values. A similar case applies to climate regulation services, which show positive values for GHG sequestration (in CO₂ equivalent units). In this illustrative example, we recorded the net uptake of carbon emissions. In future, carbon uptake and emissions might

be recorded separately, corresponding only to land use and land cover change. That level of attribution was not feasible in this illustrative application.

In the accounting context, information in Table 10 is used to record the ecosystem services in a supply-use table. Supply-use tables record flows of final ecosystem services between economic units and ecosystems (final ecosystem services) and flows of intermediate services among ecosystems. Appendix 1 shows the supply-use table for ecosystem services in physical terms for the case of cocoa agroforestry in Lachuá, Guatemala. The aggregate measure GEP, used in Sect. 4.2 of this report, is derived from these tables.

A supply-use table is important not only to identify which ecosystem supplies the services, but also who is the user (beneficiary) of the service. For example, crop-provisioning services usually contribute to the agricultural economic sector, where labour and capital are invested along with crop-provisioning ecosystem services to produce and sell crops (or consume within the household).

In the measurement of NbS outcomes, it is relevant to modify the traditional supply-use table to distinguish whether the ecosystem service flow was generated within or outside the area of intervention. For example, farmers may implement agroforestry practices in some of their plots and intensive agriculture practices in others. In the stylized SEEA EA supply-use tables, benefits for the farmers are recorded as kilograms of crops from agricultural land. For NbS outcomes, the ecosystem flow needs to be differentiated between the crops produced in agroforestry versus other areas.

Ecosystem Services (Monetary)

An ecosystem services flow account records the monetary value of flows of ecosystem services based on their exchange value. That is, estimating the price for individual ecosystem service output and multiplying it by the physical quantity of ecosystem services (from the ecosystem service flow account measured in physical terms). Measuring the value of ecosystem services from NbS in monetary terms allows the measurement and comparison of ecosystem services and ecosystem assets that are consistent with standard measures of products and assets as recorded in the national accounts, including GDP.

In the case of market goods such as crops and timber, monetary valuation can use market prices observed from actual market transactions of those goods. However, in many cases, prices for ecosystem services are not transacted through conventional markets, so their prices cannot be readily observed. In such cases, monetary valuation of ecosystem services regularly requires using non-market valuation methods developed in economics over the last several decades. Appendix 1 shows valuation approaches for main ecosystem services in NbS interventions in Table 7. Table 10 lists the monetary valuation of ecosystem service annual flows for the case of cocoa agroforestry in Lachuá.

For global climate regulation services, carbon markets are currently quite well established, and the current exchange value for carbon sequestration can be plausibly

observed (though questions remain whether current market values of, for example, carbon offsets adequately reflect their true long-term social value). Other valuation methods might need to be applied for other indirect services for which markets do not exist, like flood control services.

In addition, several regulating services are intermediary services embodied in other final services, such as soil erosion control that benefits crops provisioning. In this case, a method to disentangle the contribution of each service to the final service value needs to be implemented. In Table 10, the value of soil erosion control is assumed to be embodied in the total value of crop provisioning services, and hence, not disaggregated separately into soil erosion control and other functions of ecosystems that support crop provisioning.

Ecosystem Asset Valuation

Monetary ecosystem asset accounts denote the economic value (wealth) of ecosystems as natural capital assets. The monetary asset value is derived as the net present value of the supply of ecosystem services over the valuation period (typically perpetuity, though shorter periods such as 25 years are also sometimes used). In addition, the monetary value of ecosystem assets can be compared to the monetary value of other types of assets, including produced assets, to compare NbS with other policy alternatives such as investing in grey infrastructure. As ecosystems change in their extent and condition in the accounting area, and change the flow of ecosystem services, their asset value also changes. These changes in ecosystem services represent changes in the current and future contributions of ecosystems to society, effectively, changes in current and future wealth.

Table 11 summarizes the monetary asset account in the case of agroforestry cocoa farming in Lachuá applying the net present value approach. The first row shows the opening value of the monetary asset value before the implementation of NbS. The total value of the ecosystem asset monetary value before NbS reaches Q 41,892,769 (quetzales), explained mainly by ecosystem services in cardamom plantations providing crop services. The last row lists the closing value of the ecosystem asset monetary value. The total ecosystem asset monetary value after the NbS reaches Q 79,882,188, mainly because of cocoa pod provisioning. This result means that the total ecosystem asset monetary value of the 304 ha plots in Lachuá nearly doubles its value as a result of NbS.

The rows between the opening and the closing values decompose changes in the monetary asset value attributed to ecosystem enhancement, ecosystem degradation, ecosystem conversion, and revaluations if any. For the purpose of the illustration, we assumed that changes in the ecosystem asset monetary value all relate to ecosystem conversions.

Note that some portion of the ecosystem asset monetary value (and ecosystem services monetary account value) related to monetary quantification of the value of ecosystems is ignored in SNA. This is the case, for example, for global climate regulating services that were not traded (and, thus, included in SNA). However,

Table 11 Illustrative ecosystem asset monetary account for agroforestry cocoa farming in Lachuá, Guatemala (all estimates in local currency quetzales 2016)

	T7.1 Annual croplands	T7.3 Plantations	T7.5 Derived semi-natural pastures and oldfields	Total
Opening value	\$2,607,468	\$39,845,988	−\$560,687	\$41,892,769
Ecosystem enhancement	\$0	\$0	\$0	\$0
Ecosystem degradation	\$0	\$0	\$0	\$0
Ecosystem conversions				
Additions	\$0	\$77,072,371	\$560,687	\$77,633,058
Reductions	−\$2,607,468	\$0	\$0	−\$2,607,468
Other changes in volume of ecosystem assets				
Catastrophic losses				
Upward reappraisals	\$0	\$0	\$0	\$0
Downwards reappraisals	\$0	\$0	\$0	\$0
Revaluations	\$0	\$0	\$0	\$0
Net change in value	−\$2,607,468	\$40,036,199	\$560,687	\$37,989,419
Closing value	\$0	\$79,882,188	\$0	\$79,882,188

some other services, like crop provisioning, were already accounted for in national accounts, not explicitly but as part of crop production. Ecosystem accounting allows understanding what share of the outcome value is contributed by ecosystems.

4.2.2 Sectoral and Economy-Wide Impacts

NbS outcomes can go beyond those explicitly measured and reported in ecosystem accounts. The SEEA EA measures the changes in the extent and condition of ecosystems and subsequent changes in ecosystem services. However, this framework does not comprehensively account for the sectoral and economy-wide impacts of NbS.

Assessing sectoral and economy-wide impacts depends on the NbS assessed. In the case of cocoa agroforestry farming in Lachuá, Guatemala, these can be of two kinds. First, those farmers who convert their land to cocoa agroforestry produce a total amount of crops and income that goes beyond the contribution of ecosystems (Table 12). The total cocoa pod production per year is expected to be 1,368,450 kg, from which 19.8% is contributed exclusively by the ecosystem asset (270,950 kg). This last amount is the one recorded in Sect. 2.3 on ecosystem services flows in physical terms. In addition, the implementation of cocoa agroforestry practices in 304 ha demands 18,300 labour days per year. Accounting for the employment created is often politically and economically an important outcome to consider.

Table 12 In-farm annual impacts for the case of sustainable cocoa farming in Lachuá, Guatemala

	In-farm
Hectares	304
kg cocoa pods	1,368,450
Income (Quetzales 2016)	9,031,770
Contribution by ecosystem to cocoa pods production (kg)	270,953 (19.8%)
No. of labour days	18,300

Source Elaboration by authors based on López Mérida et al. (2016)

A second dimension to consider is the role of value chains, including the forward and backward linkages associated with the NbS. For example, in the case of agroforestry cocoa farming in Guatemala, farmers demand inputs to nurseries and sell the cacao pods to a collector, who runs the fermentation and drying process, packaging, and selling to an exporter. The exporter takes care of the further transportation and delivers the product to the company that produces and puts the final product on the market. This process in its entirety creates value and jobs at different stages of the value chain that are relevant to consider and measure. Using methods consistent with the System of National Accounts ensures comparability to other routinely compiled economic statistics. An illustration of the direct and indirect creation of employment associated with forest landscape restoration in El Salvador is shown in Raes et al. (2021).

Please browse the supplementary material for more explanation on specialized words and the case study about using SEEA EA for a NbS assessment in Lachuá, Guatemala.

4.2.3 Discussion and Conclusions

Section 4.3 develops and illustrates a measurement framework for NbS outcomes, including changes in ecosystem extent and condition, ecosystem services in physical and monetary terms, and the monetary value of ecosystem assets as natural capital. The framework measures contributions from NbS in a comprehensive way consistent with international standards and principles. By doing so, the measurement framework allows consistency across scales (e.g., between country and NbS intervention), countries, and over time. Importantly, the framework is consistent with ecosystem accounts that are currently being developed by a large number of countries around the world as a consequence of the adoption of SEEA EA in 2021. As such, the framework would enable including NbS as a distinct management and policy option separately included in future ecosystem accounts.

The measurement framework allows for the compilation of complementary aggregate measures in monetary terms, including the GEP used in other sections of this chapter. Aggregate measures may be of particular interest in making comparisons to national economic aggregate variables, including GDP, and to understanding the

absolute and relative contribution of NbS to the national economy and at an industry level, e.g., for agriculture [5]. The proposed measurement framework highlights the need to construct measures in both physical and monetary terms to understand NbS outcomes in different dimensions.

Some challenges and limitations are applicable to the measurement framework developed here. For example, ecosystem accounts can provide a snapshot of the state of ecosystems and their services in different moments of time, but they do not directly reveal the mechanisms behind these changes. Moreover, while the conceptual scope of ecosystem services included in ecosystem accounts is broad, there is a range of other benefits that are not captured, for example concerning relational and intrinsic values.

Additionally, the ecosystem accounts can be disaggregated by relevant groups of the population, like Indigenous People, or consider gender aspects. For example, ecosystem extent can be recorded by type of landowner; and ecosystem services users open by gender of head of the household in the case of small-scale farming. These developments would need careful data gathering but would be very helpful to better understand the distribution of the NbS outcomes across population groups.

As the SEEA EA has been recently recognized as the international statistical standard, countries are beginning to develop ecosystem accounts to support policy and decision-making processes in both the public and private sectors and contribute to expertise regarding its implementation [14]. This brings with it considerable synergies, decreasing the investment in capacity required for the implementation of the proposed NbS measurement framework. These efforts include the Natural Capital Accounting and Valuation of Ecosystem Services Project in China, implemented jointly by the UN Statistics Division and UNEP to advance ecosystem accounting [5]. As a result, several of the ecosystem accounts have already been implemented in China (and elsewhere around the world), and their inputs can be used to support the measurement of NbS outcomes as proposed in this chapter.

4.3 GEP Appraisal in the SEEA EA and the Practices in China

The SEEA EA represents the international standards and principles for ecosystem accounting, and it is a globally influential document on ESV. It proposed that the valuation of an ecosystem should be conducted by measuring ecosystem extent, ecosystem condition, and ecosystem services in physical and monetary terms. SEEA EA notes GEP as an indicator of monetary ecosystem services flows to evaluate certain administrative areas' ecosystem services. GEP is a measure of the aggregate monetary value of ecosystem-related goods and services (hereafter "ecosystem services") in a given region in an accounting period.

By comparing the GEP discussed in the SEEA EA and China's GEP assessment indicator system, we can find their indicator relations are shown in Table 13. Their

similarity lies in an emphasis on final services' values. Yet they are different in indicator categories. SEEA EA did not provide the exact indicator calculation method, while China proposed definite GEP calculation method and has put it into practice. It is safe to say that China's GEP and the SEEA EA share the same theoretical logic. For GEP to be consistent with SEEA EA, it shall be based on methods to measure ecosystem assets and services in physical and monetary terms recognized in UN ecosystem accounting standards and principles. What China's GEP does is the exploration and practice of SEEA EA's concept of GEP. In NbS ecological service evaluation, this system can be adopted.

GEP is equal to the sum of all final ecosystem services at their exchange value supplied by all ecosystem types located within an ecosystem accounting area over an accounting period less the net imports of intermediate services.¹⁰

Please browse the supplementary material for more explanation about SEEA EA and GEP methods.

China started studying and exploring GEP as early as 2000. The Ministry of Ecology and Environment issued the first official technical specification for GEP accounting in 2020. In September of the same year, Lishui, a city in Zhejiang province, issued its first local official technical specification for GEP accounting. In March 2021, Shenzhen established the first GEP accounting platform sponsored by the government. In November 2021, Shenzhen established the first GEP accounting specification at the government level.

5 Gender Dimensions of NbS in China

Against a background of rapid urban development in China, the characteristics of women's NbS participation in China are different from those of men. Women and men also benefit differently from different types of NbS. Similarly, inclusive governance is of critical importance for the success of an NbS intervention, for safeguarding people and culture. Multiple dimensions of gender and gender-responsive approaches have to be considered in the design and implementation of NbS interventions in order to understand and overcome gender-based gaps. Such gaps and inequalities in the context of NbS relate to the roles of men and women in society and the economy and how these roles impact access and control over resources, participation, decision making, and protection and enforcement of rights. Not considering the needs and perspectives of women, local communities, Indigenous People, and marginalized groups in the design and implementation of NbS could lead to their exclusion from

¹⁰ This definition reflects a production-based approach (i.e., outputs less inputs) to determining the contribution of the ecosystems of an EAA to benefits and well-being. Also note (i) that the supply of final ecosystem services will include exports to non-resident economic units; and (ii) imports of final ecosystem services are not included in this measure as they are contributions by ecosystems located in other EAA. The measure is "gross" in the sense of not deducting any associated ecosystem degradation arising in the supply of the services. The measurement of GEP has been actively pursued in China, see for example Ouyang et al. (2020).

Table 13 Relations between China's GEP accounting methods and SEEA EA's relevant methods

Categories	Accounting indicators	Corresponding ecosystem service types in SEEA EA
Substance provisioning	Biomass provisioning	Crop provisioning services
		Grazed biomass provisioning services
		Wood biomass provisioning services
		Wild fish and other natural aquatic biomass provisioning services
		Wild animals, plants, and other biomass provisioning services
Regulation services	Water conservation	Water flow regulation services (Baseline flow maintenance services)
	Soil retention	Soil and sediment retention services, non-point pollution control services
	Wind prevention and sand fixation	Storm mitigation services
	Coastal zone protection	Coastal protection services
	Flood mitigation	River flood prevention and mitigation services (hydrologic regulation services)
	Air purification	Air pollutant absorption and filtration services
	Water purification	Water environmental pollutant degradation purification services
	Carbon sequestration	Global climate regulation services
	Local climate regulation	Local (micro and meso) climate regulation services
	Noise attenuation	Noise attenuation services
Cultural services	Ecotourism	Recreation-related services and visual amenity services
	Recreation	
	Landscape added-value	

the benefits derived from such solutions and reinforce gender discrimination and inequalities.¹¹

¹¹ See IUCN (2021). *Gender Analysis Guide: A technical tool to inform gender-responsive environmental programming for IUCN members, partners and peers*. First edition. Gland, Switzerland: IUCN.; IUCN (2020a). *Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS*. First edition. Gland, Switzerland: IUCN; IUCN (2020b). *Guidance for using the IUCN Global Standard for Nature-based Solutions. A user-friendly*

This section will discuss the relationship between the benefits created by ecosystem services and the role of women, demonstrating the importance of integrating gender considerations in planning and design of NbS.

5.1 Women and Ecosystem Provisioning Services

With the speeding up of reform and opening, along with urbanization, the flowability of the Chinese population is increasing. Meanwhile, the internal migration of male labour from rural to urban areas persists, while a large number of women remain in the countryside, leading to the “feminization of agriculture.” This is a situation of shifting gendered divisions of labour within the family, where rural women replace men in agricultural production and men enter non-agricultural fields to achieve higher economic value. National census data from 1982 to 2010 show that females account for 46.24%, 47.48%, 48.57%, and 49.22% of the labour force in the agricultural field each year, with the number having risen by 2.98 percentage points over 30 years. Women are gradually becoming a key power within agricultural production in rural environments. For instance, women in Houping Town, Wulong District, Chongqing municipality have organized to establish an agricultural brand to develop the vegetable planting industry. This not only contributes to the social and economic empowerment of these women, but reinforces the importance of considering the capacities and needs of women as well as men within ecosystem provision services.

5.2 Women and Ecosystem Cultural Services

Xiangxi Tujia and Miao Autonomous Prefecture are located in the subtropical zone, with fertile land, and rich in ramie, sericulture, and cotton. The process of urbanization has led to women comprising a large proportion of the local population. Women who live here are skilled in creating wonderful traditional handicraft products using fabric and woven brocade. In order to encourage this group of women to progress in their economic activities, the local government established a company to market the local products and developed an associated cultural industry. In relation to cultural services, the aesthetic value provided by women in creating those products processes ecological value while promoting an appreciation of the value of cultural services. This demonstrates the importance of drawing on the capacities of both women and men in progressing cultural services.

Furthermore, women are also users of NbS culture services. Urban parks bring value to people in terms of recreation. Research on the use of some parks in China

shows that local women represent a higher proportion of people using urban parks for recreational activities than men. For example, a survey counted the local and non-local respondents who visited Guangzhou People's Park: its results show that among the men, 35.84% were local respondents, while among women, local respondents accounted for 46.25%. And in the case of Xi'an Fengqing Park, women users account for 54.2% of visitors. In terms of frequency of use, 55% of women users surveyed use the park regularly for relaxation, while only 26% of men users surveyed do so. This means women can receive more benefits from using urban parks than men. Studies also found that compared with men, women require more stable and regular urban recreational space, and as a result, the construction of urban parks can provide more benefits for women. As such, during the planning and design process for urban parks, it is important to identify and consider gender differences, which can be done through the use of gender-sensitive data collection tools and inclusive consultations with both women and men. This can help ensure that the recreational needs of both women and men are taken into account in urban park planning and design.

5.3 Women and Ecosystem Regulating Services

Research shows that women engaged in environmental research, evaluation, planning, design, and monitoring in the institutions directly under the Ministry of Ecology and Environment represent 40.7% of employees, while the average proportion of women engaged in scientific research, technical services and geological exploration industries was 37.01%. This shows that women are more involved in environmental scientific research than in other scientific research. At the same time, according to the Chinese General Social Survey in 2003, more women than men are inclined to environmental protection behaviours in daily life, such as garbage sorting and preparing for shopping bags. From the perspective of participatory environmental protection behaviour, the percentage of donations to environmental protection from women was 50.7%, while the proportion of women amongst active participants in environmental protection activities held by non-governmental environmental protection groups was 51.3%. Overall, women's participation in the environmental field, especially in environmental research, is significantly higher than that of men. This shows that women are more enthusiastic about maintaining and improving ecosystem stability and the provision of regulation services. As such, it is essential that women are given equitable opportunities with men for engaging in NbS at every level and that barriers to their participation and leadership are removed.

In conclusion, NbS can improve ecosystem services. Women, with their special socio-economic status, can not only promote NbS construction but continually gain benefits from it. Therefore, gender differences should be taken into consideration in all aspects of the design and implementation of NbS.

6 Policy Recommendations

China attaches great importance to the conservation and sustainable use of ecosystems and has formulated and implemented policies and measures related to NbS to varying degrees in all six major ecosystems. NbS can increase carbon sinks to different degrees in agriculture, forests and other terrestrial ecosystems, and marine ecosystems, and at the same time bring about multiple synergistic effects, such as protecting biodiversity and promoting economic development, and act as an effective pathway and important link to address climate change and biodiversity conservation synergies. However, as a new concept, China has not yet formed a policy and action system with NbS as the entry point. The following challenges have been identified for China: (1) relevant policies and actions are scattered among different functional departments, and there is a lack of communication and coordination mechanisms among different departments, making it difficult to form a top-down, efficient and integrated management mechanism; (2) the source of funding is relatively limited, and financial input is still the main source, and a diversified funding mechanism with broad social participation has not yet been formed; (3) scientific research on NbS is still inadequate, and there is a lack of scientific assessment of cost-effectiveness, which makes it difficult to provide effective information support for decision-makers and investors.

We propose the following recommendations, hoping that through the implementation of these recommendations, we can promote the integration of NbS into the policy mainstream across sectors, build a top-down management mechanism, establish a diversified funding mechanism, strengthen the research from theory to practice, then from practice to policy, and enhance capacity guarantees and public participation.

6.1 *Expand and Mainstream the Application of NbS*

- Formally adopt a definition of NbS, based on the definitional framework provided by UNEA and IUCN.
- Comprehensively integrate NbS into the process of policy formulation and implementation in all relevant sectors, including Ecological Red Lines.
- Propose quantitative standards for NbS; strengthen monitoring and evaluation; and promote NbS as a mainstream approach for addressing climate change.

6.2 *Establish a Coordinated NbS Management Mechanism*

- Establish a centralized NbS management mechanism, aligned with established international and national standards and safeguards.

- Strengthen interdepartmental communication and coordination; build a collaborative governance platform for NbS participation in multiple fields; improve data- and information-sharing mechanisms; and create an efficient and coordinated working mechanism.

6.3 Broaden NbS Investment and Financing Channels

- Broaden the funding channels for NbS and establish a diversified capital investment mechanism.
- Carry out research on incentive policies, regulatory frameworks, and mechanisms; assess the potential to redirect existing harmful subsidies toward NbS; give full play to the market's role in resource allocation; encourage social capital and the public to actively participate in capital investment; and facilitate cooperation between the government and social capital.
- Formulate investment and financing policies in the NbS field; encourage innovative green financial models; focus on reducing and effectively responding to potential risks of investment in the NbS field; and stimulate and guide more social capital to invest in NbS.

6.4 Accelerate the China-ization of NbS Evaluation and Implementation

- Accelerate the formulation of Chinese standards for NbS and the development of monitoring and evaluation mechanisms, liaising, as appropriate, with the International Standards Committees of the IUCN Global Standard for Nature-based Solutions™.
- Use the IUCN Global Standard for Nature-based Solutions™ as a means to benchmark and assess NbS project design, implementation, and monitoring in China and to facilitate convergence and comparability of practices between Chinese and international NbS interventions.
- Carry out systematic research on NbS theory, pathways, and policies; formulate China standards for NbS; establish a monitoring and evaluation mechanism for NbS; and provide systematic solutions and technical support for policy making.
- Establish an NbS monitoring and evaluation index system, including monitoring and assessment technical specifications, and pathways for strengthening quantitative research on NbS costs and benefits, e.g., quantitative evaluation of NbS in carbon storage and biodiversity protection.

6.5 Increase Awareness of NbS and Their Benefits Among All Sectors and Levels of Society

- Use multiple channels to strengthen awareness of NbS and their benefits among both decision-makers and the general public and encourage the public to actively participate in NbS-related actions.
- Utilize the mainstream media to raise general awareness of NbS and their benefits, and take advantage of the opportunities offered by occasions such as World Environment Day, World Forest Day, and other thematic campaigns.
- Disseminate information from NbS case studies to project designers, engineers, urban planners, public and private institutions, financiers, etc.
- Promote the establishment of more voluntary/private environmental organizations and encourage and assist them in incorporating NbS into their work.
- Strengthen the capacity to design and implement NbS within relevant professions, enterprises, research institutions, social organizations, and the public.

6.6 Emphasize the Role of Women in NbS Development and Implementation

- Integrate women's needs and perspectives into the design, implementation, and monitoring of NbS and ensure equitable and inclusive participation, benefit-sharing and governance processes.
- Increase efforts to promote NbS among women and other marginalized groups.

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Chapter 3

Ecosystem-Based Integrated Oceans Management Under the Vision of Carbon Neutrality



1 Introduction

1.1 *The Ocean and Climate Change*

Over the last century, human activities around the globe have contributed substantially to unprecedented changes in climate and biodiversity. Changes in the climate mean increased risk of natural disasters, changing habitats, biodiversity loss, and food safety jeopardized by fluctuating productivity. Climate change and biodiversity loss combined increasingly threaten nature, as well as human lives, livelihoods, and well-being around the world. Strong, impactful and consolidated efforts to tackle and meet the climate and biodiversity crises are required to achieve and enable societal equality on all levels. The ocean-based solutions do, can, and should play a fundamental role in this regard.

As it is, the world's oceans play a critical role in capturing carbon dioxide (CO₂) from the atmosphere. Around 25% of all anthropogenic CO₂ emissions are absorbed by the ocean, thereby making it one of the world's largest "carbon sinks." Ocean-based mitigation options to remove/sequester and store greenhouse gases (GHGs) offer significant potential to contribute to global efforts to limit global warming and for achieving the goals of the Paris Agreement. The High Level Panel for a Sustainable Ocean Economy estimates that by 2050 ocean-based climate mitigation and carbon storage options could make up 21% of the emission reductions needed to limit global warming to 1.5 °C [1]. However, the penetration of CO₂ into the ocean causes ocean acidification which has diverse impacts on biological, biogeochemical, and ecological components of the ocean, and consequential impacts are of concern as the ocean's absorption of anthropogenic CO₂ continues. While atmospheric CO₂ is the major driver of ocean acidification, eutrophication can exacerbate ocean acidification in coastal areas. In addition, permanence is crucial in considering carbon

storage in the ocean given the ocean's high turnover rates. Therefore, it is essential to take advantage of forces that efficiently sequester carbon at least on a decadal time scale.

Nevertheless, there is a wide array of potential ocean-based mitigation options that can contribute to carbon-neutrality goals that would not add to burdens such as acidification. The ocean can contribute to mitigating climate change, while maintaining the carbon balance, and in doing so also safeguard marine biodiversity. Such ocean-based mitigation options have so far had insufficient exposure in nationally determined contribution (NDC) considerations or long-term low GHG emission development strategies under the agreements of the United Nations Framework Convention on Climate Change (UNFCCC), such as the Paris Agreement, although their potential is quite potent [2]. The most relevant potential ocean-based mitigation options to consider include, but are not limited to, the grooming, restoration and long-term climate-smart management of carbon-efficient ecosystems ("blue forests"¹), the use of the ocean's inherent energy potential, minimizing the carbon footprint of ocean-based activities such as shipping, the use of the ocean floors' ability to store carbon and reusing carbon in marine production, as well as restructuring of the fisheries and human consumption of aquatic products toward low-carbon ocean-based protein and other sources of nutrition [1]. Other emerging opportunities that require further assessment include: resetting biomass goals for the management of fish and perhaps other large-bodied organisms to increase long-term living biomass and ensure adequate protection of carbon processing and storage functions in ocean ecosystems; protecting existing unfished stocks of mesopelagic fishes that rapidly and effectively move carbon into the deep sea through their vertical migrations; and large-scale investments in macroalgal production, especially in offshore waters, that can then be used—in part—for long-term sequestration, assuming that can be done with prudent climate and biodiversity side effects.

The ocean's potential to contribute toward China's 2060 Carbon-Neutrality goals has already been recognized by Chinese authorities. For example, the Ministry of Ecology and Environment (MEE) has been urging local governments to accelerate ecological restoration of oceanic habitats and organizing monitoring and evaluation on carbon sinks in the ocean.

1.2 Ocean's Health and Society

A healthy ocean environment that also meets people's other needs is a prerequisite. A healthy ocean is thus also necessary if we are to enable an efficient and beneficial utilization of the ocean-based carbon-goal opportunities. An ocean with ecosystem integrity, with properly functioning biogeochemical and physical processes which

¹ "Blue forests" are coastal and marine ecosystems, including mangrove forests, seagrass meadows and tidal salt marshes, which have the ability to store carbon and provide a range of important ecosystem services for coastal communities.

have not suffered serious or irreversible harm, is required for the ocean, seas, and marine resources to successfully contribute to this end. The global ocean and marine ecosystems are changing rapidly due to the ongoing large-scale climate change which is causing wide-ranging effects such as ocean warming, acidification, and oxygen loss. Marine ecosystem degradation has also greatly accelerated during the last five decades due to the multitude of direct human-induced stressors affecting the ocean, including coastal reclamation of land, aquaculture, fisheries and pollution from land-based sources. China has been experiencing a similar trend since the 1950s, with 57% of the coastal wetlands, 73% of the mangrove coverage, and 80% of the coral reefs being lost. Along China's coasts, most of the seagrass beds have disappeared, two-thirds of the coastline is suffering from erosion, about 44,000 km² coastal seawater is severely polluted, and fishery resources have been severely depleted.

A healthy and resilient ocean that maintains its capacity to deliver food, income, support transportation, and many other elements of sustainable development will also contribute to human well-being. The ocean is one of the main repositories of the world's biodiversity. It constitutes over 90% of the habitable space on the planet and contains some 250,000 known species, with many more remaining to be discovered. Marine biodiversity plays an essential role in underpinning a healthy planet and social well-being. The fishery and aquaculture sectors are a source of income for hundreds of millions of people, especially in low-income families, and contribute directly and indirectly to their food security. One-third of the total human population, nearly 2.4 billion people, live within 100 km (60 miles) of an oceanic coast—and all human life is dependent upon the oxygen and freshwater it creates. The annual economic value of the ocean is estimated at USD 2.5 trillion, equivalent to the world's 7th largest economy. It provides nutrition, medicines, and mineral and renewable energy resources. It supports jobs in fishing, seafood, leisure, and science. Maintaining a healthy ocean is vital to improving global health and increasing global prosperity for everyone, expanding opportunities for all people, including women and underrepresented or marginalized groups. With all these as a background, there is a global recognition that saving our ocean must remain a priority and that careful management of this essential global resource is a key feature of a sustainable future (UN Sustainable Development Goal [SDG] 14). The effort needed to maintain and support healthy ocean systems will require and encourage scientific research and innovative technologies that connect ocean science with the needs of society, an opportunity that *inter alia* has been key in shaping the UN Ocean Decade which aims to encourage the production of “the science we need for the ocean we want,” catalyzing transformative ocean science solutions for sustainable development.

Ecosystem-based integrated ocean management (EB-IOM) is an approach for ecosystems and resources management that involves finding a proactive balance between the use and protection of rich, productive ecosystems and the ecosystem services they provide, thus promoting an equitable system of conservation and sustainable use. Integrated management is considered an appropriate approach for ensuring the protection and sustainable use of the ocean and coasts, taking sufficiently into account knowledge and the particularities of the ecosystems to be managed. Fully integrated ocean management strikes a balance between the environment,

economy, and society, and between short-term economic gains and long-term prosperity of the ecosystem services. EB-IOM provides a basis for the protection of the ocean ecosystem from unsustainable cumulative impacts caused by multiple maritime activities in different parts of the global ocean, as well as for the fair and balanced management of competition and conflicts between ocean users. This will benefit ocean ecosystems, the habitats and species within them, and humans who depend on them.

Framing the study by the principles and criteria of sustainable and inclusive management of the ocean, the special policy study (SPS) provides directions on ocean actions considering the carbon-neutrality goals. This study aligns the synergies between marine carbon and ecosystem-based management/governance, looking in particular at the following aspects relevant to delineation of China's ocean climate actions:

1. Nature-based Solutions (NbS) and other safe and effective marine CDR;
2. Non-damaging technological ocean-based carbon capture and storage, such as CCUS;
3. Reduction of the CO₂ footprint from ocean activities; and
4. Renewable energy.

This study has been carried out in the last year of CCICED Phase VI, and it has only unveiled the ocean's role in the international and national efforts required to tackle the global climate and biodiversity crisis, and to reach China's carbon-neutrality goals. The findings should be considered a transition to the next CCICED Phase, when further work will be required to provide concrete policy guidance on the issues raised in this study.

The study also recognizes gender equality as essential for the effective protection of oceans, the sustainable management of ocean and marine resources, and the accomplishment of the UN's SDGs. As such, the study notes the need to strengthen understanding of the requirements around gender-responsive and inclusive ocean management as part of a sustainable framework.

Several topics and actions discussed in this study interlink with and complement other ongoing studies under the auspices of CCICED, such as the special policy studies on climate, biodiversity, and Nature-based Solutions. Exploiting these interlinking issues is of similar importance as exploring the ocean's potential in mitigating climate change within the future SPS framework of CCICED.

2 Four Ocean-Based Approaches to Carbon Neutrality

For humanity to tackle the planetary challenges and crises that it faces today and in the future, a systemic, integrated, and holistic approach concerning ocean issues and the governance of this space must be taken. This also applies when exploring the opportunities provided by the ocean in contributing toward the carbon-neutrality goals. In this chapter, we explore four ocean-based approaches toward carbon neutrality. Next,

this chapter describes the necessity to frame these approaches within an ecosystem-based, integrated, and holistic thinking. When exploring and implementing actions within these four approaches, there is also a valuable opportunity to consider how to promote gender equality and diversity, including the engagement of women in the efforts.

2.1 Marine Carbon Dioxide Removal and Nature-Based Solutions

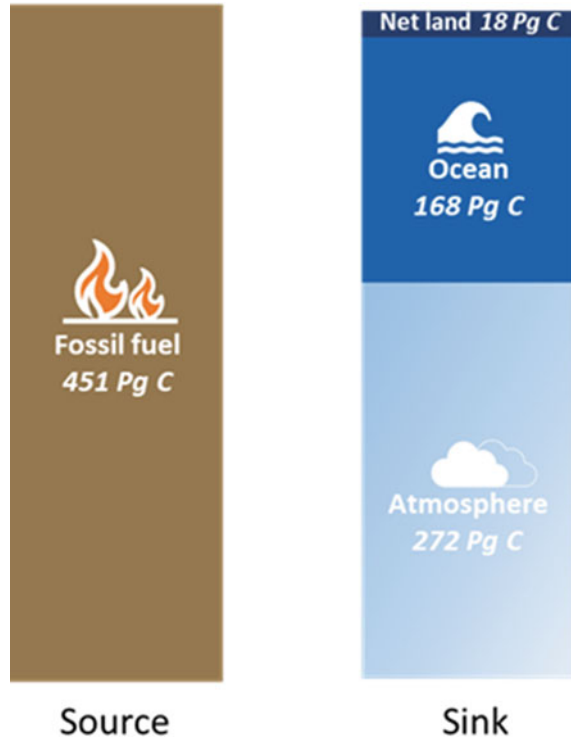
2.1.1 How the Ocean Takes Up Carbon

The ocean covers ~ 71% of Earth's surface; and contains 90% of the carbon on the Earth's surface. The ocean possesses much of the global capacity for atmospheric CO₂ sequestration and mitigated annually 22–26% of the anthropogenic CO₂ emissions comprised of fossil fuel burning and land-use change during 1960–2019 [3]. In the preindustrial era, the ocean was a net source of carbon to the atmosphere [4]. Now it is a substantial net carbon sink of around 1.9 Pg of carbon per year [3]. On long timescales, the land carbon sink is equivalent to accelerated GHG emissions associated with land-use change, leaving the ocean as the primary carbon sink of the last 200 years (Fig. 1) [5].

The injection of anthropogenic CO₂ into the atmosphere leads to an increase in the partial pressure of atmospheric CO₂. Driven by the partial CO₂ pressure difference between the air and the surface ocean, CO₂ diffuses into the ocean via air–sea interface exchange. Unlike many other gases, CO₂ combines with water to form a CO₂-carbonate system which is the most important buffering system in the ocean [6]. The CO₂-carbonate system holds the predominant available carbon as dissolved inorganic carbon (DIC, ~ 38,000 PgC) in the ocean, that is carbonic acid (dissolved CO₂ in water), bicarbonate ions (HCO₃⁻) and carbonate ions (CO₃²⁻), which are tightly coupled via chemical equilibrium. In addition, the ocean contains a pool of dissolved organic carbon (DOC, ~ 700 PgC), a substantial fraction of which has a turnover time of thousands of years [7]. The marine biota, predominantly phytoplankton and other microorganisms, represent a small organic carbon pool (~3 PgC), which is turned over very rapidly in days to a few weeks.

Carbon is transported and sequestered within the ocean by three mechanisms: (1) the “biological pump,” (2) the “carbonate pump,” and (3) the “physical pump.” The biological pump utilizes autotrophy, such as photosynthesis by phytoplankton, to convert CO₂ and HCO₃⁻ into organic biomass, including particulate organic carbon (POC) and DOC. POC and DOC create a flux of carbon via gravity sinking, the vertical migration of midwater biota, diffusion, and advection from the surface to the deep ocean or seafloor sediments, where it is isolated from the atmosphere for decades to centuries. The carbonate pump is a process of ocean carbon sequestration driven by calcifying plankton, which releases CO₂ back into the atmosphere but

Fig. 1 Cumulative carbon sources and sinks since the start of the industrial revolution



sequesters part of it by more rapid sinking to the seafloor; this is why this process is also referred to as the carbonate counter pump. The physical pump is the physio-chemical process whereby carbon is transported from the ocean surface to its interior, where it can be stored for hundreds of years [8, 9].

In addition to the carbon sinks in oceanic regimes as described above, coastal ecosystems typically composed of mangroves, salt marshes, and seagrass meadows also sequester atmospheric CO₂ via high photosynthetic rates and rapid carbon sedimentation rates that result in accumulation in associated soils and sediments [10]. Non-vegetated tidal flats, which are rather extensive along the coasts have also been shown to be a potentially important carbon sink. A varying fraction of this carbon is buried in tidally inundated suboxic and anoxic sediments and thereby largely prevented from returning to the atmosphere [11]. Studies suggest that mangroves and coastal wetlands annually sequester carbon at a rate 10 times greater than mature tropical forests. They also store three to five times more carbon per equivalent area than tropical forests. Most coastal blue carbon is stored in the soil, not in above-ground plant materials as with tropical forests. This coastal wetlands carbon is now often regarded as coastal blue carbon. It has been gaining great attention due to its disproportionately large contribution to global carbon sequestration. This is also true in China where the three blue carbon ecosystems maintain high carbon accumulation rates. Among them, mangrove forests mainly on the southern coasts covers a total

area of $\sim 2.56 \times 10^4$ ha with a carbon buried rate of 0.28 TgC annually. Intertidal salt-marshes are widely distributed along the subtropical and warm temperature coasts, with a total area coverage of $10.2 \sim 3434$ km², maintaining a carbon burial of 0.23–0.91 TgC annually. Seagrass beds are mainly distributed in the northern coasts around Bohai and along the tropical coasts with 1.68×10^4 ha of total areas, while their carbon burials remain unclear. It should be pointed out that these coastal blue carbon ecosystems are facing challenges of anthropogenic disturbance from coastal squeeze, water pollution, and urbanization as well as invasive species *Spartina alterniflora*. A grand challenging question thus points toward how these coastal blue carbon will evolve under future climate scenarios.

2.1.2 Approaches to Strengthen and Increase the Ocean Carbon Sink Within a Sustainable Framework

The ocean and its ecosystems hold great potential for uptake and longer-term sequestration of anthropogenic CO₂ for several reasons [12]: (1) the ocean acts as a large natural reservoir for CO₂, holding roughly 50 times as much inorganic carbon as the preindustrial atmosphere; (2) the ocean already removes a substantial fraction of the excess atmospheric CO₂ resulting from human emissions; and (3) there are a number of physical, geochemical, and biological processes that are known to influence air–sea CO₂ exchange and ocean carbon storage. The High Level Panel for a Sustainable Ocean Economy identified that ocean-based mitigation options could reduce global GHG emissions by about 4 billion tonnes of CO₂ equivalent per year in 2030 and by over 11 billion tonnes per year in 2050, reducing the emissions gap by up to 21% on a 1.5 °C pathway, and by around 25% on a 2 °C pathway [1].

Ocean-based CDR techniques can be identified in two broad categories—biological and chemical [12] (Fig. 2).

(1) Biological pathways include:

1. Nutrient fertilization: Addition of micronutrients (e.g., iron) to the surface ocean may, in some settings, increase photosynthesis by marine phytoplankton and can thus enhance uptake of CO₂ and transfer of organic carbon to the deep sea where it can be sequestered for timescales of a century or longer. As such, nutrient fertilization essentially locally enhances the natural ocean biological carbon pump using energy from the sun, and in the case of iron, relatively small amounts are needed. Of course, the abundant risks of artificial anthropogenic nitrification are also known in general, but inadequately known at scale in practice.
2. Artificial upwelling and downwelling: Artificial upwelling is a process whereby water from depths that are generally cooler and more nutrient and carbon dioxide rich than surface waters is pumped into the surface ocean. Artificial upwelling has been suggested to generate increased localized primary production and ultimately export production and net CO₂ removal. Artificial downwelling is the downward transport of surface water;

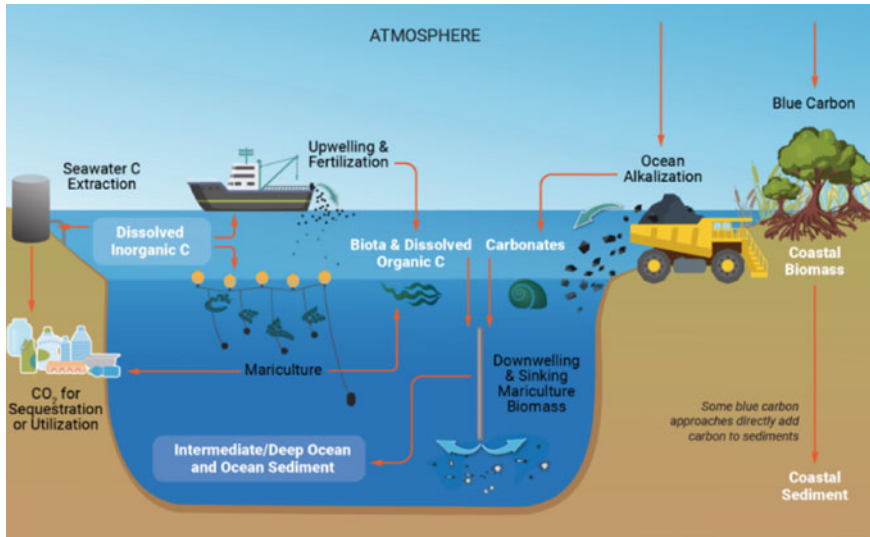


Fig. 2 Marine CDR (Energy Future Initiative [13])

this activity has been suggested as a mechanism to counteract eutrophication and hypoxia in coastal regions by increasing ventilation below the pycnocline and to carry carbon into the deep ocean.

3. **Seaweed cultivation:** The process of producing macrophyte organic carbon biomass via photosynthesis and transporting that carbon into a carbon reservoir removes CO_2 from the upper ocean. Large-scale farming of macrophytes (seaweed) can act as a CDR approach by transporting organic carbon to the deep sea or into sediments. Seaweed can also be processed to make long-life products or produce biofuel for carbon sequestration or utilization. It must be pointed that the risks of unintended ecological outcomes and cascades associated with large-scale deep-sea vegetative deposition remain unknown.
4. **Recovery of ocean and coastal ecosystems:** Carbon dioxide removal and sequestration through protection and restoration of coastal ecosystems, such as kelp forests and free-floating Sargassum, and the recovery of fishes, whales, and other animals in the ocean. Rebuilding global fish and perhaps large-bodied animal stocks toward higher abundance than supported by current management might also contribute to improved carbon processing and storage, though those outcomes remain inadequately evaluated. Precautionary management of emerging fisheries in the high latitudes and the mesopelagic realm until carbon processing consequences are better known and incorporated into goalsetting is also a possibility.

(2) Chemical pathways include:

1. Ocean alkalinity enhancement: Chemical alteration of seawater chemistry via addition of alkalinity through various mechanisms including enhanced mineral weathering and electrochemical or thermal reactions releasing alkalinity to the ocean, with the ultimate aim of removing CO₂ from the atmosphere. Induced ecological cascades would need to be assessed and interpreted in light of the systems goals expressed in this document.
2. Electrochemical approaches: Removal of CO₂ or enhancement of the storage capacity of CO₂ in seawater (e.g., in the form of ions, or mineral carbonates) by enhancing its acidity, or alkalinity, respectively. These approaches exploit the pH-dependent solubility of CO₂ by passage of an electric current through water, which by inducing water splitting (“electrolysis”), changes its pH in a confined reaction environment. As one example, ocean alkalinity enhancement may be accomplished by electrochemical approaches.

These CDR approaches broadly include both NbS and geoengineering-based approaches. NbS are defined as “actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.” A major attraction of NbS as a strategy for climate change mitigation is that they can deliver multiple benefits. These benefits include retained and restored ecosystem services from forests, croplands, grazing lands, wetlands, and other coastal ecosystems that support human health and well-being [14], as well as biodiversity conservation and sustainable livelihood development. Geoengineering-based CDR often takes intervention techniques, which are more controversial but are emerging as potentially indispensable in meeting the goals of the Paris Agreement, if unintended negative consequences at scale can be understood and avoided [15].

It must be pointed out that all CDR measures have limitations and trade-offs. It is thus of vital importance to thoroughly assess CDR techniques, individually or collectively, and adopt ecosystem-based approaches to combatting climate change, but they must be considered comprehensively inclusive of their effect on ecosystems, their synergies with other land and ocean systems, and the impacts on the natural ocean carbon sink. For example, mangroves planted in Siangshan Wetland, north-western Taiwan Island since 1997 resulted in negative impacts on the local ecosystem, including the loss of the benthic organisms and habitats for birds, sediment accumulation and flooding, and increased mosquito populations. A mangrove removal project was subsequently launched in 2015 [16]. Similar examples of replanting efforts with weak comprehensive assessments and large negative consequences are found globally. Thus, integrated ecosystem-based governance for both NbS and beyond is important. A successful example is offered in Case Study 1 demonstrating the co-benefits of ecosystem-based approaches between blue carbon and other ecosystem and societal services.

Case Study 1: Quanzhou Blue Carbon Project

The project is implemented in Luoyang River Estuary of Quanzhou Bay Wetland Nature Reserve in Quanzhou, Fujian Province, China. Established in Sept. 2003, this nature reserve aims to protect subtropical coastal wetlands, mangroves, waterfowls, Chinese white dolphins, and other rare animals and plants, with a total area of 7065 ha. The invasive smooth cordgrass, *Spartina alterniflora*, was first introduced to Luoyang River Estuary in 1982 and became invasive in the early 2000s. Since 2002, the local government and the nature reserve have continued to restore mangrove forests by clearing the invasive cordgrass. At present, the total mangrove area of the Luoyang River has increased from the original 17 ha to nearly 467 ha, becoming the largest artificial mangrove forest in China.

Luoyang River Estuary is also known for the Luoyang Bridge, a large stone bridge across the sea built during the Song Dynasty (1059 AD). Luoyang Bridge was one of the four famous bridges in ancient China. It has been of great importance to local transportation by land and sea for thousands of years. Local communities with a long history of maritime culture have been formed around this ancient bridge. Now, Luoyang Bridge has been listed as a heritage site of Quanzhou World Heritage of UNESCO (Quanzhou: The World Maritime Trade Center of Song and Yuan China). Now, the Luoyang Bridge and mangrove forests have formed a unique coastal landscape showing the harmonious coexistence of humans and nature.

In this project, a total of 29 ha of mangrove forests composed of two native species, *Kandelia obovata* and *Aegiceras corniculatum*, were restored by clearing the invasive cordgrass in 2010. In the project area, these newly restored forests formed a closed canopy after 10 years of management. The total carbon sequestered by the restored forests was calculated by the Methodology of Mangrove Afforestation for carbon trading developed by Blue Carbon Group of Xiamen University in 2011. Additionality and permanence of emission reductions from the project were tested. In total, 2000 t CO₂-e of emission reductions in the project area were traded on the platform of Xiamen Carbon and Emissions Trading Center. The Industrial Bank Xiamen Branch purchased and launched carbon-neutral air tickets with the cooperation of Xiamen Airlines, through which the passengers could participate in mangrove conservation and restoration by purchasing the tickets.

In this project, the invasive vegetation was removed, and the restored mangrove wetlands provides habitats for waterbirds, e.g., the Chinese Egret (*Egretta eulophotes*, vulnerable species on IUCN Red List) and greatly increased the biodiversity of the Luoyang River Estuary [17], reflecting the synergistic effects of biodiversity conservation and carbon sequestration. Furthermore, the mangrove wetlands enhance the landscape of the ancient

Luoyang Bridge, and benefit the local community by improving the living environment and increasing their income from ecotourism. Thus, the project also embodies the synergistic development of biodiversity, climate, and community.

2.1.3 Knowledge and Policy Gaps

For decision-makers, the emerging knowledge gaps related to the ocean carbon sink that are of paramount importance for our environment and society can be categorized as:

1. Understanding whether the ocean will continue as a sink for human-produced CO₂ and its climate change mitigation capacity, such as regarding climate-carbon coupled systems, zero-emission strategies and actions; and how will the coastal blue carbon evolve?
2. The vulnerability of ocean/marine ecosystems to increasing CO₂ levels.
3. Adaptation options and needs to changing ocean/marine conditions.

Research and development policy needs with respect to ocean-based CDR include:

1. Defining the RD&D (research, development, and demonstration) portfolio of specific biological and nonbiological CDR pathways for technology development, optimization, and scalability, including anticipating new and emerging pathways, as well as their likely risks and co-benefits.
2. Improving the methods for monitoring, quantifying, and verifying CDR benefits, ecosystem effects, and life-cycle impacts, including under future conditions anticipated through climate change.
3. Developing predictive modelling and planning tools for siting and operations.
4. Creating markets for co-products from ocean CDR pathways and integration into carbon markets, and for co-benefits of NbS where the carbon benefits are inadequately known in terms of high-quality carbon credits.
5. Creating enabling national and international governance and finance frameworks.

2.1.4 Priority Actions

1. Ecosystem-based mitigation and adaptation action can be synergized while also positively impacting the ocean carbon sink. Mitigation action includes reducing GHG emissions to minimize ecosystem consequences, using ecosystem-based CDR to advance climate action and benefit ecosystems, and minimizing pollution to enhance the natural capacity of ecosystems to store carbon. Adaptation approaches such as disaster risk management, sustainable and climate-smart management, and implementing marine spatial planning and protected

areas rely heavily on data, modelling, policies, and mitigation action that reduce the chance for tipping points to occur. Successful adaptation increases climate resilience through technological innovation, partnerships, and codesign of solutions. Ecosystem-based approaches should be enforced in both mitigation and adaptation. In general, all goalsetting for coastal and ocean uses should also factor in an assessment of the degree to which opportunities for climate adaptation and mitigation are adequately known and accounted for.

2. China has been practicing ecosystem restoration projects to different extents along the China coasts with successes and failures. This is also true in area-based management practices such as marine protected areas (MPAs). Revisiting these practices by considering experiences and lessons (including from a gender-equality perspective) and articulating new policies and best practices is urgently needed in developing carbon-neutrality strategies which are underway.
3. Urgent and deep emissions reductions are vital to protect the ocean from further climate change impacts. However, the ocean is also a space where mitigation can take place. Most importantly, Earth system models show that after peak emissions are reached, atmospheric CO₂ will begin to decline. This will lead to a weakening of the ocean and land sink as projected under RCP 2.6 [18] (Dai et al., 2022 and references therein). To maintain atmospheric CO₂ and temperature at low levels, not only does anthropogenic CO₂ in the atmosphere need to be continuously removed by CDR, but anthropogenic CO₂ stored in the ocean and land needs to be removed when it outgasses to the atmosphere. This must be considered when designing future pathways. Ocean-based solutions provide excellent opportunities for both mitigation and adaptation and should be considered in Nationally Determined Contributions and UNFCCC deliberations, and this shall take international and collective efforts while China is in a good position to promote ocean-based carbon solutions.

Key recommendation: Accounting for ocean CO₂ sinks in international climate reporting

Given the ocean's sustained and paramount role in mitigating anthropogenic CO₂ over the last 200 years, it is fundamentally important to note that such an ocean carbon sink could be dramatically reduced if $p\text{CO}_2$ in the ocean is not synergized with the air $p\text{CO}_2$ under low-emissions conditions when designing future pathways. *We call upon establishing an international task force with a mandate to promote the ocean carbon sink as a potential NDC and as part of UNFCCC deliberations.*

2.2 Offshore Carbon Capture, Utilization, and Storage

2.2.1 The Ocean's Role in Capturing, Utilizing, and Storing CO₂

To reach the target of carbon neutrality by 2060, greenhouse gases emitted by carbon sources into the atmosphere must be mitigated and preferably permanently sequestered. Several methodologies have been presented to potentially mitigate CO₂ emissions, such as increasing energy efficiency, replacing coal-fired power plants with natural gas, enhancing wind and nuclear power plants, biomass creation, reforestation, and carbon capture, utilization, and storage (CCUS), etc. Compared to more natural ways (see Sect. 1 in Chap. 2), technological methodologies are potentially faster and more complete on carbon sinks. To realize one-off GHG removal, the produced CO₂ is expected to be captured and compressed, transported via ship or pipeline to offshore platforms, and injected into sub-seabed reservoirs for permanent isolation from the atmosphere [19, 20]. Thus, a technically feasible full chain of offshore CCUS is formed (Fig. 3) and can be developed by mobilizing contractors and suppliers [18]. Like any other large-scale industrial operation, of course, the potential risks—especially at scale—must be fully characterized and unacceptable risks mitigated.

In 2020, China emitted 10.67 Gt CO₂, with coal, oil, and gas contributing 70%, 15%, and 6%, respectively. The coal-burning power plants alone accounted for 50% of China's fossil fuel-related CO₂ emissions. To reduce the consumption of coal, China has justified ongoing efforts to support the use of renewable energy and natural gas, combined with improving the ambient air quality as one of the country's strategies. In addition to this, CO₂ separation and capture from industrial processes are also undertaken, such as H₂ manufacture, synthetic ammonia, limestone calcination, and

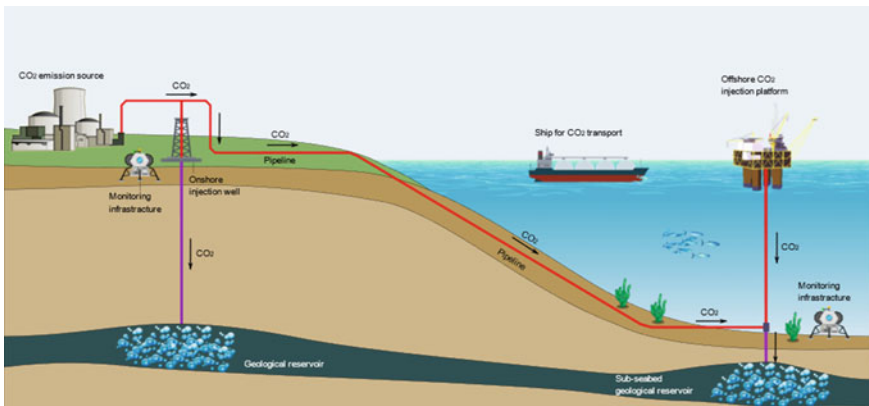


Fig. 3 Key elements and processes in offshore CCUS. Offshore CCUS captures CO₂ from industrial emission sources, transports it via either pipeline or ship, and injects it into sub-seabed geological reservoirs, contributing to the isolation of CO₂ from the atmosphere

ethylene oxide production. Further, to prevent emissions from these plants, advanced low-carbon coal technologies are promoted with a number of action plans released to require the adoption of high-efficiency and the development of CCUS retrofits. In China, a significant portion of the electricity mix is still from coal generation. The more worrying thing is that some of the world-class CO₂ emission sources are from relatively newly-built power plants, the average age of which is less than 15 years, which could still be operating in 2060. This poses a particular challenge to achieving the national goal of net-zero emission, and the geological storage has the greatest potential to realize the one-off carbon removal. In the east region, more than 43% of coal-fired power plants could be suitable for CCUS retrofits, which account for more than 35% of the cumulatively CO₂ volume to be captured. To permanently isolate the captured CO₂ from the atmosphere, particularly for the coastal region with significant carbon emissions, offshore geological storage with carbon source-sink matching is introduced.

Of the 34 provinces in China, 13 are along the coast, which occupy less than 14% of the nation's territorial area. These coastal regions contribute 64% of national GDP, account for 43% of the country's energy use, and possess 39% of the country's population. As is expected, China's economy was dominantly driven by these developed coastal regions in the last 40 years, showing significant regional economic differences [21]. While contributing to the economy, these regions also account for ~ 41% of the country's annual CO₂ emissions, that is, ~ 4.2 Gt [22, 23], scattering notable CO₂ emission hotspots in the east and southeast. In coastal provinces such as Guangdong and Fujian, fossil fuels are widely used to provide energy supplementation [19], and the location of large stationary sources, e.g., power plants, refineries, and cement plants [18] are heavily scattered along the coast. Not far from the coastal region are the 11 offshore sedimentary basins that spread ~ 1.7 million square kilometres, the geologic storage capacity of which is accounted ~ 573 Gt CO₂ [24]. This provides potential large-scale carbon storage reservoirs far exceeding that would be captured annually and can provide sufficient permanent geologic sequestration capability for more than 100 years' carbon storage, addressing long-term greenhouse gas emissions.

To safely and permanently lock CO₂ in deep underground geological reservoirs, offshore CCUS storage sites should be carefully selected. In the sedimentary basins offshore China, deep saline formations with layers of porous and permeable rocks are widespread, involving Miocene deltaic, coastal plain, and neritic clastic rocks. The regional seal-capped tertiary strata of these basins contain thick and high-quality aquifers, which are of mainly neritic and deltaic facies having lateral continuity. The utilization of the substantial pore space in these basins for CO₂ storage would require an efficient injection strategy to maximize the dissolution, residual trapping sealing, capping, and permanence. Recent research has shown that basalt deposits can quickly incorporate injected CO₂ to form carbonate minerals, which can permanently convert the injected CO₂ into immobile stone, and thus reduce the risk of leakage into the ocean and environmental pollution. In addition, the basalt deposit also has a translational impact on informing the fate of injected CO₂-bearing magnesium silicates and reactive calcium.

In the last decade, CCUS facilities have been commissioned in China, Australia, Brazil, Canada, Saudi Arabia and the United Arab Emirates [25]. CCUS in China has been investigated both onshore and offshore [16, 19, 26–29]. Onshore geologic reservoirs in China are mostly located in the northern and western regions, which are distant from the industrialized and populated coastal region and may raise extra costs and safety issues. In contrast, offshore CCUS will not have issues like ownership, holdings, activities, CO₂ contamination of drinking water aquifers, and potential damage to agricultural and industrial operations, etc. [30], as the offshore storage site is in no one's backyard. Therefore, offshore CO₂ storage offers potential jurisdictional simplicity. Further, the relatively easier management of sub-seabed saline formation pressure would reduce the offshore storage costs.

2.2.2 Current Status of Offshore CCUS

An increasing number of countries and organizations have adopted net-zero emissions targets, drawing attention to the need for CCUS. To date, there are 21 CCUS facilities around the world with the capacity to capture up to 40 Mt CO₂ each year [24]. Some of these facilities have been operating since the 1970s and 1980s, when natural gas processing plants in Texas began capturing CO₂ and supplying it to local oil producers for enhanced oil recovery (EOR) operations. Since these early projects, CCUS deployment has expanded to more regions and more applications. The first large-scale CO₂ capture and injection project with dedicated CO₂ storage and monitoring was commissioned at the Sleipner offshore gas field in Norway in 1996, which has now stored more than 20 Mt CO₂ in a deep saline aquifer. For technical and commercial reasons, the CO₂ needs to be removed from the gas before it can be sold; a CO₂ tax on offshore oil and gas activities introduced by the Norwegian government in 1991 made the project commercially viable [31]. Norway is also funding the development of a full-chain CCUS project (Langskip), involving CO₂ capture at a cement factory and a waste-to-energy plant and its storage in a large facility in the North Sea—Northern Lights—being developed by a consortium of oil and gas companies. More countries are now developing offshore CCUS strategies, for instance, the Netherlands is expanding its Sustainable Energy Transition Scheme to a wider set of clean energy technologies, including CCUS and low-carbon hydrogen; and the UK government has also announced significant public funding for new offshore CCUS projects [24].

To date, four large-scale offshore CCUS projects (Sleipner, Snøhvit, Quest, IBDP) are launched internationally, with which ~4 Mt CO₂ per annum together are dedicated to being injected into geologic saline formations [32], while the underlying deployment of offshore CCUS technology in China is at a pilot scale. In 2021, China launched its first offshore CCUS project in the Pearl River Mouth Basin of the north South China Sea, to explore the storage of CO₂ in a sub-seabed saline aquifer. In this project, the injection of 1.46 Mt CO₂ into sub-seabed saline formations by 2026 was planned, which would achieve a near-zero emissions of offshore oil production [33]. This is currently generating valuable information about the costs, operation,

and market conditions for offshore CCUS in China, providing a prior feasibility test of long-term performance and security of offshore CO₂ storage as an attractive and efficient long-term strategy [31, 34], particularly for those industrialized coastal provinces to achieve their “ahead of time” carbon-neutrality claims.

2.2.3 Knowledge and Policy Gaps

The cost of CCUS is highly variable, e.g., the cost of CO₂ transport via pipeline depends on the pipeline length, diameter, terrain and route, from 2.0 to 15.3 USD per ton CO₂ per 250 km; storage in depleted oil and gas fields is less expensive than storage in saline reservoirs, from 8 to 25 USD per ton CO₂ [35]. Many of the early CCUS projects focused on industrial applications where CO₂ can be captured and utilized. For example, in natural gas processing, any CO₂ contained in the gas usually needs to be separated out to meet market requirements or prior to liquefaction for liquefied natural gas (LNG) production to avoid the CO₂ freezing and damaging the production facilities. In other applications, such as bioethanol production or steam methane reformers to produce hydrogen, the CO₂ stream is relatively concentrated, which reduces the cost and the amount of energy required in the capture process. Until the 2000s, virtually all the CO₂ captured globally at large-scale facilities came from gas processing plants, but other sources now make up about one-third of the total [24].

CCUS deployment tripled over the last decade, albeit from a low base, but it has fallen well short of expectations. In 2009, the IEA roadmap for CCUS set a target of developing 100 large-scale CCUS projects between 2010 and 2020 to meet global climate goals, storing around 300 Mt CO₂ per year. Actual capacity is only around 40 Mt—just 13% of the target. Investment in CCUS has also fallen well behind that of other clean energy technologies. Annual investment in CCUS has consistently accounted for less than 0.5% of global investment in clean energy and efficiency technologies [24].

There are several reasons CCUS has not advanced as fast as needed; many planned projects have not progressed due to commercial considerations as they are expensive, and there is a lack of consistent policy support. In the absence of an incentive or emissions penalty, CCUS may simply not make any commercial sense, especially where the CO₂ has no significant value as an industrial input. The high cost of installing the infrastructure and difficulties in integrating the different elements of the CO₂ supply chain, technical risks associated with installing or scaling up CCUS facilities in some applications, difficulties in allocating commercial risk among project partners, and problems securing financing have also impeded investment. CCUS is also often viewed as a fossil fuel technology that competes with renewable energy for public and private investment, although, in practice, it has substantial synergies with renewables [24].

Despite the relatively fewer concerns of safety and easier management of formation pressure for the deployment of offshore CCUS [36, 37], policy-makers and communities retain doubts about its viability and effectiveness due to the existing uncertainties in high costs and the technology's maturity [31, 32]. Such uncertainties largely reflect the lack of integrated applications of large-scale commercial operations [30]. Moreover, the full-chain CCUS operation requires significant energy, which poses an efficiency penalty, as well as generating GHG emissions. This is expected to be reduced by the improvements in technology and the risk-premium reduction faced by first-movers [38], while it is heavily dependent on offshore CCUS-focused regulatory policies.

In China, regulation of the offshore disposal of CO₂ and ocean jurisdiction remain unclear, including the development of appropriate procedures and standards for undertaking a full-chain offshore CCUS, as well as concrete legal framework to guide public participation and consultation of offshore CCUS [37]. Because of this, CCUS project developers could purposely withhold information or even ignore the public perception. This leads to significant uncertainties and hinders offshore CCUS activities along with little guidance provided to treat future projects. To avoid such "interaction without rules," associated regulations and laws at the national, provincial, and local levels are expected to be formulated as a specific and legitimate mandatory basis prior to large deployment of offshore projects [39].

Regarding the diversity of involvement, the CO₂ emission sources in China are scattered in the main industrial clusters along the coast, while the offshore geological investigation and exploration are operated by various enterprises, such as large state-owned petroleum companies. Moreover, offshore CCUS research and development are conducted by research universities and institutes [40] and financial support and debts are provided by public sector banks. The integration of the development of offshore CCUS is often inefficient. For example, research institutes play an important role in developing offshore CCUS-related techniques, economic, and political framework, the feasibility of which has rarely been proved by commercial-scale offshore projects, as very few opportunities are given to reduce the associated risks. Particularly for the implementation of new projects, despite some research results suggesting offshore CCUS success, the associated risks are relatively high for long-term commercial adoption and commitment to carbon credits [34].

2.2.4 Priority Actions

In the coming decades, to ensure that offshore CCUS is an attractive and available option, important actions can be taken by the government and industry in China, involving continuing technology innovation, cost reduction, boosting CO₂ storage development, and risk management in both environment and commercial debt [37]. To facilitate the reduction of the cost of offshore CCUS, commercial-scale adoption of the technology is necessary, and initiatives of environmental policy should be supported by the Chinese government to incentivize first-of-a-kind construction.

This is particularly important as it will allow for learning, feasibility testing, and risk reduction for accelerating commercial implementations [34].

China should formally announce its intention to prioritize offshore CCUS to provide the impetus for government agencies, companies, financial institutions, civil society organizations, and partners to work together to create and implement a robust CCUS-focused financial supporting environment. China could pursue the following near-term windows of opportunity to communicate its ambition and commitment to offshore CCUS. Specifically, actions can be taken as follows.

1. Develop a financial framework to build a regulated free market environment

In China, an acceptable risk allocation of commercial debt has yet to be demonstrated, and a “standardized” financial template has yet to be developed due to the lack of consistent offshore CCUS development [30]. Large-scale offshore CCUS projects are complex and expensive, where debt could potentially be available, particularly for early offshore projects where grant funding can help to close a significant financial gap [30].

The state-owned enterprises of China have been major players in the execution of CCUS projects, which have a duty to fulfill their social function. However, they often face incentive opportunities and frameworks to access financing that differ from their private sector counterparts, particularly for those operating in more regulated market environments, such as the Shenhua Group and the China Huaneng Group [30]. For private ownership in the orbit of free initiative, they can carry out activities in a free competition environment [41]. Such competition in offshore CCUS can either be a priority to access the best CO₂ storage location or a shared preferred offshore CO₂ storage site. This could provide a guidance to construct CO₂ transporting networks with the lowest costs and the best storage options [37].

To make offshore CCUS projects commercially viable, a tax on CO₂ emissions from the industry could be introduced by the Chinese government. This would provide a strong revenue and viable incentive which will draw down the cost of offshore CCUS as that has been introduced by Norway and the United States (45Q tax credit) for CO₂ utilization and storage [42, 43]. While uncertainty does exist in all CO₂ pricing systems, the 45Q tax credits allot more than USD 35 per ton for CO₂ utilization and more than USD 50 per ton for permanent sequestration of CO₂ in geologic reservoirs [44]. This helps business provide offshore CCUS solutions for developing supply chains in a coordinated manner [37]. If China introduces a carbon tax, it should avoid most part of offshore CCUS costs for the infrastructural establishment of the supply chain, involving the construction of offshore pipelines and platforms [45].

2. Demonstrate full-chain offshore CCUS project with cross-disciplinary engagement

In terms of designing offshore CCUS projects, a wide range of procedure and risks must be specifically examined and evaluated. This involves coordination in studying the feasibility of storage reservoirs, carbon source-sink database, identifying knowledge gaps, front-end engineering, and design (FEED), leakage monitoring, as well as

external quality assurance, etc. Moreover, specific non-technical uncertainties would need to be addressed, involving full-chain supply, regulatory framework, liabilities, financial drivers, social acceptability, as well as making a case for gender considerations in the regulatory framework to ensure that women have equal opportunities in offshore CCUS projects. All these essential factors would require a clear regulatory framework to be established. Therefore, continuous research on full-chain CCUS technologies and the development of pilot demonstration offshore CCUS projects should be carefully conducted, which will accelerate incremental steps toward maturing offshore projects and minimizing uncertainties and comprehensive risks [46]. The current challenge is to break through science, technology, finance, governance, and social barriers to enable widespread deployment of offshore CCUS projects.

To date, the total cost of offshore CCUS exceeds 350 CNY per ton in China without an industrial utilization to take economic benefits [47]. To increase the economic effect, offshore CO₂-enhanced oil recovery (CO₂-EOR) [26] can be introduced, where oils in geological layers could be substituted by the injected supercritical CO₂ [48]. Through CO₂-EOR, most of the injected CO₂ will be permanently locked in the geological reservoir under the right conditions as well as improving the recovery of oil [43], making it a cost-effective way of reducing carbon emissions. Such implementation can effectively make the cost of storage negative from incremental oil production. It can yield an additional 5–17% of a reservoir's original oil in place more than conventional oil production practices (typically producing 35–50% of it). In China, CO₂-EOR has been estimated to offer > 100 Mt CO₂ per year of storage resources, while the economic viability of it is subject to the cost per ton of CO₂ delivered and the evolution of the oil price [49, 50]. However, the reservoir capacity of offshore oil and gas fields is relatively small compared to that of saline formations offshore China, which makes the demand for CO₂ for EOR projects decline over time [37]. Therefore, it is expected that offshore CO₂-EOR activities may exist in the near to medium term, while CO₂ storage in saline aquifers will be in the medium to long term.

Among the sedimentary basins offshore China, ~ 2.5% are oil and gas fields, leaving existing infrastructures for CO₂ transportation and injection. The advantage of existing infrastructure and framework in mature fields could be taken for carbon offsets, which significantly reduces the level of public funding and policy support, benefiting the maturation of carbon market-based mechanisms [51]. For near-term large-scale storage in depleted fields, these infrastructures could potentially be reused to reduce the costs of constructing new offshore facilities, particularly in the case of short-term underinvestment [52]. However, some existing offshore facilities are aging and the window of opportunity to reuse existing facilities could be limited. Hence, it is required to develop multiple phases of technical evaluation and possibility timelines and ranking availabilities of these platforms.

To guarantee regulated income for service providers on full-chain CCUS components, a future model should be presented to separate the procedure of CO₂ transport

and storage from capture [37]. This will allow agencies with offshore CCUS expertise to concentrate on CO₂ transport and storage while carbon emitters focus on capture [41]. However, such a model will require a thorough monitoring, reporting, and verification system to account for captured, transported, and stored CO₂.

To manage carbon storage from the emission sources, flexible services such as bookable storage should be presented, that is, temporal and spatial source-sink matching. To efficiently perform the carbon source-sink matching, the nearest suitable geological storage reservoir is usually required to be identified for each emission source [31]. Emissions from power plants in the industrialized east and southeast China would potentially be the first selection to store offshore.

3. Perform detailed site characterization and prevent environmental risks

The initial development of dedicated offshore CCUS projects is a costly and time-consuming process. For large-scale CO₂ storage beneath the seabed, detailed geological mapping and site characterization of abandoned drills and possible reservoirs are needed. These necessary works require substantial capital investment, which deters independent bodies from investing in offshore storage infrastructures and related technologies, particularly when combined with the uncertainty of future revenue. China has large state-owned enterprises, where direct investment can be used to support early offshore CCUS projects, such as funding site characterization and sharing data and knowledge. This could boost the deployment of offshore CCUS, guarantee sufficient investment returns, and help mature the carbon market through procurement policies [24, 37].

Safety is a key issue the government and society are concerned about regarding offshore CCUS. Ensuring the integration of sub-seabed geologic reservoirs is a substantial challenge, where the sub-seabed CO₂ leakage could lead to negative reaction in the marine ecosystem [53]. Assurance of environmental performance of CCUS with thorough research and assessment should be a prerequisite for solution to environmental problems and ensure that the problem is not transformed into another one. Any form of CCUS should adhere to strict environmental and social safeguards in order to minimize negative consequences, and must be applied as a means of minimizing atmospheric carbon as opposed to prolonging reliance on fossil fuels or carbon-rich lifestyles. Hence, careful selection and long-term monitoring of undersea geologic reservoirs are therefore required [54, 55].

Renewable energy and other green technologies should be mainstreamed in CCUS projects. To supply energy to the offshore CCUS infrastructure, low-carbon opportunities from wind, solar, wave, and tides could be introduced [41] (see Sect. 44 in Chap. 2). This would offer sustainable development of offshore CCUS in the long run, not only for storing captured CO₂ from the coastal industry sectors, but also for sequestering CO₂ from direct air or ocean capture in the future.

Key Recommendation: Accelerating research on carbon dioxide removal

Noting that there would be unavoidable emissions from fossil fuel burning even under carbon-neutrality scenarios, accelerating technology innovation of marine CDR, offshore CCUS, and development of its governance framework will become increasingly urgent. *We advise the establishment of policy and financial frameworks for accelerating research for scalable ocean-based carbon dioxide removal (CDR) and offshore carbon capture, utilization, and storage (CCUS).*

2.3 Reduction of the CO₂ Footprint from Ocean Activities

2.3.1 Ocean-Based Activities Contributing to Carbon Release

Not only do human activities produce huge amounts of CO₂ on land, but ocean-related industries also continue to produce anthropogenic emissions. With its productive ecosystems, the ocean itself is a powerful carbon-sequestering zone, absorbing about one-third of anthropogenic CO₂ emissions [56]. Human activities in the ocean and coastal zones not only increase total CO₂ emissions but also reduce the ocean's ability to absorb CO₂ by causing the degradation and even destruction of marine ecosystems. Reducing CO₂ emissions from ocean activities and restoring the carbon sequestration function of marine ecosystems will help society adapt to and mitigate the climate change crisis.

Shipping

The maritime shipping industry is one of the major contributors to anthropogenic carbon emissions in the ocean, mainly from the usage of fossil fuels to power its ships. According to estimates by the International Maritime Organization (IMO), 0.1 Gt CO₂e is generated by the combustion of ship fuels, currently accounting for nearly 3% of total human activity emissions [1].

Currently, heavy fuel oil (HFO), which is used in most ship engines, generates serious air pollution represented by sulphur dioxide. As a result, some shipowners are building new ships with more environmentally friendly power systems or modernizing existing ships with alternative fuels such as liquefied natural gas (LNG). While such efforts may lead to improvements in air pollution, they have had limited success in addressing climate change. Even though LNG can reduce CO₂ emissions by 25% compared to existing heavy fuel oil, the methane released by its combustion remains a greenhouse gas with a very high heat-trapping capacity. At the current stage of technology, clean energy sources that can completely replace fossil fuels in shipping do not yet exist.

Capture Fisheries

Like the shipping industry, carbon emissions from marine capture fisheries are also mainly from vessel fuel consumption. A secondary consideration, still inadequately understood, has to do with emissions associated with seafloor disturbance from fishing gears, especially on the continental shelf. In 2016, global CO₂ emissions from fuel combustion in capture fishing vessels were about 207 Mt CO₂e, with motorized vessels accounting for about 98% of emissions, industrial fishing for 77% of global capture fisheries emissions, and small-scale fisheries for 23% [57]. Considering that carbon emissions from illegal, unreported, and unregulated (IUU) fishing are difficult to include in statistics, the actual emissions may be even higher [58]. The carbon emissions from fisheries targeting different species also vary, with demersal fish, crustaceans, and pelagic fish (> 30 cm) accounting for 42%, 24%, and 23% of total emissions, respectively [59].

Despite the gradual increase in carbon emissions from marine fisheries, global fish catches are on a declining trend [56]. Fuel-intensive fishing gears, such as dredging, bottom trawling, and beam trawling, not only emit more greenhouse gases but also tend to damage important habitats for aquatic animals such as the seafloor and coral reefs, further depleting fishery resources and affecting the carbon sink function of marine ecosystems [60]. This unsustainable pattern of fishery resources exploitation will lead fishers to continue to intensify their fishing effort, which in turn will result in increased fuel use per unit of catch, creating a vicious cycle of CO₂ emissions and marine ecosystem degradation. It has been shown to be possible to rebuild marine fish populations with effective stock-scale management, at least to levels associated with maximum sustainable yield. New research has suggested that rebuilding target fish populations to higher levels could not only increase carbon stored in living biomass—and potentially sinking to the seafloor—but also have indirect effects on carbon processing and sequestration through ocean ecosystem structure and function. In addition, precautionary management in emerging fisheries—especially at high latitudes where maximum fish productivity is most likely to increase [61] and related to ecosystem compartments known to be essential to downward fixed carbon movement, including in the mesopelagic realm—could help protect these as-yet inadequately understood but potentially large carbon processing and storage functions.

Mariculture

The carbon footprint of mariculture is thought to originate mainly from the upstream, such as the production process of different aquafeed ingredients, and the downstream, such as processing and transportation, and the upstream and downstream carbon footprint of mariculture is often higher than the carbon emissions from fish farms. The main species of mariculture in China are bivalves and algae, which account for 81.6% of national mariculture production in 2020 [62]. The culture of these low trophic levels species relies on almost no feeding, so there is basically no feeding pollution and corresponding feed production carbon footprint. Mariculture of these non-fed

species is mostly carried out in cages or rafts at sea or in mudflats, so the external inputs and pollution outputs are low [63]. However, the large-scale reclamation of coastal wetlands by mariculture activities or the unreasonable layout of nets can also lead to serious pollution of organic matter, nutrients, and heavy metals, which affect the water quality of the aquaculture area and the surrounding seawater [64], further degrade coastal ecosystems, such as mangroves, seagrass beds, and salt marshes and their ecological service functions, thus weakening the ocean's ability to sink and store CO₂. It is important to note that increasing macroalgal-related carbon fixation only results in climate benefits when some part of that production is dedicated to long-term storage through non-respiring product mixes. Related opportunities may exist in using cultured seaweed to reduce net GHG emissions associated with terrestrial agriculture through soil amendments or through methane production inhibition in livestock if that pathway turns out to be actionable at scale.

The Post-harvest Processing and Distribution of Aquatic Products

There is a significant demand for energy in post-harvest refrigeration, processing, and transportation of aquatic products. From the perspective of life-cycle assessment (LCA), the post-harvest refrigeration (onboard and onshore), processing, and marketing of seafood, whether captured or farmed, are all part of the life cycle of seafood, and the energy inputs in these processes also generate large amounts of CO₂ emissions. Projections indicate that future demand for energy in the seafood chain will continue to increase. Though relatively more energy options are available to sectors of the chain other than fishing, the price of alternative energy sources will be reflected in the end product, with the potential to affect food security [65].

Through the application of emerging technologies and the promotion of management measures, it is possible to reduce carbon emissions from human activities involving the sea and to enhance the function of the ocean as a carbon sink. Studies have predicted the carbon-reduction potential of various sectors with full potential: maritime transport has the potential to reduce GHG emissions as much as 0.24–0.47 Gt CO₂ equivalent by 2030, and as much as 0.9–1.8 Gt CO₂ equivalent by 2050. The conservation of coastal ecosystems has the potential to reduce GHG emissions by 0.32–0.89 Gt CO₂ equivalent by 2030 and up to 0.5–13.8 Gt CO₂ equivalent by 2050. Marine capture fisheries and mariculture have the potential to reduce GHG emissions by 0.34–0.94 Gt CO₂ equivalent by 2030 and up to 0.48–1.24 Gt CO₂ equivalent by 2050 [1].

2.3.2 Assess Mitigation and Adaptation Strategies

Shipping

The bottleneck for decarbonization and emission reduction in the shipping sector is that zero-carbon technologies that can be extensively applied to vessels have not yet

been established. Technologies for the commercial preparation of alternative zero-emission fuels, such as hydrogen and ammonia, are still in the development stage, with uncertain progress. Another challenge is that ocean-going vessels often require large amounts of fuel storage and must be able to obtain rapid replenishment at port. Batteries using renewable energy sources can only be used on short voyages such as ferries or coastal trips. Nuclear energy as a shipping fuel is only used on military or special-purpose ships in very few countries due to safety risks and is not ready to be promoted in the civilian sector.

In addition, another difficulty in reducing carbon emissions from the shipping sector is the difficulty of clearly assigning emissions responsibility to the appropriate country. Different choices based on where the ship's fuel is sold, where the ship is registered, and where the ship's cargo is sourced or destined will all result in very different emission responsibilities and associated costs for each country. IMO is coordinating maritime emissions among more than 170 member countries, but each has varying interests.

Most shipowners are in favour of using market-based instruments of carbon pricing to address emissions. This echoes the calls from the international trading industry, and more than 90% of the world's merchant ships are driven by trade. The trade industry has asked IMO to prioritize the implementation of a carbon tax in shipping to encourage shipowners to invest in the development and application of alternative fuel technologies. But some shipowner representatives also favour letting political forces set the rules so that the shipping industry follows through with compliance. For IMO, it needs to develop international standards around the core issue of who is responsible for emissions, and it needs countries with large fleets to actively participate to drive the standards on the ground. But IMO's resolution will take years to develop and even longer for its member states to ratify.

Currently, feasible decarbonization measures for the shipping industry in the short term include advancing the design of more efficient ship power systems, switching to cleaner fuels, building supporting port facilities, and establishing responsible parties for emissions. Long-term adaptation and response measures should focus on developing clean energy sources with zero emissions.

Capture Fisheries

Given the lack of breakthroughs in clean energy technologies for ships, capture fisheries face the same dilemma as the shipping industry. In addition to the issue of improving vessel fuel, capture fisheries can reduce their carbon footprint mainly by transforming fishing gear, such as promoting the transformation of fossil fuel-intensive gear, including dredging, bottom trawling, and beam trawling to methods with a lower carbon footprint, such as gillnets and longline fishing. This switch could also lessen the trawling-based GHG footprint exacerbated by seafloor sediment disturbance. Fisheries management should also phase out environmentally harmful vessel fuel subsidies and fuel tax exemptions while providing financial and other

incentives to shift fishing gear/practices, such as the allocation of exclusive fishing quotas or fishing areas for more energy-efficient practices.

In addition, the management authorities and distribution industry should highlight the nurturing of low-carbon awareness among consumers and prioritize the provision of products with a low carbon footprint to the market. The increase in consumer demand for the corresponding products will facilitate the fishing industry to shift to fishing gear and fishing methods that consume less energy and have less environmental impact.

Finally, goalsetting in fisheries should be examined to assess the degree to which current practices support effective carbon processing and storage through ecosystem structure and function. “Climate-precautionary management” could become a new target for fisheries sustainability.

Mariculture

The sustainable management, conservation, and restoration of marine and coastal zone ecosystems are essential for the continued provision of carbon sequestration and other critical ecosystem services [66]. Artificial wetland restoration, through the planting of specific plants (e.g., seepweed and reeds) in farmed areas, can absorb pollutants in the trail water [57]. The degradation of ecosystem services caused by aquaculture can be mitigated by restoring coastal ecosystems through the recovery of farmed mudflats by the “returning aquaculture land to beach” policy. Policies to prevent the conversion of these ecosystems to other land uses, such as strict management of coastal development practices and spatial planning of the coastal zone, can also ensure that important habitats in the coastal zone are protected (see also Sect. 1.3). In addition, promoting the use of low-carbon footprint and wild fish-free aquafeeds can help reduce CO₂ emissions from aquaculture.

Other than reducing the negative impacts of mariculture, the mariculture sector can actively address climate change by increasing sinks by cultivating certain species (e.g., seaweed and bivalves). Seaweed culture is one of the largest scalable NbS [67] and the main embodiment of “carbon sink mariculture.” Global seaweed absorbs 61–268 Tg CO₂ equivalent per year. Seaweed has the function of CO₂ capture, acting as a powerful carbon sink, and helps to protect coastal land from flooding and erosion; seaweed helps decarbonize the economy by replacing emission-intensive products; seaweed can also be used as biofuel to replace fossil fuel emissions; as animal feed, it can reduce the methane emissions of farm animals and thus contribute to CO₂ emission reduction.

Integrated multi-trophic aquaculture (IMTA) is a system that grows organisms of different trophic levels in appropriate proportions to create a balance between environmental sustainability, economic stability, and social acceptability. Considering that macroalgae-dominated IMTA can reduce pollution from mariculture itself, increase the climate resilience of coastal societies, and economically compensate seaweed farmers through carbon trading [68], macroalgae IMTA can be considered a powerful nature-based solution tool for mitigating and adapting to climate change.

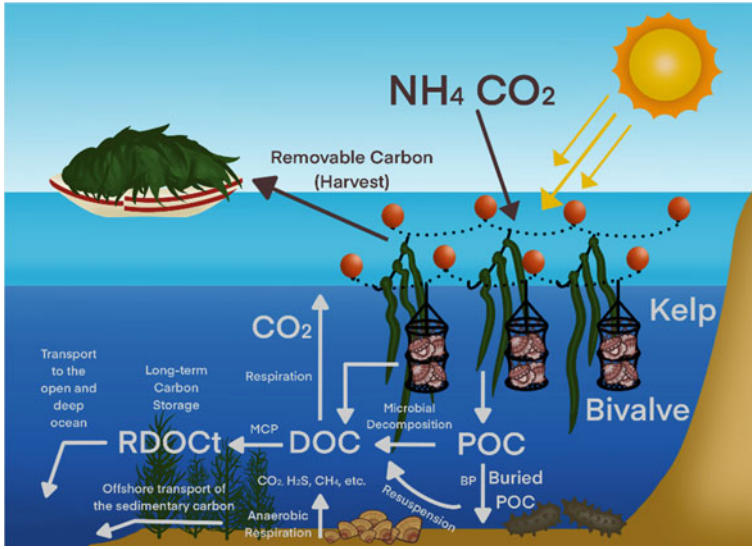


Fig. 4 Carbon pathways of integrated mariculture of seaweed and shellfish. POC: particle organic carbon; DOC: dissolved organic carbon, RDOct: refractory dissolved organic carbon; MCP: microbial carbon pump

The IMTA mode of kelp and scallops as the main cultured species in Sanggou Bay, China, can be considered a typical NbS case (Case Study 2).

Case Study 2: Integrated Multi-trophic Aquaculture, Sanggou Bay

Sanggou Bay in Shandong Province is one of the sea areas where mariculture is the most maturely developed in China. Integrated multi-trophic aquaculture emerged as early as the 1980s in Sanggou Bay [69], with kelp (*Laminaria japonica*) and scallop (*Chlamys farreri*) as the main cultured species, and has gained worldwide recognition and promotion. Such mode is essentially a nature-based solution: shellfish excrete inorganic nitrogen by feeding on phytoplankton and organic debris in seawater, while algae need to absorb inorganic nitrogen through photosynthesis to grow and reproduce. The integrated model of shellfish and algae achieves a balance of inorganic nitrogen supply and demand in the sea, and algae can also release dissolved oxygen to prevent seawater hypoxia, which not only reduces pollution from mariculture activities, but also improves production and quality performance and provides certain ecosystem service functions. After decades of development, characteristics of different water layers have been fully utilized to adjust the culturing depth and further formed a three-dimensional mixed mariculture mode in Sanggou Bay, including seaweed, wakame, scallops, oysters, abalone, and other species.

In addition to food supply and water purification, the carbon sequestration capacity of the cultured species makes the Sanggou Bay mariculture system have the function of climate change regulation (Fig. 4). Large algae consume inorganic carbon through photosynthesis, and shellfish form shells by absorbing bicarbonate ions in seawater, and the carbon thus fixed can be removed from the ocean through harvesting. Studies have shown that kelp aquaculture contributes the most to carbon sequestration in Sanggou Bay, over 80% [70]. Based on the typical culturing density, the carbon sequestration capacity of kelp per unit area is outstanding, three to four times the carbon sequestration capacity of common afforestation tree species on land [71]. As the world leader country in shellfish and algae aquaculture, China has the potential to achieve the dual goals of food security and climate change mitigation through such activities. In 2022, China has completed the first-ever mariculture carbon sink transaction in Fujian Province, and with the improvement of such incentive systems in the future, ecosystem-based mariculture will also have an excellent prospect of sustainable development.

The Post-harvest Processing and Distribution of Aquatic Products

Reducing the carbon footprint of marine aquatic products generated during the post-harvest process relies mainly on the reduction and transformation of energy consumption. At the macro level, the carbon footprint can be reduced at the processing and transportation stages of seafood through changes in power generation, improvements in transmission and distribution efficiency, and optimization of seafood transportation processes. At the local scale, promoting consumers' choice of locally produced seafood can also reduce redundant transportation and thus carbon footprint, as well as reduce seafood waste (e.g., promoting the input of residues from seafood processing into aquaculture) [72]. Considering that current studies on LCA of seafood are not comprehensive, a better understanding of the whole chain and data collection would contribute to carbon-reduction actions.

Unlike the harvest process of seafood (including capture and mariculture), which is often dominated by individual and small-scale operators, the post-harvest process of seafood is more industrial. Management and industry associations should actively encourage the relevant enterprises to obtain corporate social responsibility certification to reduce the carbon footprint in the production process, while also reducing other negative environmental externalities, promoting employment, and strengthening labour rights protection. Meanwhile, enterprises can build a positive image through the process, meet management requirements, and enhance corporate sustainability. Considering the fact that the majority of the world's seafood processing workers are women [73], CSR certification will also be a powerful tool to promote women's rights.

2.3.3 Knowledge and Policy Gaps

The ocean is the link among continents and countries around the globe, and ocean-related human activities have distinctive cross-border characteristics, thus posing a serious challenge to global governance efforts to reduce a sector's carbon footprint. This challenge is first and foremost reflected in the shipping industry's efforts to decarbonize. Even with the revolutionary breakthroughs in science and technology that have made it possible to power ships with low- or even zero-carbon fuels, the responsibility and costs of the transition are still difficult to precisely assign to countries. As the pivot for coordinating the global shipping industry, IMO is required to establish a guiding framework for the industry to reduce carbon emissions. However, defining the responsibility for carbon emissions generated by shipping activities involves a huge conflict of interest among different countries. IMO has difficulty coordinating effectively if the high-level political forces of the major shipping countries cannot reach a consensus.

Compared to the shipping industry, capture fisheries have weaker cross-border characteristics and clearer management boundaries. However, capture fisheries are the pillar of employment and livelihoods for many people, and small-scale fisheries composed of artisanal workers have a vast scale, especially in developing countries. The fishing gear and fishing methods employed by fishers are often constrained by geography, catch composition, and even cultural traditions, which are highly region specific and difficult to quickly transform. Meanwhile, regarding the fully exploited status of global fishery resources, the economic profits of capture fisheries are relatively limited and unstable, making it difficult for fishers to bear the additional costs of transition (e.g., changing fishing gears and fishing methods). The combination of these factors makes it rather difficult to establish carbon-reduction awareness among capture fishers. In addition, as marine aquatic foods are increasingly transported and distributed, carbon-reduction-driven changes may also bring about wide-ranging food security issues, thus posing the challenge of transboundary governance. If the WTO succeeds in reaching an agreement on fisheries subsidies, it would be an enforceable global rule that would not only help address overfishing but also have an indirect impact on carbon emissions. New approaches to fisheries management that result in better biological and economic performance can help address these problems, as could the decision for fair compensation of some avoided harvest to help attain climate goals, should that prove feasible. Fishers and fishing interests—especially small-scale fisheries—would need to be intimately involved in the discussions about how to approach these problems over time.

In terms of global aquatic food production, mariculture is increasingly replacing marine capture. Although estimates of carbon emissions from mariculture are unclear, there is still a need to establish a carbon-reduction awareness in the aquaculture industry. Along with economic development, growing consumer preference for high-value aquatic foods is likely to lead to more feed being put into the aquaculture of these high-trophic-level species; and rapidly developing recirculating aquaculture systems often require high levels of energy. In addition, post-harvest processes such as preservation, transportation, and marketing of aquatic foods (both captured

and cultured) also contribute significantly to carbon emissions. To develop corresponding carbon-reduction policies, it is necessary to strengthen research on the LCA of aquatic foods and to cover the complete industry chain. It is worth noting that mariculture itself (i.e., carbon sink aquaculture) can also be a powerful tool for climate change adaptation and mitigation. Algae and bivalves are good at capturing carbon, and their culturing processes require little feed, thus producing a negative carbon footprint. However, incentives to promote such aquaculture practices (e.g., carbon trading mechanisms) are still in the initial stages.

2.3.4 Priority Actions

Reducing the carbon footprint of ocean-related human activities is largely dependent on technological advancements and breakthroughs and is obviously difficult to achieve overnight. However, we should quickly establish and consolidate a distinct awareness of carbon reduction in marine industries, incorporate gender-equality considerations, develop a progressive planning route, and start working on it from now on.

In the short term, actions that can be undertaken by industries include:

1. Strengthen ship design optimization and power technology innovation to improve the efficiency of fossil fuel for shipping vessels.
2. Implement stricter fisheries management measures, restrict high-energy fishing gear and fishing methods such as bottom trawling, and gradually eliminate fuel subsidies for fishing vessels.
3. Develop specific types of mariculture (e.g., algae and bivalves) to achieve synergy between increasing carbon sinks and ensuring food security.
4. Elucidate gender relations in fisheries and aquaculture by collecting sex-disaggregated data where possible to identify challenges toward gender equality and visualize women's contributions to sustainable and low-carbon seafood production and promote their effective participation in decision making.
5. Conduct scientific coastal zone spatial planning, promote establishment of fully protected MPAs, strengthen the conservation and restoration of coastal wetlands, thus adequately realizing the carbon sink function of coastal ecosystems, and better link MPA network design with larger-scale management programs for fisheries and biodiversity.

In the medium and long term, actions that could be undertaken include:

1. Encourage research and development of low/zero-emission marine fuels and corresponding ship power systems to achieve technological breakthroughs.
2. Begin research to assess opportunities for “climate-smart” fisheries management, engaging both adaptation and potential mitigation approaches.

3. Promote innovation in financial instruments and social capital input mechanisms (including gender-related measures) to increase investment in sustainable blue economy activities, including green technology to reduce carbon emissions and environmental damage, and conservation and restoration of blue carbon ecosystems.
4. Encourage scientific researchers to assess the carbon emissions of marine aquatic foods over their complete life cycle to provide a basis for policy intervention.
5. Raise public awareness on low-carbon footprint food consumption habits and promote the production of low-carbon aquatic foods from the demand side.

At the same time, carbon reduction in marine industries involves political, scientific, industrial, and public communities, and requires a strong alliance of stakeholders at all scales, from global to local. At the international level, international organizations that play a global coordinating role in marine industries, such as IMO and FAO, should accelerate the establishment of a framework for carbon reduction-oriented industry standards and reasonably allocate responsibility for emissions in cross-border issues. Similarly, regional scientific institutions like PISCES could provide leadership in assessing the science behind climate-smart fisheries. At the national level, countries with significant influence in each industry should take the lead in promoting global cooperation, take the initiative to undertake governance responsibilities, and promote the sharing of key technologies while optimizing institutional arrangements and implementing ambitious incentives in domestic governance to promote the carbon-reduction transition of corresponding industries. At the societal level, enterprises should actively respond to governance requirements, fulfill their social responsibilities, build certification mechanisms, and provide abundant and high-quality climate-friendly products and services.

Key Recommendation: Develop a green marine industry

Recognizing that ocean-related industries will continue to produce anthropogenic emissions, *We recommend aiming for more ambitious goals, including within the International Maritime Organization (IMO), toward dedicated efforts to accelerate the low-carbon transformation and upgrading of the marine industry and stimulate scientific and technological research and development of clean fuels, including establishing “green corridors” between ports to accommodate the use of renewable fuels for the deep-sea fleet.*

2.4 Ocean Renewable Energy

The Ocean Economy in 2030, a major report issued by the Organisation for Economic Co-operation and Development (OECD) in 2016, estimates the gross value added (GVA) of the Blue Economy at more than USD 3 trillion by 2030 (at 2010 prices), and at 2.5% of total global GVA. Within this, ocean energy is notable as an emerging sector, defined by the key role that cutting-edge science and technology play in the delivery of projects and technology. There are significant areas of collaboration and overlap between ocean energy development and the development of our existing maritime infrastructure and capacity. For example, the UK maritime sector contributes GBP 14.5 billion to the UK economy, and directly supports an estimated 186,000 jobs [74]

Ocean Renewable Energy (ORE) is notable as an emerging sector of the maritime industry. China, the world's biggest energy consumer, is stepping up on using a larger portion of renewable energy in the overall energy mix and proposing higher green power consumption targets, including in the ORE area. Achieving the needed renewable energy transition will not only mitigate climate change but also stimulate the economy, improve human welfare, and boost employment worldwide.

In 2020 the CCICED Special Policy Study on *Global Ocean Governance and Ecological Civilization: Building a Sustainable Ocean Economy for China* completed an in-depth study on ORE [73]. The following descriptions and observations draw on and build on the findings of the report from that study.

2.4.1 Utilizing the Ocean to Produce Renewable Energy

ORE technologies (wind, wave, current, tidal range, ocean thermal) are at different stages of development and each presents its own unique challenges and opportunities. The optimal portfolio of future ORE options will vary in different places around the world. ORE, specifically offshore wind, has seen and will likely experience rapid growth in installed capacity, such that environmental, socio-economic, and technical challenges need to be considered, especially as these new industries move toward scale. Achieving a viable cost of electricity is a significant challenge to the offshore wind industry but provides an even bigger challenge to other ORE technologies. Understanding and assessing the environmental impact of ORE installations, operations, and decommissioning is substantially challenged due to such things as baseline data, socio-economic situations, and diverse developing technologies. Full-scale development of ORE affects or is also affected by numerous stakeholders. Understanding who the stakeholders are and how they are engaged in the process is necessary for improving the responsible development of ORE technologies. Key stakeholders may include fishers, community members, regulators, developers, scientists, and tourists that depend on the specific ORE project and the specific location.

The seabed off China's east coast is characterized by soft, silty soils which are unlike soil conditions in other countries contemplating significant ORE growth. This causes difficulty regarding structural foundation type and installation techniques. Furthermore, the technical challenges for the offshore wind industry are much greater in other typhoon-prone regions, where the weather conditions can be quite impactful on turbine performance. China's current legal system of environmental consideration related to ORE activities is limited, and further regulations need to be developed.

2.4.2 Current Status of Developing and Utilizing ORE

China is particularly active in developing offshore wind technologies, an area which is set to become an important sector for the global energy future, while also demonstrating wave and tidal energy technologies. The Chinese government has made a commitment that the proportion of non-fossil fuel energy will be 20% by 2030, and an operational installed capacity of ORE (offshore wind) in 2019 reached 3.7 GW in total, with another 13 GW under construction and over 41 GW permitted. The development of offshore wind in China reached a turning point in 2018, moving toward zero subsidies. China's first auction for offshore wind projects in 2019 achieved a price of electricity at 0.75 Yuan/kWh, lower than the guide price of 0.8 Yuan/kWh. China has become also one of the few countries in the world that have mastered the technology of large-scale tidal current energy development and utilization.

ORE is a fast-growing ocean economy that is advancing the goals of a low-carbon and circular economy. Only recently, offshore wind technology reached a policy turning point, while other ORE technologies are at an early stage of development. Nevertheless, there are encouraging signs that the investment cost of technologies and the price of electricity generated will decline further toward commercially viable ORE energy generation. Enhancing knowledge of the ORE technologies' potential impacts is crucial to informing future growth plans and effectively licensing ORE activities. Ongoing review of environmental impacts associated with the growing ORE sector and emerging ORE technologies will ensure that the best and most up-to-date information is available to decision-makers, developers, and stakeholders. Furthermore, the opportunity of integrating emerging ORE technologies into military applications, electricity generation for remote communities, freshwater generation, or aquaculture applications, could be further opportunities. ORE technologies offer opportunities for China to develop a new domestic industry and take advantage of engaging in global markets.

2.4.3 Knowledge and Policy Gaps

Knowledge production and management play a significant role in many kinds of industries to deal effectively with changes, increasing their productivity and paving the way to development and innovation. One example from **data sharing**: Ørsted A/S

successfully shared data from earlier generations of offshore wind farms with technical universities aiming at further improving wind farm design and inspiring future engineers to join the green energy industry. Sharing this data has led to improvements in wind-flow modelling and monitoring of wind turbines.

Before the ocean energy sector can reach the bankability and commercial viability necessary for industrial roll-out, the first ocean energy pilot projects must reach financial close. Demonstration and pre-commercial farms and plants require a specific financing solution, as high levels of uncertainty and risk make them unsuitable for commercial debt or pure revenue-based finance. Thus, we recommend the creation of an **Investment Support Fund** for ocean energy farms that creates a fund providing flexible capital and enabling further private capital to be leveraged, and an **Insurance and Guarantee Fund** to underwrite various project risks. The latter would be targeted to cover risks such as availability, performance, unforeseen events, failures, etc.

National authorities need to adequately **support new technologies** as they emerge and move through demonstration and pre-commercial stages to reach industrial roll-out. An explicit distinction must be made between support for mature technologies and support for emerging technologies. Emerging technologies such as ocean energy require investment- or project-specific support rather than pure revenue support.

Overall, the development of ORE in China is highly dependent on revisions of regulations and policies from the central government, such as the Renewable Energy Law and in upcoming Five-Year Plans for China's National Economy and Social Development. Additionally, policies at the provincial/regional level—and the interplay between central and provincial levels—play a crucial role. China can be a world leader in the movement toward sustainability through ORE.

2.4.4 Priority Actions

The following actions emphasize that an industrial supporting policy mechanism should be established and improved. Furthermore, the scale of ORE utilization should be promoted, while financial or venture capital communities as well as private capital should be encouraged by governmental policies. Finally, offshore wind should be accelerated while environmental and socio-economic impacts assessed; mechanisms to accelerate commercial realization of other ORE technologies should be supported by the government.

Policy

1. Industrial supporting policy mechanisms should be established and improved.
2. Scale up of ORE utilization should be promoted.
3. Develop ocean-related taxonomy principles and criteria.
4. Enable RD&D to address challenges to reduce costs further to reach parity with other energy technologies.
5. Enhance capacity to accelerate innovative and resilient technology development.

6. Engage at an early stage with a wide range of stakeholders including fishers, community members, regulators, developers, scientists, and tourists—ensuring the expression of perspectives from women, as well as underrepresented or marginalized groups.
7. Integrating emerging ORE technologies into wider applications such as military applications, electricity generation for remote communities, desalination, hydrogen production, or aquaculture applications.

Market

8. Assessing the creation of an Investment Support Fund and an Insurance and Guarantee Fund.
9. Financial or venture capital communities, as well as private capital, should be encouraged by governmental policies.
10. Develop and adopt blue bond standards on ORE.
11. Strengthening the global export and market opportunities.
12. Scaling up ORE industry, creating jobs, and taking advantage of opportunities within its competency to global markets.

Offshore Wind

13. Offshore wind should be accelerated while environmental and socio-economic impacts assessed. Understanding scaling needs while also establishing key pilot projects will be important.
14. Increase offshore wind deployment by addressing many strategically important goals such as decarbonization, security of supply, and new business opportunities.

Marine Energy

15. Tidal current energy research and development should be encouraged by government as expected to be the next type of ORE.
16. Mechanisms to accelerate the commercial realization of ORE technologies (wind, wave, current, tidal range, ocean thermal) should be supported by the government.

Key Recommendation: Developing climate-smart ports

Ocean renewable energy (ORE) is notable as an emerging sector of the maritime industry. Achieving the needed renewable energy transition will not only mitigate climate change but also stimulate the economy, improve human welfare, and boost employment worldwide. *We recommend that transportation systems of large coastal cities and the shipping sector should be decarbonized through scaling up offshore wind production and promoting hydrogen and ammonia production and that other potentially high-value ocean energy approaches be developed as quickly as possible.*

3 Sustainable Management of the Ocean as a Solution for Achieving Carbon Neutrality

3.1 The Need to Consider the Ocean System Holistically

To tackle societal challenges from climate change, biodiversity loss, and inequality, we need to strike a proactive balance between production and protection, and the ocean has a critical role in addressing these challenges. However, the importance of the ocean as part of the solution for meeting global challenges has long been overlooked. For humanity to tackle the planetary challenges and crises that it faces today and in the future, a systemic, integrated, and holistic approach concerning ocean issues and the governance of this space must be taken. In this sense, we argue that integrated ecosystem-based integrated ocean management (EB-IOM) approach is fundamental for achieving the carbon-neutrality goals, protecting biodiversity, and developing an ecological civilization. IOM considers multiple uses and pressures simultaneously, and helps reconcile competing uses with the objective of ensuring the sustainability of societies and marine ecosystems. The need for a comprehensive perspective on the management of marine ecosystems and their resources is now widely recognized at all levels of governance. Clear and directed actions are needed to limit the threats and minimize the impacts on the ocean, and thereby laying the foundation for the ocean's ability to continue to serve as a basis for human and planetary life.

A holistic and integrated management can support more effective use of carbon storage in ecosystems, the decarbonization of marine industries, and the transition to low-carbon ocean-based activities. In an increasingly busy ocean space, there are opportunities to maximize economic growth and meet the needs of people without compromising the environment, but rather restoring and/or regenerating it. This could be unlocking the co-location benefits with other offshore industries; for example, ocean-based energy could meet the increasing demand for energy-intense desalinated seawater or support marine aquaculture operations, as well as offer protection of critical ocean ecosystems and biodiversity at the same time. Any such ocean-based activities should not be undertaken in isolation but rather in a cross-sectoral and integrated way. This will avoid stranded assets, and with long-term marine spatial planning in ocean and coastal spaces, benefits will be accrued in terms of economic, human, and environmental health.

An integrated approach that is climate smart and focuses on NbS, integrating well-managed MPAs and other effective area-based conservation measures alongside sustainable infrastructure development, will be vital to protect and support coastal communities and marine habitats. This could increase seafood production, enable pharmaceutical innovation, enhance climate change mitigation and adaptation, meet energy needs, and protect, regenerate, and restore biodiversity and cultural values (www.oceanpanel.org).

This climate-smart integrated approach has proved to be economically smart and viable as well. Recent research has found that investing USD 1 in key ocean actions

can yield at least USD 5 in global benefits, often more, over the next 30 years. Specifically, investing USD 2 trillion to USD 3.7 trillion globally across four key areas—conserving and restoring mangrove habitats, scaling up offshore wind production, decarbonizing international shipping and increasing the production of sustainably sourced ocean-based proteins—from 2020 to 2050 would generate USD 8.2 trillion to USD 22.8 trillion in net benefits, a rate of return on investment of 450%–615% [75].

Globally, there are still many challenges relating to the lack of truly integrated approaches, insufficient involvement of local stakeholders, inadequate harnessing of and respect for science and knowledge, weak adaptation to climate change, inadequate enforcement of existing and often complex governance frameworks, knowledge and capacity shortages, incomplete legislation, and poor coordination and integration among ministries, other governmental bodies, civil society organizations, and research institutions [76]. There also needs to be a recognition that ecosystem-based ocean management and governance requires gender-sensitive and gender-responsive planning, implementation, monitoring and evaluation at project, policy, and grassroots levels to be successful. China, housing great technological and economical resources, has the capacity to implement a wide variety of adaptive and mitigative measures that will have an impact on societal development nationally as well as internationally. A key to achieving ecological civilization and carbon neutrality lies in implementing a cross-sectoral knowledge and EB-IOM.

3.2 Approaches to Sustainable Ocean Management Toward Carbon Neutrality

Ocean-based mitigation options offered through sustainable ocean management could reduce the “emissions gap” (the difference between emissions expected if current trends and policies continue and emissions consistent with limiting global temperature increase) by up to 21% on a 1.5 °C pathway and by about 25% on a 2.0 °C pathway, by 2050 [1]. There are five main areas, in the context of sustainable ocean planning, that will make considerable strides toward mitigating GHG emissions and thus carbon neutrality: ocean-based renewable energy; zero-emission maritime transport; stewardship of coastal and marine ecosystems; the ocean-based food system (wild capture fisheries, aquaculture, and shifting human diets toward food from the sea); and carbon storage in the seabed. Ocean-based renewable energy production currently offers the greatest potential for delivering clean energy and reducing GHG emissions, with the expansion of floating wind and solar facilities being important frontiers. When wider impacts on the environment and social well-being are considered, nature-based interventions—especially protection and restoration of mangroves, seagrass and salt marshes (i.e., blue forests)—offer the best combination of carbon mitigation and broader co-benefits for people, the economy, and the planet.

Blue forests hold enormous potential for capturing and storing CO₂. Research indicates that marine flora and fauna are substantially more efficient than terrestrial forests in capturing CO₂ (particularly mangroves, which capture several times more CO₂ than trees on land). Preventing the loss of natural habitats, restoring natural conditions if destruction has occurred, and ensuring that any future activities are conducted in a regenerative manner—NbS—must be a key strategy in reaching the carbon-neutrality goals.

Here, coastal wetlands play a particular role, being effective at sequestering carbon and serving as key habitats for many marine species, and an important source of food and livelihoods. Since urbanization, especially the development of coastal cities, poses a challenge for preserving natural habitats, measures such as an **ecological damage compensation system** should be assessed. In support of a compensation scheme, a **natural capital accounting system** could be further developed. Fenichel [77] discusses a system of national accounts with multiple indicators and how they should be applied to the sustainable ocean economy, and the Global Ocean Accounts Partnership (<https://www.oceanaccounts.org/>) looks at developing a shared technical framework for ocean accounting. Although central authorities like the Ministry of Ecology and Environment will oversee such instruments, local involvement and engagement are very important [75]. Conservation measures at sea should also be given adequate attention, for example, assessment and development of MPAs, as well as seaweed farming which is increasingly gathering attention for its multiple benefits (especially climate change and food security related), and a rapidly expanding global market and demand.

MPAs and other area-based conservation measures offer a range of benefits which includes the creation of employment opportunities, enhancing production of fisheries adjacent to the protected area, increased carbon sequestration through healthy marine ecosystems and the protection of critically important biodiversity. MPAs should not only be viewed as a mechanism to deliver on the targets of the SDGs but also seen as part of a country's infrastructure and invested in as such. Financial support and investment for protected areas and other area-based conservation measures, and providing incentives for sustainable seaweed farming, could be considered within China and along the BRI via international collaborations.

Second, achieving a sustainable ocean economy (“blue economy”) requires innovation and development of new, **climate-smart technologies** in both existing and new ocean-based industries. The need for developing these green technologies has implications for all ocean-based industries in China. Examples from the maritime sector could be to establish early national targets and strategies to support decarbonization of vessels, and to incentivize sustainable, low-carbon ports that support the transition to decarbonized marine transport and shipping fleets—and possibly some parts of the fishing fleet—through renewable energy and zero-carbon fuel supply chains. Another example, from the aquaculture sector, could be to put into place policies and management frameworks to minimize the environmental impacts of aquaculture, including inefficiencies in the feed supply chain, and enable the acceleration of fed and non-fed aquaculture production that fits local environmental, governance, and economic priorities. Targeted **government procurement and investment in**

addition to preferential fiscal and tax policies in green technologies could help industries overcome financial obstacles which sometimes impede the creation of environmental technologies. Internationally, through the **BRI**, China could be proactive in developing offshore wind and green solutions in ports, fishing vessels, mariculture, and tourism, as well as promoting the concept of integrated ocean management as a management principle [1].

Third, knowledge is a fundamental value for societal development. The use of **scientific knowledge and monitoring** relevant to the sustainable and climate-smart management of marine ecosystems and economies should be encouraged and enforced by providing mechanisms and opportunities for access to a common knowledge base. This would underpin coordinated and holistic use of knowledge in instituting overarching policies on the development of the ocean economy and the implementation of EB-IOM. Maintaining an up-to-date knowledge basis (science and technology) and data sharing capabilities requires investments in national and regional systematic programs for data and knowledge gathering and technology development, as well as innovative methods for disseminating data and knowledge. Investing and engaging in the **IOC Ocean Decade** would be an important international contribution by China.

Fourth, by active participation and spearheading relevant discussions in key **international processes and fora** that provide a framework for sustainable ocean management, China will contribute to global ambitions for reaching carbon neutrality. Central bodies here are the Paris Agreement (UNFCCC), the Biodiversity Convention (CBD), the ongoing discussions on Biodiversity Beyond National Jurisdiction, the International Maritime Organization, and the International Seabed Authorities. By doing so, China would inter alia also contribute to the timely development of appropriate legal and environmental framing of novel and emerging ocean industries, such as ORE, seabed minerals, and biotechnology. Great care must be taken to ensure that any areas to which China contributes are science based and avoid any consequences that may further compromise the health of the ocean.

3.3 Priority Actions

The following priority actions are suggested to support the implementation, and the continuous development of knowledge-based and EB-IOM in all marine areas of China, and in areas where China has influence.

1. Halt the net loss of (and increase the extent and improve the condition of) coastal and marine ecosystems, in particular critical ecosystems such as mangroves, seagrass beds, salt marshes, kelp forests, sand dunes, reefs, and deep ocean ecosystems. Improve climate-ready management of those ecosystems.
2. Use NbS in planning and developing coastal infrastructure to reduce grey infrastructure where possible, incentivize their use to sequester and store carbon and improve coastal resilience.

3. Establish and effectively manage science-based networks of MPAs and other effective area-based conservation measures that conserve biodiversity while also delivering climate, food, socio-economic, and cultural benefits. Link those explicitly to larger-scale management programs for fisheries, biodiversity protection, and other natural amenities.
4. Collaborate with all relevant partners, including Indigenous People and stakeholders, through relevant global and regional organizations to promote sustainable management of all marine and coastal ecosystems. Enhance the participation of women and their financial profile in all aspects of the ocean economy.
5. Capitalize on knowledge and spatial analysis tools to identify carbon sequestration potential and optimal locations for MPAs and other effective area-based conservation measures in the development of Sustainable Ocean Plans.

Key recommendation: Capture and storage of CO₂ by nature itself

To tackle societal challenges caused by climate change, biodiversity loss, and inequality, we need to strike a balance between production and protection, and the ocean has a critical role to play in addressing these challenges. The ecosystem-based integrated ocean management (EB-IOM) approach is fundamental for achieving the carbon-neutrality goals and developing an ecological civilization. *Immediate action should be taken, from local to national levels, seeking to avoid further marine habitat and coastal wetland destruction, and where possible, mitigate those losses: (i) By 2030, restore degraded/destroyed coastal wetlands and protect critical marine habitats; (ii) By 2030, invest in, and implement, a resilient network of MPAs (including national parks, nature reserves, and marine redlines), to protect large-scale marine habitats that contribute significantly to carbon storage and marine biodiversity through NbS; and (iii) Incorporate climate-smart management of these blue carbon ecosystems into China's national GHG inventory following the approved IPCC guidelines and China's NDCs, and explore collaborations with BRI-countries to facilitate similar measures through international collaboration.*

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Chapter 4

Low-Carbon and Resilient Urban Development and Adaptation to Climate Change



Focus on the Yangtze basin

1 Risks and Challenges of Global Large River Basins Under Climate Change

1.1 *Impact of Natural and Human Activities on Large River Basins*

Globally, large river areas hold huge social, ecological and economic importance. As the birthplace of human civilization, large river basins have played a central role in human history, culture, religion and society. They form regions that provide critical agricultural productivity and support growing populations, provide natural resources for the development of towns and cities, and have fostered the development of some of the world's most diverse and important ecosystems.

As key areas of interrelation between humans and nature, river basins are being affected by a host of natural and human factors, which has posed a series of challenges to river basin governance of the present day. The Netherlands PBL study team, in preliminary studies, identified 17 factors affecting river basins, mainly emphasizing two aspects: The first is the impact of natural environment on river basins, including flooding, droughts, high waves, landslides, erosion, wildfires and other disasters. These extreme events become natural hazards when people, buildings, or infrastructure are in harm's way. The second is the impact from socio-economic development, including both the impact of traditional activities in river basin areas such as dams, water diversions and transfers, sediment mining and fisheries, and the impact from urban settlement and industrial development, such as urbanization and industrialization, port and industrial development, agriculture, and deforestation in the catchment area. These natural and socio-economic impacts interact, correlate and combine with each other, undermining functions and ecological systems of river basins and posing a host of changes, threats and challenges to river basin management (Fig. 1).

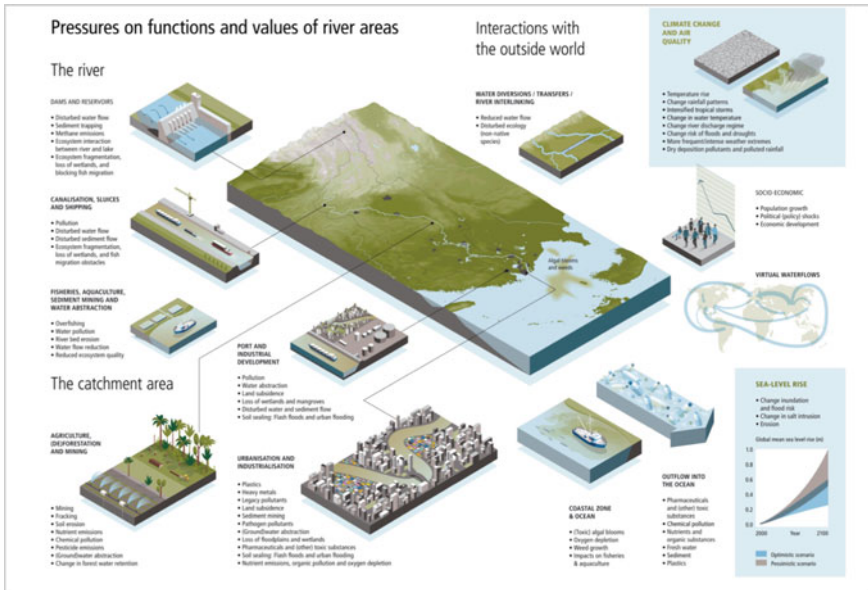


Fig. 1 Overview of challenges in the river and the catchment area, and in relation to interactions with the outside world. *Source* CCICED [1]

1.2 Possible Impact of Climate Change on Hydrology of Large River Basins

Hydrological cycles of river basins are seeing changes due to climate change, altering the distribution, timing, and quantity of water in river basins, with implications for human and natural systems. Therefore, the TNC study team conducted a literature review on the hydrological impact of global large river basins under climate change, reaching the following conclusions:

Possible exacerbated seasonality of flow in large river basins by climate change. For instance, river discharge for rivers such as the Ganges, Yangtze, and Yellow River, influenced by monsoonal precipitation, is projected to increase during the high-flow season [2].

Possible higher water temperature of rivers by climate change. Global mean river water temperatures are projected to increase on average by 0.8–1.6 °C for 2071–2100 relative to 1971–2000; the largest water temperature increases are projected for the United States, Europe, eastern China, and parts of southern Africa and Australia [2].

Increasing impact of global climate change on extreme weather in large river basins. Global and regional extreme weather and climate events are increasing, both in frequency and intensity [3]. Addressing climate change and the frequent occurrence of extreme climate-related weather events and arriving at targeted and practical

strategies to improve the level of resilience in river basins is a critical need in today’s river basin management.

Uncertainty in predicting hydrological changes in specific river basins. There are still significant uncertainties to be resolved in terms of directionality (increases or decreases), magnitudes (relative size of changes) and time scales (seasonality, frequency, short term vs. long term) of climate change impacts, despite the significant progress in understanding the impact and significance of climate change on river basins in the current scientific literature.

Box 1 Study on the Uncertainty of Future Scenario for River Basin Water Discharge Under Climate Change

TNC conducted a comparative analysis on the Yangtze River Basin, the Rhine River Basin and the Amazon River Basin, showing an obvious upward trend between the flow of the Rhine River and the climate change, and no statistically significant trend of the Yangtze River and the Amazon River in different RCP scenarios. The fluctuation range between the minimum and maximum values of the Rhine River is less than 1.2 times, while that of the Amazon River is nearly 5 times, that of the Yangtze River is within 3 times. One credible explanation is that the Yangtze River and the Amazon Rivers are larger in scale, with more influencing factors (Fig. 2).

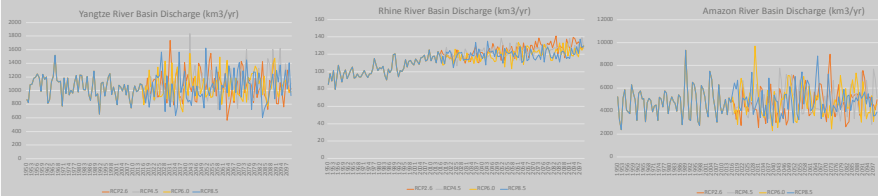


Fig. 2 Discharge flow under four Representative Concentration Pathways scenarios in the Yangtze River (left), the Rhine River (middle) and the Amazon River (right). *Source* Results are obtained from the ensemble of CMIP6 models, which have been calibrated to the year 2015, and projected through the year 2100

1.3 Risks and Pressures in Large River Basins

In the context of climate change, changes in river hydrology will affect flood control, water resource availability, water quality and biodiversity of large river basins. In addition, socio-economic activities affect air quality conditions, land use for agricultural and food production, energy and mining exploitation, as well as power generation, aggravating water risks of current river basins and the pressure faced by water

systems. According to PBL preliminary studies, the risks and challenges of climate change to current global river basins mainly focus on the following aspects:

Risks of heavy rainfall and flooding. In general, climate change will increase the intensity of heavy rainfall events because air can retain more water vapor when it heats up. As a result, flash floods and urban flooding may occur more often unless infiltration and water retention capacities in urbanized areas are increased. The past few decades saw a sharp rise in losses due to river floods globally, with an upward trend of losses caused by floods: from 2010 to 2050, the global population affected by river and coastal floods is expected to increase from 992 million to 1.3 billion [4]. The frequency of mountain torrents and urban floods will be increased if the infiltration and water retention capacity of urbanized areas remain unimproved. A higher intensity of heavy rainfall events may also increase soil erosion in agricultural areas and nature areas affected by wildfires and may wash down more nutrients to the river [5].

Drought and water shortage. On a global scale, droughts increased in the early half of the twentieth century, decreased in the mid-twentieth century, and increased again starting the 1980s [6]. Model simulations indicate that by the end of this century, the global land area and population in extreme to exceptional droughts could more than double, each increasing from 3% during 1976–2005 to 7% and 8%, respectively. An assessment of global water scarcity by mid-century, based on scenarios of population growth and climate change, has indicated that most of the projected water scarcity is due to climate change [7]. Since the world may face water shortage of 40% by 2030, water mismanagement will exacerbate the impact of climate change on water resources and the whole society.

Hydropower development. Decarbonization development may prompt further development of hydropower potential as renewable energy. The impacts of climate change itself, such as increased flood frequency or intensity, can also lead to increased pressure to build more dams [8]. The increasing use of hydropower dams, however, may exert various pressures on river basins, like disturbing water flow and sediment flow, and damaging aquatic biodiversity.

Inland water transport. The functionality of inland waterways can be affected by changes in both high and low flows. High flows can have major impacts such as the suspension of navigation, damage to port facilities due to increased loads on structures, damage of banks and flood protection works, silting, and changes in river morphology. Changes in low water conditions have a higher impact on inland waterway transport, affecting the loading capacity of (mainly) larger freight ships for longer periods of time [9], and on saltwater intrusion in deltas.

River pollution. Usually, river pollution can be seen in populous, industrialized and agriculture-intensive river basins. Climate change, globally, is expected to worsen water quality like that of the—even routinely treated—drinking water, posing health risks. These risks stem from rising temperature, higher concentrations of sediments, nutrients and pollutants caused by rainstorms, reduced pollutant dilution capacity during droughts and interruption of treatment facilities during floods [10]. In addition,

increased water temperature reduces oxygen solubility and concentration, and raises the toxicity of pollutants (such as heavy metals and organophosphates) to fish and other freshwater species [11].

1.4 Multiple Challenges of River Basin Governance

High complexity of river basin issues. The complexity of river areas can be seen in two aspects: the first is the complexity of river basins themselves, which is reflected in the linkages among the upper, middle and lower reaches of the river system, the interdependence between all activities and land use types within river basins, and the interaction between river basins and the outside world. The combined action of different pressures often has non-linear results, leading to amplified effects [12, 13]. The second is the complexity of multiple impacts of climate change on river basins, and different influencing factors may have cross effects, or act on river basins simultaneously to produce additional effects. This destroys functions and ecosystems of river basins and brings a chain of changes and challenges in managing river basins, which requires us to see river basins as a whole for systematic studies when studying river basin governance.

Uncertainty of risks of short-term shock on river basins by climate change. People have made great progress in understanding the impact and significance of climate change on river basins in the scientific field, believing that the long-term impact of climate change on river basins is relatively certain, such as higher water temperature, increased seasonality of flow and precipitation. However, there is great uncertainty in the short-term prediction of risk shock to river basins due to limited hydrological directionalities, amplitudes and time scales of specific river basins in existing studies, intensifying the difficulty of river basin governance. It is, therefore, necessary to adopt empirical studies to analyze specific river basin problems, so as to provide successful schemes and strategic cases for decision makers.

The safe resilience of urban and rural settlements in river basins is the most urgent. The obvious upward trend of frequency and intensity of global and regional extreme climate events [3] also makes river basin management more and more urgent. There exists a large divide in infrastructure construction and vulnerabilities to disasters in urban and rural settlements, due to great gaps in development stages of different river basins. With climate change, frequent extreme climate-related weather events and better living standards of people, the requirements for the safe resilience of river basins are also greatly increased. As for river basin management, it is imperative for us to work towards resilience-oriented river basin governance, combine hydrology, ecology and social sciences into a new and forward-looking scientific method of river basin resilience, and formulate targeted and practical strategies for better river basin resilience.

Integrity, synergy and coherence of river basin governance. River basin governance policies face multiple challenges due to the complexity of river basin issues. In most cases, natural boundaries of river basins do not match their administrative boundaries, and many river basins even stretch over more than one country. What's more, the management of river basins also involves multiple fields, multiple departments and different administrative levels. Therefore, this results in disadvantages of segmentation, separate policies and repeated construction in governing large river basins. How to cross administrative boundaries at different levels to ensure the consistency, synergy and coherence between cross-border policy objectives and the implementation of cross-sector and cross-level policies is a major challenge. We need to make overall coordination and systematic institutional mechanism design for many fields, departments and places of large river basins in terms of related policies.

The complex interweaving of interest groups in river basin areas. The river basin is a complete and complex system, with complicated ecosystem functions, big regional divides in socio-economic development levels, multiple development forms of different degrees, complex relations, diversified interests and needs, which brings numerous challenges to river basin governance in terms of interest selection and interest balance. We should not only coordinate all interest relations of upstream and downstream reaches, left and right banks and different regions, industries and departments, but also focus on the risks and challenges brought by climate change to regions with different development levels and groups. In formulating related policies of river basin governance, we should pay attention to all interest relations in the natural, economic, social and cultural systems in river basin areas, comprehensively consider the sustainable development of river basins, make a good choice and balance of interests for fairness, justice and social harmony.

1.5 The Urgency of China's River Basin Issues and the Importance of the Yangtze River

More and higher pressures of China's river basins compared with other global river basins. In preliminary studies of the Netherlands PBL team, 16 major international rivers, including the Rhine, and 20 major rivers in China were selected for qualitative comparisons for pressures in 17 aspects. According to the studies, it is expected that by 2050, all large river basins will face more pressures, with China's large river basins facing more pressures and bigger impact. These pressures bring problems and risks not only in dams, wetlands and glacier melting in upper reaches of rivers, but also in fisheries, aquaculture, floodplain and wetland loss, as well as in catchment area pollution, deltaic land subsidence, groundwater exploitation, soil erosion and other problems and risks.

	Damming	Canalisation/river training/shipping	Fisheries/aquaculture/threat to fish	Sediment mining	Loss floodplains/wetlands	Pollution (nutrients)	Deltaic land subsidence	Soil sealing	Groundwater abstraction	Flood risk (population exposed)	Droughts	Relative sea-level rise	Water transfers/river interlinking	Virtual water flows	Non-native species	Socio-economic developments (GDP)	Transboundary impacts
Rivers (partly) in China																	
<i>Amur</i>	o				o	o			o	?	+						o
Liao & Coastal Rivers																	
Hai					d	i			d	?							i
Huang He (Yellow) (1)	o	o			d	i			d	?				U-D			i
Shandong Coastal Rivers									d								
Huai (1)														U-D			
Changiang (Yangtze) (1)	d				o	i			d	?				U-D			i
SE River basins (2)	*	*	**		***	*	d*		+	***	*		*				
Xun Jiang (Pearl)	o				d	i			d	?	o						i
Red	d																
<i>Mekong</i>	d				o	o			o	?	o						o
<i>Salween</i>	d				o	o			o	?	o						i
<i>Irrawaddy</i>	d				d	o			o	?	o						o
<i>Indus</i>	d				d	d			o	?	o						d
Ob-Irtysch	o				o	o			d	?	i						o
Gansu-Inner Mongolia																	
Qinghai																	
Tarim-Junggar																	
Ili																	
Tibetan																	
International Rivers																	
Amazon	d				d	o			d	?	i						o
Congo	d				d	d			d	?	i						d
Mississippi	o				d	i			o	?	d						o
Nile	d				d	d			d	?	i						o
Paraná	d				d	d			d	?	i						o
Lena	d				o	o			o	?	i						o
Niger	d				d	d			d	?	i						o
Murray-Darling	o				d	o			o	?	i						o
Ganges	d				o	d			o	?	i						i
Orinoco	d				d	o			o	?	i						o
Tigris-Euphrates	d				d	d			o	?	i						o
Yukon	o				o	o			o	?	i						o
Brahmaputra-Jamuna	d				o	d			d	?	i		d				i
Sao Francisco	d				d	o			d	?	i						o
Magdalena	d				d	d			o	?	i						o
Rhine	o	d	i	i	i	o	d		o	o	d	d	o	o	o	o	o

Qualitative Pressure Indicator - Reference 2021	
	Low
	Medium
	High
	Insufficient Data

Qualitative Pressure Indicator - Projection 2050	
i	Improvement
o	No change
d	Deterioration
?	Insufficient Data

(1) U-D: upstream-downstream virtual water flows in the same basin
 (2) * = Quiantan River; ** = Min River; *** = Quiantan and Min Rivers

Fig. 3 Impacts of pressures on rivers now and in the future: an example of indicative fingerprinting using qualitative scores [1]. *Note* In the table, a qualitative low, medium, and high impact label is suggested to characterize the pressures on the rivers in their current situation. In addition, where possible, an i, 0, or d is included to indicate whether an improvement (i), deterioration (d) or no change (0) is projected by 2050. *Source* CCICED [1]

The next 50 years will be a key time window for China's river basin management. Compared with the development of large global river basins in developed regions, China's river basins will face more complex challenges in the next 50 years. The study team compared the Rhine River in Europe with the Yangtze River in China, showing that various problems caused by industry and pollution had been solved in the Rhine River as early as the 1950s. Today, people pay more attention to frontier issues like biodiversity and energy decarbonization in governing the Rhine River. While the development of China's river basin economy is much later, as China didn't see the beginning of rapid industrialization and urbanization until the 1980s. However, in today's large river basins in China, in addition to solving water pollution, improving prevention and control, and addressing water shortage, ecological environment restoration and flood control brought about by urbanization and industrialization, people also put forward issues such as energy decarbonization and biodiversity protection to achieve the strategic goal of "peak carbon in 2030 and carbon neutralization in 2060". Therefore, the development of China's large river basins will face more complex challenges in the next 50 years.

The Yangtze River Basin is the most important support for China's development and has the most vitality and potential for the socio-economic development of the country. Covering a total area of 1.8 million square kilometers, the Yangtze River basin, rich in natural resources, accounts for 18.8% of China's land area, with the total population and economy exceeding 40% of the country. The Yangtze River Basin, since ancient times, has always faced natural pressures such as floods, droughts and extreme weathers; After the reform and opening up, it faces a series of challenges brought by the rapid socio-economic development. Today, people have adopted a series of major strategies, such as *the Yangtze River Protection Law of the People's Republic of China*, *the Outline of the Development Plan of the Yangtze River Economic Belt*, and the overall policy of eco-priority and green development is taking shape. Understanding complex pressures of the Yangtze River Basin under climate change, the way of addressing climate change and solutions to sustainable development of the basin are not only of great significance to China's ecological civilization, but also of key reference value and demonstration to the governance of other river basins in the country (Fig. 3).

Box 2 Comparison of the Development Stages Between the Yangtze River Basin and the Rhine River Basin

The countries along the Rhine River Basin have entered the post-industrial development stage, the urban population has witnessed lower growth, so pollutant emissions have peaked after the 1980s, and environmental pollution problems have been basically under control; in recent years, the total carbon emissions and per capita carbon emissions of the coastal countries have begun to decline as low-carbon development was accelerated in response to climate change.

In the next 15 years, economic scale and urban population of the Yangtze River Basin will also maintain rapid growth, and outstanding pressure still emerges when controlling the total amount of pollutants and carbon emissions. At present, the total emissions of major pollutants of the Yangtze River Basin began to decline after 2015; However, the total carbon emissions and per capita carbon emissions are still increasing (Figs. 4 and 5).

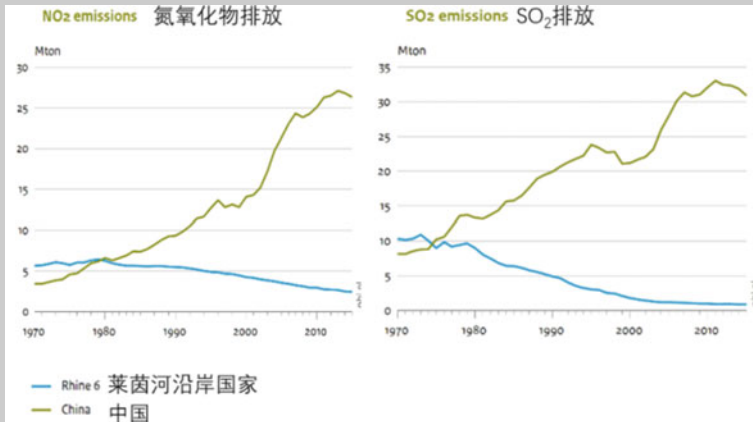


Fig. 4 Emissions of nitrogen oxides and sulphur oxides in the Yangtze River Basin and the Rhine River Basin. *Note* nitrogen oxides expressed as NO₂. *Source* Harbers [14]

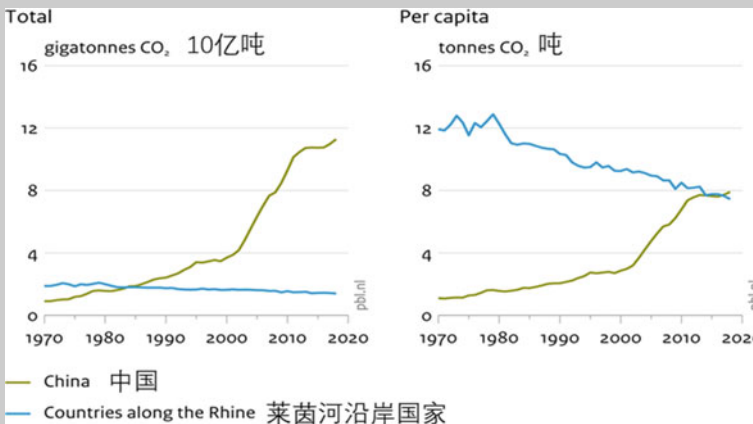


Fig. 5 Carbon emission of China and countries along the Rhine River *Source* Harbers [14]

2 New Path Forward and International Experience Reference in Governance of River Basin

2.1 *Eight Critical Steps and Framework for River Basin Management Assessment*

The prospect of climate change and the need for ambitious decarbonization of our economies both exacerbate the challenges and open opportunities. We need to redefine the interaction between the use of rivers for socioeconomic development and securing healthy, sustainable water systems. This calls for a transformation towards sustainable river management that addresses both human interventions and the consequences of climate change. This transformation will not happen overnight. The world is complex, and rivers are not stand-alone silos that can be managed in isolation. Agriculture pollutes the river with nutrients, hydropower is an important part of decarbonization that fragments river ecology and disturbs the continuity of water and sediment flow, and the high demand for sand for construction leads to illegal sand mining, to name a few aspects of this complexity (Fig. 1 in Chap. 2; Fig. 6).

There is no ‘golden bullet’ to solve all problems. Bending the trend towards climate resilient and sustainable rivers requires a machinery of eight steps to shift the outcome of policy and investment strategies in the intended direction (Fig. 7).

This will require—amongst other things—a leap in ambitions, thinking beyond 2030, requiring policy integration and coherence across sectors, new transformative

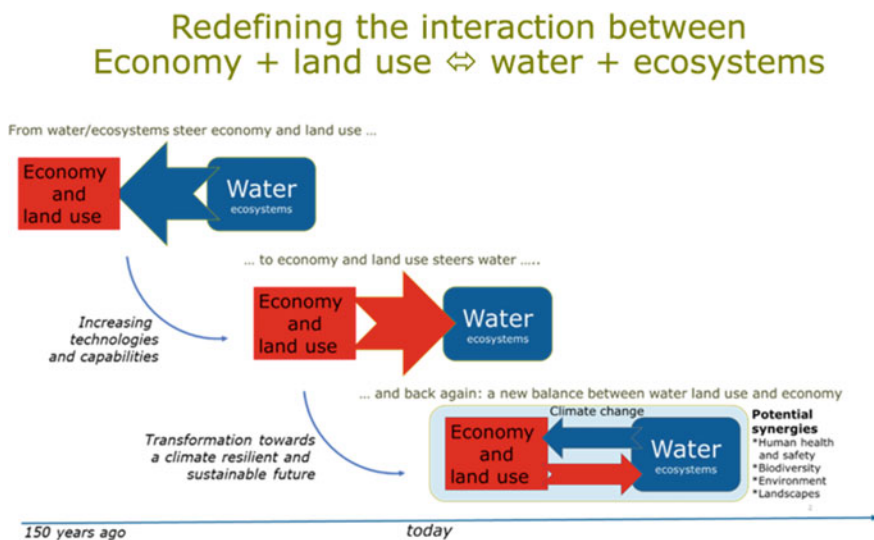


Fig. 6 The shift of water steering economy and land use to economy and land use steering water, calling for the redefinition of the interaction between the two. *Source* Harbers [14]

The way forward: 8 critical steps

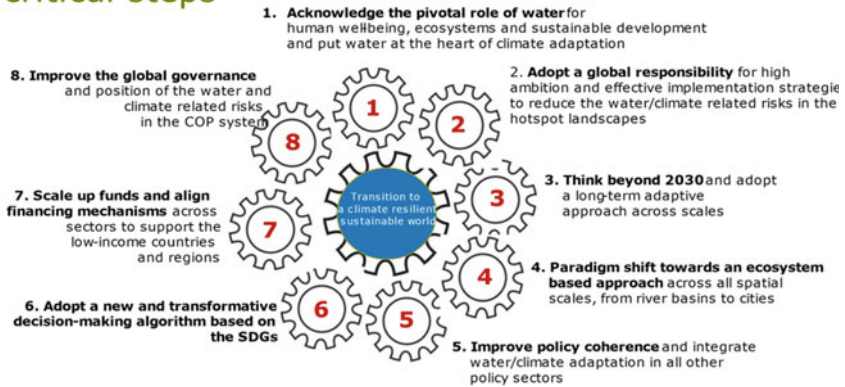


Fig. 7 Eight critical steps of the ‘machinery’ to bend societal trends towards climate resilient and sustainable rivers. *Source* Harbers [14]

algorithms for decision making, integrated spatial development, and speeding up and scaling up efforts and investments, especially in low-income countries and high-risk regions in order to prevent structural loss of human habitats.

A framework is presented that helps us to investigate river basins and river basin management under climate change by comparing cases and drawing lessons from practices around the globe. Focus is on current and future developments in river basins due to socioeconomic developments, land use and climate change, on river basin resilience and adaptability, and on river basin management and governance. The investigative framework distinguishes the basin characteristics that define the possibilities in the river basin, stresses that act on the basin, and the response of the river system that leads to outcomes in terms of changes in risk and resilience, prosperity and decarbonization, security of the supply of water, food and energy, and progress in achieving the SDGs. The stresses acting on the river basin are climate change, socio-economic development, and internal strategies and policies.

The investigative framework aims at providing evidence-based recommendations building on experiences from case studies in the Rhine and Yangtze Basins and from river basins around the world. Each case needs to be analysed following a structured approach to identify as good as possible the drivers, the enabling environment, the hurdles, thresholds, catalysts, deciding measures and actors (Fig. 8).

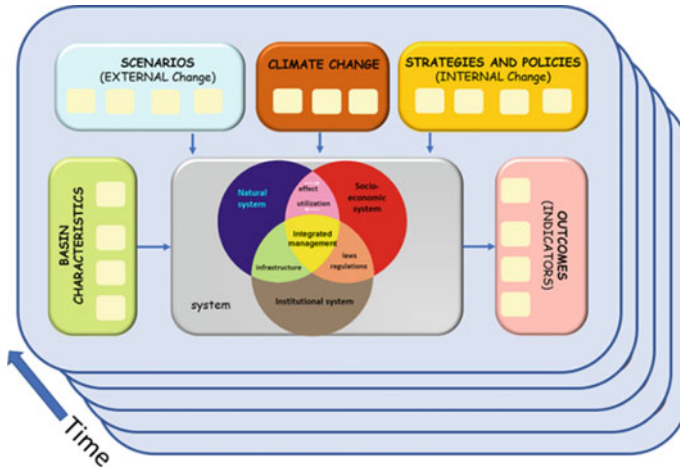


Fig. 8 Components of a conceptual framework for river basin management assessment

2.2 *The Changing Game: Understanding and Building Resilience in River Basin*

Climate change, its interaction with a wide range of anthropogenic and natural stressors, and the challenge of decarbonization are altering all aspects of river basins, especially the use of land and water resources within the basin, as well as the corresponding ecosystem services provided by river basins. This is the ‘Changing Game’ of river basin management we are facing now. The changing game is largely about dealing with uncertainties that pose important challenges in the governance and management of river basins that need to be met. Decisions need to be made, planning needs to proceed, operations need to continue in areas such as water allocation, storage management, infrastructure, and provision of ecosystem services in general. This calls for understanding and building resilience.

Historically, from an ecology perspective, the concept of resilience focused on bouncing back to previous functions, species, and ecosystem services; resilience in this sense involves resistance to change and recovery from change, or ‘persistence’. In addition, two complementary concepts in resilience, particularly applicable to river basins, have emerged: adjusting in the face of change (‘adaptation’) and transition to new ecological states (‘transformation’). Persistence, adaptation, and transformation can be thought of as modes that apply to the various dimensions of resilience, e.g., hydrological, ecological, social, institutional/governance, cultural, engineering/infrastructure, among others (Fig. 9).

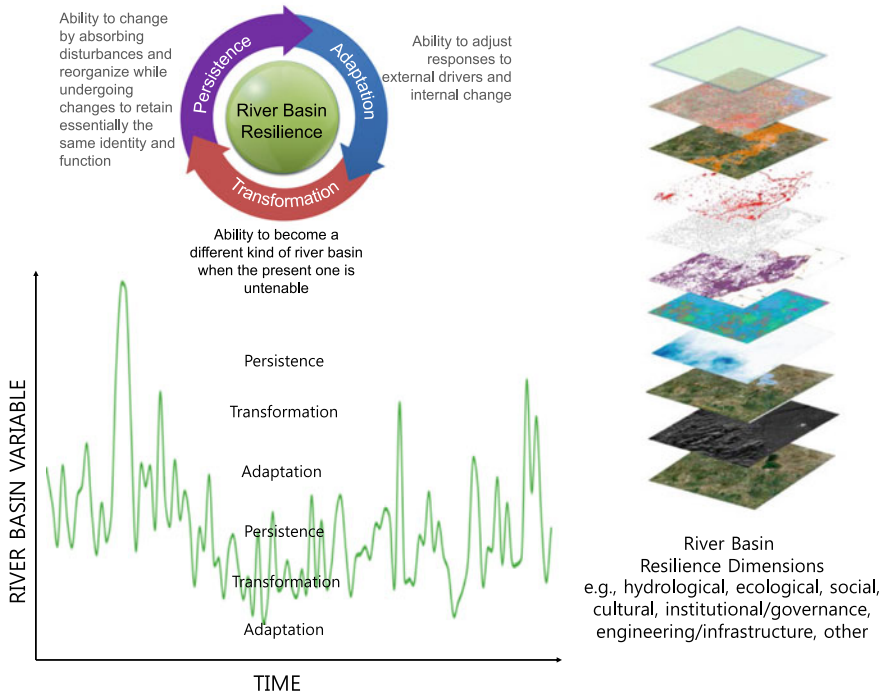


Fig. 9 Conceptual framework to define and characterize river basin resilience [15]. The upper left panel shows the persistence-adaptation-transformation cycle. The right panel shows various resilience dimensions (layers). Each layer is characterized by several variables. The lower left panel shows a time series of a hypothetical river basin variable (e.g., flow, land cover, population, water demand), illustrating the transitions between resilience modes

Managing river basins under a resilience paradigm suggests a more dynamic, interactive form of engagement, whereby basins may be managed for desired conditions and services (either persistence or adaptation), but potentially with physical and biological characteristics that exhibit limited resemblance to their recent historical state (transformation). The development of holistic management strategies from headwaters to floodplain to groundwater may be necessary as single system approaches are not sufficient [16]. This represents a new frontier for hydrologists, ecologists and social scientists, and will inevitably require novel and more intensive forms of stakeholder engagement and collaborative decision-making to define watershed objectives and management actions. The science of river basin resilience will need to combine insights from these disciplines into a new, forward-looking framework that is only beginning to emerge operationally.

2.3 Framework for Disaster Risk Assessment

Globally, climate change will affect the number and intensity of extreme events, but the extent to which is uncertain. Pro-active strengthening is needed of protection against a wide range of natural hazards, including floods, droughts, wildfires, and landslides. Future predictions of global risk must also integrate climate change with socio-economic factors. Disaster risks are rapidly increasing around the world; many regions are experiencing greater damage and higher losses than in the past. Increasing exposure to flooding and increasing damage vulnerability are the main causes of the steeply rising trend in global river flood losses over the past decades. The IPCC [17] has high confidence that “increasing exposure of people and economic assets has been the major cause of long-term increases in economic losses from weather- and climate-related disasters.”.

In 2015, the Third World Conference on Disaster Risk Reduction, held in Sendai, Japan, approved the 2015–2030 Sendai Framework for Disaster Risk Reduction and confirmed four priorities for action including global disaster prevention and reduction, and called on countries around the world to increase investment in disaster reduction, strengthen resilience construction, and reduce losses caused by natural disasters. The four priorities for action are: understanding disaster hazards, strengthening disaster reduction management, increasing investment in disaster reduction, and disaster prevention and recovery and reconstruction. The Sendai Framework for Disaster Risk Reduction also put forward 6 key dimensions and 10 specific elements to enhance resilience against disasters (Fig. 10).

It should also be recognized that restoring ecosystems can enhance protection against disasters and risks to some extent, and thus rebalancing natural and man-made elements of the river basin landscape. Focus should be on co-management of water and land, for instance by using the opportunities of more wind and solar on land

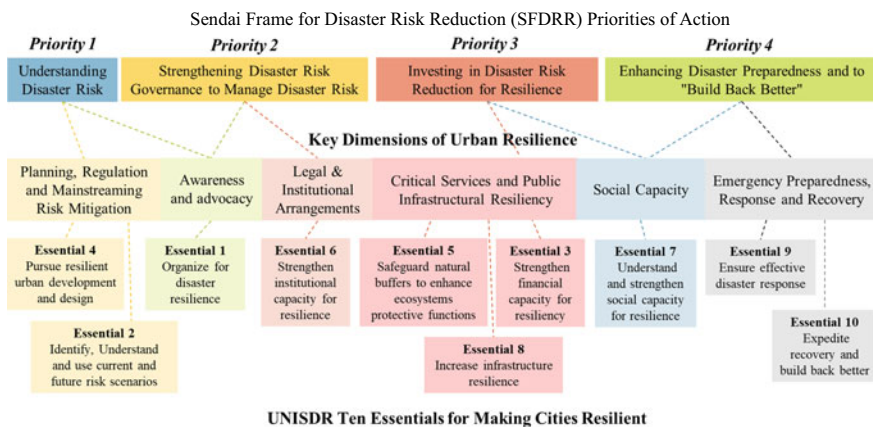


Fig. 10 Priorities for action key dimensions and specific elements of resilience of Sendai Framework for Disaster Risk Reduction (sorted according to the data of UNDRR [18])

to reduce the adverse effects of hydropower on river systems. A shift to regenerative agriculture can bolster lands resilience, while renewables should be sited on lands less suitable for other uses.

2.4 *Nature-Based Solutions*

In theory, Nature-Based Solutions (NbS) can address multiple dimensions and modes of river basin resilience while providing co-benefits to communities, businesses, and nature [19, 20]. Although some functions of NbS can be fulfilled by built infrastructure, the high flexibility and adaptive capacity of NbS, highly relevant in the context of uncertain future change, are specific advantages.

Uncertainties created by climate change and an unpredictable future render static solutions with high sunk costs and low adaptive capacity, such as large reservoirs and similar gray infrastructure, increasingly risky investments. NbS are often smaller, more affordable, more flexible, and more multipurpose than conventional interventions [21, 22]. For example, single NbS interventions can mitigate both effects of floods and droughts, which is rarely found in engineered interventions, or can address water quality through interventions that also improve habitat, capture additional carbon dioxide, and can improve health and well-being of communities. As such, NbS are more compatible with the type of adaptive solutions and no-regret strategies that are advocated in the context of uncertain future change.

Box 3 Nature-based Solutions (NbS)

An umbrella-type approach to achieve the UN Sustainable Development Goals (SDGs) includes actively using ecosystem services, encompassing many ecosystem-based solutions for various sustainable development issues, such as solutions for ecosystem-based adaptation, ecosystem-based disaster risk reduction, natural infrastructure, green infrastructure, and nature-based climate change. The IUCN defines NbS as actions that effectively and adaptively address societal challenges and bring benefits to human well-being and biodiversity through the protection, sustainable management, and restoration of natural or man-made ecosystems [23]. Eggermont et al. [24] used two gradients to classify NbS types involving the extent of NbS intervention on ecosystem/biodiversity diversity, and the magnitude of ecosystem service enhancement resulting from the implementation of NbS (Fig. 11).

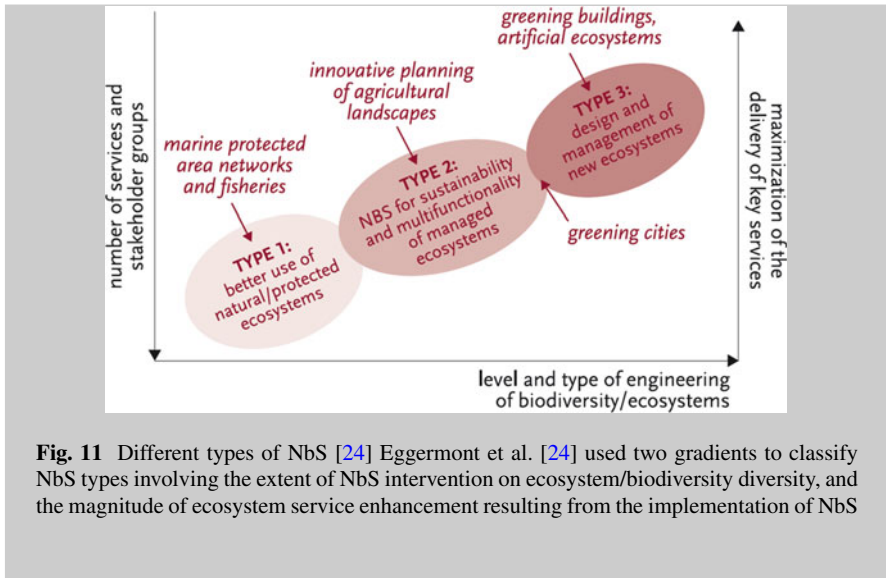


Fig. 11 Different types of NbS [24] Eggermont et al. [24] used two gradients to classify NbS types involving the extent of NbS intervention on ecosystem/biodiversity diversity, and the magnitude of ecosystem service enhancement resulting from the implementation of NbS

2.5 Learn from Other River Basins, Globally

2.5.1 The Rhine River: The Room for the River Programme

Since the mid-twentieth century, the Rhine River has faced increasing problems of river pollution and flood risk, and the focus of governance has gradually expanded from pollution control to flood control and biodiversity restoration. A major disaster (fire in Basel, Switzerland) in 1986 caused unprecedented, large-scale pollution of the Rhine. This has led to a governance shift of more strict and transboundary pollution control and ecological restoration of the river. Peak river discharges occurred in 1993 and 1995. The one in 1995 almost caused dike failure (and flooding) of one of the branches of the Dutch Rhine River system. This initiated the program (with 39 measures) to give more ‘Room for the River’. This program was a governance shift: before the 90s river flood protection policy was all about high and strong dikes; since the near-floodings of the 90s policy is about combining strong and high dikes with increasing the discharge capacity of the river (and hence ‘more room for the river’).

Box 4 The Netherlands “Room for the River”: Nijmegen Practice Project

The floods of 1993 and 1995 in the Netherlands cast doubts on the old approach to flood prevention strategies: that land reclamation and building dikes were positive approaches to water management. Thus, Room for the River as a newer approach was considered—rather than coping with higher flood levels, the discharge capacity of the river cross-section was increased to accommodate higher discharges levels without further raising the dikes. This is done through a series of over 30 measures, in which the area will have been “...lowered and broadened [the] floodplain and created river diversions and temporary water storage areas.” Marshy riverine landscapes have also been restored to protect biodiversity and aesthetic value.

One of the *Room for the River* measures exemplifying environmental adaptation is the ‘Room for the Waal’ project in Nijmegen. This measure includes moving the dike at Lent (on the north side of the city of Nijmegen), inwards and dredging a secondary channel in the floodplain in order to increase the discharge capacity of the river during high water. The project of moving the dike had a double goal of protecting the city from floods and improving the urban spatial quality. Building the channel created an island along the Waal, which forms a city park for Nijmegen with urban development possibilities (Fig. 12).



Fig. 12 Before and after the construction of Nijmegen “Returning Land to River” project
 Source <https://www.ruimtevoorderivier.nl/room-for-the-waal/>

2.5.2 The Danube River: Climate Change Adaptation Measures Toolbox

From the nineteenth century to the mid-twentieth century, the core issues of early governance of the Danube River basin were navigation and hydro-energy development. After the 1980s, focus was on water pollution prevention and ecological protection problems. In 1994, the 11 countries along the Danube established the

International Commission for the Protection of the Danube River (ICPDR) to coordinate water pollution prevention and control, flood control and disaster reduction, and other governance work.

After 2010, the International Commission for the Protection of the Danube River began to attach importance to the impact of climate change on the Danube River Basin, and formulated two editions of the *Strategy on Adaptation to Climate Change* in 2012 and 2018 respectively. For the impacts and challenges of climate change on the Danube River, a Climate Change Adaptation Measures Toolbox is proposed to deal with aspects such as climate change and basin vulnerability analysis, water resources and water environment management, flood risk management and response, and drought management [25].

Box 5 Climate Change Adaptation Measures Toolbox

ICPDR formulated the Climate Change Adaptation Measures Toolbox for the Danube River basin, which provides comprehensive and easy-to-use governance measures from governance fields, types of measures, time scales, and other different dimensions. The governance fields involve agriculture, ecosystem, biodiversity, navigation, hydropower, flood, and so on; The types of measures include basic preparation measures, ecosystem-based measures, technical measures, action and management measures, and policy measures; The time scales include long-, medium-, and short-term. The toolbox is available on the website: <http://www.icpdr.org/main/climate-changeadaptation>.

2.5.3 The Mississippi River: Ecological Restoration of the Lower Reaches and the Estuarine Delta

From the nineteenth century to the mid-twentieth century, the governance focus of the Mississippi River was navigation and flood control, and a series of relevant projects were implemented along the river, causing some damage to the ecological environment of the Mississippi River. By the 1980s, 67% of the wetlands along the main stem had disappeared. Since the 1950s, increasing attention has been paid to restoration of the ecological system. Since the 1980s, basin ecology restoration plans such as the “Plan for Restoring the Upper Mississippi River” and “Plan for Restoring America’s Greatest Rivers” have been implemented in the Mississippi River [26]. In particular, after 2006, comprehensive ecological restoration work was carried out in the lower reaches and the delta coastline, which specifically included restoration of wetlands and woodlands on both sides of the shoreline and on the river island, as well as shoreline restoration and protection measures for the estuarine delta [27].

Box 6 Ecological Restoration Measures for the Lower Reaches of the Mississippi River (“Plan for Restoring America’s Greatest Rivers”)

After 2006, comprehensive ecological restoration work was carried out in the lower reaches of the Mississippi River and the delta coastline, coordinated by 6 state governments along the shoreline for more than 200 implementation projects, including 3 aspects to respond to climate change. First, the dikes were cut to restore tributary flow and aquatic habitat; currently 30% of the downstream dikes have been trenched. Second, frequently flooded land in the floodplain was restored to wetlands and woodlands, with approximate 110 km² (27,000 acres) of land already subscribed for restoration to ecological space [28]. Third, measures such as sediment transfer and shoreline restoration were implemented in the estuarine delta to mitigate shoreline erosion and flooding caused by storms and sea level rise. Two “diversion” projects are planned in Louisiana at the estuary of the river to restore sediment flow into the estuarine delta.

3 Governance Vision, Guidelines and Actions of the Yangtze River Basin for 2050

3.1 Vision and Guidelines for the Governance of the Yangtze River Basin

3.1.1 Vision of River Basin Governance

We should deeply analyze the changing characteristics of water resources in the Yangtze River under climate change and the coordination between socio-economic development and biodiversity protection in river basins, adhere to “Step up conservation of the Yangtze River and stop its over-development”, build the Yangtze River Basin into a greener, low carbon, more coordinated and balanced, safer and more resilient, more inclusive, more open and co-governed “river basin life community” to provide a “Yangtze River example” for the governance of global river basins.

3.1.2 Eight Governance Principles

Principle 1: Shared vision and co-governed river basins. We must pay attention to synergies among central and local governments, departments and industries, regions, governments and market society, and to the synergies among the main stream and

tributaries, upstream and downstream areas, urban and rural intensive areas and marginal areas, villages and cities. Additionally, we must form a long-term vision based on common understandings of issues and values, as the basis for multi-party policies and concerted actions, and formulate policies and action programs crossing department authorities, administrative levels and regional boundaries; Also, we must give full play to the power of the market and society and combine top-down policies with bottom-up actions for real sustainable river basin governance.

Principle 2: Shared responsibilities from sources to coastal areas. Taking river basins as a whole, we should not transfer problems from upstream to downstream areas, nor transfer them through time. We must adopt a river basin-based comprehensive approach, recognize key roles of water in river basin development for human-nature coordination, combine climate change with socio-economic development, fulfill overall responsibilities from sources to estuaries of different regions, departments and groups. Furthermore, we must make use of overall functions of river basins to establish an integrated and coordinated governance system for the adaptation and mitigation of climate change.

Principle 3: Blueprint based on 100 years. In terms of river basin governance, we must have long-term goals and value orientation, pay attention to longer-term interests, comprehensively consider major issues related to the survival and development of human civilization such as carbon neutrality and biodiversity, and incorporate river basin governance into key actions of the *United Nations Convention on Biological Diversity* and the *Convention on Climate Change*.

Principle 4: Focus on and respond to uncertainty. For river basin development, we should confront the long-term pressure brought by climate change, and deal with the short-term impact and uncertainty of disaster risks. Also, we should systematically understand long-term roles of river basins on economy, population, nature, water areas and oceans, and form multi-scenario prediction through long-term monitoring, comprehensive modeling and real-time data analysis to deal with the complexity of river basin problems and the uncertainty of climate change.

Principle 5: Controlling the relation between river basins and settlements. We should not only respect and control macro integrity of river basins, but also respect and understand their divides between medium and micro zoning, especially in urban and rural settlements with highly dense population and economy. We must pay attention to the vulnerability of such highly exposed areas and formulate zoning and classified governance strategies based on urban and rural settlements from aspects of ecological protection, space optimization, facility construction, collaborative response and so on.

Principle 6: Controlling the relation between regional development and social equity. In terms of river basin development, we should improve resident well-being in the whole river basins and pay close attention to imbalance of river basin development, not only focusing on marginal and disaster-prone areas such as villages, small towns, flood storage and detention areas and ecological protection areas, but also on vulnerable groups such as women, the elderly population and left-behind children. We should also pay attention to vulnerabilities of such areas and groups,

and strengthen the construction of regional equity, social equity and gender equity mechanisms and the security of vulnerable groups in disaster-prone areas.

Principle 7: Controlling the relation between artificial measures and nature-based solutions. As for river basin governance in response to climate change, we should be people-oriented, respect nature and fully understand system operation modes and ecological service functions of river basins, not only centering on underlying roles of systematic defense projects in improving river basin safety, but also on the advantages of nature-based solutions in alleviating pressures of water security, maintaining the integrity, flexibility and adaptability of the ecosystem for better overall integration to effectively enhance the resilience of river basins to resist disaster risks.

Principle 8: Innovative exploration and strengthened actions. We should continue to strengthen innovative exploration in management methods, knowledge plans, policy tools, forward-looking financing mechanisms, the relevant knowledge of sustainable development under climate change, global exchange and share, in order to further transform the knowledge into joint global actions.

3.2 Key Areas Requiring Continuous Attention and Actions

Improving the resilience of urban and rural settlements in river basins. With climate change and socio-economic development, dealing with disaster risks and reducing vulnerabilities are the most urgent in River Basins. Therefore, we must firmly abide by the bottom line of water security, attach great importance to urban and rural settlements along river basins, and adopt classified and zoning response strategies to improve the adaptability to climate change.

Comprehensive governance of river basins and coastlines. Catchment areas are main sources of stressors for river basins, which will have a large-scale and long-term impact on other systems, highlighted by the pressure brought by the utilization of shoreline spaces to river basins. Therefore, strengthened comprehensive assessment of shorelines and optimized shorelines governance are critical to deal with pollution in densely populated urban and rural areas of river basins, which should be paid special attention.

More attention to deltas and other key areas. Contradictions between the protection and development of large river basins are prominent in deltas, one of the areas that are most sensitive to the impact of climate change in the future. Therefore, in addition to urban and rural settlements and river shorelines, we should also pay close attention to key areas such as estuaries and deltas, flood storage and detention areas and important agricultural natural ecological zones, speed up the identification of all risks in key areas and strengthen the risk response under climate change.

More attention to disaster-prone areas, groups and fields. We should fully consider the differences of the impact of climate change on spaces and factors of river basins, monitor and identify disaster-prone areas, groups and fields in river basins that are seriously affected by climate change. Targeted and diversified measures

shall be taken for disaster-prone areas and fields and vulnerable groups to ensure that different regions and groups have equal disaster prevention capacities and the right to equitable development when facing disaster risks brought by climate change.

Optimized ideas and methods of river basin planning and design. In river basin-related planning, facilities and architectural design, we should fully consider the impact of climate change, put forward comprehensive solution systems integrating engineering measures and non-engineering measures, so as to foster the sustainable development capacities of river basins. Also, we should, with holistic and systematic thinking, coordinate river basin development planning, land space planning, ecological protection, resource utilization, disaster prevention and other special plans, and make multiple subjects be part of the planning preparation for better joint implementation mechanisms.

A mechanism for long-term monitoring of pressures of the by climate change. We should strengthen monitoring, establish a monitoring and evaluation information network throughout the whole river basin, and timely understand the long-term trend and short-term risks of climate change in river basins. Additionally, we should realize early warning through combined modeling scenarios and data analysis, scientifically and pragmatically formulate adaptation paths and measures, and make timely adjustments based on uncertain factors.

Advocating and promoting nature-based solutions. We should take NbS as important tools to alleviate water pressure and protect ecological security in river basins, combine NbS with traditional system engineering solutions, and maintain integral ecosystem while reducing floods and other disaster risks. Using NbS, we should also improve the flexibility and adaptability of river basin governance, and dynamically adapt to the uncertain impact of climate change on river basin governance in view of complex geographical conditions and socio-economic spatial differences of the Yangtze River Basin.

4 Climate Change and Disaster Risk Analysis of the Yangtze River Basin

Disaster risk is currently the primary and urgent issue in the Yangtze River basin in the face of climate change, which is mainly affected by four major climate change factors: heavy precipitation, warming, drought and extreme weather. By retracing the frequency, impact scale, loss and spatial distribution of disasters in history, we combine the distribution of population, towns and economic industries in the basin in order to study the exposure of disaster impacts and further study the spatial characteristics of disaster risks in the Yangtze River basin under the influence of climate change.

4.1 Basic Characteristics of the Yangtze River Basin

The Yangtze River is the largest river in China and the third largest river in the world, with a total length of 6300 km and an area of about 1.8 million square kilometers; From west to east, it flows through 11 provinces, autonomous regions and cities, then into the East China Sea.

Geographical characteristics. The Yangtze River Basin crosses China's three-level topographic ladder, with great differences in the physical and geographical characteristics of the upper, middle and lower reaches. The terrain of the Basin is high in the west and low in the east, with the total drop from the river source to the estuary of about 5400 m. Its upper reach is dominated by plateaus, mountains and canyon terrains, with a big riverbed gradient and rapid flow. Its middle reach is with alternatively distributed plains, hills and mountains; rivers herein are tortuous and wide, with various tributaries. Its lower reach is dominated by plains, with deep and wide water and short tributaries.

Climatic characteristics. Most parts of the Yangtze River Basin are in the subtropical monsoon region, with big regional climate differences due to its terrain. Cold winter and hot summer, obvious dry and wet seasons represent basic characteristics of the climate, with an average annual precipitation of 1067 mm. It sees uneven temporal and spatial distributions of annual precipitation and rainstorms, being greatly subject to extreme climate events.

Hydrological characteristics. The Yangtze River Basin is rich in water resources, but with uneven distributions in its upper, middle and lower reaches. Its average annual water discharge is 995.9 billion cubic meters, accounting for about 36% of China's total water resources, and its water resources per unit land area is $595,000 \text{ m}^3/\text{km}^2$, about twice China's average. Its middle reach sees the most surface water resources, while its upper and lower reaches see less.

Demographic characteristics. The Yangtze River Basin is the main gathering area of China's population and economic activities. The land area is only 21.3% of the country, with 42.9% of China's population though. The year 2020 witnessed the total population of the region of about 606 million, with a population density of about 296 people/ km^2 , twice the national average.

Economic characteristics. There is a significant gradient divide in development levels of economy and urbanization along the upper, middle and lower reaches of the Yangtze River Basin. The Yangtze River Delta, in the lower reach, is densely populated and economically developed, with a population density of about 800 people/ km^2 and per capita GDP close to 20,000 US dollars. The urbanization rate of Yangtze River Delta is generally higher than 70%, close to the development level of the Rhine River Basin in the 1990s. The population density in its middle reach is about 330 people/ km^2 , the per capita GDP is about 10,000 US dollars, and the average urbanization rate is about 60%, close to levels of high-income countries in the World Bank. In its upper reach, the population density is low, about 180 people/ km^2 , the per capita GDP is less than 10,000 US dollars, the urbanization rate is between 50–55%, still in a relatively underdeveloped stage.

Urbanization characteristics. Cities and towns in the Yangtze River Basin are densely distributed, with the urbanization rate of 63.2% in 2020, ushering in middle and later stages of urbanization. There are 243 autonomous regions and cities, coupled with 584 county-level cities, most of which are distributed along the Yangtze River. Twenty-eight large cities of more than one million, along with numerous small and medium-sized cities and towns are perched on both sides of its main stream and main tributaries. Urban agglomerations have developed in the Yangtze River Delta and the middle reach of the Yangtze River, including Chengdu and Chongqing.

4.2 *Climate Change in the Yangtze River Basin*

Pressures of climate change in the Yangtze River Basin are mainly heavy precipitation, droughts, rising temperatures and extreme weather.

Heavy precipitation. Climate warming leads to more heavy precipitations. According to studies, there is no significant change of the total rainfall in China, but the intensity of rainfall is increasing. Extreme precipitation (extremely low and high amounts of rain) throughout the Yangtze River Basin and its tributaries occur regularly as a result of time change. On the whole, there was an increase in heavy precipitation intensity in the Yangtze River Basin since 1960 [29].

Among 60 cities with serious waterlogging identified by the State Council in 2017, 36 are in the Yangtze River Basin. There were 166,000 geological disasters and hidden dangers in 11 provinces (cities) along the Yangtze River Economic Belt in 2018, about 58% nationwide.

Rising temperature. Affected by global warming, the average temperature in the Yangtze River Basin significantly increased from 1970 to 2014, by about 0.4°/decade, and average temperatures in the four seasons, and in the coldest and hottest months soared [30].

From 1970 to 2015, the glacier area in the Yangtze River Basin has shrunk by 14.5%, the thickness of frozen soil in the source region of the Yangtze River, Yellow River and Lancang River decreased by 5.6 cm per decade since 1984. In 2018 [31], the number of summer hot days (temperature $\geq 35^\circ\text{C}$) of more than 30 in the whole Basin affected about 220 million people in 40 cities. The rate of sea level rise along China's coastline is slightly higher than that of the global average, and it is predicted to reach 0.145–0.2 m by 2050.

Droughts. Climate change may lead to droughts in some areas of the Yangtze River Basin. Based on relevant studies, under the scenario of global warming of 1.5 °C, the annual precipitation in the middle and lower reaches of the Yangtze River is projected to drop by 5% compared with that in 1986–2005; Under the scenario of global warming of 2.0 °C, it may drop by 3% [32]. The drought risk is mainly in the upper reaches. The year 2018 saw 862 forest fire events in the whole Basin. The number of fire events went down from 2010 to 2018 [33].

Extreme weather. Relevant studies predict that under the goal of global warming of 1.5 °C, extreme precipitation intensities in the Yangtze River Basin that occur once

in 20 years and once in 50 years will rise by 10% and 9%, respectively, from 1986 to 2005; Under the goal of global warming of 2.0 °C, they will increase by 14% and 15%. Spatially, they generally increase in the middle and lower reaches, and drop in the upper reaches. Typhoons can be seen usually in the lower reaches of the Yangtze River. From 1949 to 2010, the average number of times cities in the Yangtze River Delta were affected by typhoons was 65.4 [34] with an increasing trend in recent years. Jiangsu, Anhui, Hubei, Hunan and Yunnan saw serious low-temperature freezing disasters in China [35], and in recent years, the low-temperature freezing disasters and wind hail have shown a decreasing trend. In terms of overall losses caused by extreme weather events, casualties and house damage have decreased, but direct economic losses like infrastructure damage are increasing.

4.3 Risks Caused by Heavy Precipitation

Increased flood risks in the main stream and main tributaries of the middle and lower reaches of the Yangtze River. Since 1840, catastrophic floods and severe floods in the Yangtze River Basin mainly occurred along the main stream of the middle and lower reaches. River basin flooding occurred in the Yangtze River in 1998; five provinces in the middle and lower reaches were seriously affected. 334 counties (cities and districts) were affected, 2.2185 million houses collapsed and 1526 people died [36]. In 2020, there were river basin floods in the Yangtze River, with five numbered floods in the main stream and the maximum inflow of the Three Gorges Reservoir since its establishment. A total of 378 rivers in the whole Basin saw floods exceeding the alarm water level, 156 rivers saw floods exceeding the guaranteed water level, and 51 rivers saw floods exceeding historical highs [37]. From 2010 to 2020, the population of in the middle and lower reaches of the Yangtze River continued to move to large cities along the main stream of the Yangtze River and the main tributaries, causing higher flood risks in big cities.

Higher risks of waterlogging in large and medium-sized cities along the main stream and main tributaries. A total of 36 cities with serious waterlogging along the Yangtze River Basin determined by the State Council are mainly in Hubei (10), Hunan (9), Anhui (6) in the middle and lower reaches and Sichuan Basin (5) in the upper reach, most of which are cities along the main stream of the Yangtze River and main tributaries such as the Jialing River, the Han River, the Xiangjiang River and the Ganjiang River. The total population of 36 cities is 93.37 million, an increase of 18.97 million from 2010 to 2020. Affected by heavy rainfalls, risks of waterlogging in major cities like Chengdu, Chongqing, Changsha, Hefei, Wuhan and Nanchang may further increase in the future.

High risks of geological disasters in mountainous areas of Sichuan, Chongqing, Yunnan and Guizhou along the upper reach of the Yangtze River. Geological disasters in the Yangtze River Basin are mainly in mountain areas in west Sichuan, some

areas in south Sichuan, northeast and southeast Chongqing, west and south Guizhou, the Xiaojiang River, the Lancang River and the Jinsha River in Yunnan. The overall population density in the upstream areas is not high, the population of some counties (autonomous regions, cities) in west Sichuan, northeast Chongqing, Southeast Chongqing, west Guizhou, south Guizhou, and west Yunnan has increased in recent years. Among them, the population of Dali City in west Yunnan and Dafang County in west Guizhou increased by more than 80,000, with further increasing risk of residential safety.

4.4 Impact of Regional Warming

Glacier retreat and frozen soil thawing at the source of the Yangtze River threatening the ecosystem. Glacier retreat and snow line rise are mainly concentrated in Tanggula Mountain and Bayankala Mountain, threatening the upstream ecological areas such as the source of the Yangtze River, the Yellow River and the Lancang River, which may lead to less biodiversity and changed community structures and functions. Glacier retreat also affects the hydrological cycle of the Yangtze River Basin and trigger floods in the lower reach. About 40 glacial lake floods have occurred in the Qinghai Tibet Plateau since 1935, with the average glacier melt runoff in the Tuotuo River Basin at the source of the Yangtze River increased by 120.89% from 1960 to 2000 [38].

The depth of frozen soil in Qumalai, Zaduo, Chengduo, Maqin [31]. Frozen soil degradation greatly changes soil temperature and humidity, reduces the content of organic matter in the soil surface, leading to risks of vegetation degradation, reduced vegetation coverage and shortened plant heights, especially in alpine meadows and alpine swamp meadows.

More threat of heat waves in Chongqing along the upper reach, most places along the middle reach, metropolitan area in the south along the lower reach. In 2018, the number of summer hot days (temperature ≥ 35 °C) of more than 30 in the whole Basin affected the surrounding areas of Chongqing, most areas of Hubei, Hunan and Jiangxi in the middle reach, Anhui and south Zhejiang in the lower reach. If the global temperature rises from 1.5 to 2 °C, the intensities of extreme heat waves in the Yangtze River Delta, the middle reach of the Yangtze River, Chengdu and Chongqing may increase by 4.1 times [39]. The metropolitan areas in the Yangtze River Basin are densely populated and growing fast. From 2010 to 2020, the metropolitan areas in 11 provinces along the Yangtze River Economic Belt increased by 30 million, 91% of the total increment. In the future, Chongqing, Wuhan, Changsha, Nanchang and other metropolitan areas will face more severe high temperature and heat wave risk.

Coastal and lakeside areas along the lower reach threatened by sea-level rise. Coastal areas like Shanghai, Nantong and Zhoushan have low terrains and high risks of sea-level rise. Areas around the Hongze Lake, the Chaohu Lake and the Poyang Lake in the middle and lower reaches are low-lying, which may be easily submerged.

Shanghai, Zhejiang province, Jiangsu province and Anhui province along the lower reach have dense and fast-growing population. The population in areas with high risk of sea-level rise was 15.46 million in 2020, with a total increase of 550,000 from 2010 to 2020; The population in the medium risk area was 63.98 million in 2020, with a total increase of 8.64 million from 2010 to 2020. As population in low-lying areas grows, the threat posed by sea-level rise will further intensify.

4.5 Risks Caused by Droughts

Risks of water shortage in some areas in the middle and upper reaches. From 1981 to 2010, regions with annual drought days exceeding 50 mainly include Sichuan Basin, Panxi of Sichuan, the junction of Yunnan, Guizhou and Sichuan, southeast and south Yunnan, among others. Regions with annual drought days exceeding 40 include most parts of Yunnan, southeast Guizhou, north Hubei, north Hunan, south Jiangxi, among others [40]. Among these areas, water consumption in some places like Sichuan Basin, southeast Yunnan and south Jiangxi has seen continuous increase in recent years, and the ability to address droughts needs to be further improved.

High risks of forest fire in southern mountainous area of the upper and middle reaches. There are many forest fire events in south Sichuan, south Yunnan, west Guizhou, south Hunan, south Jiangxi and north Hubei, where the overall population density is low, with increased population from 2010 to 2020 and possibly more residential safety risks. Since ecological protection in south Sichuan and south Yunnan is quite important, forest fires may threaten biodiversity there.

4.6 Risks Caused by Extreme Weathers

More severe typhoon threats in coastal areas, tropical cyclones affecting parts of Yunnan. Typhoons mainly hit coastal areas of Shanghai, Jiangsu province and Zhejiang province in the lower reach of the Yangtze River, possibly flooding coastal areas. Shanghai has high levees to resist storm surges with medium and low intensities, but typhoons in extreme weathers are still risky. Yunnan is partially hit by tropical cyclones landing on the South China Sea, reflected by disastrous weathers like strong wind and heavy rainfalls.

Affected agricultural production in the middle reach of the Yangtze River by low-temperature freezing disasters. Low-temperature freezing disasters and snow disasters mainly hit Hubei, Hunan and other areas along the middle reach, some areas in Yunnan, Guizhou along the lower reach, and some in Anhui along the lower reach. Since high-quality agricultural production areas of the middle-lower Yangtze Plain are in areas with low-temperature freezing disaster risks; it is necessary to have better abilities of agriculture to deal with these risks.

Wind hail-affected upper and middle reaches of the Yangtze River. Wind hails occur mostly in Chongqing, Yunnan and Guizhou, followed by Hunan and Jiangxi. Specifically, such areas include Dazhou City, Chongqing metropolitan area, Yibin City, Luzhou City, Bijie City, Liupanshui City, Qujing City along the upper reach in the border area between Sichuan and Chongqing, along with Changde City, Yueyang City, Yiyang City, Jiujiang City, Yichun City and Jingdezhen City along the middle reach. Among them, Chongqing, Changsha, Nanchang and other metropolitan areas are densely populated, with high risk of wind hail. Wind hail also hits high-quality agricultural areas in northeast Sichuan and north Hunan, triggering risks to agricultural production.

4.7 Spatial Characteristics and Risk Analysis of Major Disasters

4.7.1 Spatial Characteristics of Major Disasters

Floods and geological disasters caused by heavy rainfalls in the upper reach of the Yangtze River are the most prominent, with high frequencies, wide ranges and serious losses. Disasters like wind hails and low-temperature freezing disaster are also common in the area. Areas around the Sichuan Basin, including Longmen Mountain, Daba Mountain and Wushan Mountain, often see mountain torrents, landslides, debris flows and other geological disasters caused by heavy rainfalls; In the middle of Sichuan Basin, represented by Chengdu Plain, heat waves and urban waterlogging are the most common; In the Yunnan-Guizhou Plateau, mountain torrents, geological disasters, drought, low-temperature freezing disasters are common; And forest fires, mountain torrents and geological disasters often occur in Panxi of Sichuan and mountainous area of south Yunnan.

Middle reach of the Yangtze River is vulnerable to flooding, with frequent droughts and low-temperature freezing disasters. Jiangnan Plain is often hit by floods, droughts and low-temperature freezing disasters; Areas along the Yangtze River in the middle reach are often hit by heat waves, urban waterlogging and river floods. Dongting Lake Plain is usually hit by floods, droughts and low-temperature freezing disasters; Floods and waterloggings often occur in Poyang Lake Plain; While Nanling area is often struck by forest fires, landslides and other geological disasters.

Coastal areas in the lower reach of the Yangtze River are greatly affected by sea-level rise and typhoons. The Yangtze River Estuary faces rising sea-level and typhoon storm surges; Areas along the Huaihe River mainly face floods and droughts; Areas along the lower reach are often hit by floods and typhoons; Mountainous areas in south Zhejiang are often hit by mountain torrents, geological disasters and typhoons (Fig. 13).

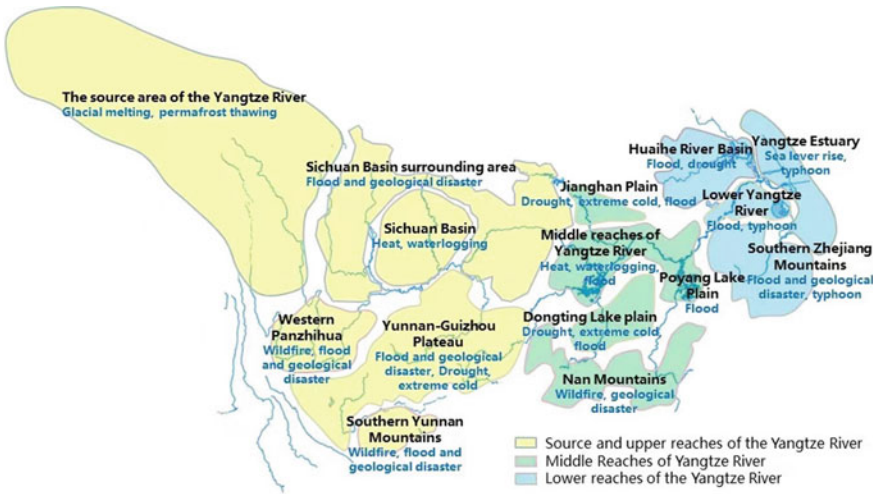


Fig. 13 Sub-divisions of major disasters caused by climate change in the Yangtze River Basin

4.7.2 Risk Analyses of Key Areas

Municipalities directly under the central government, provincial capital cities and their metropolitan areas have fast-growing population, with high disaster risks caused by climate change. Chengdu, Chongqing and Changsha are often hit by heat waves and urban waterlogging; Guiyang and Wuhan are often hit by floods, droughts, low-temperature freezing disasters; Nanchang, Hefei and Nanjing often see floods; Shanghai and Hangzhou often see typhoons, while cities in south Zhejiang are struck by mountain torrents and geological disasters. The population of the above regions and counties in the metropolitan area has generally gone up by more than 100,000 in recent ten years.

Agricultural production areas in the north of the upper, middle and lower reaches are at high risks of floods, droughts, low-temperature freezing disasters. Agriculture is widely distributed in Sichuan Basin, Hanjiang plain, areas along the middle reach, Dongting Lake Plain, Poyang Lake Plain and Huaihe River Basin, which are affected by floods, droughts, low-temperature freezing disasters, with higher agricultural industry risks under climate change. Among them, Sichuan Basin along the upper reach is mainly hit by short-term floods; Jiangnan Plain and Lianghu Plain along the middle reach are key rice producers in China, which may be hit by low-temperature freezing disasters during flower stage of early rice booting in late May, and low-lying floods and waterlogging in summer, along with droughts in spring and autumn are likely to reduce agricultural production. Areas along the lower reach can be hit by floods and typhoons.

5 Resilience Strategies of the Yangtze River Basin in Response to Climate Change

The safety and resilience of urban and rural settlements along the Yangtze River basin is the key to cope with climate change and disaster risks at present, and it is necessary to improve long-term disaster prevention and adaptation capabilities, as well as to be more adequately prepared for short-term impacts of extreme weather. Specifically, engineering measures and nature-based solutions (NbS) should be integrated to form a comprehensive safety and resilience strategy through four aspects: ecological protection, spatial optimization, facility construction, and emergency management.

5.1 *Strategies on Improving Resilience of the Yangtze River Basin*

5.1.1 Strategies on Ecological Protection

Ecological protection strategy reduces risks from the source by reducing the frequency and intensity of disaster events, and plays an important role in increasing carbon sinks and helping China achieve its “double carbon strategy”.

Manage and control ecological function areas and nature reserves. Multiple important ecological function areas are distributed in the Yangtze River Basin, and the implementation of the strict “Ecological Protection Red Line” system and the “Compensation for Environmental Damage” system can maintain and improve the ecological level of important ecological function areas and nature reserves. The use of carbon sinks in nature reserves is encouraged to achieve carbon neutrality and carbon sinks in nature reserves is further explored to meet the relevant requirements and conditions of carbon emissions permit trading for carbon sink additionality and cooperation so as to improve the efficiency of ecological compensation [41–45].

Strengthen the comprehensive governance of water and soil conservation. The Yangtze River Basin is one of the most serious areas of water and soil loss in China, and climate change will create more pressure on water and soil loss. We should delineate and announce by law the areas with serious water and soil loss and fragile ecology as soon as possible, scientifically promote the comprehensive governance of the areas with serious water and soil loss, improve the monitoring service capacity and the problem detection, and strengthen the supervision of industrial soil and water conservation. Comprehensive governance can adopt a series of technical methods, including: intercepting and draining slope runoff and interflow, and storing a certain amount of water in the rainy season; returning farmland to forest and grass on steep slopes, and greening barren mountains and hills; promoting the projects of changing slopes into terraced fields, soil conservation tillage, and other soil conservation measures on gentle slopes; reasonably deploying small intercepting and draining storage projects and field roads on slopes during planting forestry and

fruit; configuring mutual cooperative engineering measures to control the development of channel erosion. In general, the foundation of scientific research on soil and water conservation in the Yangtze River Basin is still weak, and current research should focus on the critical areas such as soil and water mechanism and water–sand dynamics of the river basin under climate change [46–48].

5.1.2 Strategies on Spatial Optimization

The land use and spatial layout of urban and rural settlements should not be based solely on development efficiency but should also fully consider the multiple objectives such as safety, livability, and ecology. The spatial optimization strategy can avoid disaster impact space and reduce disaster risks through scientific urban land site selection and achieve symbiosis with disasters and adaptation to disaster development by increasing disaster tolerant cushion space. In the selection of the spatial optimization strategies, emphasis should be laid on the selection and implementation of nature-based solutions.

Establish a strict disaster safety assessment system for site selection of a new city and a new district. The mainstream and major tributary areas of the Yangtze River are affected by river flooding and thus they are closely related to urban site selection. Where involving off-site reconstruction after major earthquakes or geological disasters, the site selection of new cities and relocation sites should be subject to strict disaster safety assessment and full scientific appraisal, and safe sites should be used as far as possible to reduce disaster risks by using natural conditions and reduce site exposure from the source. The development of waterfront and coastal area must be based on scientific safe defense system planning and vertical site planning; The site selection and construction methods by filling rivers and lakes, cutting mountains and filling valleys should be strictly limited.

Control the population layout of urbanized areas and land development intensity. Prevent excessively high population density from leading to expanded disaster losses. There are still a large number of residential areas in some provincial capitals in China where the population density is above 20,000 people/km² and this density should be reduced.

Implement the group layout model of urban space. Optimize and improve the layout of urban land use which has neglected safety and ecology in the rapid development, change the “big pie” layout to group layout, and introduce the large-scale green belt, green wedge and wind corridor, which can not only mitigate the heat wave and heavy precipitation disaster impact, but also provide more space for the city to avoid disasters. **“Returning land to river” to leave space for river.** The spatial organization of river waterfront areas is critical for long time scale. In respect of the natural and historical water systems the historical and flood discharge river channels occupied by industrial land and housing development shall be returned to the rivers for floodwater drainage and storage. At the same time, natural riparian land should be preserved as much as possible to provide strategic flexibility for future suitability initiatives and increase the safe resilience of the river basin. This concept, proposed by The

Netherlands, summarizes a solution with “retaining, storage, and drainage” strategy to create a resilient buffer capacity of the river basin to accommodate high precipitation volumes and discharge from upstream by modifying the river system. The main technical measures for “returning land to river” include embankment relocation, restoration of river floodplains, and lowering of the riverbed.

Delineate disaster risk areas and leave disaster tolerance space. The cushion space for disaster tolerance is delineated according to the scope and intensity of disaster impact, especially in risk areas of torrential floods, earthquakes, landslides, mudslides and other mountain disasters. If necessary, the relocation project in high-risk areas is implemented, and the construction of disaster prevention engineering facilities is strengthened at population accumulation points; At the same time, the disaster monitoring and early warning as well as emergency response system of disaster risk areas and surrounding areas is perfected, and the evacuation of people in the risk areas is timely guided.

5.1.3 Strategies on Facilities Construction

Disaster defense system and infrastructure construction are the basic guarantees of urban safety resilience, and the long-standing inertia of local governments that emphasize development rather than safety and focus on over-ground rather than the underground must be changed fundamentally. In the construction of facilities, the engineering thinking of individual projects should be avoided. Instead, the emphasis should be placed on implementing the systemic disaster defense. Special attention should be paid to the construction of disaster defense system, sponge city resilience adaptation system, emergency supply guarantee system, and lifeline facility system for urban and rural settlements in the river basin.

Strengthen the construction of systematic and engineering disaster defense systems. On the basin scale, the reinforcement of embankments is organically combined with the construction of flood storage areas and the joint optimal scheduling of reservoirs in the main stream and tributaries of the Yangtze River to form a more complete “embankment + reservoirs + floodplain” comprehensive flood control system of the Yangtze River, so as to realize the prevention, blocking, evacuation, drainage and interception of floods; Great importance should be attached to the overall plan and coordination of flood control capacities of cities and basins so as to avoid the risk of urban disasters caused by different flood control standards in the basin. At the level of urban and rural settlements, the actively adaptive disaster prevention and mitigation measures combining with “blue, green, and gray” facilities should be taken as much as possible to form a comprehensive disaster prevention and mitigation strategy.

Promote the construction of sponge cities. Reduce emissions at source first, build green facilities, enhance the “resilience” of the city in response to climate change and storm disasters, and promote the formation of an ecological, safe, healthy, and sustainable urban water cycle system. According to the rainfall characteristics, flooding problems, and water resources problems of specific cities along the Yangtze

River Basin, on the basis of full analysis and demonstration, reasonable targets are selected to carry out reasonable design by combining with local groundwater level, soil geology, meteorological characteristics and other factors. The combination of multiple measures such as “seepage, retention, storage, purification, use, and drainage” is selected flexibly to enhance the local rainwater absorption and storage capacity [49–51].

Attach importance to the emergency supply guarantee system. The construction of regionalized and localized production, distribution, and consumption systems can greatly reduce the cost and carbon emissions of daily food and product consumption, and it is an important measure for carbon reduction and zero carbon in developed countries. The regionalized and localized supply system is also an important guarantee of urban safety resilience which enjoys obvious advantages in the case of long-period natural disasters, epidemic control, and so on. The renewable distributed energy is used for urban emergency supply security systems, which is not only green and low-carbon, but also improves the supply resilience in disasters.

Strengthen the construction of lifeline facilities. The toughness of telecom, medical treatment, rescue, and other lifeline systems can reduce the vulnerability of urban and rural settlements, guarantee that cities maintain basic operations during disasters, and support rapid recovery after disasters. In the terms of engineering measures, the flexible connection of the pipeline network system can be strengthened to cope with uneven settlement, earthquake, and other disasters. In aspect of network reliability enhancement, multi-source and multi-route connections should be built and a distributed layout should be adopted so as to improve supply reliability. Hierarchical prevention is used to cope with different levels of disaster scenarios, as well as adapt emergency security needs in case of disasters. Emergency supply security facilities should be configured in combination with emergency service facilities to enhance rescue security capabilities under catastrophes. In the planning of municipal pipeline network, the toughness measures for reliability enhancement should be finally determined through the reliability analysis of water supply nodes under multiple scenarios of medium, large, and giant earthquakes.

5.1.4 Strategies on Emergency Management

Improve cross-regional and cross-sectoral cooperation mechanisms in response to climate risks. We should implement the requirements of the *Yangtze River Protection Law* and promote the establishment of a cooperative governance mechanism in cities and towns at the upper and lower reaches as well as the left and right banks of the Yangtze River and its major tributaries. Joint scheduling and mutual assistance mechanisms should be established with a sub-basin as a unit.

Establish a monitoring information network for climate change and disaster assessment in the Yangtze River Basin. A monitoring and early warning system

should be built with the basin as a unit, and a risk assessment and scenario simulation platform should be established to provide risk assessment and disaster avoidance guidance for government departments and residents in the basin. The integration of Radarsat remote sensing, artificial intelligence, cloud computing, 5G and other advanced information technologies with disaster monitoring business should be promoted to achieve collection, storage, sharing, and exchange of disaster risk information of floods, earthquakes, typhoons and other multi-hazards. The “Disaster Risk Map” information platform should be established to send warning information to relevant governments, social organizations, and residents at first time after formation of a disaster, reduce information difference, and help residents perform self-help and mutual assistance within golden 72 h.

Promote the emergency response capabilities of local governments, grassroots organizations, and the public. The grassroots emergency response plans should be made according to local conditions and the emergency decision-making process should be shortened in the face of sudden disasters. The public emergency training should be strengthened by referencing the experience of Hong Kong’s “wind-ball response mechanism”. The resilient communities should be established to enhance the autonomy of community emergency response.

5.2 Resilience Strategies of Regions Along the Upper, Middle, and Lower Reaches

5.2.1 Strategies on Resilience of Regions Along the Upper Reaches

Headwater region of the Yangtze River: To cope with habitat changes brought about by melting of glaciers and the thawing of permafrost, we should continue to strengthen biodiversity conservation and improve glacier monitoring mechanisms. We should continue carrying out ecological restoration in ecologically important areas such as SRYYL. Combining with the change of animal living and migration area, we should optimize and adjust the scope of the reserves and control wildlife migration passages. In the aspect of management method, we should establish a sound monitoring system and early warning mechanism for glacier ecosystem.

Middle part of the Sichuan Basin: To cope with high temperature and heat wave, the first step is to optimize the layout of urban ecological space, reserve space for urban ventilation corridors and upwind cooling sources, and use natural means to reduce the heat island effect; the second step is to strengthen high temperature early warning and adjust high temperature working hours when available. To cope with urban waterlogging, the first step is to restore natural lake water systems, control the urban blue and green line, and increase the space for flooding within the city; the second step is to construct green infrastructures such as sponge cities, strengthen the construction of grey infrastructures such as drainage networks and flood pump stations, and renovate drainage and flood prevention facilities for flood-prone areas.

Circumference area of the Sichuan Basin: To cope with landslides, mudslides, and other geological disasters, the main measures are disaster early warning and staged opposition transfer, and locally adopted engineering. First, strengthen ecological protection, promote ecological returning of farmland, and reduce the risk of geological disasters. Second, strengthen spatial optimization, and gradually promote relocation due to geological disaster. Third, strengthen the construction of lifeline, optimize the location of municipal facilities, and reduce the vulnerability of facilities. Fourth, improve management methods, issue timely rainstorm and disaster early warnings, and enhance the guarantee of emergency material reserve. Strengthen the comprehensive governance of the hydro-fluctuation belt of the Three Gorges Reservoir Area.

Yunnan-Guizhou Plateau: To cope with drought, emphasis should be put on enhancement of monitoring and reasonable construction of water conservancy facilities. First, strengthen ecological protection, optimize vegetation structure, and reduce strong transpiration. Second, moderately adjust agricultural planting structure and layout. Third, strengthen engineering measures, build farmland water conservancy facilities and emergency water sources, and implement irrigation. Fourth, improve management methods, establish dynamic analysis and early warning system, and construct water-saving society.

Southern mountainous regions of Yunnan and Sichuan: To cope with forest fire risks, we should integrate ecological, engineering and management measures to improve the capacity of forest fire prevention. First, strengthen ecological measures by introducing fire-resistant tree species and building fire prevention belts. Second, take engineering measures to increase firefighting water points and forest firefighting channels, such as the establishment of aerial firefighting water points in Danba County, Sichuan. Third, improve management methods, including the establishment of no-fire zones, intelligent monitoring, early warning systems, etc.

Mitigate the impact of the upstream hydropower development on ecological environment. We should strengthen the protection of rare and endemic fish nature reserves in the upper reaches of the Yangtze River. The environmental impact assessment of hydropower development should be strengthened, and the needs of fish habitat and breeding should be met through measures such as enhancement and release, setting up fish passage, and ecological dispatching of reservoirs. We should also study the dismantling of small- and medium-sized hydropower stations in ecologically sensitive areas of rivers such as the Qingyi River and the Anning River to restore the natural state and habitat of rivers and implement ecological restoration in the river basins.

5.2.2 Strategy on Resilience of Regions Along the Middle Reaches

Western mountainous regions of Hunan and Hubei: To cope with geological disasters, we should attach importance to source ecological governance and engineering measures and strengthen monitoring and forecasting. We should conserve soil and

water through ecological afforestation, slope governance, and other source management methods, reserve disaster tolerance buffer space, and avoid disaster high-risk areas. We also need to construct interception ditches, slope protection and other geological disaster prevention and control projects, stabilize slopes by engineering interventions, improve monitoring and early warning and information release mechanism to guide people to move to avoid danger and protect life and property. In aspect of low temperature and freezing, we should improve the monitoring and early warning capability and promote the construction of facilities. We should also focus on scientific and technological innovation, and construct energy supply projects, improve the monitoring and early warning and information release mechanism to guide the people to avoid danger; improve the regional coordination and mutual assistance mechanism.

Jiangnan-Dongting-Lake Plain and Poyang Plain: To cope with rainstorm and flood, we should adopt a systematic approach combining river and lake system protection linkage, embankment construction, pump station upgrading, river channel governance, ecological restoration, and sponge cities. Strict control of ecological space is carried out to maintain and increase the area and shoreline length of urban lakes and ensure the storage function. A water resource utilization system with river and lake cut-through and ecological storage should be established to play a role in waterlogging prevention and control; Strengthen the construction of source sponge facilities, build over-standard drainage channels and rainwater and sewage diversion transformation; Carry out over-standard emergency research and make an over-standard storm waterlogging prevention and control plan, while enhancing public awareness of disaster prevention and avoidance and self-rescue ability through publicity and education. **To cope with high temperature and drought**, improve ventilation conditions. We should alleviate the heat island effect by improving the local microclimate and ventilation conditions, and creating ventilation corridors.

Nanling region: We should focus on fire isolation, improve the rescue system, and cultivate public awareness of fire prevention. We should set fire prevention barriers, plant fire prevention trees, build and improve monitoring stations in forests and surrounding areas, and equip efficient monitoring equipment. In addition, we should also strengthen public education and propaganda to cultivate the awareness of fire prevention, improve monitoring and early warning and information release mechanism to guide people to avoid danger and improve the forest fire rescue system. The construction of professional staff teams shall be strengthened and regional coordination and linkage mechanism shall be built.

5.2.3 Strategy on Resilience of Regions Along the Lower Reaches

Stem stream of the Yangtze River and the great lakes region: We should establish a water and land ecological safety network, protect important natural spaces such as wetlands, mudflats and islands, build landward buffer zones along the river front, and restore the water and land ecological corridor along the River. To cope with the impact of flood in the plum-rain season, we should carry out the “returning dikes to

water” to increase the flood storage space in the basin and increase the flood discharge capacity in the great lakes region through the linkage of rivers and lakes. The flood control standards of the Yangtze River main stream and the Great Lakes should be raised, and the construction of flood control levees and sluice pumps in the lower reaches of the Yangtze River should be strengthened in a green low-impact manner.

Estuary and coastal regions: To cope with the impact of sea level rise and surging typhoon storm, the structure of shoreline land use should be adjusted; a control system for zoning and segmentation of the coastal zone should be established. The restoration of wetland mudflats and the construction of key reserves and biological habitats should be strengthened by combining with the complexity and fragility of the ecosystem in the estuarine region; increase the resilient water storage area by using the space of coastal saline polder. In terms of facilities construction, we should strengthen the construction of coastal defense engineering to cope with extreme storm surges and strengthen the construction of urban drainage projects. In aspect of emergency management, we should improve the safety early warning mechanism at the estuary and coastline.

Mountainous regions of southern Anhui and northern Zhejiang: We should establish a smooth water system network of the upper, middle, and lower reaches, and build a mutually complementary rainwater storage system consisting of rivers, lakes, reservoirs, and wetlands. We should restore the floodplain area of the natural water system and take the initiative to incorporate rainwater floods into the site. In terms of facilities construction, we should build the storage reservoirs in the upper reaches for staggered regulation of transit flood peaks, strengthen embankment construction in the middle reaches to ensure safety of flood drainage, and carry out river dredging and chokepoint clearance in the lower reaches to enhance the overflow capacity of the river. In aspect of ecological protection, we should strengthen the construction of mountainous woodlands and wetlands to enhance the function of soil and water conservation. In terms of emergency management, we should establish a joint prevention and control system mechanism of the upper, middle, and lower reaches.

Regions of the Huaihe River Basin: To cope with the impact of floods, we should strengthen the construction of flood storage and detention areas and water-front buffer zones, build gentle-slope river flood zones for improvement of the storage capacity of river channels, and improve regional engineering measures such as reservoir scheduling, water transfer of flood storage and detention areas, and cross-basin. To cope with the impact of drought, we should strengthen the use of water-saving facilities to improve the efficiency of agricultural irrigation and encourage the cultivation of water-saving agriculture. We should also improve the management of river catchment areas, and replenish water for large lakes and reservoirs.

6 Shorelines Utilization Problems and Optimization Strategies in the Lower Reaches of the Yangtze River

As an engine of economic development and a densely populated region in China, the lower reaches of the Yangtze River are facing the stage problem accumulated in the previous development, namely a sloppy development model with high resource consumption at the cost of the environment, one of the main manifestations of which is shoreline utilization. Therefore, it is crucial and beneficial for the downstream region to help the sustainable development of the basin around a higher quality of shoreline protection and utilization.

6.1 Analysis of the Current Situation of Shorelines Utilization

Based on the image data of Google Maps in 2010 and 2020, this study systematically sorted out and mapped the utilization situation of the shorelines of the main stream of the Yangtze River from Nanjing to the estuary and the shorelines of the island. According to the purpose, shorelines could be divided into two categories: artificial and natural, and six subcategories: living, port, industrial storage, other use, ecological protection, and nature reserve (see Table 1).

According to statistics, the total length of the Yangtze River shorelines below Nanjing in 2020 is about 2020 km. Among them, the natural shorelines account for

Table 1 Shorelines drawing method classification

Shorelines classification		Drawing method and specific explanation
Category	Subcategory	
Natural shorelines	Ecological protection	Including the relevant shorelines involved in the provincial and municipal ecological protection red line list
	Natural reserved	The main ecology and agriculture function within 1 km of the land area
Artificial shorelines	Port	Drawing according to the current ports in cities along the river and other data
	Industrial storage	industrial parks and industrial enterprises within 1 km of the land area
	Living	The function of urban life within 1 km of the land area, including life and recreation shorelines, landscape shorelines, urban water intake shorelines, etc
	Other use	Including river crossings, municipal infrastructure, special-purpose shorelines, etc

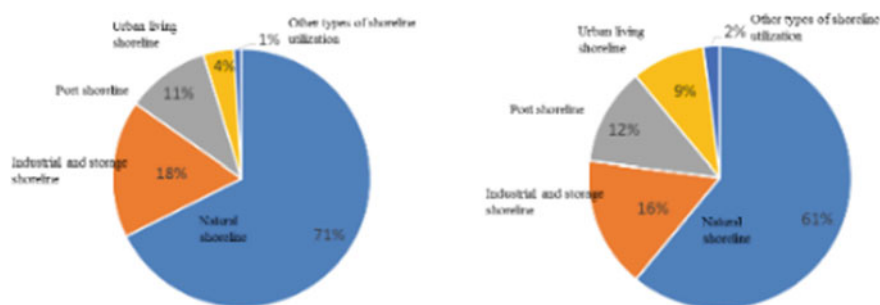


Fig. 14 Classification and statistics of the lower reaches of the Yangtze River in 2010 (first half of the year) and 2020 (second half of the year)

61%; the artificial shorelines account for 39%. With respect to artificial shorelines, industrial storage shorelines account for 41%, port shorelines account for 32%, living shorelines account for 23%, and other use shorelines account for 4%. From 2010 to 2020, the length of the shorelines has increased by 42 km: the natural shorelines have decreased by 170 km and the artificial shorelines have increased by 212 km.

Shorelines utilization is extensive and inefficient, and lacks overall arrangement. Nearly 60% of the main river shorelines has been developed as artificial shorelines. Among them, the length of the port shorelines accounts for 32% of the length of the artificial shorelines. The utilization efficiency of the port shorelines varies greatly. Shanghai, the highest utilization efficiency area, is 3.5 times that of Nantong, the lowest utilization efficiency area. A large number of high-quality shorelines are occupied by enterprise wharves, which often leads to idle and waste of shorelines resources. The various utilization methods of some ports are disordered and cross-mixed, making it difficult to form economies of scale. In the lower reaches of the Yangtze River, there are 107 km of shipyard shorelines, of which the shorelines of low-level, small-scale, and scattered shipyards reach about 30 km, accounting for 28% of all the shipyard shorelines (Fig. 14).

The heavy chemical industry is concentrated in the areas along the river, which puts great pressure on energy saving and carbon reduction. There are 322 km of industrial storage shorelines in the lower reaches of the Yangtze River. Among them, the length of chemical enterprises shorelines is 72 km, including 13 provincial chemical parks (concentration areas) and several small scattered chemical parks in Jiangsu Province. The iron and steel enterprises shorelines is 28 km, dominated by large steel mills such as Baosteel, Nangang and Shagang, etc. The thermal power plant shorelines is about 25 km, and 14 large power plants are distributed on both sides of the main river. Such a high-density distribution of heavy chemical and energy enterprises will bring about extremely high-intensity carbon emission pressures.

The chemical industry parks in the lower reaches of the Yangtze River are located at short distance from one another, with the nearest distance of only 7 km. The artificial bank is obviously a water pollution zone, and the contaminant content of nitrogen and phosphorus in ports, urban bank zones, urban inland river estuaries

and sea estuaries is generally higher than that of natural river sections and riverside wetlands. The risk of heavy metal pollution in the waters of the middle and lower reaches of the industrial shorelines is prominent, and the surface sediments and persistent organic pollutants in the waters adjacent to the shorelines tend to increase from upstream to downstream [52]. At the same time, 23% of environmental risk enterprises in the lower reaches of the Yangtze River are located within 5 km of drinking water sources [53], the water intakes and sewage outlets are staggered, and the situation of drinking water safety is grim.

High-intensity and continuous development along the river has compressed the water and land ecological space. From the changes in the past ten years, the total length of the natural shoreline has decreased by about 170 km, and the ratio of natural shorelines to artificial shorelines has changed from 7:3 in 2010 to 6:4 in 2020. Taking the Zhangjiagang-Changzhou section as an example, the artificial shorelines are more than 55 km long, which has concentrated the function of industrial, wharf, and urban living. High-intensity development has resulted in the upstream and downstream of important ecologically sensitive areas such as ecological protection red line, and drinking water sources being surrounded by chemical parks and ports. Large-scale artificial development has also encroached on tidal flats, wetlands, islands in the middle of the river, etc.

A Large number of extensive artificial constructions and activities affect biodiversity. First, the “blockade of rivers and lakes” in the middle and lower reaches has led to the blocking of the ecosystem. Since the mid-to-late 1950s, a large number of lakes in the middle and lower reaches have been reclaimed and turned into farmland, and the lakes have been isolated from the Yangtze River by control gates. At present, only the “two lakes” maintain natural connection with the Yangtze River, and the effective lake area for supporting fish in the Yangtze River has decreased by 76% [54]. Second, the artificial shorelines along the river greatly compress the living environment of fish. Artificial shorelines, especially industrial and port shorelines, will seriously affect the living space of fish seedlings. At the same time, the terrain along the middle and lower reaches of the Yangtze River is relatively low. In order to prevent the scouring of the shorelines, it is often necessary to stabilize the embankment and cut the river channel to be straight, which also reduces the habitat or breeding ground of fish in the river channel to a certain extent.

The riverside public space serving the citizens needs to be increased. The length of living shorelines in the lower reaches of the Yangtze River has increased by 109 km during the decade of 2010–2020, and its growth rate ranks first among all artificial shorelines. However, the proportion of living shorelines is still low. In 2020, the proportion of living shorelines in artificial shorelines was only 23%, being concentrated in the main urban area of Nanjing, Zhenjiang urban area, the north side of Jiangyin urban area, Shanghai Baoshan Wusongkou, Qidong Yuantuoqiao and so on. In some cities, the road from the urban area to the riverside is blocked, and the sight lines and viewing corridors leading to the river are blocked by dock cranes, storage yards and inefficient industrial plants. In Zhenjiang, Jingjiang, Yizheng and other places along the riverside suburbs, the land use is mixed, and it is still common

for a large number of shorelines to be occupied by low-end functions such as small shipyards, bulk cargo terminals, and building materials enterprises.

The contradiction between the management department of water, shorelines, and land areas is prominent. Before the promulgation and implementation of the *Yangtze River Protection Law of the People's Republic of China*, the relevant management departments seldom coordinated management from the perspective of water and land coordination, resulting in problems such as the layout of non-port industries along the river, more shorelines being occupied and less used or not being used. At the same time, the development and management of the shorelines involves many departments such as development and reform, water conservancy, land, transportation, and environmental protection. In the management and control of local shorelines, the division of responsibilities of different departments is too detailed, and there is a lack of cross-departmental overall management at the river basin level [55]. A typical example is pollution control. Although the past “water and shore do not manage each other” phenomenon has been improved, the current contradiction of pollution discharge in water and land areas still exists.

The coordinated governance of cross-regional shorelines lacks overall planning. During the period of rapid economic development, the cities along the river focus on the “GDP championship”, and take shorelines development as a weight for attracting investment and expanding the economic scale. There is a lack of overall planning, development and utilization of the shorelines between adjacent administrative entities. The high-intensity and continuous development along the river has led to the lack of ecological buffer space and facility layout space. Even during the period of great development, relatively complete berth types have been formed, and there are problems of repeated port construction, such as Taicang Port, Changshu Port and Zhangjiagang Port, which all belong to Suzhou City.

6.2 *International Experience in Shorelines Utilization and Management*

Adopt a more active and flexible shorelines utilization strategy to adapt to the new situation of flood control safety. Under the influence of more frequent extreme weather events due to climate change and aggravation of major natural disasters around the world, ensuring the long-term security of shorelines and land areas has become a primary concern. Pay attention to the overall toughness of water and land areas, combine engineering methods with natural solutions, and “breathe and loosen” the downstream shorelines developed with high strength. Learning from the Netherlands’ “Towards Adaptive Delta Management”, which advocates “more space for rivers” and leaves blanks on land along rivers to provide strategic flexibility for future suitability initiatives.

Support the goal of green carbon reduction in the river basins through optimal utilization of shorelines and replacement. For a long time, the main body of carbon emission along the Yangtze River has been high energy-consuming industries such as chemical industry, steel and power plants, as well as port shipping. Learning from the experience of the Rhine River and other places, the values should change from “controlling water with functions” to “guiding functions with water”, promote the iterative upgrading of industrial structure, energy structure and transportation structure through the extensive adjustment of the use of shorelines, and change from the previous high-carbon and high-pollution development model to a low-carbon and clean development mode.

Protect, improve and expand ecologically important areas and restore typical habitats of the Yangtze River. The lower reaches of the Yangtze River are a treasure trove of biodiversity. Today, downstream regions are under enormous pressure. The protection of biodiversity depends on our natural values. Learn the previous editions of the *Rhine Action Plan*, gradually restore suitable habitats for animals and plants, restore the natural appearance of the river, and protect a healthy biosphere with all ecosystems, a wide variety of flora and fauna, fertile soil, pure water and clean air [56].

Return the waterfront to life, and continuously improve the happiness and satisfaction of citizens. With the increase in income level, people pursue a higher quality of life. With the increase of leisure time, allow people to have more opportunities to enjoy nature, enhance their yearning and aesthetics for nature, and resonate with its future development [57]. Learning from the practices of other cities to change the shorelines from production functions to living functions and create waterfront spaces with local characteristics to meet the needs of citizens for leisure, recreation, sports and other aspects. With the renewal of shorelines and ports as catalysts, the overall function of the city will be upgraded.

6.3 Green, Low-Carbon and Livelihood-Oriented Shorelines Optimization Strategies

6.3.1 Promote the Green Transformation of the Shorelines Along the Industrial Belt

Accelerate the relocation and transformation of heavy chemical industry, and the clearing of low-level, small-scale, and scattered industrial shorelines and shipyard shorelines. It is recommended to take safety, environmental protection, and energy consumption as preconditions, and guide the heavy chemical enterprises along the river in downstream areas with overloaded resources and environment transfer outside the river basin from the perspective of the layout of productivity in the river basin. For areas within 1 km away from river and outside the centralized chemical park, it is necessary to speed up to guide enterprises to relocate and integrate into provincial chemical parks and chemical concentration areas. Promote the

gradual withdrawal of low-level, small-scale, and scattered shipbuilding shorelines, and reduce the occupation of waterfront and fine shorelines resources. Combined with the national green energy transformation, reduce the scale of thermal power plants along the shorelines, and promote the transformation of high-polluting thermal power plants to new energy sources. In view of the relatively concentrated steel smelting shorelines, it is recommended to optimize, compress and carry out clean production.

Encourage the integration and merger of ports and promote the transformation and exit of inefficient terminals. In response to the extensive adjustment of energy structure and industrial structure in the future, predict the changing trend of transportation structure and flow direction in advance. In the future, it is necessary to speed up the promotion of “road to railway, road to waterway” for bulk materials, and to speed up the construction of an efficient and green and multimodal transport system consisting of large ports along the river, and the inland ports. Give play to the basic allocation role of the market, and promote the integration and merger between ports in the lower reaches of the Yangtze River. Coordinating port transportation functions, on the one hand, realizes the specialization of cargo development and promotes dislocation development; on the other hand, for the industrial supporting wharf with insufficient throughput and low utilization rate, it is necessary to guide the public transformation and open to the society.

Promote the “co-management of water and land” and carry out comprehensive management of pollution and consumption reduction. Learn from the “Three Lines and One List” system of the Ministry of Ecology and Environment to establish a zonal management and control of shorelines utilization and an access threshold mechanism for shorelines utilization, including the red line for natural shorelines protection, the upper limit for shorelines resource utilization, the control bottom line of environmental quality and economic benefits, and the negative list of shorelines utilization access. Improve the national and local, upstream and downstream, and left and right bank collaborative management of water and land areas.

6.3.2 Strengthen Protection and Restoration of Typical Aquatic and Terrestrial Habitat Networks

Restore animal and plant habitats. Improve the construction of river basin biodiversity survey and observation network in the basin to deal with climate and environmental changes. Fully study the habits and characteristics of protected organisms. Create a better living environment for organisms by means of shorelines near-natural form design and natural habitat reconstruction. Continue to improve and enrich the fish and bird biological reserves along the Yangtze River, speed up the improvement of the list of natural protected areas, and carry out boundary survey and demarcation to anchor the protection space.

Construct the riverside-land buffer zone and restore the water-land ecological corridor along the river. In order to effectively intercept and purify surface source pollution, it is recommended to build a landward buffer zone with a width of 0.5–1.0 km along the main stream of the lower reaches of the Yangtze River [58].

Establish ecological isolation corridors between riverside towns and groups through vegetation restoration, water system connectivity, retreat of low-efficiency land, and environmental improvement, and restore ecological corridors between tributaries, lakes, mountains, other important land ecological spaces and the main stream of the Yangtze River.

Combine natural and engineered measures to create a safer resilient defense.

On the one hand, strengthen the construction of disaster prevention and safety projects in a low-impact and greener way. Through the construction of green and ecological embankment and shorelines, the promotion of “gray, green, blue, and management” measures to improve urban drainage and water logging prevention capabilities, and advocate sponge cities. On the other hand, seek natural solutions. For example, in response to the frequent floods in the Great Lakes Basin, it is necessary to advocate “returning the polder to the water”, restore free water surface, increase the flood storage space in the basin, and increase the flood discharge capacity in the Great Lakes Basin through the linkage of rivers and lakes.

6.3.3 Create a More Dynamic Waterfront Space

Actively create a people-oriented waterfront living space. Overall consideration should be given to the life cycle of the port and industry, to promote the transformation of production-oriented functions to comprehensive service-oriented functions. Make the waterfront public space connected, and gradually becoming a multi-functional living shorelines. The shorelines play a leading role in planning the process of renewal, promoting the combination of government macro-guidance and market-oriented operation, guiding diversified investment and social participation, thus achieving a win-win situation for all parties.

Pay attention to the cultural value of water, create a pleasant waterfront landscape, and continue the urban culture. Fully respect the original spatial texture and pattern, protect industrial heritage, historical buildings, structures and elemental symbols, and closely integrate with subsequent functions. Shape a pleasant open space system and waterfront pedestrian environment by promoting the organic integration of work, residence, and leisure, and organizing diversified public activities. Taking the historical and cultural space of waterfront as the catalyst, cultural activities, festivals, etc. are implanted to drive the overall renewal of the port and the old industrial base.

Build leisure areas with suburban and wild scenery to improve the quality of urban and rural environments. Restore the natural and original ecological environment and become a space for urban people to enjoy the scenery and relax. Carry out ecological restoration, demolish land used for inefficient shipyards and building materials, and build a landscape with regional characteristics. Meanwhile combined with flood control embankments, county and township roads, etc., to build country greenways and post stations, connecting scenic spots and towns along the riverside (Table 2).

Table 2 Cases of shorelines transformation in the lower Yangtze River in recent years

Case classification	Transformation of industrial terminal shorelines		Ecological restoration of natural shorelines
	Transformation to natural shorelines	Transformation to living shorelines	
Yangtze River shorelines	Ecological restoration of Nantong's five mountain areas and riverfront; "Ten miles of spring river in Yangtze River" line in Qiaolin; Renovation of shipbuilding belt in the 12 polders of Yizheng	Connection of "two rivers" in Shanghai; Yangpu Riverside, Xuhui Riverside, etc. in Shanghai; Renewal of Xiaguan, Pukou Riverside in Nanjing; Construction of riverside park in Jiangyin	Lvshuiwan Wetland of Jiangbei New District in Nanjing; Longpao Wetland in Nanjing
Important Island	Ecological restoration of Changqing Sand Island in Rugao; Chongming East Beach and Jiuduansha Wetland; Remediation and restoration of dolphin reserve in Zhenjiang; Xinjizhou National Wetland Park in Nanjing; Ecological restoration of Shuangshan Island in Zhangjiang Port		

6.4 Continuing Concern for Sustainable Development in a Delta Region

6.4.1 The Delta Region is a High-Value and Highly Sensitive Area Under Stress Globally

Delta regions are generally faced with the challenges of climate change-related weather extremes such as sea level rise, flood erosion, and storm surge. For a long time, the excessive human activities in the delta region have changes the hydrological conditions and natural landforms in the estuarine area, resulting in a fragile ecological environment and serious threats to biodiversity. The Netherlands, for example, being a delta region where most of the country is formed by sedimentary basin systems, is actively advocating the transition from "resistance to water" to "coexistence with water" [59], and gradually forming the consensus like "untouched estuaries and deltas will not be touched if there is a choice" [60].

All the countries are actively exploring the methods of rational development and utilization of the delta region. The delta region is a highly dense area in terms of both population and economy, and it is also an important carrier of urban space expansion and economic growth. On the one hand, the unique water system, wetlands, and polder landscape are conducive to carrying out extensive engineering technology, agriculture, and aquatic city experiments to shape the unique delta landscape. For example, in the 1970s, the Netherlands gave birth to a new generation of "garden cities" represented by Almere and Lelystad in the polder area. On the other hand, in the context of globalization, the shipping function of international ports has always

been one of the focuses of the estuarine area. For example, the Port of Rotterdam in the Netherlands has consolidated its central position in international shipping by continuously expanding to the estuary area.

Box 7 History of the “Seaward Expansion” Phase of the Port of Rotterdam in the Dutch Delta

The Port of Rotterdam is located on the North Sea coast, at the confluence of the Rhine and Maas Rivers. By the nineteenth century, the Port of Rotterdam had become increasingly important in terms of transit trade, and the construction of the Waalhaven (the orange part of the picture) made it become one of the largest dredging ports in the world. The Port of Rotterdam was extended in the period of 1946–1960 (the blue and purple part of the picture). Another expansion took place in the period of 1960–1970 (the light blue part), and a huge area to the west was subsequently developed as the “Gateway to Europe”, turning the Port of Rotterdam into the world’s largest port at that time. In 1970, the Port of Rotterdam launched the Maasvlakte, and created a man-made port at the sea-river interface of the delta. The second phase started in 2008 and was put into service in 2013. The total area of the Port of Rotterdam is now 12,500 ha (Fig. 15).

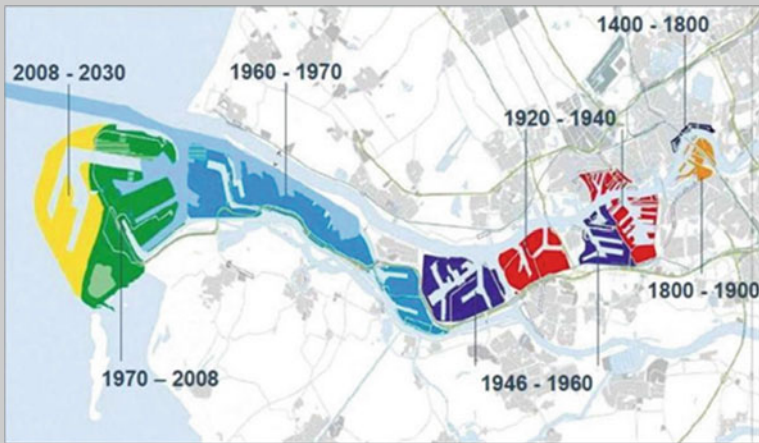


Fig. 15 History of seaward expansion of Rotterdam. *Data source* <https://www.portofrotterdam.com/en>

6.4.2 High Complexity of the Sustainable Development of the Yangtze Estuary Area

First, the evolutionary trend of the hydro-geomorphology of the delta is a fundamental factor of the primary consideration for long-term development. From the viewpoint of historical evolution, the development model of the Yangtze Estuary for 2000 years can be summarized that “the beach in the south bank spreads out, the sand island in the north bank merges with the bank, the estuary is narrowed, the river channel takes shape, and the river trough is deepened” [61]. From the perspective of a century scale, the hydrological and geomorphological evolution of the estuarine area is strongly influenced by climate change and artificial engineering construction, leading to a decrease in runoff and sediment runoff in the Yangtze River Estuary and a slowdown in the overall siltation trend [62]. Therefore, continuous monitoring of hydro-geomorphology needs to be enhanced to allow for more refined simulation and prediction of future development trends.

Second, from the perspective of response to natural disasters under the influence of climate change, the Yangtze Estuary Area is vulnerable to the influence of rising sea level, typhoons, and storm surge, and thus it is a region with high vulnerability and exposure. The rate of sea level rise in the Yangtze Estuary Area is slightly higher than the global average, and the frequency and intensity of surging typhoon storm faced in recent years also show an increasing trend [63]. Under this superimposed influence, the conservation and development of the Yangtze Estuary Area needs to dynamically adjust the land use structure of the coastal zone and make resilient flood control strategies in response to natural disasters.

Third, the Yangtze River Estuary Area, as a channel for material exchange between land and sea, has rich biodiversity and ecological specialties. The Yangtze River Estuary is not only a spawning ground, a feeding ground, a nursing ground, and a migration channel for fish, but also a habitat for more than 200 species of migratory birds, and an important water source for the city. In order to consolidate and enhance biodiversity, it is also necessary to strengthen the construction of targeted multi-category ecological reserves and strictly control the impact of human activities such as fishing, water conservancy construction, and shipping.

Fourth, the Yangtze River Estuary Area needs to meet the busy shipping pressure and international large port construction needs under the premise of overall planning of ecological protection. The trend of large-scale international shipping vessels has led to the continuous extension of port construction to deep-water shorelines. In the process of port development, first the ecological damage and pollution problems that may be brought about should be assessed and corresponding ecological compensation and restoration measures should be carried out. Second, port construction needs to be comprehensively intelligent and green and low-carbon to improve the competitiveness of ports and the ability to adapt to climate change.

6.4.3 Construction of an Ecological Green Beach at the Yangtze River Estuary Area to Reserve Strategic Space for the Future

On the one hand, attention should be paid to the enhancement of the security and resilience capacity of the Yangtze River Estuary Area. Engineering measures should be combined with natural means to build a green barrier for ecological flood control. Key wetland mudflat protection zones and biological habitat protection zones are established to meet the unique biodiversity protection requirements of the delta. On the other hand, the ecological green beach of the Yangtze Estuary should be built to reserve a flexible space for long-term sustainable development. Under the premise of integrating various factors, the sediment resources from the dredging of the Yangtze River waterway should be used rationally, and the ecological land in the estuary area should be increased through measures such as promoting siltation and enclosure to reserve national strategic space for long-term development, in order to cope with the uncertainties of the external environment such as international shipping, energy revolution, and scientific and technological agriculture in the future.

7 Social Equity and Gender Issues in the Yangtze River Basin

7.1 Situation Analysis and Problem Identification

Gender and social equity are key issues in global river basin governance today.

On the one hand, vulnerable groups such as women, children, old people, and the poor are significantly less able to cope with disasters caused by climate change and are exposed to significantly higher risks and suffer greater physical and mental health damage from disasters such as food shortage, high temperature, and floods caused by climate change [64]. 80% of people displaced by climate-related disasters and changes around the world are women and girls [65]. On the other hand, vulnerable groups have low awareness and opportunities to participate in river basin governance and policy decisions. Among all adverse factors affecting gender and social equity, the impact of poverty is particularly critical, making rural areas in developing countries the most prominent in terms of gender equity and social equity issues [66].

Significant urban–rural and regional gaps in disaster resilience capacity are key factors affecting gender and social equity issues in the basin. The former national poor counties within the Yangtze River Basin (2014) are mainly distributed in the upper and middle reaches of the basin. The resilience of poor rural areas is generally low, leading to a higher vulnerability to disasters brought by climate change than that in towns. There are a great number of reasons, including the low standards of house and infrastructure, the high number of hidden hazards of environmental disasters such as mountainous areas, the high sensitivity of agriculture, forestry, animal husbandry and fishery industries, and the weak disaster resilience and relief at the grassroots

level. According to statistics from the Ministry of Emergency Management, more than 70% of meteorological disasters in China occur in rural areas, especially in the western region; the phenomena of disaster chains, multiple disasters, and disaster encounters in rural areas show an increasing trend.

Population outflow leads to higher concentration and deeper poverty of women, old people, children, and the like in rural areas. According to data from the census, there is a general outflow of young people in rural areas in the Yangtze River Basin, and the proportion of old people in rural areas is significantly higher than that in urban areas. Taking Sichuan Province for example, the people at 60 years old or above accounted for 27.32% in 2020, which was 9.89 percentage points more than that in urban areas. There are more than 700,000 left-behind children in Jiangxi, Sichuan, Guizhou, Anhui, and other provinces along the Yangtze River. The total number of left-behind women in rural China has tended to decrease in recent years as the female labor force has become more mobile; however, the data from provinces show that women still take a high percentage of the population in rural areas, mainly including left-behind mothers and girls. In relatively poor areas and rural areas, a large number of women, old people and children left behind are the most vulnerable population in response to climate change risks because they are responsible for both agricultural and sideline production and taking care of the family, are far from social support systems, and lack social participation, security and health services, and flexible livelihood opportunities. The limited disaster records of the Yangtze River Basin area demonstrate that children, old people, and women in rural areas suffer from greater mental and physical health impacts after disasters [67]. Guaranteeing the resilient security and livelihoods of these populations is the key point for sustainable management of the Yangtze River Basin.

7.2 Strategies on Social Equity and Gender in River Basin Governance

- (1) Formulate and monitor the implementation of gender-sensitive and socially inclusive basin climate strategic plan so that gender and social inclusion objectives become a priority consideration for all fields in the planning, implementation, and assessment phases of policies and projects.** In this process, it is critical to review and amend the relevant legal frameworks and policies for river basin resources, environment, and industry. At the same time, multidimensional performance indicators sensitive to gender and social equity for sustainable development of river basins should be developed through participatory methods to assess social equity impacts of various policies. Indicators measuring environment and equity can be aggregated for a comprehensive assessment. Finally, the availability of gender and population division data needs to be particularly ensured among social and community information and disaster impact statistics in each field.

- (2) **Focusing on poor and backward areas and rediscover the value of social contributions of people left behind in villages:** We should pay attention to the local planning, implementation and management of policies related to relatively poor areas and villages, and continuously innovate rural management modes. In combination with the new urbanization and rural revitalization strategies, a variety of support policies are used to raise the economic incomes of women and old people left behind, enhance the capacity of climate-adapted modern agriculture, and protect the rural ecological environment and biodiversity. It is necessary to develop a long-term system of health services for people left behind under climate stress, strengthen talent training, professional studies and incentives, and establish rural culture, health, education, activity, psychology and legal service places. Enterprises and private capitals are encouraged to jointly build special disaster response spaces for women and other marginalized populations. To meet the needs of women, old people and children, we should update community-based information-based medical and disaster management systems and coordinate cross-sector and cross-system service guarantee capabilities. We should also raise the guaranteed standards of new-type pension insurance and increase funding for accidental injury risk prevention work for children and women left behind in rural areas.

Box 8 Koshi Basin Initiative Fully Integrated Gender and Social Equity Issues into Assessment Through Data System

From 2012 to 2022, Koshi Basin Initiative, sponsored and carried out by the International Centre for Integrated Mountain Development (ICIMOD), was dedicated to sustainable development and cross-border governance of the river basin which flows through China, Nepal, and India. With gender equality as a prerequisite for sustainable development, the project believed that women and vulnerable people were key transformative power in building strong and resilient communities in the Koshi Basin, and therefore gender and equity issues were considered at first in the perspective long-term plan, issue assessment, policy selection, and program implementation phases of the river basin. To support evidence-based decision-making and enhance communication, the project established a long-term public information system for the Koshi Basin, which contained a gender data subsystem. The system integrated the existing knowledge on gender inequalities in access to and control resources and emerging gender nuances related to water, food and energy insecurity. Through detailed analysis of gender data, the research team made several work suggestions on gender equality in the river basin [68].

(3) **Promote gender equity in the river basin governance decision-making**

process: Gender perspective should be included in the mainstream of the structures of river basin governance institutions and relevant departments; women are empowered at all administrative levels to equally participate in and lead river basin governance decision-making and climate change-related policies. The abilities of technical staff are trained to integrate gender issues into work plans and project implementation, and gender and public participation methods are created and carried out to raise awareness. The ability building is conducted in grassroots women organizations, children and older people organizations, non-governmental organization to assist their participation in the river basin governance process and encourage women in organizations to develop and implement their own climate actions. The ability building is done in central and local governments to enable them to include gender perspectives in their own analytical work and planning work. Gender alliances and mechanisms are established between climate change-related organizations and institutions. Gender and social equity participation is used as an opportunity to expand society-wide discussion and cooperation in response to climate change. We should also focus on the gender equality perspective of male groups and increase the active participation of men in equitable and inclusive actions.

Box 9 The Nile Basin Initiative Focused on Poverty and Gender Equality and Developed a Range of Policy Measures

The World Bank took actions through CIWA and carried out the Nile Basin Initiative (NBI) to build the capacity for cross-boundary issues in Integrated Water Resources Management (IWRM). At the beginning of the project, NBI formulated a formal gender mainstreaming policy and strategy at first. In the ancillary action plan, 0.14% of the social development budget was set aside for gender-related activities, and the allocation and implementation of funds was tracked to assess the actual effect of projects on improving women's lives; At the same time, the formulation of gender-sensitive budgeting was attempted in some projects. A project to build the ability of national controlling authority staff was developed and women were encouraged to actively participate in internship programs at regional river basin management agencies, which was highly successful. The work experience of NBI points out that: gender equality training should be ongoing and continuously refreshed, as well as specific and suitable for operational activities, clearly demonstrating the relevance of gender and the priorities of each institution; At the same time, schemes and projects must allocate sufficient resources to carrying out gender analysis and promoting gender-responsive planning [69].

- (4) **Strengthen river basin management mechanisms and funding guarantees for gender and social equity:** We should review and update management methods and incentives for basin-related aquatic and land resource systems, ecosystems, and economic systems. River basin planning and management process should be reviewed from the perspective of gender and social inclusion and the results should be used as an important source of information for evidence-based policy and social advocacy of each relevant department so as to focus on the experience, priorities, and needs of vulnerable groups in the design of research and actions. Pilot study work should be conducted suitably to raise awareness of proactive participatory and inclusive risk management and sustainable planning at the local level. Gender and social equity audit should be done for social security-based financial compensation and incentive plans. The degree of key institutions' priorities for gender issues in their daily work and the reflection in their budgets should be assessed, and gender perspectives should be included in budgeting, auditing and financing. Equal participation and profitable opportunities for men and women should be created in the financing process of climate related actions.

8 Policy Recommendations on River Basin Governance

- (1) **Act now on climate change and build a “watershed community of life”.** China should organize and disseminate a thorough understanding of the changes in its large river basins—because of human interventions and climate change—now and in future decades. This includes advocate of a “watershed community of life”, setting of new monitoring focused on the impacts of anthropogenic stresses and climate change, carrying out a risk assessment focused on a long-term basis (2050–2100), and preparing for more than one scenario.
- (2) **Improve security in view of extreme events and restore ecosystems.** Climate change will affect the number and intensity of extreme events, but the extent to which is uncertain. Pro-active strengthening is needed of protection against a wide range of natural hazards, including floods, droughts, wildfires, and landslides. Part of this strengthening can be obtained by applying nature-based solutions such as “room for rivers” action to restore river and lake systems, and thus rebalancing natural and man-made elements of the river basin landscape. A shift to regenerative agriculture can bolster lands resilience, while renewables should be sited on lands less suitable for other uses.
- (3) **Build resilient urban and rural settlements to improve Security and Resilience.** By making the right choices in the spatial layout of river basins, exposure and vulnerability to extreme events can be reduced, disaster risk is reduced at the beginning, and resilience of urban and rural settlements—including vulnerable groups—is increased. Using spatial layout wisely means taking the layout of the natural environment including rivers and streams—the

blue-green space—as a starting point for spatial planning and combining classical engineering with nature-based solutions. Accelerate the construction of “sponge cities”, a successful experience from China; advocate the group layout of cities to reduce the population density and land development intensity of built-up areas; pay attention to the coordination of urban and watershed flood control capacity to avoid disaster risks caused by different flood control standards.

- (4) **Develop comprehensive planning for key industrial port cities in a low-carbon era, selecting major tributaries and deltas for pilot exploration.** The economic planning horizon of 2050 will be heavily influenced by the global transition to a low-carbon future. This will particularly affect key industrial port cities. Ports will have to transform in response to the transition of handling large volumes of fossil fuels to facilitating regional growth based on renewable energy. Carbon-neutral and resilient infrastructure will require careful planning and smart investments. Many large port cities are flood-prone, necessitating foresight to address the risks and uncertainties of climate change. Thus, the spatial layout of ports will change, and so will shipping, industry, and the urban environment. Given the longevity of the hardware involved, the uncertainty of regional climate projections and the complexity of changing port city economies, it is urgent to start planning and consulting now. It is proposed to select major tributaries with high value and sensitivity, and the Yangtze River Delta region to carry out pilot exploration of comprehensive planning.
- (5) **Strengthen integrated water and land management of the basin.** Focus on shorelines. In particular, as a means to reduce risks and increase basin-wide resilience, promote transformation of selected downstream industrial port shorelines into ecological and living shorelines. Focus on integrated water and land management, treating river shorelines as long-term resource management. To ensure future strategic flexibility, shorelines should be maintained in their natural state as much as possible. Through the optimal use of shorelines and their replacement, we can support the goal of green carbon reduction in the river basin; we should pay attention to the cultural value of water and promote shoreline renewal and public space construction. At the national level, the “three lines and one list” of shoreline management should be formulated as soon as possible and the implementation should be monitored.
- (6) **Strengthen response capacities to improve the emergency response capabilities of local governments and the public.** An important element of resilience is being able to respond quickly and adequately to emergencies. Adaptation to the consequences of climate change calls for investments in monitoring and early warning systems, and in the response capacities of local governments and the public. In addition to these investments in disaster risk management, innovative insurance instruments will increase people’s resilience to extreme events. The Government should pay more attention to gender equality and social equity issues in disaster-prone areas and among disaster-prone people; and may well need to plan for flooding and drought scenarios simultaneously.

9 Programmatic Recommendations

In the scoping study for this SPS—Managing River Areas in Times of Climate Change—five high-level guiding principles were introduced as a framework to both select river cases for in-depth analysis by this SPS and structure Chinese or CCICED input for the 2023 UN Water Decade Conference. These principles address the system approach—from the headwaters to the coastal seas, a long-term perspective, the engagement of all relevant stakeholders, the inclusion of all stressors, and the need to strengthen and continue innovation. As stressed in the scoping study, these principles will play out differently in each individual river area. We will learn more about these principles, and possibly redefine them as we learn from the analyses of cases, globally.

The five high-level guiding principles are defined as five ‘themes of annual research’ for the successive years of the 5-year programme. Important aspects to be addressed throughout the 5-year program are decarbonization and green development (including ecosystem and wetland restoration, and keeping river banks free from urban and industrial development), sustainable development in the delta region, biodiversity conservation, systematic governance of river pollution, shipping modernization, sediment flows (including the link with biodiversity and ecology, and the link with hydropower), planning for both flood and drought scenarios driven by increased glacier melt, balancing adaptation and mitigation, and balancing engineering and nature-based solutions. In addition, a possible focus of research on these themes is presented as well (Table 3).

Table 3 Proposal for research foci in 5 subsequent years based on the 5 high-level guiding principles presented in the scoping study managing river areas in times of climate change

Research year	Principle/Theme of annual research	Possible research focus ^a
2022–2023	Make good on your responsibility stretching from the headwaters to the coastal seas	The mechanism for regional collaboration
2023–2024	Adopt a 100-year perspective and plan your steps	A proactive approach to adapt to projected climate change and increase resilience
2024–2025	Engage everybody who can contribute and develop a shared vision	The organization of collaboration in multi-subjects’ interests
2025–2026	Adapt to climate change and other principal river stressors in every aspect of the management of river areas	Dealing with the uncertainty of climate change and other stressors, and of disasters
2026–2027	Continue to strengthen and innovate	Management approaches, knowledge programs, policy tools and forward-looking financing mechanisms, etc.; international exchanges

^a The order over the years should be fine-tuned in view of opportunities to align with international events

The analysis and design focus questions for working visits should consider feedbacks between policies, such as the impact of decarbonization (moving away from fossil fuels) on land and water resources (such as water for irrigation of biofuel crops), and not address issues in isolation. Also, in designing future management of river basins, one should always consider more than one scenario.

The proposed 5-year program should take advantage of special occasions in each given year, such as the UN Water Decade Conference in early 2023, as they emerge. The work programme each year would see:

- A stock-taking paper.
- A work conference, with field visits if possible (otherwise, good video reports).
- A report to the AGM and the wider community reporting on lessons drawn and, importantly, identifying areas for development.

Along this line, it is proposed to co-organize, or align with, the following events:

- 2022/2023: (i) an international seminar considering River basins and Delta areas of the Yangtze, Rhine and Mississippi, with special focus on the transformational challenges of port city economies—October 2022; (ii) a side event or similar on water and biodiversity in the context of maintaining river systems, at or around the Biodiversity COP 15 in Montreal; (iii) building on the results of the envisaged event at the Biodiversity COP: a side event or similar at or around the UN Water Conference, March 2023.
- 2023/2024: work conferences on quantification of river basin health, of important e-flows such as sediment, and of progress towards acknowledged goals.

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Chapter 5

Sustainable Food Supply Chain



1 The Vision

China has several aspirations that will require dramatic transformations in the country's agriculture and food ("agrifood") systems (Box 1). Two aspirations in particular stand out and are the focus of this Special Policy Study: (1) Peaking national carbon emissions before 2030 and achieving carbon neutrality before 2060, and (2) achieving food security and resilience.

Box 1 Agrifood System

As used in this Special Policy Study, the "agrifood system" encompasses both the "on-farm" agricultural and food production activities, as well as the inputs upon which this production depends (e.g., production of synthetic fertilizer), processing and packaging, distribution, retail, and consumption. Land-use and land-use change associated with the agricultural and food production activities is also included in the agri-food system.

1.1 Achieve Carbon Peak Before 2030 and Neutrality Before 2060

In 2020, the Chinese government announced an aspiration to peak national carbon emissions (Box 2) before 2030 and achieve carbon neutrality before 2060 [1]. To jump start this effort, *the 14th Five Year Plan for National Agriculture Green Development* calls for reducing greenhouse gas (GHG) emission and increasing carbon

sink capacity within the agriculture and land sector (Ministry of Agriculture and Rural Affairs [2]). Both policy ambitions align with China's vision of becoming an "Ecological Civilization" [2, 3].

Box 2 "Carbon" = "Greenhouse Gases"

As used by the Chinese government, the term "carbon" in the context of the 2060 neutrality ambition means carbon dioxide equivalent (CO₂e), which encompasses all greenhouse gases (GHGs). Therefore, this Special Policy Study will address all GHGs generated by the agrifood system, primarily carbon dioxide, methane, and nitrous oxide. This study will consider direct GHG emissions (and sinks) in China. In addition, this study will consider GHG implications associated with agriculture goods imported into China from overseas, although those emissions are beyond China's direct control. Food import is an integral part of China's food security, while China is committed to global emission reduction. China can play a positive role in reducing emissions of these overseas agriculture systems.

As for achieving carbon neutrality, China's agrifood system must feature prominently in the overall national plan to address climate change. As President Xi Jinping said, "Decreasing GHG emissions and increasing the carbon sink of the agriculture sector and the rural area are critical measures for achieving carbon peaking before 2030 and carbon neutrality before 2060. Scientific accounting, actionable proposals and efficient measures should be taken". China's domestic agrifood system generates 8% of the country's annual total GHG emissions, including 40% of the country's total methane emissions and 50% of its total nitrous oxide emissions [4]. These emissions will need to be significantly reduced. Moreover, carbon neutrality can only be achieved if China's remaining unabated emissions (from energy, industry, and/or agriculture sectors) are counterbalanced by a dramatic increase in the country's carbon sink (e.g., sequestering carbon dioxide via reforestation).

1.2 Achieve Food Security

In April of 2020, President Xi Jinping declared that "food security is an important foundation for national security" [5]. Later in December of 2020, he stated, "The food of the Chinese people must be made by and remain in the hands of the Chinese. Everyone needs to take responsibility for food security" [6]. In the same vein, China's new "dual circulation strategy" calls for greater self-reliance in terms of production and consumption (including of food) in order to reduce international supply chain uncertainties [7]. More recently, in March 2022, President Xi articulated the importance of adequate grain and other food supplies, better farmland management, and

application of new technologies in support of food security [8]. It is important to note that these are not calls for full self-sufficiency with regard to food or other commodities but rather one for an appropriate combination of self-sufficiency and open trade. In addition, the agrifood system—especially with respect to improving human health, accessing safe and nutritious food, and reducing agriculture-generated pollution—is an important component of China’s efforts to achieve “common prosperity”. These and other priorities highlight that ensuring a sustainable supply of primary products, including food, is a major strategic issue for the country.

Given the above, a key question the country faces is, “*How can China transform its agrifood system in a manner that simultaneously supports food security and contributes to carbon neutrality?*” This CCICED Special Policy Study attempts to provide an answer. The Study begins by outlining the nature and scale of the challenge—the current state of play and developments within China’s agrifood system which pose obstacles to the achievement of these two aspirations. It continues by articulating the types of solutions that could address these obstacles. It concludes by proposing a suite of institutional innovations for pursuing smarter solutions. The report does not propose technical solutions to the myriad of food challenges a large, diverse country such as China is bound to have. In asking, “how could China implement these solutions?” the study highlights opportunities for institutional arrangements and leadership that can infuse the innovation and concerted effort needed to bring about the change at scale and within the timeframe sought.

The past two years have seen globally an unprecedented interest on the future food (particularly alternative proteins). A cursory review of studies and reports shows how much of this interest has been centered on China. We explicitly recognize the recent reports by Academy of Global Food Economics and Policy (AGFEP) given their comprehensiveness and sound analysis. We hope that our report adds value to our understanding of the future food in China and can help inform ongoing and future public and private sector policy discussions on these important issues for China.

2 The Challenge

In just 10 years, from 2000 to 2010, China also became one of the few developing countries where undernourishment is less than 2.5%. Daily calories supplied in that same period grew from 1800 to 3201 kcal/per person across the country and protein from 83 to 101 g/per person [9]. Most indicators of food availability and affordability are still growing, but, with that, the concern of policy makers and food experts about the hidden natural and social capital costs bankrolling this growth and the vulnerability of long supply chains. This section identifies the main challenges China will confront and be able to feed its population while protecting and restoring natural and social capital as the basis for a sustainable food system.

Last year and earlier this year, a consortium of leading academic institutions produced the China and Global Food Policy Report (2021 and 2022) which today are the most thorough and comprehensive account of China’s food systems and future

scenarios. The SPS relies heavily on these reports [10, 11] data and analysis of current trends as well as scenarios for the medium to long term. The SPS’s added value to this discussion is to focus on cross cutting and institutional issues that are critical to implement recommended actions.

2.1 Challenges to Achieving Carbon Neutrality (Aspiration 1)

China’s agrifood system generated 1.09 billion tons of CO₂eq in 2018, the third annual highest level [10]. This amount represents 12% of the 13 billion tons of CO₂eq emitted by China that year, a substantial increase from the 1997 level of 0.94 billion tons CO₂eq. Today, China’s food system carbon emissions make China the largest emitter in the sector, rivaling with India. But on a per capita basis, it is at 0.47 tons, one of the lowest emitters in terms of emissions from agricultural activities.

While GHG emissions from the country’s agrifood system span multiple sources, the majority come from agricultural activities (Fig. 1). Among the latter, methane from ruminant livestock (enteric fermentation and manure) and rice paddies are the primary sources of GHGs.

China’s agrifood system footprint also includes the GHG emissions of the food the country imports for domestic processing and/or consumption. Improvements in Chinese living standards and associated changes in diets (in particular rising animal product demand) are underway. Growing demand is difficult to satisfy solely by domestic production and supply, and therefore imports of a number of agricultural products have increased. For example, while Chinese consumer demand for beef in

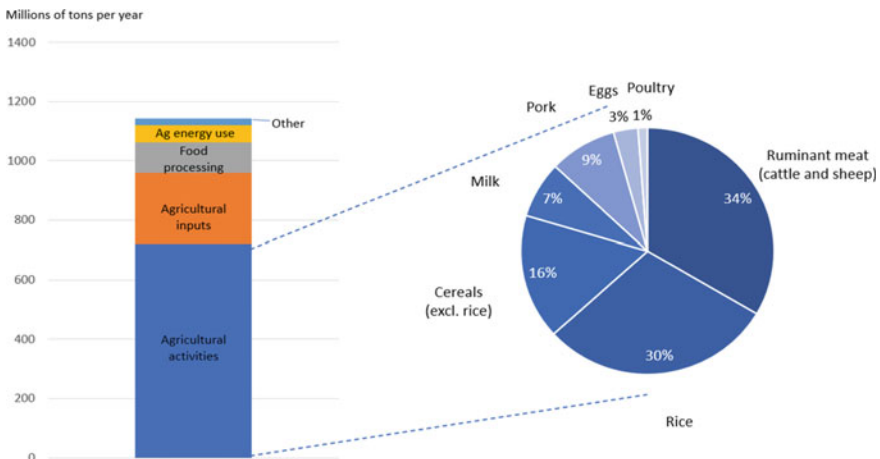


Fig. 1 Greenhouse gas emissions from China’s agrifood system (2017). *Source* AGFEP, CARD, CIFAIE, IAED, and IFPRI. 2021. 2021 China and Global Food Policy Report

2019 was 8.3 million tons, the country domestically could only supply 6.7 million tons [12].

The carbon footprint of China's agrifood system also includes GHG emissions from imported food used for domestic processing and/or consumption. With the improvement of Chinese people's living standard and shifts in diet (especially the increased demand for animal products), domestic production and supply cannot meet its growing demand. Therefore, the agricultural imports have increased accordingly. For example, China's consumption demand for beef in 2019 was 8.3 million tons, but China could only supply 6.7 million tons domestically [12].

Some of these imported foods are associated with a high climate footprint. For instance, beef, soybeans, and palm oil are leading direct causes of tropical deforestation [13]. Although the GHG emissions associated with the imports of agrifood products overseas should not be counted into the total emissions of China, the country can play an increasingly active role in global carbon emissions reduction through South-South cooperation in trade, foreign direct investment (FDI), and science and technology (S&T). This is consistent with President Xi Jinping's statement of the community with a shared future for mankind.

2.2 Challenges to Achieving Food Security and Resilience (Aspiration 2)

China's agrifood system faces at least four challenges to achieving food security.

2.2.1 Increased Environmental Pressures that Undermine Domestic Food Production Capability

- **Farmland degradation.** Agricultural production over a long time period has resulted in loss of soil fertility and heavy-metal pollution. According to the Ministry of Agriculture and Rural Areas (MARA), of the more than 2 billion mu (133 million ha) of cultivated land in China, more than two-thirds is considered "low-quality" (i.e., fourth to tenth grade in a 5–10 scale) [14].
- **Stressed domestic water supplies.** China is one of the countries with the poorest per capita water resources in the world while also having the largest water consumption in the world. In 2018, China's total freshwater consumption was more than 600 billion m³, with 369 billion m³ of this (61%) being consumed by agriculture [15]. Due to regional and climate differences, the distribution across time and space of agricultural water resources is uneven, and the shortage of water negatively affects agricultural development in water-deficient areas [16].
- **Increased risks from extreme weather due to climate change.** Studies show that, on average, climate change will reduce food production, raise prices, increase net imports of most food, and lower China's overall food self-sufficiency [17]. At

present, the per unit yield of China's three major grain crops decreases by about 2.6% when temperatures rise by 0.1 °C, and every 1% increase in precipitation levels increases 0.4% of yields. Considering the impact of temperature and precipitation on grain yield, climate change will have a certain impact on China's food security, which may partially offset the positive effects brought by technological progress [18]. In addition, natural disasters and extreme weather events (e.g., floods, droughts, unseasonably high/low temperatures) due to climate change can cause a significant loss in domestic agricultural and food production. In 2018, about 140 million people were affected by natural disasters with a total loss of 4 billion yuan, while in 2019 about 20 million ha in China were affected by natural disasters [19].

- While women account for a growing share of agricultural workers, women are more vulnerable than men to the negative effects of environmental damage in much of the developing world [20]. Gender awareness of climate change is gradually being strengthened and improved in social welfare guarantee policies, specifically regarding women's vulnerabilities in China. But more needs to be done to integrate gender to food and climate security strategy.

2.2.2 Increased Pressures on International Food Imports into China

- **Increased reliance on foreign imports.** Since China's accession to the World Trade Organization (WTO), the country's agricultural trade has entered an unprecedented stage of rapid development. While both agricultural imports and exports have grown, imports have grown much faster. Even with the EU countries taken as a whole, China is now the second-largest importer and fifth largest exporter of agricultural products in terms of economic value in the world, and its total trade volume of agricultural products has leaped to second place in the world [21]. In 2021, China imported 165 million tons of grain, an increase of 18% over the same period last year [22]. In particular, China's imports of soybean accounts for 86% of total domestic demands in 2021. Imported dairy products and beef contribute 35% and 24% of total supply amount respectively in 2020 [23].
- **Disruptions to global supply chains due to COVID-19 and trade conflict.** Given China's increased reliance on international trade for agricultural products, recent sources of disruption may have negative consequences for Chinese food security aspirations. The COVID-19 pandemic had a huge disruption on international trade during 2020 and 2021. Ramifications are still being felt, and future implications are unknown. Protectionist-oriented trade disputes with the United States continue to impact agricultural trade, especially for commodities such as soybeans and maize where the United States previously was a major supplier. Moreover, the 2022 Russia-Ukraine crisis is impacting agricultural trade in terms of food price and availability, particularly given the scale of grains and vegetable oils previously exported from Russia and Ukraine onto the global market.
- **Rise of sustainability expectations.** As outlined in a recent SPS on greening soft commodity value chains [24], "tomorrow's markets" are increasingly demanding

more sustainable food consumption and production. Domestic Chinese consumers appear to be moving in this direction. For instance, according to a survey conducted in 2022, more than 90% of consumers are willing to pay a premium for low-carbon food, and more than half of consumers are willing to pay a premium of more than 10% [25]. The business norms of multinational retailers and manufacturers of agricultural goods are rapidly shifting towards greater sustainability and are being applied equally across all geographies. Walmart's sustainability policies, for instance, apply to all Walmart stores [26]. These business norms include value chain policies. Walmart is working with its global suppliers to evaluate and share progress on key environmental and social issues in supply chains covering more than 100 product categories, including pulp, paper, and timber products [26]. The company applied this policy to all its stores worldwide; there was no separate policy for stores in Europe versus those in China. Financial markets are taking notice, too. A growing critical mass of institutional investors are developing investment guidelines to limit access to capital by borrowers whose investments in agricultural commodity production and trade result in tropical deforestation or high GHG emissions. In September 2019, for instance, 230 institutional investors representing \$16.2 trillion in assets under management called on companies to take urgent action in light of the devastating forest fires in the Amazon [27].

2.2.3 Pressures on Pollution and Food Safety

- ***Pollution due to overapplication of fertilizers, pesticides, and plastic films.*** According to the Bulletin of the First National Survey of Pollution Sources, agriculture was the main source of chemical oxygen demand (COD), total nitrogen (TN), and total phosphorus (TP) in China in 2007—accounting for 44%, 57%, and 67% of these total national emissions, respectively. In the *2020 Bulletin of the Second National Survey of Pollution Sources*, the emissions of COD, TN, and TP from agricultural pollution sources had decreased by 19%, 48%, and 26%, respectively, by 2017 compared with 2007, but these are still the main pollution sources. In terms of fertilizer utilization rate by crops, the rate for rice, corn, and wheat in China was 38% in 2017, a significant gap compared with the utilization rate of 50–65% of food crops in Europe and the United States [28]. Low utilization rates mean that a lot of fertilizer ends up polluting the air (e.g., in the form of the GHG nitrous oxide) or waterways.
- ***Concerns about food contamination and safety.*** In terms of crop production, excessive application of chemical fertilizers, pesticide residues, and heavy metal pollution threaten food safety, affect food quality, and can have a negative impact on dietary health. The risk of these pollutants exceeding health standards can restrict availability of safe and high-quality edible agricultural products. In terms of livestock, high stocking densities and risk of diseases can foster excessive antibiotic use. This in turn can result in the emergence of antimicrobial resistance, threatening both livestock and human health.

2.2.4 Impact on Food Consumption

- **Persistent malnutrition.** China achieved zero rates of poverty in 2020. Despite this, malnutrition problems remain, including micronutrient deficiency caused by unbalanced diets (mainly due to the lack of vegetable and fruit consumption). It is noticed that certain population groups such as infants, women in childbearing age, and the elderly face anemia and other malnutrition (National Health Commission [29]). The AGFEP (2022) [11] found that the intake of fruits, dairy, and aquatic products among rural residents is deficient. Moreover, the intake of vitamin A, vitamin C, and calcium is insufficient, especially for rural populations. The diet of urban residents mainly has the challenge of mild excessive intake, while the diet of rural residents has the double burden of mild excessive intake of calories and insufficient intake of nutrients.
- **Increase in share of population that is overweight or obese.** More than half of China's adult residents are overweight or obese, and the rate of overweight and obesity among children and adolescents has soared in recent decades [29]. Compared with the last decade, the dietary nutrition and health status of women have been greatly improved, but the intake of cooking oil and salt is still higher than the recommended value, and the overweight rate of women between 18 to 49 years old has increased significantly, reaching 30% [30].
- **High rates of food loss and waste.** In 2016, the comprehensive loss rate of all links of China's grain varieties after delivery was as high as 18% [31]. Post-harvest losses for meat are around 6.6% for pork, 5–9% for chicken, 8% for beef, and 4% for mutton [32]. Food loss rate of fruits and vegetables during storage and distribution was 15% and 10%, respectively [33].
- **Consumer food waste in China is high, too.** For example, the amount of food waste per person in school canteens (buffet meals) ranges from 61 to 74 g per meal, while restaurants range from 74 to 144 g per meal [34]. Based on a survey in Beijing, Shanghai, Chengdu, and Lhasa from 2013 to 2015, the food waste rate in China's catering industry is nearly 12%, and waste at large gatherings rises to as high as 38% [35].
- **Increased plastic pollution (from packaging).** China is the world's biggest plastic producer and consumer, and the food sector is a primary user. It is estimated that total plastic packaging for annual household packaging consumption is 5.4 million tons. A significant share of this plastic ends up as waste or even pollution.

3 The Solutions

A suite of solutions exist that can mitigate these challenges—reducing China's agri-food system's climate footprint while improving food security. These solutions would

help China *produce* more (and more nutritious) food, *protect* nature, *reduce* agrifood system inefficiencies and pollution, and *restore* degraded lands. These four categories of solutions should be implemented at the same time to avoid negative rebound effects.

3.1 Produce

Increasing China's ability to produce nutritious food while reducing the associated greenhouse gas emissions (and other forms of pollution) is an important pillar for achieving the two aspirations of carbon neutrality and food security. A range of technologies and practices exist to decouple food production from greenhouse gas emissions and pollution throughout the value chain (Table 1). These approaches address the main sources of greenhouse gas emissions from the agrifood system: ruminant livestock, rice, fertilizers, and agrifood-related energy use. These technologies and practices range from being "evolutionary" (e.g., they have been established for some time and merely need to scale adoption) to "revolutionary" (e.g., they are recent or future breakthrough innovations). Moreover, some offer opportunities for China to build a new industry to meet domestic (and increasing global) demand. For example, China could build an industry that manufactures plant-based alternative proteins (à la "Impossible Foods") or synthetic starches/proteins to meet growing Chinese demand (and at the same time reduce dependence on foreign food sources).

Complementing Table 1 are information and data technologies (e.g., land monitoring, agriculture input monitoring, early warning and response systems) that support implementation of the technologies and practices. Such information technologies also can integrate with risk-informed and shock-responsive social protection systems to strengthen risk management and early response capacities.

3.2 Protect

Protecting natural ecosystems and productive agricultural land from conversion to other uses are important components of achieving the two aspirations of carbon neutrality and food security.

- ***Avoid natural ecosystem conversion in China.*** Avoiding loss of natural ecosystems such as forests, wetlands, and grasslands helps retain the size of China's terrestrial carbon sink. Conversely, conversion of these ecosystems into farmland, settlements, and other forms of development would increase China's land-related carbon emissions. China has a number of measures already in place to avoid such conversion, including drawing ecological "red lines" and incorporating them into the national spatial plan, creating national parks, and establishing an eco-compensation scheme.

Table 1 Technologies and practices to reduce GHG emissions from food production

GHG emissions source	Annual emissions at stake (MtCO ₂ eq)	Technologies and practices that can reduce those emissions by an amount TBD
Ruminant enteric fermentation (meat and milk)	180	<ul style="list-style-type: none"> • Utilize enteric methane inhibitor feed additives (e.g., 3-NOP, seaweeds) • Improve ruminant breeding
Livestock manure	140	<ul style="list-style-type: none"> • Separate solids from liquids and manage dry solids (reducing emissions in animal housing) • Acidify manure or other options for improved liquid manure management (reducing losses during manure storage) • Utilize digesters in warm locations with large lagoons and use the CH₄ as biogas (at large-scale locations like communities or larger farms)
Livestock: cross-cutting (enteric fermentation, manure management)		<ul style="list-style-type: none"> • Boost ruminant livestock productivity and efficiency—reducing methane emissions per kg of meat and milk or per hectare of pasture—through improvements in: <ul style="list-style-type: none"> • Feed quality • Animal breeds • Veterinary care • Improve pasture and grazing management (e.g., rotational grazing, better grass mixes) • Produce plant-based or lab-grown alternative proteins (e.g., “Impossible Foods China”) and/or synthetic starches and proteins

(continued)

Table 1 (continued)

GHG emissions source	Annual emissions at stake (MtCO ₂ eq)	Technologies and practices that can reduce those emissions by an amount TBD
Rice cultivation	150	<ul style="list-style-type: none"> • Promote System of Rice Intensification (SRI) • Accelerate yield gains to reduce needed flooded paddy area • Breed lower-methane-emitting rice • Remove rice straw from fields or incorporate it into soils in the off season • Reduce flooding periods (e.g., alternate wetting and drying, single mid-season water drawdown, dry seeding) • Use biodegradable plastic films for rice cultivation
Crops: cross-cutting	120	<ul style="list-style-type: none"> • Boost crop yields per hectare (thereby reducing cropland needs per given amount of crop production, reducing emissions per hectare and liberating land for restoration)
Fertilizers	160	<ul style="list-style-type: none"> • Reduce overapplication of fertilizers (e.g., “4R management” = right amount, right type, right time, and right places) • Increase plant absorption of fertilizers (nitrogen use efficiency) through management changes, nitrification inhibitors, and/or breeding biological nitrification inhibition into crops • Boost crop yields via better breeding and varieties (thus reducing need for more fertilizers) • Use nitrogen-fixing legumes in crop rotations and inter-cropping
Food processing and packaging	110	<ul style="list-style-type: none"> • Improve energy efficiency • Shift to renewable energy sources • Reduce food packaging

(continued)

Table 1 (continued)

GHG emissions source	Annual emissions at stake (MtCO ₂ eq)	Technologies and practices that can reduce those emissions by an amount TBD
Direct agriculture energy use	120	<ul style="list-style-type: none"> • Improve energy efficiency of farm equipment • Shift to renewable energy sources for farm equipment • Electrify farm equipment
Indirect agriculture energy use		<ul style="list-style-type: none"> • Reduce NH₃ and N₂O emissions during fertilizer manufacturing • Improve energy use efficiency during fertilizer, film, and pesticide production
Total	980	

Memo Annual emissions at stake are calculated figures from FAOSTAT 2021. The amount from this total to be potentially reduced through the technologies listed remains to be determined. Data obtained from FAOSTATS 2021

- ***Avoid triggering natural ecosystem conversion outside of China.*** Besides protecting *domestic* natural ecosystems, it is also important that Chinese avoid imports of agricultural commodities (e.g., beef, soy, palm oil) associated with *international* ecosystem conversion and associated GHG emissions. Strategies include implementing “deforestation free” or “ecosystem conversion free” supply chain agreements with source country governments and companies, putting in place monitoring and tracking systems to support such agreements, and providing gender-responsive and inclusive technical and financial assistance to exporting countries to support their efforts to supply agricultural commodities while avoiding deforestation. China’s “Food Silk Road” programs provide an opportune vehicle for putting in place such measures.
- ***Prevent loss of prime Chinese agricultural land.*** Ensuring that productive Chinese croplands and grazing lands remain in production is a critical component of achieving domestic food security. Absent any changes in demand, loss of prime agricultural land reduces China’s ability to feed itself and increases pressure to convert natural ecosystems into agricultural land—domestically and/or internationally. According to the Ministry of Natural Resources, China’s farmland area decreased by 7.3 Mha from 2009 to 2019 [36]. Satellite imagery shows large areas of cropland loss throughout mainland China, especially in the eastern portion of the country, since 2000. A number of measures could counter this trend. For instance, the Chinese government has already set a “red line” of 120 million ha of cropland to prevent the “non-agriculturalization of arable land” [37].
- ***Prevent loss and degradation of freshwater resources.*** Besides arable land, a critical resource for food production is freshwater. Like land, this resource needs to be conserved, especially since China on average is one of the most water-scarce

countries in the world [38]. The agriculture sector uses 62% of total freshwater consumption in China [39] and accounts for 50% of chemical oxygen demand, 47% of nitrogen pollution, and 67% of phosphorus pollution in China [40]. The effective utilization coefficient of farmland irrigation water is 0.56 [39], which is lower than that of developed countries (0.7–0.8) [15]. Measures for conserving clean freshwater resources for agriculture include water-efficient irrigation, more efficient water transmission and distribution infrastructure, drought and stress tolerant crop varieties, reduced fertilizer applications, and better recovery of livestock manure.

3.3 Reduce

Reducing inefficiencies and pollution in China's agrifood system and reducing levels of unhealthy diets can contribute to China achieving its carbon neutrality and food security aspirations. Five areas needing some form of "reduction" include:

- **Reduce food loss and waste.** Reducing food loss and waste would provide a triple win of improved food security, reduced financial losses for farmers and consumers, and lower environmental impacts (e.g., GHG emissions, water consumption, pesticide/fertilizer pollution). Numerous approaches to reducing food loss and waste per stage of the food value chain exist [41], with many relevant for China. Modeling suggests that reducing Chinese food loss and waste relative to the baseline would lower the country's agricultural GHG emissions by 2.0–5.6% by 2030 and 4.0–7.0% by 2060 [10].
- **Reduce chemical pollution from agricultural production.** Several approaches for doing so exist. For example, precision agriculture can increase the utilization rates of fertilizers and pesticides, thereby lowering the total amount of inputs applied and amount of runoff into the environment. Buffer zones of natural vegetation around farm fields and in riparian areas can reduce input runoff. In some situations, integrated pest management approaches can lower pollution while maintaining yields.
- **Reduce use of plastics in agrifood system and increase rates of recycling.** Options include promoting the promulgation and implementation of new national standards for plastic films, improving plastic film thickness standards, increasing the tensile strength and elongation at break of plastic films, and ensuring the recyclability of plastic films from the source.
- **Reduce inefficiencies and use of fossil fuels in agriculture energy.** Options include renewable energy sources for farm equipment, food storage, and transportation.
- **Reduce consumption of unhealthy, unsustainable, carbon-intense diets.** A first step in improving the health and sustainability of Chinese diets is to encourage citizens to follow the Chinese Dietary Guidelines and, even better, the EAT-Lancet diet [42]. Such diets would reduce GHG emissions while ensuring nutritional requirements. Such a shift could reduce GHG emissions by 150 million to 200

million metric tons by 2030, a reduction of 18–25% [10]. Future Chinese nutrition and dietary guideline should take into consideration gender implications, sustainability, and climate change.

3.4 Restore

Restoration of natural ecosystems and agricultural soils are important components of achieving the two aspirations of carbon neutrality and food security.

- **Restore natural ecosystems.** Restoring native ecosystems in China is the primary means of generating the “negative carbon emissions” the country needs to compensate for its difficult-to-abate agriculture and energy GHG emissions. Without such restoration, China will be unable to achieve “carbon neutrality” before 2060. Ecosystems to restore include forests (which have the largest carbon content per hectare), grasslands, and wetlands. Forests are particularly important because, among terrestrial ecosystems, they currently contribute about 80% of the country’s annual carbon sequestration [4]. Targeting restoration in marginal areas such as slopes, riparian zones, and low-agriculture-productivity areas would reduce the risk of creating land-competition for food production. To maximize carbon sequestration, biodiversity benefits, and resilience to climate change, ecosystem restoration should prioritize a diversity of native flora and fauna; monoculture restoration efforts tend to generate fewer benefits and be more susceptible to collapse due to weather extremes or disease [43].
- Currently, forests occupy 23% of the country’s land mass. China already has a stated goal of restoring “up to 25% of land area in forests” by 2030 [3]. Following through on this goal would lead to annual carbon sequestration on the order of 230 million tons per year by 2030 [43]. Some studies suggest a maximum potential of China’s forest coverage to be 28–29% of national land area [43]. Achieving that level of forest coverage would boost China’s carbon sink to 2.1 billion tons per year by the year 2060 [43].
- **Restore degraded agricultural soils.** Restoring soil health can help reduce carbon losses to the atmosphere and reduce pollution of waterways. More importantly, it can contribute to the “Produce” strategy by improving long-term farm yields, moisture retention, soil organic matter, farmer livelihoods, and resilience. Likewise, it supports the “Protect” strategy by reducing the need to expand agricultural area to meet national food needs. Approaches to such restoration include agroforestry and silvopastures practices (integrating trees into croplands and grazing lands), reduced or conservation tillage, mulching, crop rotations, and cover crops. Ensuring that women farmers also have access to restoration techniques, given their concentration in agricultural activities and lesser access to technical training and information, would support expansion and widespread adoption of these practices.

- China is already taking some steps in this direction. For example, China has implemented a conservation tillage plan in the “black land” area in the northeast of the country. By 2030, the restored area will be 17 Mha [44]. Estimates are that organic matter in soil will increase by 10% after 5 years and by 52% after 15 years [45].

3.5 Quantification of Emissions Reduction Potential

This combination of solutions—produce, protect, reduce, and restore—could result in China’s agrifood system contributing to national 2060 carbon neutrality. The level of contribution to neutrality will be a function of the degree of implementation. Figure 2 shows the impact on domestic Chinese GHG emissions of many of the “produce” and “reduce” strategies, against 3 implementation scenarios. Table 2 describes the scenario designs. Emission reductions would be even greater if the “protect” and “restore” strategies were pursued.

The scenarios highlight several important insights, including:

- Under BAU, GHG emissions from agrifood systems reaches 1.17 billion tons in 2030, an increase of 7.7% compared with 2020, and then they further decline to 1.09 billion tons in 2060, returning to their level of 2018.
- Measures such as improving agricultural technology, reducing food loss and waste, shifting dietary patterns, enhancing energy efficiency, and optimizing the energy consumption structure substantially reduce GHG emissions from agrifood systems.
- In the low, medium, and high scenarios, GHG emissions from agrifood systems in 2060 are 17–63% lower than under BAU and 19–63% lower than in 2020.

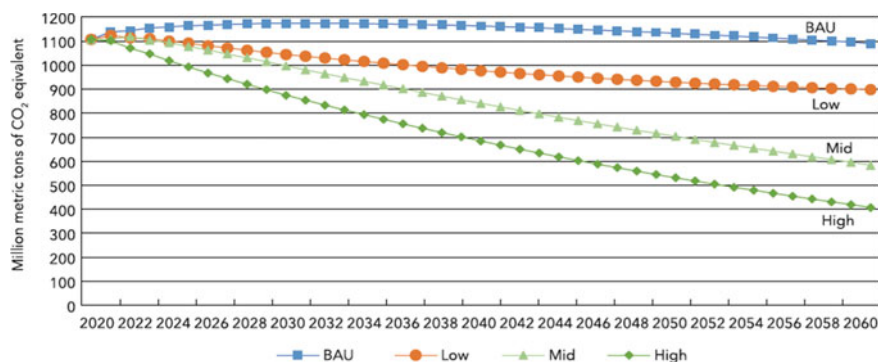


Fig. 2 Greenhouse gas emissions from agrifood systems in China under different scenarios, 2020–2060. *Source* Results of China Agricultural Sector Model (CAAS and IFPRI) and China Dynamic General Equilibrium Model (AGFEP, 2021). *Note* BAU = business as usual

Table 2 Scenario design for modeling greenhouse gas emission reduction of agricultural activities in China, 2020–2060

Area	High-level scenario	Medium-level scenario	Low-level scenario
BAU	<p>Yields of rice, wheat, and maize in 2020 were 7, 5.7, and 6.3 tons/ha, respectively, which will be increased by 10%, 15%, and 25% in 2060, reaching 7.7, 6.6, and 7.9 tons/ha, respectively</p> <p>The loss and waste rate of rice, wheat, and maize is 15%; of vegetables and fruits are 55% and 50%, respectively; and of pork, beef, and mutton are 15%, 10%, and 10%, respectively</p> <p>Urban and rural residents' per capita consumption of livestock and poultry meat will be 223 g per day in 2060</p> <p>In 2060, fertilizer use efficiency will be increased by 20%; the emission coefficient of rice fields will be reduced by 20%; the coefficients of carbon emissions from pork, mutton, and poultry meat will be reduced by 15%, 25%, and 30%, respectively; and the coefficients of carbon emissions from beef, poultry eggs, and milk will be reduced by 10%</p>		
Tech-CR	<p>Yield of rice, wheat, and maize in 2060 will be increased by 25%, 40%, and 50%, respectively, as compared with 2020; fertilizer use efficiency will be increased by 50%; and the coefficient on emissions from rice fields will be reduced by 50%</p>	<p>Yield of rice, wheat and maize in 2060 will be increased by 20%, 35% and 45%, respectively, as compared with 2020; fertilizer use efficiency will be increased by 40%; and coefficient of emission from rice fields will be reduced by 40%</p>	<p>Yield of rice, wheat and maize by 2060 will be increased by 15%, 25%, and 35%, respectively, as compared with 2020; fertilizer use efficiency will be increased by 30%; and coefficient of emission from rice fields will be reduced by 30%</p>
Tech-LV	<p>The coefficient of emissions from livestock products in 2060 will be reduced by 50%, with the feed conversion rate improved by 30%</p>	<p>The coefficient of emissions from livestock products in 2060 will be reduced by 40%, with the feed conversion rate improved by 20%</p>	<p>The coefficient of emissions from livestock products in 2060 will be reduced by 30%, with the feed conversion rate improved by 10%</p>
Waste	<p>The loss and waste rate of each product in 2060 will be 67% lower than that in 2020</p>	<p>The loss and waste rate of each product in 2060 will be 50% lower than that in 2020</p>	<p>The loss and waste rate of each product in 2060 will be 33% lower than that in 2020</p>
Diets	<p>Per capita consumption of livestock and poultry meat by urban and rural residents in 2060 will be reduced to the lower limit recommended by the dietary guidelines, of 40 g per day</p>	<p>Per capita consumption of livestock and poultry meat by urban and rural residents in 2060 will be reduced to the median level recommended by the dietary guidelines, of 60 g per day</p>	<p>Per capita consumption of livestock and poultry meat by urban and rural residents in 2060 will be reduced to the upper limit recommended by the dietary guidelines, of 75 g per day</p>
Comb	<p>Combination of the above scenarios</p>	<p>Combination of the above scenarios</p>	<p>Combination of the above scenarios</p>

Source AGFEP (2021)

- The medium-level scenario would contribute to a reduction of 47% of GHG emissions in agrifood systems in 2060, compared with 2020.

4 Recommendations

Six policy, governance and institutional innovations are recommended to enable the leadership, innovation, and concerted effort to accelerate China's food system transformation. The arch of these recommendations is not linear, although a certain degree of sequencing will be needed. As stated above, the objective of this Special Policy Paper is not to formulate products or practices that can be deployed to achieve prescribed outcomes. The food system is a complex system that requires not a cluster of projects, but a process to engage the relevant institutions in developing solutions that respond to multiple interdependencies. These six recommendations are intended to create and support this process.

4.1 Develop a National Food System Transformation Strategy

To draw clear national objectives and paths to realistic, necessary, and sufficient outcomes, a “China National Food System Transformation Strategy” could define a 2060 vision and a 2030 Action Plan, which will need to be:

- Science-based—incorporating the latest technical advances supporting a food and land use system transformation and the approaches or tools for assessing and managing trade-offs between solutions and objectives.
- Accountable—internally coherent to deliver explicitly stated and measurable goals while supporting and relying on the relevant components of China's Carbon Neutrality Plan, 5-year plans, and the National Determined Contribution (NDC) to the Paris Agreement on climate change.
- Multisectoral—governed by an inter-ministerial committee to ensure various ministries and other relevant institutions contribute what is in their purview, address and manage trade-offs inherent to the solutions, and streamline decision-making.
- Gender responsive—as the different goals are agreed, the strategy will explicitly bring the voices of women in the establishment of a vision for the future food system and the charting of pathways to get there.

The strategy should ideally be driven by an inter-ministerial committee responsible for overseeing the development and implementation of the strategy, ensuring various ministries do what they need to do for their contribution to the strategy, discussing and managing trade-offs, and streamlining decision-making. The council could include representatives from ministries of agriculture, environment, trade, health and food safety, women, planning, and finance. The committee could be

the same one that was recommended by the 2020 CCICED Special Policy Study, “Greening China’s Soft Commodity Value Chains”, tasked with overseeing China’s green value chain strategy. Thus, there would be one inter-ministerial committee for the entire agrifood system transition, covering domestic and international food systems.

Relevance of the recommendation. Food, as vitally important as it is, is for the most part not treated as a sector by most governments. Food is defined by the institutional and market forces impinging on it. Without a deliberate effort to make this institutional space coherent and oriented towards shared goals, it is unlikely that the challenges listed in Section II can be overcome. This is not a recommendation to create an additional bureaucratic structure, but to create a process to develop a vision shared by the relevant stakeholders and to identify the trade-offs across the sectors that need to be resolved if the food system outcomes are to be achieved.

4.2 Repurpose Agricultural Fiscal Incentives and Finance

To advance the solutions, China could launch a concerted effort to redirect significant financing in support of its national food and climate security goals. Much of this repurposed agriculture support should be geared toward research and development (R&D) for technology solutions that are not yet market ready, as well as toward deployment programs to increase market penetration of solutions that are already in the market. Such repurposing and design of cross-sectoral fiscal incentives can signal a shift away from traditional production toward better production efficiency, nutrition, and sustainability.

- Potential sources of public financing may include: (a) redirecting existing agricultural subsidies away from programs incentivizing agricultural practices that have proven unsustainable; and (b) taxing activities that increase the climate footprint of China’s agrifood system.
- Potential uses of these resources may include: (a) financing solutions delineated in this study as framed by the National Food System Transformation Strategy; (b) funding of place-based ecological compensation programs, applying lessons learned from the inter-provincial ecological compensation mechanism used for the Xin’an River; and (c) and providing technical assistance to farmers for adoption of improved land-use management.
- Additional financing may be attracted from the private sector by the government providing policy and financial support (e.g., “first-loss” risk reduction) to encourage private sector companies and banks to invest in research, development, and/or deployment of solutions outlined in this study.

Relevance of the recommendation. Clearly, the transformation of China’s food system will require substantial financing. New research will need to be funded, capacity to develop and apply new technologies will need to be enhanced, etc. But in many ways, stop funding or subsidizing that which moves the system away from

its desired outcomes is as, if not more, powerful to shift norms and help develop the behaviors that are needed to align investment with desired outcomes.

Parallel to this SPS, another study sponsored by the CCICED is being developed on Innovative green finance. The study on finance provides an in-depth assessment of the different mechanisms that can be established to bankroll the food transition, particularly as some of the solutions identified in our food paper represent opportunities for integrating climate with nature finance. A subsequent step in the development of this ideas could be a join seminar of the groups working on each of the two SPS and further identify areas of opportunity for mutual leverage.

4.3 Healthy Diets and Consumption

China's major food production and consumption transformation over the last three decades have been largely driven by specific changes in dietary preferences and affordable choices available. The overall trend in food consumption is characterized by a reduction in the consumption of basic grain staples and an increase in the consumption of animal-based food. While the rural population lags behind the urban population in these trends, most assessments indicate a significant growth potential in rural areas.

The major consequences of nutrition levels of these changes include an initial improvement on caloric and proteinic intake followed by an increase in cardiovascular disease and prevalence of obesity once a certain level of carbohydrates has been surpassed. The access to richer foods is largely facilitated by the processing and retailing of food products that tend to recreate the western diet, including a prevalence of processed and ultra-processed food. Up until now the government's dietary guidance has been limited, leaving the door open for supermarkets and other commercial retailers to shape the diet of many in China.

A dietary-guidance initiative could center on the development of a gender-responsive and inclusive national program for encouraging a healthy and sustainable diet (in accordance with recommended dietary guidelines), that takes into account the needs of a diversity of women and men from both rural and urban areas, based on, but not limited to:

- Strengthening awareness messaging, package labeling, and food marketing laws, etc.
- Linking a healthier diet with a sustainable production scheme aimed at increasing the production of fresh fruits and vegetables by Chinese smallholders (an oft overlooked sector) and increasing access to fresh fruits and vegetables by Chinese consumers
- Expanding the national Clean Plate Initiative to tackle food waste (and associated plastic waste) at retail (including the shopping environment), food service (including e-commerce), and household levels

- Promotion of alternatives to animal protein, particularly from beef, including synthetic meat, plant-based processed protein rich meals, etc.

Relevance of the recommendation. When well informed, citizens prioritize health and healthy lifestyles as a major factor in shaping their diets. Public health and the environment overlap around food in a significant way; decisions by food processors have health and environmental consequences at a significant scale. Food produced and processed as guided by the opportunities in the market need to be balanced with a non-commercial set of guidelines that consumers feel compelled to base their food choices on. Fortunately, in many ways what is good for health is also good for the environment. Getting the right alignment between what is marketed and what is nutritionally needed should be achievable in the short term, but for that to happen information, education and government incentives need to be adequately aligned.

4.4 Accelerate the Agrifood System Transformation Through Private Sector Leadership

In close coordination with public institutions, including the proposed National Food System Transformation Strategy and the inter-sectoral food system committee, the private sector could specifically help accelerate investment and innovation across the supply chain through:

- Supporting efficient but fair consolidation of farmland. Farm size is critical when deploying the adoption of new technologies at scale, with larger areas being preferred given the investments needed. Private companies could help create financial arrangements whereby small landholders can participate in collective efforts to achieve scale without risk of losing their land.
- Supporting food safety programs. While food safety is ultimately a responsibility of government at different jurisdictional levels, the private sector can make this task more manageable and efficient by introducing the traceability protocols and technology needed to manage integrated supply chains.
- Providing and enabling dietary guidance. While remaining commercially viable, large food retailers can play a significant role in educating and guiding consumers on practical ways to adhere to government-backed dietary guidelines.

This private sector initiative calls for the development of mechanisms that favor the exchange of information among supply chain actors, including the perspectives of women and other marginalized groups within the supply chain, agreement on standards, and feedback to government agency on policy application challenges and opportunities.

Relevance of the recommendation. The private sector has evident advantages in the pursuit of a secure, safe and sustainable food system. Through business consolidation, supply chains become more manageable and controllable. This is because fewer actors can exert influence at a scale that a highly fragmented producers base,

distribution and retail simply cannot. Businesses can innovate practices and products at a rapid rate to adapt both to regulations and consumer demand. By being a key point of contact between production and consumption, businesses are in a privileged position to educate and guide residents towards healthier and more sustainable consumption behaviors.

4.5 Incentivize Alternative Sources of Protein and Food Technology

Most analyses on the impact of diet and health and the environment conclude that reducing the amount of meat consumption is the single-most efficient way to curb the rapid growth rate of cardiovascular disease and carbon (particularly methane) emissions. Reduction on overall meat consumption should be part of a multi-faceted initiative to sensitize residents to the risks and impacts of meat consumption while actively seeking for and developing alternative sources of protein, including plant-based and synthetic meat. Such efforts are today being developed largely by private entrepreneurs facing a significant learning curve.

As stated above, the private sector efforts in this regard can be accelerated with the right policies and incentives in place. As a key stakeholder, the government should create the enabling conditions and incentives for Chinese companies to become major global manufacturers of alternative proteins (e.g., plant-based meats like *Impossible Foods*, lab-grown meats) and alternative starches. Doing so the government will be helping:

- Meet growing domestic and foreign demand for protein
- Address climate change and land competition
- Create an entire new industrial sector for China that China could lead the world on.

Relevance of the recommendation. A significant accelerator of the desired transformation of the food system in China will be innovation and technological leadership. China as a food powerhouse in the world is in a unique position to develop its own food revolution given the virtuous cycle shaped by tradition and innovation. Moving away from the position of “taker” of western food habits to one where China sets the future of protein uptake, for instance, can have tremendous positive impact both domestically and globally.

4.6 Green International Food Value Chains

China could pursue a program to ensure that the food it imports is low carbon, thereby helping reduce food supply GHG emission. The 2021 report of the CCICED Special Policy Study, “Greening China’s Soft Commodity Value Chains”, identified several

measures for this program. Food and other agricultural goods are the dominant form of “soft commodity” (Box 3). The recommendations from the 2020 Study were approved and endorsed by the China Council in 2020. These recommendations are a critical component for sustainable food supply chains overall and would help meet China’s food and climate security goals. As such, the 2020 recommendations are worth reinforcing in this current Special Policy Study:

4.6.1 Establish a National Green Value Chain Strategy and Provide Policy/Institutional Support

- Announce a new Chinese policy initiative on greening soft commodity value chains
- Establish an Inter-Ministerial Committee (see above)
- Establish a “Global Green Value Chain Institute”

4.6.2 Adopt Mandatory and Voluntary Measures to “Green” Soft Commodity Value Chains

- Strengthen measures to reduce the import of soft commodities from illegal sources
- Strengthen due diligence and traceability systems
- Invest in domestic capacity to rationalize food value chains and improve sustainable diets

4.6.3 Leverage Existing Chinese Policy Levers and Initiatives Including the Belt and Road Initiative

- Incorporate green value chain measures into trade agreements
- Increase Chinese South-South development assistance to support green soft commodity value chains
- Integrate finance for green soft commodity value chains with green finance and the work of the BRI International Green Development Coalition

Box 3 What Are “Soft Commodities”?

“Soft commodities” refer to raw materials and their derivatives that are grown or produced by the agriculture and forestry industries. These include plant- and animal-derived material for use as food, fiber, feed, medicines, cosmetics, detergents, and fuels. These contrast with “hard commodities”, which are raw materials and their derivatives that are extracted or mined, such as metals, oil, and natural gas.

In parallel to this SPS, another CCICED study has been developed on Sustainable Trade and investment. There are several points of overlap between green supply chains and trade and investment. For instance, how to use and work within trade rules to ensure that environmental and climatic priorities can coexist with fluid trade, for the benefit of importer and exporter. It is in the best interest of traders to lift the standards of the commodities they trade around the globe. The study on trade provides an excellent analysis of synergies that food mediates between trade and the environment, but also of the difficulties and frictions that can occur in trying to resolve trade-offs across countries without positive cooperation.

5 Concluding Remarks

Combined, these six policy, governance, and institutional recommendations would set China's agrifood system on a path to simultaneously achieve food security and carbon neutrality. Each of these recommendations is within China's power to implement. And each would generate many co-benefits including improved human health and new Chinese industries.

The time to act on these recommendations is now. The emerging global food crisis triggered by the Russia-Ukraine conflict, inflation, and climate-induced crop failures is putting food security near the top of national agendas. These recommendations ensure that when China addresses the near-term food challenge it does so in a way that addresses the long-term challenge of climate change.

For China, as for the world, food security and climate security must go hand in hand.

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Chapter 6

The Key Pathways on a Green and Low-Carbon BRI



1 Developing Green and Low-Carbon Energy: Key Path to Green and Low-Carbon BRI

On September 21, 2021, at the General Debate of the 76th Session of the UN General Assembly, President Xi Jinping announced that China will step up support for other developing countries in developing green and low-carbon energy, and will not build new coal-fired power projects abroad. This is another key move since China announced its “twin carbon goals”, made the commitment to strictly control coal-fired power projects and coal consumption growth during the 14th Five-Year Plan period (2021–2025), and launched the National Carbon Emission Trading Market, gaining positive response from the international community and creating new momentum for global climate governance. In his opening remarks to High-Level Dialogue on Energy, UN Secretary-General António Guterres also pointed out that “investing in clean, affordable energy for all will improve the well-being of billions of people. It can create the green jobs that we urgently need for COVID-19 recovery” [1].

Developing green and low-carbon energy is not only a **key move** to link to the United Nations 2030 Sustainable Development Goal (SDG) 7 “Affordable and Clean Energy”, SDG 12 “Responsible Consumption and Production”, and SDG 13 “Climate Action”; but also a **key path** to promote the green and low-carbon development of the Belt and Road. For many developing countries, access to affordable, renewable and sustainable clean energy is **the realistic need** to reduce the reliance on fossil energy, secure green and low-carbon energy development, and actively respond to global climate crisis. It is also a **prerequisite** to realize post-pandemic green recovery and march towards a “carbon-neutral” future.

Given such context, this chapter will start from the real-life demand of BRI participating countries to address the global climate crisis, and elaborate on their most significant needs in developing green and low-carbon energy from three perspectives: industrial and technology upgrade, financing, and international cooperation.

The following chapters will further propose key paths for promoting green and low-carbon energy development under the framework of the BRI from the aspects of technological cooperation, investment and financing cooperation, and environment and climate cooperation.

1.1 Real-Life Demand for Solutions to Global Climate Crisis

As of March 2022, China has signed more than 200 cooperation documents with 149 countries (including 52 African countries, 38 Asian countries, 27 European countries, 11 Oceanian countries, and 21 American countries) and 32 international organizations such as ESCAP and UNDP to jointly build the Belt and Road [2]. According to current researches, most of BRI participating countries¹ (hereinafter referred to as “participating countries”) are developing countries with fragile ecological environment, relatively low ecological carrying capacity, and economic development with prominently high carbon emission levels and intensity, so that they are quite sensitive to climate change [3, 4]. Among them, there are some emerging economies with strong economic growth, but there are more developing countries with monotonous economic structure, prominent resource and environmental constraints, and low levels of infrastructure development and energy accessibility. Compared with a few emerging economies, most of these countries are at the stage of development where economic growth is the prominent demand and people’s livelihood and welfare are the priority. With limited economic, human and technological resources at their disposal, these countries are more dependent on their natural resource endowments and are lack of climate resilience, while being highly susceptible to path dependence on a high carbon emission development model driven by fossil energy.

As a study shows, for the 68 participating countries alone as of the end of April 2017, their total CO₂ emissions increased by about 85% between 2000 and 2015, more than twice the world average. At the same time, the carbon intensity of these countries was also relatively high, at 0.83 tCO₂/kUS\$ in 2015, which was 1.8 times the world average [5]. Recent studies have also pointed out that by the end of 2019, the carbon emissions of the 146 participating countries accounted for about 30.8% of the world’s total, significantly higher than their share of 22.1% of the world’s GDP, and the growth rate in the last five years was much higher than that of other regions [6]. Since most of the participating countries are still in the early stage of economic and social development with heavy tasks of modernization, industrialization and urbanization, the trend of high carbon emission intensity will be maintained for a certain period of time, resulting in a fact that the total carbon emissions will continue to increase. Studies have shown that if the high-carbon growth pattern in history (the “worst-case scenario”) continues, the global share of carbon emissions in the participating countries will be as high as 76% by 2050 [7]. **Therefore,**

¹ The BRI participating countries mentioned in this report refer to countries that have signed cooperative agreements or MOUs with China with regard to BRI.

under the global trend of carbon neutrality, promoting BRI green and low-carbon energy development is of outstanding strategic value and positive practical significance for addressing the climate crisis and achieving the UN 2030 Sustainable Development Goals in participating countries.

1.2 Transition Demand for Energy Mix Adjustment and Technology Upgrade

Energy mix adjustment and technology upgrade are important tasks in green and low-carbon energy transition. For many participating countries, achieving green and low-carbon transition in the energy sector requires balancing two needs. On the one hand, there is a need to balance the accessibility and affordability of energy supply while ensuring energy security; on the other hand, there is a need to accelerate the development of clean energy and get rid of the over-dependence on fossil energy while ensuring smooth and efficient energy supply.

Take Southeast Asia as an example. Due to the convergence of the world's fastest-growing economies including Indonesia, the Philippines, Vietnam, etc., the energy demand in Southeast Asia has been growing at a yearly rate of about 3% over the past 20 years. According to IEA estimates, this trend will continue until 2030, and about 75% of the new energy demand will be met by fossil energy, leading to a nearly 35% increase in CO₂ emissions in the region [8]. As one of the world's most vulnerable regions to climate change [9, 10], although Southeast Asian nations are actively promoting green and low-carbon development in the energy sector, they are still facing outstanding challenges featured with the contrast between surging demand and fragile energy security environment, strong willingness for transition and heavy reliance on fossil energy, great potential for renewable energy development and low contribution, as well as accelerated regional power infrastructure development and insufficient investment. For the broader range of BRI countries, **there is also an urgent need to transform the energy sector with clean energy technology development, and balance the needs for energy supply, affordability, energy efficiency and energy security as much as possible, as a key step towards regional green and low-carbon development.**

The existing studies have concluded that the demand for climate change mitigation technologies in the energy sector of the BRI countries is mainly focused on renewable energy development and energy efficiency improvement, and has certain regional characteristics [11]. On the one hand, from the perspective of types of needs, based on the content analysis and need assessment of 138 countries' TNA reports, it is revealed that nearly 90% of the participating countries have put forward technology needs in the energy sector. Among them, 75% of the countries need renewable energy power generation technologies, such as photovoltaic

power generation, hydroelectric power generation, etc. (photovoltaic power generation technology has the highest demand); 44% of the countries need clean and efficient combustion technologies, such as high-efficiency boilers, combined cycle gas turbines, etc.; 38.5% of the countries need non-fossil fuel production technologies, such as biomass energy, etc. On the other hand, in terms of regional characteristics, there are significant differences in technology needs in different regions due to geographical and economic factors. Asia has the most prominent technology needs in the energy sector. In addition to the significant demand for renewable energy technologies, its demand for clean and efficient combustion technologies is much higher than other regions. The technology needs of African countries (especially landlocked countries) in the energy sector are mainly in renewable energy generation, such as photovoltaic power generation and hydroelectric power generation. Small island countries in Oceania, Latin America and the Caribbean are highly vulnerable to climate change and extreme weather events, and their technology needs in the energy sector are mainly in renewable energy generation and non-fossil fuel production.

In addition, the integration and application of traditional energy technologies with digital information technology, represented by Energy Big Data, AI, cloud computing, blockchain, IoT, etc., is also an important force in driving the green and low-carbon transition of the energy sector. A recent study by the Global System for Mobile Communication Association (GSMA) and the Inter-American Development Bank (IDB) also shows that mobile technology will become one of the key technologies for countries in Latin America and the Caribbean to protect the environment and address climate change, and that Latin America urgently needs to develop intelligent solutions and mobile technologies to ensure economic growth throughout the region [12]. The *14th Five-Year Plan for Scientific and Technological Innovation in the Energy Sector* of the Ministry of Science and Technology of China also proposes to focus on the integration of new-generation information technology and energy development, promote the deep integration of traditional industries such as coal, oil and gas, power plants and power grids with digital and intelligent technologies, carry out integrated pilot demonstrations of various energy plants and regional intelligent energy systems, and lead the energy industrial transformation and upgrading [13].

1.3 Demand for Capital Supply to Support Green and Low-Carbon Development

The financial system plays an indispensable role in the development of real economy. The resource allocation capacity, efficiency and direction of the financial system will have a profound impact on the green and low-carbon cooperation under the BRI framework. As China's green financial system continues to improve and the concept of ESG responsible investment spreads globally, the green-based BRI finance and investments are playing a more active role in resource allocation and investment guidance. In a long-term follow-up study of BRI finance

and investments, Nedopil [14] finds that China's investment cooperation with BRI participating countries was around USD 59.5 billion in 2021, down by about 48% (USD 53 billion) from the level of 2019, the year before the COVID-19 pandemic, but there were no longer any investments in coal projects. In the meantime, the total green energy finance and investments in the BRI grew steadily to USD 6.3 billion (USD 6.2 billion in 2021). This trend is expected to continue due to the *Guidelines for Greening Overseas Investment and Cooperation* issued in July 2020, and the *Guidelines for Ecological Environmental Protection of Foreign Investment Cooperation and Construction Projects* issued in January 2022 [14].

However, the existing green investment and financing market is still not large enough to meet the “trillion-dollar” supply demand for green and low-carbon development in the Belt and Road. Based on a study of the renewable energy demand in 112 BRI participating countries, Cabré et al. [15] found that over the next decade, renewable energy investments will reach about USD 1.03 trillion, and this size is likely to continue to rise given that a number of countries have updated their NDC targets in 2021 [15]. A study by Vivid Economics and Tsinghua University (2019) showed that to achieve the target of keeping the global temperature rise within 2 °C, between 2016 and 2030, green investments needed in 126 BRI countries in four key sectors, including power, transport, construction and manufacturing, would be about USD 11.8 trillion in total, with an average annual capital requirement of about USD 785 billion [16]. According to a study by CICC in 2021, based on the estimation of a sample of 117 participating countries, between 2021 and 2030, the demand for green investments is expected to be USD 3.6 trillion, of which a large part is for climate mitigation measures, exceeding USD 2.5 trillion. The demand in renewable energy sector will reach USD 1.6 trillion, showing great potential for development. If the 117 sample countries are projected to 146 participating countries based on the share of their carbon emissions, the overall green investment demand of BRI participating countries may reach USD 5.7 trillion between 2021 and 2030, with the demand for renewable energy investment reaching USD 2.5 trillion. The study also pointed out that based on Liu and Raftery's (2021) assumption that “countries should increase their emission reduction efforts by 80% on the basis of their NDCs in order to achieve long-term goals for climate”, over the next 10 years, renewable energy investments in the BRI participating countries will be as high as USD 2.84 trillion [17].

On the other hand, due to the constraints of economic development and capacity in green financing, the public sector funds and financial market resources that can be coordinated and invested by BRI participating countries are quite limited compared with the large capital demand arising from green and low-carbon development goals. In the long run, there is still a huge gap between the supply and demand of green finance and investments in those countries. Take climate finance as an example. According to Li and Wu [17], the global climate finance was about USD 541 billion in 2018, and if estimated by the proportion of carbon emissions, the climate finance for non-OECD BRI participating countries was only USD 64.3 billion [17]. However, according to the Climate Policy Initiative [18], to achieve the target of keeping the global temperature rise within 1.5 °C,

the global climate finance needs to reach USD 4.35 trillion by 2030 (from 2021 onwards, annual climate finance must increase by at least 590%) [18]. **Establishing and developing regional green investment and financing markets, innovating and improving green investment and financing mechanisms and tools, encouraging and attracting the engagement of diversified entities, and guiding and restraining green investment and financing behaviors—all of the above are still the prominent demand of the BRI to enrich its green capital supply.**

1.4 Demand for International Cooperation to Solve Global Deficits

Global sustainable development is facing unprecedented complex challenges, with climate change compounded with resource and environmental constraints, the lingering pandemic triggering economic growth concerns, and geopolitical conflicts aggravating unbalanced regional development. The deficits of peace, development, governance and trust (hereinafter referred to as “global deficits”) are serious challenges in front of all mankind [19]. According to the *Human Development Report-2022 Special Report* prepared by the United Nations Development Programme (UNDP), behind this development-security disconnect looms the Anthropocene context, and development approaches with a strong focus on economic growth over equitable human development have led to stark and growing inequalities and risks such as climate change and the COVID-19 pandemic. In response, there is a need for greater solidarity [20].

The Belt and Road Initiative (BRI) is committed to enabling more countries to share development opportunities and outcomes [21] and to jointly achieve the 2030 Sustainable Development Goals [19]. As the largest international cooperation platform in the world [22], the BRI has laid a solid foundation for participating countries to cope with the impact of the COVID-19 pandemic and economic recession, enhance exchanges and mutual understanding, and work together to solve global deficits under the framework of multilateralism. At the moment, given the phased requirements as well as the overall trend of BRI green and low-carbon energy development, the following two aspects deserve special attention.

First, understand the strong willingness of BRI participating countries to achieve green and low-carbon development, and identify the key needs of transition in their energy sector. The progress of carbon neutrality actions in 129 countries collected by Net Zero Tracker shows that by June 2022, 84 BRI participating countries have proposed a specific target time² for carbon neutrality, and that the will and consensus for green and low-carbon development is getting stronger. In

² By analyzing the progress of 129 countries’ carbon neutrality actions collected by Net Zero Tracker, we notice that a total of 84 BRI participating countries have proposed a specific target time for carbon neutrality. Among them, 37 countries have made public declarations or specified the target time for carbon neutrality at the policy or legislative level, 4 countries have already achieved

addition, the regions along the Belt and Road have abundant wind, sunlight and hydropower resources, showing great potential for renewable energy development. However, given the large number and wide distribution of participating countries, as well as their significant differences in resource endowment, transition base, energy production and consumption structure, it is imperative to study, identify and clarify the differentiated needs of different regions and countries, so as to promote green and low-carbon energy development from concept to action at the practical level. Therefore, it is necessary to encourage the active participation of and deep cooperation among the governments of BRI participating countries, international cooperation platforms, multinational investment companies, NGOs, research institutions, etc., so as to ensure that the key needs of transition in BRI participating countries' energy sector are met first, thus laying a solid foundation for more extensive BRI renewable energy cooperation.

Second, on the basis of the phased results of green BRI development, consolidate and strengthen the construction of international cooperation platforms and mechanisms for BRI green and low-carbon energy development. The BRI, being green in nature, has established several international exchange and cooperation platforms for green and low-carbon development, such as the BRI International Green Development Coalition (BRIGC), the BRI Environmental Big Data Platform, and the Belt and Road Environmental Technology Exchange and Transfer Center, implemented initiatives including the Green Silk Road Envoys Programme and the Belt and Road South-South Cooperation Initiative on Climate Change, facilitated international cooperation in developing the *Green Development Guidance for BRI Projects*, which have received positive responses from both private sectors and governments in BRI participating countries, and advanced the process of policy dialogues, knowledge sharing, technology exchange and capacity building. In addition, China has also interacted extensively with BRI participating countries in areas of industrial energy cooperation, green investment and financing, sustainable infrastructure construction, etc., including organizing Belt and Road Energy Ministerial Conferences, promoting the establishment of Belt and Road Energy Partnership, and launching the *Green Investment Principles for the Belt and Road (GIP)*. In addition, regional cooperation mechanisms including China-ASEAN, BASIC and BRICS have also paid close attention to issues such as energy, climate and efficient use of environmental resources.

However, facing the new challenges of global carbon neutrality and post-pandemic green recovery, policymakers must recognize that, due to the complex coupling features of climate change impacts on natural ecosystems and on socio-economic systems, to promote green and low-carbon energy development under the BRI and support BRI participating countries in addressing climate change and achieving sustainable development goals, it is necessary to strengthen the participation of both public and private sectors, seek broader support from international, regional, bilateral and multilateral cooperation, and coordinate resources concerning policy,

carbon neutrality, and the remaining 43 countries have got a clear target time for carbon neutrality, but still further discussion is needed.

industry, technology and finance on the basis of existing international cooperation. Given the above needs, consolidating and strengthening the construction of cooperation platforms and mechanisms is still a key move and necessary action to promote international cooperation on BRI green and low-carbon energy development.

2 Pathway 1: Promoting Industrial Cooperation on Clean Energy to Support BRI Green and Low-Carbon Development

As many countries in the world have successively proposed carbon neutrality goals, green and low-carbon transition of energy development has become a global consensus. Especially in the current complex situation where issues such as energy transition, energy security, and energy accessibility are intertwined and impacted, China and international community need to work more closely with hand in hand, so as to accelerate progress towards green and low-carbon transition of global energy and sustainable development. In this context, promoting industrial cooperation in renewable energy technology is an important strategic choice to boost green and low-carbon BRI energy development.

2.1 Renewable Energy: A Key Direction for Technical Cooperation in the Energy Industry Under the BRI

China's international energy cooperation has gone through a process from active participation to integration, to gradually guiding and promoting the establishment of an international cooperation mechanism on energy that meets the needs of global energy development [23]. In recent years, the BRI has undoubtedly brought new opportunities for building a more comprehensive cooperation mechanism on energy. The implementation of a number of major energy cooperation projects, the continuous improvement in multilateral (bilateral) mechanisms of energy cooperation, and the growing exchange on energy policies and technologies have created positive conditions for the BRI to support the green and low-carbon development of energy in BRI participating countries. Meanwhile, more diversified cooperation contents and models have also been formed [24], which are mainly reflected in: (1) renewable energy cooperation has become an important part of the BRI energy cooperation; (2) the partners include both energy producing and consuming countries, and the model shifts from an one-way cooperation model based on energy trade that only revolves around oil and gas imports to a two-way cooperation model with more emphasis on the role of energy investment; and (3) triangular cooperation has become a new highlight of the BRI energy cooperation.

2.1.1 Outbound Energy Investment Accelerates Expansion to Renewable Energy Sector

The proportion of China's outbound investment in renewable energy continued to increase. China has been the largest investor in production capacity of renewable energy in recent years, and investment in renewable energy and new energy fields including solar PV, wind energy, hydro power, biomass energy, and hydrogen energy has become an important area of international cooperation on energy under the BRI. According to REN21's *Renewables 2021 Global Status Report*, China's foreign investments represented for the first time more than half of the country's total overseas energy investments under the BRI—increasing from 38% in 2019 to 57% in 2020, and the projects are widely distributed in key regions including South and Southeast Asia, Europe, Oceania and Latin America [25]. **Chinese enterprises have been more and more enthusiastic to participate in overseas investment in renewable energy.** According to data from the Ministry of Commerce (MOFCOM), China has newly invested in nearly 400 energy enterprises overseas since 2018, accounting for nearly half of the cumulative number of registered new energy enterprises overseas. **Solar PV and wind power projects are growing the fastest, where private sectors are the most active to participate.** Statistics from China Chamber of Commerce for Import and Export of Machinery and Electronic Products (CCCMB) show that in 2020, Chinese enterprises grew rapidly in the overseas new energy power generation industry, signing 177 projects with a contracted value of USD 15.63 billion, an increase of 69.1%, accounting for 35.5% of the total value of projects signed by all enterprises in the power industry, and for the first time exceeding thermal power projects. The fastest growth was seen in photovoltaic power generation projects, with 117 projects signed, amounting to USD 9.98 billion, a year-on-year increase of 140.5%. China signed 45 wind power projects overseas with a value of USD 4.83 billion, a year-on-year increase of 16.3%; biomass power generation (15 projects, USD 820 million), increased by 3.3% year-on-year, with a number of private enterprises involved [26].

2.1.2 Cooperation with Countries and Regions Exporting Traditional Energies Extends to Renewable Energy

Countries and regions along the BRI, including South and Southeast Asia, Central Asia, as well as the Middle East, have been not only important strategic partners in China's energy cooperation, but also equipped with great potentials for cooperation on renewable energy. In recent years, with the transition of energy strategies of these countries and regions as well as the needs of energy structure adjustment, the energy cooperation mode has been shifting from cooperation merely around oil and gas products to diversified green energy cooperation. For example, a number of renewable energy cooperation projects have emerged in the Middle East, represented by Morocco's Noor Ouarzazate Phase II and Phase III CSP Project, the world's largest solar thermal (CSP) power station in Dubai, as well as Egypt's Benban Solar

PV industry. Pakistan, with whom China cooperated on the most intensive energy investment, has many representative projects such as Pakistan Karot Hydro Power Project, ZTE Energy Pakistan Solar PV Project, Jhimpir Wind Power Project invested by Orient Group.

2.1.3 The Potential of Renewable Energy Cooperation with Developing Countries Has Increased Significantly

China has built a large number of Solar PV power plants in Africa, and the total Solar PV power generation reached 261.1 billion kWh in 2020, providing solar PV power support for hundreds of millions of households [27]. As an important mechanism for China-Africa comprehensive cooperative partnership, the Forum on China-Africa Cooperation has put forward *ten major cooperation plans* and *eight major initiatives*, emphasizing that the BRI shakes hands with Africa's *Agenda 2063*, the *2030 Agenda for Sustainable Development* adopted by UN, and the development strategies of African countries, providing an important platform for China-Africa renewable energy cooperation. Latin America is also a key area where China's renewable energy practices are conducted, and their cooperation on renewable energy pays particular attention to innovative investment and financing methods. At present, a diversified investment and financing model [28] has been basically formed that integrates policy banking, corporate mergers and acquisitions, as well as green field investment. At the same time, the practice of BRI projects with triangular cooperation as the entry point is also in progress. For example, in the second part of this chapter, China and Denmark cooperated in a South-South project of renewable energy technology transfer in Ghana/Zambia.

2.2 *Triangular Cooperation: A Model Innovation for Accelerating Technical Cooperation in Renewable Energy Industry in BRI*

As a global leader in renewable energy capacity and investment, China can mitigate and adapt to climate change by actively carrying out South-South cooperation, responding to the UN Sustainable Development Goals (SDGs), and supporting the green and low-carbon energy transition of BRI participating countries. At the same time, China can further leverage the innovative triangular cooperation model to mobilize, integrate and utilize global renewable energy development resources, especially industrial and technological resources, to create an innovative path for triangular cooperation to promote the green and low-carbon energy development of BRI. In this chapter, the case of renewable energy technology transfer project targeting at Ghana and Zambia, which is funded by Denmark and jointly organized by the Ministry of Science and Technology of China and the United Nations

Development Program (UNDP), is examined as an example, introducing the experience, effects and implications of applying triangular cooperation in supporting the development of the renewable energy industry in BRI participating countries.

Box 1. South-South Cooperation, North-South Cooperation and Triangular Cooperation

Since most developing countries are located in the southern hemisphere or the southern part of the northern hemisphere, and developed countries are mainly in the northern part of the northern hemisphere, the terms “south” and “north” are used to refer to them respectively.

South-North cooperation: The extensive cooperation between developing countries and developed countries in the fields of economy and technology.

South-South cooperation: Economic and technological cooperation among developing countries, which is an indispensable part of international multilateral cooperation for development.

Triangular cooperation: Economic and technological cooperation on the basis of traditional South-South cooperation with the participation of international organizations, multilateral mechanisms or developed countries.

2.2.1 Triangular Cooperation Supports Renewable Energy Technology Development in Ghana and Zambia

Due to the difference in development levels between developing and developed countries, the technology transfer in South-North cooperation may encounter supply-demand mismatch and difficulty in implementation, and South-South cooperation may need to address the challenge of funding. The innovation of triangular cooperation is that it balances project efficiency and sustainability. As developing countries share a similar development environment and development needs, it is easier for them to promote technology transfer and application according to local conditions; while the funding support from international organizations and developed countries lays a solid foundation for cooperation, enabling stable operation of the projects.

In 2014, China, Denmark, Zambia and Ghana reached a consensus, agreeing that a developed country (Denmark) would fund and support China to carry out low-carbon applicable technology demonstration and experience sharing for Ghana and Zambia, taking into account the demonstration of equipment products and the creation of a soft environment for renewable energy technology transfer, so as to effectively enhance the capacity of developing countries to cope with climate change. In 2015, the Ministry of Science and Technology of China (MOST) and the United Nations Development Programme (UNDP) jointly organized and implemented China-Ghana-Zambia South-South Cooperation on Renewable Energy Technology Transfer Project (hereinafter referred to as “China-Africa Project”). The

project adopted a North-South-South cooperation model, with its funding from a developed country (Denmark), and technology transfer from a developing country with relatively mature technologies (China) to relatively low-tech developing countries (Ghana and Zambia). Since its implementation, the project has received attention of all parties and won many international awards. It was selected into the *Outcome of the 40th Anniversary of South-South Cooperation between China and the United Nations*, *Good Practices in South-South and Triangular Cooperation* of the UN, and *Good Practices in South-South and Triangular Cooperation for the least developed countries* of the UN.

(1) Strengthen the Cooperation Platform and Mechanism

The platform and mechanism development carried out by the China-Africa Project has a prominent exemplary role in technical exchanges and communication of the renewable energy industry. The professional platform of pragmatic cooperation has strongly ensured the efficiency and effects of cooperation.

A new platform for South-South cooperation under the UN framework has been built. On September 12, 2019, the Administrative Center for China's Agenda 21 (ACC21) and UNDP jointly established the Center for South-South Cooperation in Technology Transfer (hereinafter referred to as the Center for South-South Cooperation). As one of the concrete initiatives to implement the *Memorandum of Understanding between the Ministry of Science and Technology and UNDP*, the Center for South-South Cooperation aims to (1) build a technology transfer platform and database to precisely match technology demand and supply, and provide relevant partners with appropriate technical solutions for sustainable development; (2) build itself into a think tank for South-South cooperation in technology transfer, conduct strategic and policy researches, and explore ways to apply China's experience and best practices in solving common problems faced by technical cooperation; (3) establish technology demonstration and promotion hubs along the Belt and Road, to share China's technological innovation experience with countries along the routes; and (4) create technology transfer capacity-building bases, organize and implement technology transfer and aid projects for developing countries commissioned by governments and international organizations like UNDP, and carry out capacity-building activities such as knowledge sharing, training exchanges, and technology demonstrations.

A long-term mechanism of the Steering Committee has been established. In the early stage of the China-Africa Project, an efficient and standardized management mechanism has been gradually established, including a Global Steering Committee including UNDP, Denmark and the implementation side. China, Ghana, and Zambia have established National Steering Committee respectively. During the implementation period of the project, UNDP China and each country's implementation side preside over the meeting of the Global Steering Committee and each country's National Steering Committee respectively summarize the annual results, review the work plan, as well as provide guidance for the smooth implementation of various tasks.

(2) Deepen Policy Communication and Coordination

In order to better support the development of industries and technologies, the China-Africa Project focuses on policy alignment and communication between countries, which is an important guarantee for the smooth transfer and absorption of technology and experience from one country to another.

The Ghana Renewable Energy Master Plan (REMP) was compiled to support the top design of clean energy development in partner countries. By learning from China's five-year planning policy, Chinese experts assisted Ghana's partners in formulating the first mid-and long-term plan for Ghana's national renewable energy development. With a vision of enhancing Ghana's capacity for renewable energy research, production and services, and with the aim of promoting economic growth, improving social life and minimizing the adverse impacts of climate change, REMP sets out development goals and action plans for eight types of clean energy technologies based on Ghana's current energy supply and demand and policy and institutional framework, and taking into account the local business environment. REMP has been reviewed by Ghana's Congress, filling the gap in Ghana's mid- and long-term plan in the field of renewable energy, and fully implementing and reflecting Ghana's will of development in the top design, which is to take renewable energy technology development as a critical pathway.

The Roadmap for China-Ghana Renewable Energy Technology Transfer was compiled to implement policy alignment. Chinese experts analyzed Ghana's renewable energy development needs from the perspectives of local culture, technology, market as well as the regulatory framework. Based on the close communication between the two sides, focusing on Ghana's renewable energy development goals set in the REMP, experts from all sides have jointly formulated a roadmap for technology transfer of renewable energy for Ghana that includes specific actions and milestones, effectively promoting the common development of the clean energy industry on both sides.

(3) Carry out Technology Transfer and Matchmaking

After the project was implemented, a number of renewable energy technologies have been transferred to and widely applied in partner countries, laying a solid foundation for meeting the renewable energy development needs of partner countries.

Technology collection and screening have been organized according to local conditions. In the early stage of technology collection, the project team carried out demand research in various forms, such as field visits, expert discussions, questionnaires, etc., and also analyzed the influencing factors of applicable technologies, systematically sorted out the transfer advantages, existing obstacles and suitability of different technologies, and developed the *South-South Cooperation on Renewable Energy Technology Transfer Technical Manual (Chinese and English Edition)*, creating a renewable energy technology library for developing countries, which helps to carry out technology exchanges based on local conditions and facilitate the long-term and stable functioning of transferred technologies.

Active exchanges have been conducted to solve practical problems encountered in implementing technology transfer. During the implementation of projects, several China-Africa renewable energy technology exchange networking meetings were held in succession. Government officials, experts, scholars, business representatives and other relevant parties from China, Ghana, Zambia and other countries visited and learned about representative laboratories and enterprises of renewable energy. Exchanges and discussions were carried out on the current status of technology development, challenges and responses to technology transfer, etc., to enhance mutual trust among all parties. For example, the Chinese technical experts and equipment suppliers found through on-the-spot investigation that the existing renewable energy stoves in China do not match the specifications of the traditional cooking pots with oval bottoms in Ghana. According to the shape of traditional cooking tools in Ghana, China adjusted the design of stove, so that a single stove can meet the local people's needs for cooking and heating at the same time, solving practical problems for the final implementation of technology transfer.

(4) Highlight Capacity Building

The China-Africa Project actively creates an enabling environment for South-South cooperation on technology transfer and strengthens the capacity building of both sides, thus improving the quality of cooperation while effectively promoting the localization of cooperation results, and adding a long-term momentum to the development of partner countries' renewable energy industry.

In October 2016, China-Africa renewable energy technology transfer and match-making meetings were held in Chengdu, Beijing and Chongqing respectively. Through policy exchanging, technology sharing and other links, the needs of the African side have been fully expressed. The meeting also involved in-depth participation of enterprises, enabling African partners to learn more directly about management models and production concepts of enterprise engaged in technology transfer. This novel matchmaking and exchange model has greatly improved the cognitive efficiency of renewable-energy-related technologies between China and Africa, as well as promoted the application and development of renewable energy technology in Africa.

In October 2019, as a specific measure to implement the *Memorandum of Understanding on Science Technology and Innovation for Achieving Sustainable Development Goals*, the International Training Course on Science Technology and Innovation for Achieving Sustainable Development Goals provides an effective platform for developing countries to exchange and share experience in technological innovation for sustainable development. Through a combination of classroom lectures and field visits, the training course held nearly 20 thematic activities on such topics as innovation financing, intellectual property rights, roadmaps for SDGs innovation, as well as innovative demonstration zones for national sustainable development agenda. The partners shared the concepts, methods and experiences of constructing innovative demonstration zones in an all-round way.

2.2.2 Triangular Cooperation Promotes Technology Exchanges and Cooperation in the Renewable Energy Industry

Triangular cooperation is an important initiative to support the promotion of South-South cooperation in renewable energy technologies in BRI participating countries under the UN framework, and it requires the multilateral mechanism to work as a bridge in international cooperation, coordinating all parties to move in the same direction, and integrating and mobilizing the resources of the international community, so as to help developing countries enhance their capacity to address climate change, and achieve the SDGs together. As the flagship project of the UN triangular cooperation, the China-Africa Project created a “package” cooperation model featured with full research in the early stage, effective communication in the mid-term, experience exchange in the later stage, strengthening policy communication and focusing on the application of results.

In terms of content, the China-Africa Project fully demonstrates the concept of win-win situation for all parties, and is highly compatible with the development needs of the partner countries. Both Zambia and Ghana have strong demand and willingness for energy development, have relatively stable domestic political situation, and are in leading positions in Africa in terms of economic growth. On the basis of the Ghana and Zambia’s willingness to develop, and considering China’s technological strength, renewable energy has been selected as the priority area for cooperation.

In terms of cooperation model, the China-Africa Project provides a relatively complete set of BRI renewable energy technology cooperative schemes. Focusing on green and low-carbon energy development, the Project has carried out a series of high-quality technical training, technology demonstration and capacity building activities, while strengthening cooperation mechanisms and platforms in a targeted manner, and carrying out multi-level intergovernmental policy coordination by supporting partner countries to prepare national-level plans or industrial development roadmaps, and thus effectively enhancing macro and micro support for the traditional cooperation model featuring single technology exchange.

In terms of effects, the China-Africa Project has significant value of sustainable application and radiation demonstration effect in supporting international cooperation in green and low-carbon BRI energy development. The innovative exploration and successful experience of the Project provide a replicable set of solutions for the subsequent green and low-carbon BRI energy development cooperation in a broader sense, which can be introduced to other participating countries and regions. Through the cooperation with UN agencies, the Project has not only supported the renewable energy development in Ghana and Zambia, but also resulted in certain demonstration effects on the renewable energy development in neighboring countries, which is conducive to the expansion of the green and low-carbon BRI cooperation network.

With the successful experience of the China-Africa Project, in April 2019, the Chinese government signed a project agreement with Ethiopia and Sri Lanka regarding the China-Ethiopia/Sri Lanka Triangular Cooperation Project on Renewable Energy. As a practice of the successful experience of the China-Africa Project, this project was carried out within the framework of South-South cooperation, aiming

to build a platform for experience sharing and learning, adjust and optimize the local energy structure through demonstration projects, promote the sustainable development of agriculture in partner countries, reduce greenhouse gas emissions, and improve the income and productivity of local residents. The project has been included in the list of outcomes of the 2nd Belt and Road Forum for International Cooperation, and been selected as one of the *Good Practices in South-South and Triangular Cooperation for the Least Developed Countries* of the UN, becoming another successful practice of triangular cooperation in supporting the green and low-carbon energy development of BRI participating countries (Figs. 1 and 2).

Fig. 1 Chinese and international experts working with Zambian Agencies on siting of small hydropower stations



Fig. 2 Seminar on China-Africa renewable energy technology transfer exchange



2.3 Policy Recommendations for Improving the Implementation of Pathway 1

According to results from reviewing the existing practices of renewable energy cooperation and case studies of specific cooperation projects, it is important to promote the formation of a more systematic and effective mechanism for technical cooperation in renewable energy industry for China when it works together with BRI participating countries to jointly address global challenges in environment, climate, energy and equity, to promote BRI green and low-carbon development, and to achieve 2030 SDGs. To this end, it is recommended to focus on the following four aspects in terms of cooperation mechanism development and cooperation items.

2.3.1 Deeply Meet the Differentiated Needs of BRI Participating Countries, and Conduct Cooperation According to Local Conditions

In the global context of carbon neutrality and carbon peaking, there is huge space for renewable energy cooperation among countries and regions along the BRI. The data shows that from 2009 to 2018, the demand for renewable energy in the countries and regions along the BRI is increasing rapidly, among which the growth rate in the Middle East is particularly obvious, with an average annual growth rate of renewable energy consumption of 36%, followed by 21% in Asia-Pacific countries, 20% in African countries, 16% in CIS countries as well as 11% in European countries [29]. To this end, it is important to continue the efforts of strengthening the alignment of the international and regional strategies and policies of low-carbon transition. However, for countries and regions at different stages of development and with different resource endowments, policies should be implemented according to specific conditions.

2.3.2 Give Full Play to the Role of Existing Platforms, and Deeply Integrate Considerations Such as Climate Change and Sustainable Development

In mechanism development, the role of the existing cooperation platforms should be brought into full play. Especially in the relevant documents of the BRI energy partnership, the content of addressing climate change, sustainable development as well as social responsibility should be given closer attention. At the same time, it is important to strengthen exchanges and communications among countries through already established multilateral cooperation frameworks and dialogue mechanisms that have incorporated a wide range of renewable energy cooperation issues, such as South-South Cooperation, the Forum on China-Africa Cooperation (FOCAC),

China-Arab States Cooperation Forum (CASCF), Shanghai Cooperation Organization (SCO), Ministerial on Climate Action (MoCA) (jointly sponsored by China, the European Union and Canada), and the China-U.S. Dialogue on Climate Change. Such approaches can also help countries to deepen the understanding of renewable energy technology innovation and application, assist all the players to get the knowledge of local society, culture, development conditions and needs, laws and regulations and other national conditions. On this basis, identify fields of cooperation which can bring mutual benefits to all parties and create opportunities for in-depth industrial cooperation.

2.3.3 Encourage Enterprises to “Go Global” in Groups and Actively Carry Out Triangular Cooperation

It is important to develop relevant supporting policies to encourage and guide renewable energy manufacturing enterprises, project development companies, financial institutions, industry associations to “go global” in group, cooperate with each other, and play a synergistic role in renewable energy cooperation with the BRI participating countries and regions by a multi-angle holistic approach. At the same time, it is necessary to encourage Chinese enterprises to actively seek technical cooperation and joint operation with energy enterprises from a third country with regard to clean energy development and renewable power generation projects along the BRI. It is crucial to give full play to the comparative advantages of Europe and the United States and other countries in international cooperation on renewable energy in terms of industrial norms, standards, consultation, operation, and management, and combine China’s high-efficiency and low-cost renewable energy technology and experience to achieve win-win outcome in the BRI development.

2.3.4 Innovate a “Renewable Energy Plus” Model to Promote the Green and Carbon Reduction Action

Cooperation on production capacity and transportation infrastructure are both key areas of the BRI development. According to the latest data, China’s project contracting in the general construction field along the BRI has also achieved rapid growth, from USD 390 million in the same period in 2020 to USD 2.46 billion in June 2021, with tripled growth rate, making it the third largest engineering contracting investment industry subsequent to transportation and energy [30]. These above-mentioned industries are highly relevant to carbon emissions. For this reason, it is recommended to adopt the models of “renewable energy + industry”, “renewable energy + transportation”, as well as “renewable energy + buildings” to promote the green and low-carbon transition of the BRI development.

3 Pathway 2: Guiding Financial Resources to Support Green and Low-Carbon Development in BRI Participating Countries

3.1 Financing Challenges for Green and Low-Carbon Energy Development in Developing Countries

Two main types of barriers impede developing countries in their ambitions of realizing green and low-carbon energy development. Firstly, countries face barriers to accessing the technical and financial resources necessary to broadly deploy new technologies. Secondly, even low-carbon energy generation facilities can pose significant local environmental and social impacts, and these must be managed well in order to ensure effective and long-lasting investments. China is extremely well positioned to help other developing countries overcome the technical and financial barriers to renewable energy development, and in fact has already established itself as a crucial partner for countries wishing to overcome these obstacles. China's unique overseas financing model enables the country to overcome such obstacles. China has also developed a wide variety of tools and guidelines to help investors consider the local environmental conditions for renewable energy investment, but additional prioritization of this area can continue to contribute to these efforts. Given the realistic need to achieve high-quality development, the following two barriers need to be tackled.

3.1.1 Technical and Financial Barriers

One of the larger obstacles of investing in renewables in developing countries, especially those where fossil fuels are abundant, is the lack of necessary policy incentives. In many developing countries, fossil fuels and fossil fuel companies benefit from large subsidies and other policies that bias those firms despite the fact that renewables are increasingly the cheaper and more efficient option. As a result, the policy support for developing renewables from public sector is not sufficient enough, and developing. Countries face a significant technical deficit in deploying renewable energy. These are partly related to low levels of existing energy access [31, 32].

China is extremely well positioned to assist other BRI participating countries in overcoming these technical obstacles, having already developed the institutional capacity domestically [33]. Pingkuo and Peng (2022) explore five different incentive policies deployed in China that contributed to the growth of renewable energy domestically. They find that the most significant positive impact of these five was the incentive to develop capacity of development finance institutions (DFIs) to support the other aspects of renewable energy deployment, including innovation and investment intensity. Thus, the institutional knowledge gained by Chinese policy makers in this area has been remarkably effective. It is just this type of capacity that can be transmitted well across BRI projects.

A second type of obstacle emerges from the barriers to financing facing developing countries. Low- and middle-income countries face higher sovereign borrowing costs and a reduced investor appetite for the long-term commitment necessary to build and sometimes operate energy infrastructure projects in an uncertain economic context. China has already played an important role in filling this gap, and continued to do so. For example, in Africa, the Export–Import Bank of China has extended more finance for renewable energy development than any other international DFIs [32]. Another key barrier is the lack of credit-worthiness and off-taker risk facilities in host countries, as well as currency risk.

Furthermore, the unique “coordinated credit spaces” that Chinese DFIs, state-owned enterprises, PPPs, and private investors form can make ambitious investment projects feasible where they would not otherwise be considered creditworthy. Where their Western counterparts operate independently as financiers or investors, requiring shorter-term financial returns on each separate aspect of a project, these Chinese lenders and investors better coordinate their efforts to create longer-term, broader economic benefits beyond what each party gleans [34]. For example, Argentina’s Cauchari solar park—the largest in the country—was successfully developed through a combination of development finance from the Export–Import Bank of China, construction development by Shanghai Electric Power, solar panels from Talesun Solar, and inverters from Huawei. Thus, China is already using its unique lending and investment approach to help other developing countries overcome the financial barriers to renewable energy development.

3.1.2 Environmental and Social Barriers

To ensure the effective implementation of renewable energy investments abroad, particularly in countries where investors are relative newcomers, global practitioners and lenders have formed a broad consensus around appropriate due diligence and project management steps. This wide agreement has coalesced around a “whole lifecycle” framework [35–37].

Box 2. The “Whole Lifecycle” Approach to Best Practices in Renewable Energy Development

The “Whole lifecycle” approach to sustainable project management consists of four major steps: project preparation, when investors and policy makers are considering the type of project to pursue; design, when the specific project details are defined and financing is finalized; implementation, when construction and production are underway; and completion, as investors clean up worksites and wind down their operations.

In project preparation, it is important to bear in mind that host countries’ national strategies for renewable energy development can differ widely. In order to explore the type of renewable energy project that will be most likely

to succeed in the long term, it is important to interface with a wide variety of host country government ministries, whose official strategies may facilitate the development of particular forms of renewable energy [38]. For example, some health ministries may prioritize replacing urban coal-fired power plants in order to improve air quality, while other countries' ministries for women or families may have strategies for rural renewable energy development to transition away from reliance on wood-fired cooking stoves, which are associated with significant respiratory health impacts for women [39].

Once a project has been selected and designs are underway, it is crucial to conduct adequate due diligence to identify any risk factors for a smooth implementation thereafter. As during project planning, working with a variety of host country ministries can help avoid unforeseen complications. Environment ministries may recommend or require supply chain analysis on the environmental and social impacts of a project's use of water, land, and commodity inputs [40–42]. Ministries of women, families, and culture may recommend or require community consultations that are separated by gender or ethnicity. Land and water use often effects stakeholders differently by ethnicity and gender. For example, women in agricultural societies are often responsible for household energy provision and are likely to embrace renewable energy projects, but they may have limited voice in mixed-gender consultation settings [43, 44].

During project implementation and operation, project managers can safeguard the effectiveness and longevity of renewable energy projects by interfacing with national and local chambers of commerce and establishing business-to-business linkages with local suppliers of direct inputs as well as indirect inputs such as worker uniforms, catering, and other ancillary services [45, 46]. Building local capacity can ensure a project's integration with local economies and contribute significantly to its longevity [47]. Finally, the life-cycle approach ends in project operation and completion, through the safe disposal of hazardous materials used in renewable energy generation, such as mercury in solar generation or a variety of heavy metals in geothermal power generation [37, 48].

For policy makers and other entities overseeing outbound investment, two major avenues exist to ensure that investors follow the best practices outlined above: national governments and development finance institutions (DFIs), including both national and multilateral bodies.

Nationally, government policy makers can enact guidelines and tools for their outbound investors, and their DFIs can enact specific requirements for projects that receive their financing. China has developed two avenues for direct facilitation of best practices, through the development of official guidance and a broad array of toolkits for investors. The 2021 CCICED special policy report on the Green BRI covers these extensively, including policies issued by the State Council, MOFCOM

and other high-level government bodies [49]. Most notable is the 2021 *Green Development Guidelines for Overseas Investment and Cooperation* [50]. Among other advice, these Green Development Guidelines strongly encourage outbound investors to adhere to the “green development concept” throughout an entire project process, as detailed in the “whole lifecycle approach” explained above. These Guidelines make clear that investors should follow host-country law or international best practices, when operating in countries without robust domestic standards. Across this body of increasingly comprehensive policies and advice, the Chinese government has made it clear that investors are expected to follow high-level environmental practices.

Complementing these official guidelines are toolkits published to assist outbound investors in understanding the potential environmental factors that may need to be taken into account to effectively and responsibly pursue their projects of interest. For example, a group of seven Chinese associations and committees that act in subordination to Chinese government ministries, in collaboration with government and industry groups (including the Foreign Economic Cooperation Office of MEE, China International Contractors Association, China Chamber of Commerce of Metals, Minerals, and Chemicals Importers and Exporters) contain detailed advice for specific sectors, such as infrastructure, and can provide significant guidance for renewable energy infrastructure investors. More practical guidance is available through FECO’s Environmental Risk Screening Tool (ERST), through which investors can see location-specific risks that apply to the area where they are considering investing. With the ERST, investors can estimate potential biodiversity impacts and create policy compliance analysis reports [49, 51].

Despite these important steps, one additional avenue remains for China to ensure the effectiveness and longevity of outbound green energy investments: due diligence requirements and oversight by government-funded development finance institutions (DFIs) that support outbound projects. China provides crucial support for investment and the expansion of the BRI through its DFIs, both through national DFIs and through participation in multilateral development banks (MDBs) such as the Asian Infrastructure Investment Bank (AIIB) and the Asian Development Bank (ADB). These national DFIs and MDBs lend directly to outbound investors and also to overseas national governments who hire Chinese firms and public–private partnerships (PPPs) to carry out infrastructure projects. Thus, whether China’s push for renewable energy overseas operates through direct investment or through construction contracts for projects owned by other governments, these DFIs ensure that the implementing firms have the capital needed to initially invest, and continue to support them through the life cycle of the project and the repayment years thereafter. As such, they form close collaborations with the investors they support and they rely on those investors to use environmentally responsible practices in order to ensure the effectiveness and longevity of the supported projects. They have the financial incentive as well as the access necessary to guide firms through best practices.

Table 1 shows a variety of common DFI policies and practices to guide investors in best practices throughout project lifecycles. It includes two regional MDBs in which China has a significant role, ADB and AIIB, as well as two Chinese DFIs and the national DFIs of Japan and South Africa. Shortly after China announced that it

would no longer support coal projects overseas and would instead increase support for renewable energy around the world, South Africa and Japan followed suit, joining the G20 in announcing an end to overseas coal financing [52, 53]. Like China, both South Africa and Japan use their DFIs to support outbound investments. Thus, it is useful to examine the tools they have developed to encourage and facilitate the use of best practices by investors, for maximum project effectiveness and longevity.

As Table 1 shows, national and multilateral DFIs have developed tools to guide investors throughout the project lifecycle. During project preparation, DFIs may

Table 1 DFI environmental oversight processes throughout project lifecycle

	Regional		China DFIs		Peer DFIs		
	ADB	AIIB	CDB	CEXIM	DBSA	JICA	JBIC
<i>Preparation</i>							
Exclusion/inclusion lists	X	X	X	X	X	X	X
Technical support for developing green projects	X	X			X	X	
Financial support for developing green projects	X	X			X	X	
<i>Design</i>							
Use of risk/impact rating system	X	X			X	X	X
Conditions for use of host country standards	X	X	X	X			
<i>Implementation</i>							
Disclosure of lender documents		X				X	X
Facilitation of disclosure of borrower documents	X	X			X	X	
Use of independent/third party monitors	X	X			X		
<i>Operation and completion</i>							
Project completion provisions	X	X	X	X	X		
Independent accountability mechanism	X	X			X	X	X

Source Gallagher and Qi [54], Ray et al. [55], Zhuo et al. [49]

Note ADB: Asian Development Bank; AIIB: Asian Infrastructure Investment Bank; CDB: China Development Bank; EXIM: Export–Import Bank of China; DBSA: Development Bank of Southern Africa; JICA: Japan International Cooperation Agency; JBIC: Japan Bank for International Cooperation

establish inclusion and exclusion lists to avoid association with particularly high-risk sectors and encourage investment in others. China's BRI Green Light System is an example of this type of guidance, and research by the BRI International Green Development Coalition (BRIGC) shows that it has a strong potential to help ensure a successful implementation of China's push for green energy abroad [56]. In addition, they may **offer technical or financial assistance** to borrowers in developing credit-worthy green projects. Notably, Chinese DFIs are the only ones studied here to not offer these supports, and this may be an area for future policy strengthening.

Once projects have been **chosen and are being designed**, DFIs may perform **due diligence** steps to ensure that projects have considered potential environmental impacts and related risks to project viability. DFIs may establish their own risk and impact rating system in order to determine which pre-investment steps need to be elaborated before construction (as Japan and South Africa DFIs do) or establish conditions under which investors may rely on host country systems, as China does.

During **project implementation**, DFIs often support investor **transparency and monitoring** in order to crowd in additional oversight from host country stakeholders, who may notice and address potential risks before they can create problems for the projects.

Finally, during **completion and operation stages**, DFIs can require responsible handling of cleanup or establish independent accountability mechanisms for ongoing risk management after construction is complete. China's DFIs are noteworthy here in their use of post-hoc environmental assessments to track the performance of investors and contractors. These are the only institutions shown here to use post-hoc evaluations, which have great potential in informing future investment decisions. They do not yet inform the exclusion and inclusion lists that China's DFIs use, but this may be an area of future policy strengthening. In 2017, the State Council shared a directive opinion advising the creation of a blacklist system for poorly-performing overseas investors, as NDRC does for domestic investors [57]. Preparation for this step is still ongoing and could enhance the quality of China's future renewable energy investment overseas.

3.2 Public-Private Partnerships: An Effective Solution to the Barriers to BRI Clean Energy Development

3.2.1 PPP Development in BRI Countries and Chinese Companies' Embrace to PPP

To achieve the goals of the *Paris Agreement*, the world needs tremendous financial resources to develop green and low-carbon energy, especially for the BRI participating countries. On the one hand, governments have to invest large amounts of fiscal funds in response to the COVID-19 and improve people's livelihood, worsening the already limited fiscal fund. On the other hand, institutional investors make prudent

investments due to future uncertainties, presenting the difficulties and increasing cost of financing. These circumstances have seriously impacted infrastructure investment, including green energy development. This is especially the case in developing countries. Therefore, it is necessary to innovate the financing mode for green energy in BRI participating countries.

As an innovative modality to encourage the participation of private sector in infrastructure investment, the Public–Private Partnership (PPP) has been acknowledged and disseminated by the international community. The World Bank Group set up the Global Infrastructure Facility (GIF) in 2014 to provide financial support to developing countries in PPP project preparation. Asian Development Bank (ADB) established the Office of PPP in 2014. G20 founded Global Infrastructure Hub in 2014, aiming to promote the information exchange of infrastructure projects and promote PPP application. UNESCAP set up the Infrastructure Financing and PPP Network of Asia and the Pacific in 2018, whose member countries have rapidly grown to more than 50 at the beginning of 2022 from 24 at its establishment. Under the support of Heads of African States and The United Nations Economic Commission for Africa (UNECA), Africa PPP Network was formed in 2020.

At present, PPP has been applied in an increasing number of BRI participating countries, and more and more green energy projects have been developed rapidly in PPP, which benefits local people and promotes local social and economic development. Like other infrastructure investments, Chinese companies which invest in clean energy development overseas (mainly in BRI participating countries) adopt EPC (Engineering Procurement Construction) mode, mainly financed by policy funds from the Export–Import Bank of China, namely foreign aid preferential loans and preferential export buyer's credit. These facilities enjoy low interest rates (2–3%) and long maturity periods (15–20 years). Under the official preferential loan, usually, the host country applies for sovereign loans from China. The existing investment is facing challenges, mainly as follows. First, the sovereign loan will increase the debt-to-GDP ratio of the host country. Second, Chinese companies are mainly involved in project construction, but not enough in project design, financing and operation, which makes it difficult to form a long-term impact on the environment and climate. Third, project risks are unevenly distributed between Chinese export credit agency and the Chinese company. If the project operation fails, the cash flow is interrupted, and the company is unable to repay the loan, the capital loss may be borne by the export credit agency. At present, the main Chinese export credit agencies who can provide funds for Chinese enterprises include the Export–Import Bank of China, China Development Bank, and China Export & Credit Insurance Corporation. Their potential losses will eventually be passed on to China's central finance.

In the case of PPP, generally, the host country/government bears the risks pertaining to politics, policy, land acquisition, immigration, while the private mainly takes responsibility for capital, technology, and management. As an investor, the private firm can integrate various resources to provide financing for the project without increasing the debt of the host government. The return on investment comes from fees for services provided by the infrastructure built and/or agreed subsidy

from the host government. The private firm can also make the most of its technical expertise to provide life-cycle services from the front-end planning, design and consultation to the construction, operation and maintenance afterward, so as to solve the problem of lacking operation capacity for the host country, mitigate the risk in getting return of the investment, and also contributes to obtaining long-term benefits and establishing a corporate brand in the host country by through years of project operation. A Chinese enterprise, whether state-owned or private, can participate in an overseas PPP project as a role of private sector, sharing risks with the host country appropriately.

PPP can be an effective solution to the technical and financial barriers as well as the environmental and social barriers mentioned above. Chinese companies can play important roles to promote BRI clean energy development via PPP, especially with the *Guidelines for Ecological and Environmental Protection in Overseas Investment and Cooperation Construction Projects* jointly issued by MEE and MOFCOM in January 2022 and the *Opinions on Jointly Promoting Green Development of the Belt and Road* issued by NDRC, MFA, MEE and MOFCOM in March 2022.

3.2.2 Chinese Government and Enterprises Support to Implement BRI via PPP

At the First Belt and Road Forum for International Cooperation in 2017, Chinese President Xi Jinping pointed out that it is necessary to “innovate investment and financing models, promote Public–Private Partnership (PPP) for a diversified financing system and multidimensional market”. According to the *Proposals for Formulating the 14th Five-Year Plan (2021–2025) for National Economic and Social Development and the Long-Range Objectives Through the Year 2035*, to promote the high-quality development of the BRI, it is necessary to adhere to the principle of “extensive consultation, joint contribution and shared benefits”, “maintain the main-body role of the enterprise, adhere to the market-oriented philosophy, follow international practices and debt sustainability, and improve the diversified investment and financing system”.

According to a survey by China PPP Center and China International Contractors Association in 2021, Chinese line ministries, enterprises and financial institutions expressed eagerly that the traditional model of China’s outbound investment in infrastructure needs to be upgraded and transformed into PPP that involves design, financing, construction and operation among others in the life cycle of a project. Some institutions have kicked off their actions.

Since 2014, the Chinese government has promoted a new round of PPP application in China, referring to the PPP practices of the World Bank, Asian Development Bank among other international institutions, and has learned from PPP advanced countries. PPP has been turned from a method of market-based financing to one of the means of modernized governance of the country, that is, to innovate the system of infrastructure investment and financing of the government, and introduce market-oriented supply and management mechanisms in the sector of public services. As

of January 2022, 7683 PPP projects have reached commercial close, with an investment of 12.8 trillion yuan, covering all provinces in China's mainland and 19 sectors including energy, transportation, environmental protection, poverty alleviation, and rural revitalization. China has become the world's largest regional PPP market. A large number of enterprises, financial institutions and consulting agencies with infrastructure business overseas, who have gained practical PPP experience in China, have the capability to carry out PPP projects outside of China. According to the assessment of World Bank Group, China is above the average level of high-income countries in terms of PPP project preparation, procurement and contract management [58].

3.2.3 Practices of Supporting the Development of the BRI Clean Energy Infrastructure via PPP

Since the BRI was launched by China in 2013, Chinese enterprises have expanded their businesses in overseas project contracting in BRI covered regions, with an increasing growth in scale [59]. In 2019, the number of new overseas project contracts reached 6944, with a total contracted amount of USD 154.89 billion. Among them, the contracted amount of electricity projects accounted for 21.1% (shown in Table 2).

PPP is relatively feasible in the electricity sector compared with other sectors like transportation and environmental protection. Electricity projects, with good social and economic benefits, are usually among the priorities in the host country. At the same time, electricity projects can produce stable cash flow, with strong abilities of repayment and financing.

Electricity projects include power generation and transmission. Power generation projects have a large demand for funds, with high requirements for the professionalism and timeliness of project construction. Generally, the State Grid of the host country performs the obligation of payment, so that the project return will be

Table 2 Projects contracted by Chinese enterprises in 2019 by sectors

Sectors	New contracted amount		Completed amount	
	Billion USD	Share (%)	Billion USD	Share (%)
Transportation	699.0	26.9	471.0	27.2
Housing	464.3	17.8	353.6	20.4
Power development	548.9	21.1	328.4	19.0
Petrochemical	300.9	11.6	157.7	9.1
Communications technologies	240.5	9.2	151.3	8.7
Industrial development	83.4	3.2	76.0	4.4
Water conservancy construction	72.1	2.8	61.0	3.5
Manufacturing and processing facilities	39.2	1.5	44.0	2.5
Others	154.1	5.9	86.1	5.0

guaranteed. Wind power and solar photovoltaic projects are delivered more simply, with shorter development and construction cycle. Hydropower projects are relatively complex. Transmission projects are the key of power system and national energy structure transformation in all countries, especially in developing countries, with large capital demand and high professional requirements. The return of the project mainly comes from the income of power distribution fee and the value-added services provided for various users.

Due to the important position and role of the power sector in the national economic system, it is strictly supervised by the host government. The investment policies, decision-making procedures and market environment of power sector vary from country to country. Chinese enterprises, with rich experience in design, investment, construction and operation of electricity projects, especially in the field of green energy, have kicked off their green energy PPP projects in BRI participating countries, as shown in Table 3.

Table 3 Renewable energy projects delivered via PPP by Chinese enterprises in BRI participating countries

Nation	Project	Contractor	Sector	Model	Contract amount (in \$100 million USD)	Phase (As of October 2020)
Pakistan	Suki Kinari Hydropower Project	China Gezhouba Group Corporation	Hydropower station	BOOT	19.62	Under construction
Guinea	Kaléta Hydroelectric Facility	China International Water and Electric Corporation	Hydropower station	BFOT	15.67	Operation
Laos	Nam Pay Hydropower Project	China North Industries Corporation	Hydropower station	BOT	2.18	Operation
Laos	Nam Ngiep 1–2 hydropower	China International Water and Electric Corp	Hydropower station	BOOT	1.49	Operation
Pakistan	Dawood Wind Power Project	Power China International Group Limited	Wind power station	BOO	1.15	Operation

3.2.4 Challenges on Supporting the Development of the BRI Clean Energy Infrastructure via PPP

The challenges faced by Chinese enterprises in delivering green energy projects (like other infrastructure projects) with PPP in BRI participating countries are as follows.

In terms of mechanism, the current outbound investments are supervised by different authorities, including the National Development and Reform Commission (NDRC), the Ministry of Commerce (MOFCOM), the State-owned Assets Supervision and Administration Commission (SASAC), the State Administration of Foreign Exchange (SAFE), and the China International Development and Cooperation Agency (CIDCA). Each takes a specific power of administration but manages one or more aspects, resulting in scattered functions, complex procedures and long approval. There is a lack of cooperation platforms guiding BRI PPP projects in China, so no such ecosystem is formed that is guided by the government, undertaken by companies, financed by financial institutions, and assisted by consulting agencies.

In terms of financing mechanisms, the existing models have relatively high dependence on sovereign guarantee. Chinese enterprises are not using diversified methods of financing. They mostly rely on sovereign guarantees and have inadequate experience in project financing. The application for the Concessional Loan and Preferential Export Buyer's Credit Facility needs complex procedures, and is not good at project financing. The financing method for international projects is mainly credit facility provided by banks, rather than raising funds for international projects by issuing bonds and stocks and establishing funds through domestic and foreign capital markets, leading to a lack of awareness and ability to finance in the target market.

In terms of management, Chinese enterprises are in relative shortage of professionals in PPP and experience in overseas PPP market. The risk of investing in overseas PPP projects is far greater than traditional engineering projects. PPP projects require enterprises to implement the life cycle management of the project. However, Chinese enterprises are weak in project operation, compared to their strength in project construction. Chinese companies and financial institutions are not yet developed a sound mechanism for risk assessment and prevention, with limited capacities in feasibility study and survey, coordination on project operation, innovation in financing tools, operation monitoring, as well as risk management, all of which weakened the competitiveness of financing solutions provided by Chinese enterprises.

3.3 Policy Recommendations for Improving the Implementation of Pathway 2

China is to be applauded for its commitment to ramp up support for renewable energy around the world. It is in a better position to carry out these plans after several years of improving reforms for overseas investor performance, which will help ensure the effective implementation of this ambitious agenda. Several additional policy steps could help cement this progress. First, China can continue to crowd in private sector capital through cultivating a greater application of PPPs. Second, China can offer greater technical and financial support and greater accountability for outbound investors. Technical and financial support can open new possibilities and help investors meet best practice standards.

3.3.1 Strengthen Policy Support and Inter-Ministerial Coordination of the BRI PPP Projects

First, it is suggested that a BRI PPP inter-ministry coordination mechanism be set up, consisting of the Ministry of Finance, the Ministry of Foreign Affairs, the National Development and Reform Commission, the Ministry of Commerce, the People's Bank of China, the State Administration of Foreign Exchange, the State-owned Assets Supervision and Administration Commission, and the China International Development and Cooperation Agency. This mechanism is responsible for coordinating the foreign investment and external financing policies, improving the policies of enterprise performance assessment and financial supervision, for better complying with the international PPP rules and practices. China should build a top-level policy framework for high-quality development of BRI infrastructure including streamlining the approval of BRI PPP projects, and standardize the design, financing, construction and operation process and establish incentive mechanism for BRI projects. When developing BRI infrastructure cooperation, the ministries involved should take the initiative to promote PPP, especially in green energy sector which is regarded as the key growth area of BRI countries and is easier to be delivered.

Second, it is advised to establish a BRI PPP alliance, getting relevant ministries and enterprises (including construction enterprises, design institutes, engineering operators, equipment suppliers, consulting agencies, etc.) and financial institutions together for a good BRI PPP development ecosystem. This alliance also welcomes the participation of the PPP authorities, PPP units and project owners from BRI countries as well as international organizations, and joins hand with the Infrastructure Financing and PPP Network of Asia and the Pacific established by UNESCAP in 2018 with the assistance of China PPP Center.

Third, it is recommended to encourage Chinese enterprises to improve their PPP professional capacity and make rational investment. Chinese enterprises should train their own experts for overseas PPP development as soon as possible, establish prudent PPP project evaluation system, strengthen risk identification and

evaluation based on the target market, specific projects and their own capability, actively innovate the cooperation modes without ignoring the ESG rules in the process of project preparation, construction and operation.

Fourth, Chinese enterprises should be encouraged to pioneer green energy projects in appropriate countries or regions. It is suggested inspiring Chinese enterprises to make innovations in improving their international business abilities. It is necessary for Chinese enterprises to transform themselves from “enterprises that go global” to “globalized Chinese enterprises” by innovating its operation and management, improving the technology in engineering delivery, and strengthening the planning and operation ability of large-scale projects; to expand and seek for new investment and financing channels, improve the capacity in integrating domestic and international resources, and come up with a flexible design of financing structure to meet the needs of multiple market players. In addition, they need to improve the risk-sharing mechanism and build a reasonable exit mechanism.

3.3.2 Increase Technical and Financial Support for the BRI Clean Energy Investment

First, it is suggested that Chinese DFIs consider blending instruments across its overseas institutions to overcome some of the barriers to overseas renewable expansion. Blending grants with loans would expand the use of concessional loans and preferential export buyer’s credit facilities in outbound renewable energy projects in order to expand the opportunities for Chinese contractors and direct investors. Additionally, China may consider establishing special funds for grants or loans to support Chinese enterprises to participate in the construction of major projects (such as green energy projects) in BRI participating countries via PPP. Existing funds, such as the China South-South Climate Cooperation Fund and the Kunming Biodiversity Fund may also be able to effectively support these efforts. It is advised to establish a BRI PPP Project Development Facility to provide financial support to Chinese enterprises in order to encourage them to participate in PPP project development of the host country as early as possible, so as to improve their competitiveness as well as project construction and operation.

Second, it is suggested that Chinese government inspire Chinese financial institutions to improve their capacity of comprehensive service, engage in project preparation together with enterprises and guarantee agencies, and introduce appropriate financing schemes based on the situation in specific countries, markets and projects; to look for more flexible and sustainable financing solutions, such as new type of project financing and insurance products suitable for PPP projects; to strengthen risk awareness and prevention mechanism and optimize asset portfolio allocation by making good use of hedging, guarantee, insurance among other financial instruments to avoid systemic risks; to implement the concepts of sustainable development and ESG, and develop special financing products, such as green bonds and green loans; to encourage Chinese financial institutions to set up branches in key BRI countries to provide comprehensive financial services. As part

of this work, it is suggested that China continue to refine and implement the “Green Light System” of channeling investment away from high-risk activities and toward projects that are likely to be economically as well as environmentally sustainable.

Third, the Chinese government and its DFIs can continue to support its outbound renewable energy investors throughout project implementation, particularly those investors with long-term equity stakes such as those of PPP projects. These investors have longer-term commitments to these projects, and are thus exposed to a greater range of potential risks such as conflict and changing policy environments. The interests of Chinese enterprises can be better protected by means of diplomatic efforts and economic tools, such as strengthening intergovernmental cooperation, signing bilateral investment protection agreements and building a multilateral investment security mechanism. As part of this work, it is suggested to strengthen communication and publicity. It is necessary to actively participate in multilateral and bilateral PPP exchanges as well as in the formulation of international PPP rules, and share China’s PPP good practices and experience. It is valuable to advertise successful cases of BRI PPP projects in providing high-quality public services, improving local people’s livelihood, training local technical personnel and protecting the social environment.

3.3.3 Strengthen Comprehensive Service to Support the BRI Overseas Investment

First, it is suggested that China should develop a comprehensive overseas investment service system, pertaining to legal consulting, investment consulting, engineering equipment quality and safety supervision, cost consulting, risk management, finance and taxation, and provide professional services for outbound investment business. It needs to build up a domestic asset trading platform to carry out overseas asset transactions on a pilot basis so as to form a transfer mechanism for overseas investment assets and realize the refinancing or transfer of the project and its operation right, income right, operation right and equity, which contributes to the formation of a virtuous investment cycle.

Second, it is suggested that China continue developing the “whole lifecycle” approach heralded in MOFCOM’s 2021 Green Development Guidelines. First, China can continue to enhance investor accountability through the establishment of a blacklist of poorly-performing international investors, and the integration of this process with the ongoing plans for developing the “green light system” of encouraged, discouraged, and prohibited investment. Chinese DFIs are already well ahead of their peers in establishing robust exclusion inclusion and exclusion lists for outbound investments, and in developing post-hoc environmental assessments of investor and contractor performance. By combining these two streams of work, China can ensure that the post-hoc evaluations have meaningful input on future investment decisions, raising the expectation of investor performance and ensuring that the investors representing China’s push for renewable energy expansion are representing China well.

Third, it is suggested further carrying out more extensive BRI green development cooperation with other DFIs in the global south and in the world. Given that infrastructure projects are featured as large scale, long life cycle and high risks, it is important for Chinese enterprises to coordinate the various stakeholders to keep complementary advantages and risk sharing in project planning, design, financing, construction, operation and management, by means, including inter alia third-party market cooperation with developed countries and regions, cooperation with such entities as the Build Back Better World or the Global Gateway, cooperation with companies that have professional strength, and cooperation with upstream and downstream companies on the industrial chain. Combining China's significant technological and financial power with these institutions' deep knowledge of local environmental contexts in Africa and Asia, for example, can benefit host countries and ensure the effectiveness and longevity of Chinese investment in this crucial new sector.

4 Pathway 3: Enhancing International Cooperation to Support Green and Low-Carbon Energy Development Under the Framework of BRI

2021 is one of the seven warmest years on record [60], and a “crucial year” for the international community to fight against climate change [61]. The Sixth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) titled *Climate Change 2021: The Physical Science Basis* warns that human influence has led to “widespread and rapid” changes in the ecosystem and has warmed the climate at a rate that is unprecedented in at least the last 2000 years. Global warming of 1.5 and 2 °C will be exceeded during the twenty-first century unless deep reductions in CO₂ emissions and more ambitious climate change actions occur in the coming decades. In this regard, the international community is taking active cooperation across borders, fields and channels to jointly tackle the all-round impact of climate change on economic and social development. However, developing countries represented by multiple BRI participating countries restricted by the level of economic and social development and resource endowment, still face various challenges in terms of green and low-carbon energy development, including cost, infrastructure and technical capacity, etc. Strengthening international cooperation, promoting the flow and efficient utilization of resources, jointly exploring the pathway of regional green and low-carbon collaborative development, and facilitating the promotion and replication of development experience and models are still an indispensable and important force to support BRI green and low-carbon energy development.

4.1 The Positive Progress in the Global Response to Climate Change is Difficult to Break Through the Inherent Challenges Faced by Green and Low-Carbon Energy Development

4.1.1 Development Perspective: Positive Progress Has Been Made in International Cooperation to Tackle Climate Change

Cross-border: The Twenty-Sixth Session of the Conference of the Parties to the *United Nations Framework Convention on Climate Change* (UNFCCC COP 26) marks another important historical moment in the process of global environmental governance. The conference adopted the *Glasgow Climate Pact*, which puts forward new objectives and measures on climate change mitigation, adaptation, finance, technology transfer and capacity building, providing guidelines on rules, models and procedures for the implementation of the *Paris Agreement*. By the end of COP 26, nearly 140 countries had proposed the goal of “net zero emissions”, covering over 90% of world GDP; 153 countries have updated Nationally Determined Contributions (NDCs), covering around 80% of the world’s greenhouse gas emissions, and have put forward new 2030 emissions targets (NDCs); and 80 countries are now covered by either Adaptation Communications or National Adaptation Plans to increase preparedness to climate risks [62].

Interdisciplinary: The *Kunming Declaration* adopted in the Fifteenth Meeting (Part 1) of the Conference of the Parties to the *Convention on Biological Diversity* (CBD COP 15) recognizes that the crises of biodiversity loss and climate change “share many underlying drivers of change”, and that climate change is one of the main direct drivers of biodiversity loss [63]. The *Glasgow Climate Pact* notes the importance of ensuring the integrity of all ecosystems, including in forests, the ocean and the cryosphere, and the protection of biodiversity, as well as emphasizes the critical role of protecting, conserving and restoring nature and ecosystems in achieving the goals of the *Paris Agreement*. The impact of climate change on non-traditional environmental issues such as food security, health, gender equality and education has also been more widely recognized and acknowledged.

Multichannel: Although the commitment by developed countries to a goal for mobilizing USD 100 billion a year by 2020 has been officially postponed to 2023, the improvement of market-oriented mechanism and the positive actions of private sector investors are facilitating the emergence of a trillion-level green investment and financing market, which is expected to effectively offset the lack of public funding and alleviate the financial needs of developing countries to combat climate change. The parties to the *Paris Agreement* have reached consensus on relevant terms of Article 6, which has further strengthened institutional guarantee for the establishment of global carbon market. The Glasgow Financial Alliance for Net Zero (GFANZ), composed of more than 450 financial institutions with over USD 130 trillion in assets

across 45 countries, pledges to deliver USD 100 trillion of finance needed to achieve net zero emissions through private sector investment and public–private cooperation over the next 3 decades, so as to boost “decarbonization” transition of the real economy. The Net-Zero Banking Alliance (NZBA), representing 43% of banking assets worldwide, promises to accelerate its own decarbonization and promote the decarbonization transition of loan and investment decision-making [64].

4.1.2 Realistic Perspective: Green and Low-Carbon Energy Development Under the Framework of BRI Faces Great Challenges

Due to the reason that a large number of BRI participating countries are still in the stage of industrialization, some of them have underdeveloped economy, insufficient electricity and underdeveloped infrastructure, and energy shortage, which leads to the rapid increase of their energy demand. At the same time, limited by insufficient national financial resources, infrastructure construction, energy development technology and other problems, these countries’ energy structure and economic structure are relying on heavily on fossil fuels, making the green and low-carbon transition of energy sector facing greater challenges.

First, the upgrading cost of the existing high-carbon industrial structure is high. For BRI participating countries to achieve green and low-carbon transition of their industrial structure, they need to start building a green manufacturing system, including upgrading and transforming existing factories and equipment, using new technologies, increasing the proportion of renewable energy, etc. In the short term, it requires a large amount of capital investment and increases the production and manufacturing costs. This process not only needs constant financial and technical support, but also requires to improve policy and mechanisms, train industry professionals and build up capacity to enhance well coordination within the economy sector. The green and low-carbon energy transition involves all sectors of society, and for the vast number of developing countries along the Belt and Road, the low-carbon transition means a comprehensive social change. In particular, for major crude oil producers such as Kazakhstan, Nigeria and Venezuela, the high-carbon industry is an important source of government revenue. They need to afford the high transition costs needed for the smooth industrial transition, to address and defuse the impact of industrial restructure on economic growth, public income, new employment and social stability. The difficulty of financing that developing countries face is an international challenge, which exacerbates the socio-economic challenges of upgrading their industries. Besides, uncertainties in the market also create barriers for businesses to invest in developing countries, which may lead to higher investment costs. Despite the developed countries’ commitment to provide USD 100 billion per year to developing countries for their mitigation and adaptation activities under the *Paris Agreement*, the current progress is still far from the expected “sufficient, transparent and verifiable climate finance”. Due to the lack of necessary financial support for

upgrading the industrial structure, BRI participating countries face huge obstacles in their green and low-carbon energy transition.

Second, there is a need to resolve the carbon lock-in effect of high-carbon energy infrastructure. Previously, constrained by factors such as the power generation costs, high emission energy infrastructure represented by thermal power was a preference for BRI emerging economies and developing countries. Since 2021, those BRI participating countries with an energy structure dominated by coal, represented by Indonesia, Vietnam, Pakistan, and Kazakhstan, have made clear carbon neutrality commitment and promised to vigorously promote the green and low-carbon energy transformation. However, given that most BRI participating countries are still in the process of industrialization and urbanization, they have a greater demand for energy and basic raw materials. At the same time, as they lag behind developed countries in R&D and marketing of low-carbon technologies, they are more inclined to continue investing in new high-carbon infrastructure under the pressure of new demand. How to break away from high-carbon development, and how to balance the decades-long carbon lock-in effect of infrastructure and the demand for energy and economic growth remain the primary challenge for BRI participating countries, which requires long-term planning based on a country's specific national condition and needs to be solved in a step-by-step manner.

Third, different carbon emission standards make it difficult to establish rigid constraints in the process of transition. With the progress in environmental legislation, most BRI participating countries have issued corresponding environmental protection policies and formulated air quality standards according to their own green development plans. However, there are great differences in specific standards, rules and management flexibility, which makes it difficult to fully and effectively regulate the green and low-carbon investment behaviors. In addition, the investment and financing standards play a key role in the process of promoting BRI construction, but there are still some differences among them concerning the specific definition of "green and low-carbon", leading to some obstacles to the application, promotion, and supervision of green investment and financing standards. Finally, due to the huge differences in economic structure, resource endowment, human resources, technology level and development stage among BRI participating countries, there is no universally applicable green and low-carbon energy development path. In this sense, the different national conditions and different development goals of BRI participating countries are also one of the challenges that need to be addressed for BRI green and low-carbon energy development.

4.2 Promoting International Cooperation for Green and Low-Carbon Energy Development Under the Framework of BRI

In the past 8 years since its inception, the BRI has generated fruitful outcomes and positive influence worldwide. In 2021, with new goals and actions for low-carbon development being identified, the concept of green BRI has been further enriched and improved. Currently, it has become a key solution for China to work together with all sides to promote the implementation of the United Nations 2030 SDGs.

4.2.1 International Cooperation in Ecology and Environment Promotes Global Consensus on BRI Green Development

(1) The Development of Multilateral Cooperation Platforms under the Framework of BRI Green Development is Making Constant Progress

The Green Finance Committee (GFC) of China Society for Finance and Banking, in partnership with the City of London's Green Finance Initiative (GFI), published the *Green Investment Principles for the Belt and Road* (GIP) in 2018. Currently, over 40 financial institutions worldwide have signed the GIP to jointly develop the environment and climate risk assessment toolkit, climate and environment information disclosure framework and other systems and tools for the development of green finance. The BRI International Green Development Coalition (BRIGC) established in 2019 has been actively promoting dialogues, joint research and capacity building programs with a global perspective and operational model. Currently, BRIGC has over 150 partners from 43 countries, gaining positive response and extensive support from UN organizations, environmental authorities of BRI participating countries, international NGOs and think tanks, related businesses and environmental activists. In June 2021, 29 countries jointly launched the *Initiative for Belt and Road Partnership on Green Development* at the Asia and Pacific High-level Conference on Belt and Road Cooperation, highlighting the recognition of and support for green development philosophy from the international community.

(2) Policy and Legislation System to Support BRI Green Development is Being Improved

In 2017, the Ministry of Ecology and Environment (former Ministry of Environmental Protection) issued *The Belt and Road Ecological and Environmental Cooperation Plan* and released the *Guidance on Promoting Green Belt and Road* jointly with the Ministry of Foreign Affairs, the National Development and Reform Commission, and the Ministry of Commerce. The two documents identified the priority tasks and roadmap for the development of Green Belt and Road in terms of enhancing exchanges and publicity, ensuring the ecological and environmental safety of investment activities, building a green cooperation platform, and improving

policy measures, and proposed the objective of building a relatively complete eco-environment protection service, support and guarantee system and implement a cohort of key eco-environment protection projects. In July 2021, the Ministry of Commerce and the Ministry of Ecology and Environment joint issued *Green Development Guidelines for Overseas Investment and Cooperation*. The *Guidelines* identified 10 priority tasks, including preventing ecological and environmental risks, following international rules on green development, building green infrastructure, and promoting green production and operation, pointing out the direction for the green development of overseas investment and cooperation under the framework of the BRI. In January 2022, the Ministry of Ecology and Environment, together with the Ministry of Commerce, issued the *Guidance for Ecological and Environmental Protection in Foreign Investment and Cooperation Projects*, which is an amendment to the *Guidelines for Environmental Protection in Foreign Investment and Cooperation* issued in 2013. The document further optimized environmental management of foreign investment and cooperation projects. In March 2022, the Ministry of Ecology and Environment, the National Development and Reform Commission, the Ministry of Foreign Affairs and the Ministry of Commerce jointly issued *Opinions on Promoting the Green Development of the Belt and Road Initiative*. The document proposed 15 tasks for strengthening cooperation in green infrastructure development, green energy and green transportation in terms of promoting cooperation in priority areas of green development, promoting the green development of overseas projects, and improving the supporting system for green development. The document also identified the major goals for Belt and Road green development in 2025 and 2030, pointing out the direction for jointly promoting the green development of the Belt and Road [65].

(3) Capacity Support for the Green Development of the Belt and Road is Being Optimized

First, China has been enhancing the development of the BRI Environmental Big Data Platform and released the *Belt and Road Environmental Big Data Report (2021)* to build and improve the environmental risk assessment system for foreign investment and cooperation projects. Second, efforts have been made to promote the construction of the Belt and Road Environmental Technology Exchange and Transfer Center (Shenzhen). With the innovative advantages of Shenzhen Pioneer Demonstration Zone and the development advantages of Guangdong-Hong Kong-Macao Greater Bay Area, the BRI Green Innovation Conference 2021 was held and the Belt and Road Environmental Technology Transfer and Industry Incubator & Innovation Center was established to foster a flagship green technology match-making platform and promote Chinese solutions. Third, the Green Silk Road Green Envoys Programme have been implemented. The Belt and Road Youth Green Envoys Dialogue, Climate Envoys Action and other capacity building activities have been organized, providing training for about 3000 environmental officials and technical staff from nearly 120 developing countries. Fourth, the Belt and Road South-South Cooperation Initiative on Climate Change has been carried out to help developing countries that are vulnerable to the impact of climate change to better cope with climate change through

jointly building low-carbon demonstration zones, implementing climate adaptation and mitigation programs, and carrying out capacity building and training activities. Through providing green and low-carbon technology, products, knowledge and information services, the Initiative has been very effective in supporting BRI participating countries to address environmental and climate challenges.

4.2.2 International Cooperation on Clean Energy Has Built a Solid Foundation of BRI Green and Low-Carbon Development

(1) Green and Low-Carbon Development has Become an Important Factor in BRI Energy Cooperation

In 2017, the National Development and Reform Commission of China (NDRC) and the National Energy Administration (NEA) jointly formulated and released *the Vision and Actions on Energy Cooperation in Jointly Building Silk Road Economic Belt and twenty-first-century Maritime Silk Road*, which clearly stated that joint efforts will be made to build a green and low-carbon global energy governance structure and push forward global green development together. In October 2018, the first Belt and Road Energy Ministerial Conference was successfully held in Suzhou, Jiangsu. Chinese President Xi Jinping stressed in his remark that energy cooperation is a key area for BRI development, and China is willing to strengthen energy cooperation with other countries in the framework of BRI to promote establishment of Belt and Road Energy Partnership (BREP). In April 2019, the BREP was officially established in Beijing with 30 countries including China. Member states of the partnership jointly released the *Cooperation Principles and Concrete Actions of the Belt and Road Energy Partnership*, in which one of the main objectives is to promote cooperation in renewable energy and energy efficiency, so as to address climate change, secure universal access to affordable, reliable and sustainable modern energy service. On October 18, 2021, the second Belt and Road Energy Ministerial Conference was held in Qingdao. The meeting released the *Qingdao Initiative for Belt and Road Green Energy Cooperation*, which further stated the support stepped up for other developing countries in developing green and low-carbon energy. In 2021, the *Green Development Guidelines for Overseas Investment and Cooperation* issued jointly by the Ministry of Commerce (MOFCOM) and the Ministry of Ecology and Environment (MEE) also proposed to support outbound investment in renewable energy as well as build a clean, low-carbon, secure and efficient energy mix.

(2) The Twin Goals of Carbon Peaking and Neutrality are Boosting the BRI Green and Low-Carbon Energy Development

In 2020, China pledged its enhanced NDC and proposed the “30 · 60 Dual Carbon Goal”. China has been promoting the utilization of renewable energy as an important part of the implementation of the dual-carbon goal written into the national 14th Five-Year Plan (2021–2025) and the 2035 Long-term Goal. The energy sector will also successively issue *the Implementation Plan for Carbon Peaking in the*

Energy Sector, the 14th Five-Year Plan for the Modern Energy System, the Opinions on Improving Institutional Mechanisms and Policy Measures for Green and Low-Carbon Energy Transition, and other top-down designs in various sub-sectors, which will not only serve the green and low-carbon transition of China's energy sector, but also point out an important direction for further promoting the green and low-carbon BRI development. Since China proposed the dual carbon goal, countries and regions including Kazakhstan, Indonesia, Saudi Arabia, Argentina, Brazil and others have successively announced their commitments to achieving carbon neutrality. Meanwhile, Uzbekistan, Kyrgyzstan and other countries and regions along the BRI have also put carbon emission reduction on the government's agenda. These countries and regions are all important partners in the BRI energy cooperation. China's commitment of no longer building coal-fired power projects abroad will also encourage other developing countries to cooperate with China to switch to renewable energy. There will be more space for cooperation in the field of renewable energy development and technology exchanges in the future.

(3) Green Investment and Financing is Guiding Clean Energy Development under the Framework of BRI in a Positive Manner

Domestically, China established a green financial system in the early days, and now has the world's largest green credit market and the second largest green bond market. In 2021, the Ministry of Commerce and the Ministry of Ecology and Environment jointly issued the *Guidelines for Overseas Investment and Cooperation on Green Development*, proposing to support foreign investment in clean energy and build a clean, low carbon, safe and efficient energy system. It is believed that with the progress towards carbon peaking and carbon neutrality, financial institutions will further improve the green financial system and a richer green financial product system with the goal of carbon neutrality. In terms of strengthening international cooperation on green finance, the G20 Sustainable Finance Working Group co-chaired by China and the United States released the G20 Sustainable Finance Roadmap. The IPSF Sustainable Finance Standards Working Group led by China and the European Union is about to release a draft of *Common Ground Taxonomy: Climate Change Mitigation*, which covers economic activities that contribute significantly to climate change mitigation, including energy, manufacturing, construction, transportation, solid waste and forestry. The cooperation will further promote the green process of Chinese investors' overseas investment as well as providing necessary financial support and investment guidance for the BRI clean energy cooperation.

4.3 Policy Recommendation for Improving the Implementation of Pathway 3

4.3.1 Exploring a New Pathway for Green and Low-Carbon Cooperation in Global Governance System

The National Determined Contribution (NDC) and diversified behavior of global inventory initiated by the *Paris Agreement* have laid the foundation for global climate governance. Although the BRI is mainly carried out and promoted according to bilateral or multilateral cooperation agreements between China and relevant countries, and is not bound by the United Nations Framework Convention on Climate Change and the Paris Agreement, the underlying theme of the green BRI is green development, and it is necessary to fully integrate the green BRI development into the framework of global climate governance according to the situation of global climate governance and the emission stages and characteristics of its own region. China should play a more active role to fulfill its green commitment, give play to the existing BRI green and low-carbon international cooperation platform, and firmly implement the objectives of the second Belt and Road Forum for International Cooperation, which is to attach importance to promoting green development and meeting the challenges of environmental protection and climate change, including strengthening cooperation in implementing the Paris Agreement [65]. China will actively align the renewal of independent contribution of the BRI participating countries with the long-term low-emission development strategy of greenhouse gas in the middle of this century, seek a fair, reasonable, win-win cooperation and support solution under the global temperature rise target, and support the BRI developing countries, especially the least developed countries, landlocked developing countries and small island developing states to address challenges brought by climate change.

4.3.2 Deepening Regional Cooperation

The resource endowments of countries along the BRI are quite different, and each country has different appeals for green transition. First of all, it is important to strengthen mutual trust in bilateral and multilateral parties in political security, and stay true to the principle of extensive consultation, joint contribution and shared benefits. Although all BRI participating countries have joined the Paris Agreement and committed to accelerating the process in addressing climate change, there are still differences in product demand, technology demand and policy priorities due to different economic development levels and climate challenges. Therefore, it is important for China to make good use of the existing multilateral cooperation mechanisms under the framework of the BRI, such as the China-Eastern Europe mechanism of “16 + 1”, China-ASEAN mechanism of “10 + 1”, Asia-Europe Meeting and China-Arab Cooperation Forum. For countries and regions that are unable to improve NDC due to great economic growth pressure, on the basis of reaching cooperation consensus,

the issue of climate change should be fully considered into policy communication, and governments at all levels should timely exchange ideas on policies to deal with climate change, so as to ensure that climate policies of different countries are compatible to avoid conflict. Secondly, it is necessary to deepen and expand the existing cooperation mechanisms. Countries along the BRI with high development level and relatively rich experience can contribute solutions through bilateral or regional cooperation, and help other countries to find a green growth path that suits their national conditions and optimizes resource utilization efficiency. In addition, make full use of the existing mechanism to promote the green and low-carbon development of the BRI to contribute to global climate governance, and explore the establishment and improvement of communication and dialogue mechanisms for other countries and regions not covered by the BRI, such as the establishment of a climate change partnership and a regular consultation mechanism, so as to provide a more solid guarantee of cooperation for the green and low-carbon development of the BRI.

4.3.3 Deepening Cooperation on Industrial Technology and Market Exchange

The BRI international cooperation has created unprecedented opportunities for BRI participating countries to enhance technological exchange in green and low-carbon industries, such as PV and solar energy, hydrogen energy and energy storage, to adopt innovative models for industrial and technological cooperation, and to optimize the spatial deployment of production capacity. In order to support BRI participating countries to realize green and low-carbon transition in industrial structure and development pathways and achieve the synergy in reducing pollution and carbon emissions, it is necessary to promote the BRI green and low-carbon industrial technology cooperation and the flow of production factors in the market. First, it is necessary to promote the low-carbon transformation of traditional industries with advanced technologies. Second, it is necessary to vigorously develop clean energy, promote cooperation in the development of PV power, solar power, hydrogen energy and other types of clean energy, and accelerate the phase-out of traditional industries based on fossil energy. Third, it is necessary to improve the management of global green value chain and incorporate ecological and environmental protection, energy conservation, low-carbon development and emission reduction into every aspect of the value chain to promote the structural transition and upgrade of traditional high-carbon industries. Fourth, it is necessary to further improve the BRI green trade and industrial cooperation system, promote the formation of an inter-regional technological cooperation and exchange platform and build up a green and low-carbon technology transfer and equity exchange system for BRI participating countries to facilitate the efficient sharing and promotion of green and low-carbon knowledge and technologies. Fifth, it is necessary to accelerate the development of regional carbon emission reduction standards and carbon markets. We need to link carbon markets of different countries and regions and develop voluntary carbon emission reduction trading and mandatory emission reduction to form regional mechanism for carbon emission pricing.

5 Synthesis Policy Recommendation

In the context of global green and low-carbon transition, the green BRI development will have richer content and further broaden its scope. To facilitate more effective and practical implementation of green BRI, it is necessary to overcome the objective constraint of carbon emissions on BRI green and low-carbon development, respond actively to realistic challenges of post-pandemic economic recovery and sluggish global green investment, fully recognize the continuous impact of the changing international situation on BRI international cooperation, and effectively balance the differentiated transformation endowments and development needs of regions and countries along the Belt and Road. The key is to stick to the key path of green and low-carbon energy development, and take effective actions centering on 3 key aspects—industrial and technological cooperation, investment and financing cooperation, and international cooperation.

Recommendation 1: Facilitate the industrial and technological cooperation in clean energy to become an important component for BRI green and low-carbon development, and provide systematic support for the BRI participating countries to address climate change, achieve green recovery, and move towards sustainable development.

- (1) Identify the key needs and overall trends of BRI green and low-carbon energy development, and expand partnerships based on the existing bilateral, multilateral, regional and international cooperation mechanisms.
- (2) Make good use of China's market advantage and development experience in the global clean energy market, and step up cooperation with focus on clean energy infrastructure construction, equipment manufacturing, and technology promotion and application.
- (3) Give full play to the key role of China's overseas development finance institutions and leverage their resource advantages. Encourage them to help bear the credit risk of overseas financing and scale up support for investment in clean energy industrial and technological cooperation.
- (4) Establish a more systematic and complete mechanism for the industrial and technological cooperation in clean energy under BRI framework, and reinforce the systematic support with policy and strategic alignment, investment and market support, capacity building, and technical assistance as the starting points.

Recommendation 2: Guide various market players to improve capacities for green investment and financing services, to actively participate in and to support BRI green and low-carbon energy development.

- (1) Scale up financial support for green and low-carbon energy development through the BRI. Establish a government-led and market-oriented BRI green development fund to facilitate innovation of multi-channel hybrid financing models that blend government finance with sovereign wealth funds, equity funds, grants, and

other financial sources. Make use of the advantages of public–private partnership (PPP) to facilitate the development and finance of green and low-carbon energy projects.

- (2) Reinforce the “whole lifecycle” approach to environmental management of BRI projects, enhance risk awareness, and improve risk prevention mechanisms. Lead Chinese policy banks and major investors to track the shares of their infrastructure portfolios dedicated to the sector of green and low-carbon energy. Soft targets may be set to further encourage growth in this area. Encourage development finance institutions (DFIs) to progress in this direction by facilitating the development of renewable energy projects, the publication of project information including environmental impact assessments, and the use of independent inspectors and accountability mechanisms.
- (3) Strengthen the refinement and implementation of existing guidelines, guidance, and opinions and steer all actors towards the effective implementation of green development concept throughout the whole process of overseas investment and cooperation. Explore the establishment of an inter-ministerial coordination, incentive, and restraint mechanism for key investment projects. Facilitate the establishment of a data platform that analyzes the extent to which BRI investments are aligned with the *Opinions on Promoting the Green Development of the Belt and Road Initiative* (released in 2022 by NDRC, MFA, MEE, and MOFCOM), the *Green Development Guidelines for Overseas Investment and Cooperation* (released in 2021 by MOFCOM and MEE), and the *Guidelines for Ecological and Environmental Protection in Overseas Investment and Cooperation Construction Projects* (released in 2022 by MEE and MOFCOM).
- (4) Further clarify the scope of support, standards and best practices of BRI green and low-carbon energy development. Actively explore the potentials of applying the *Green Bond Endorsed Projects Catalogue (2021 Edition)* in the BRI investment cooperation on clean energy. Continue the research efforts for the Green Development Guidance for BRI Projects and pilot the development of corresponding guidelines for the green and sustainable development of key industries, such as photovoltaic power generation.

Recommendation 3: Deepen international cooperation to support BRI green and low-carbon energy development, and explore a new path for green and low-carbon cooperation in a changing global governance system.

- (1) Deeply align with the BRI participating countries’ demands for green and low-carbon development. Based on multilateral cooperation platforms such as the BRI International Green Development Coalition (BRIGC) and Green Investment Principles for the Belt and Road Development (GIP), facilitate dialogues and exchanges between governments of BRI participating countries, financial institutions, enterprises, and other stakeholders. By using initiatives including the Belt and Road South-South Cooperation Initiative on Climate Change and the Green Silk Road Envoys Programme, assist the BRI participating countries, especially the least developed countries (LDCs) and Small Island Developing States (SIDS), to respond to the challenges brought by global climate change and

- achieve inclusive and resilient recovery. Facilitate the establishment of South-South platforms for green project preparation and development to align the BRI with developing countries' demands for clean energy.
- (2) Actively tackle with the challenges brought about by the changes of the global governance system, and create the more open, inclusive, mutually beneficial and win-win cooperation on BRI green and low-carbon development. Make full use of the communication and dialogue mechanisms such as the China-US Special Climate Envoy Meeting and the Ministerial on Climate Action to help China continue the effort for fruitful dialogues and cooperation on climate change with the US, the EU, the UK and other major economies, and effectively implement the United Nations Framework Convention on Climate Change and the Paris Agreement. Encourage all actors to reconcile differences and seek common ground. Facilitate synergies in areas of international investment and financing, development assistance, and third-party market cooperation. Carry out multi-faceted cooperation, multi-platform dialogues, and multi-channel communication to help developing countries improve infrastructure and facilitate common development of the world.
 - (3) Deepen platforms for South-North- South cooperation on low carbon cooperation and seek cooperation between BRI and efforts such as Build Back Better World (B3W) and the Global Gateway.

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Overview: Maintaining the Strategic Determination and Stabilizing Expectations Towards a Low-Carbon Green Transition: Opening a New Green Chapter for High-Quality Development

2022 Policy Recommendation of the China Council for International Cooperation on Environment and Development

As unprecedented global changes and the once-in-a-century pandemic intertwine, the world finds itself in a new period of turbulence and changes. Economic recovery is fragile and weak, geopolitical conflicts are escalating, energy and food prices are rising, and global ecological deficits are widening. The gap between poor and rich countries is ever increasing, while the number of people living in extreme poverty is growing. Four key climate change indicators—greenhouse gas concentrations, sea level rise, ocean heat, and ocean acidification—all set new records in 2021. Human activities are causing land, ocean, and atmospheric changes on a global scale, with lasting and detrimental effects on ecosystems and sustainable development.

In an international context of mounting instability, risk, and shocks, countries around the world are faced with the challenge of reconciling short-term security and stability goals with long-term green and low-carbon development. The international community is paying close attention to China's strategic determination and pathways toward the multiple objectives of carbon reduction, pollution reduction, ecological restoration, nature conservation, and growth under the general principle of "prioritizing stability while pursuing progress". It will not only affect the practice of China's new development concepts of innovation, coordination, green, openness, and sharing, but also drive the advancement of inclusive, green, low-carbon development at the global level.

As it marked its 30th anniversary in 2022, the China Council for International Cooperation on Environment and Development (CCICED) recommends that China should unremittingly hold firm in its strategic determination toward Ecological Civilization, by prioritizing and stabilizing expectations for a green, low-carbon transition and move from securing short-term economic, energy, food and other security to unleashing win-win short and long-term green economic stimulus, innovation,

low-carbon growth in which science links short, interim and longer-term green development targets and timetables. In this way, China will open a new green chapter for high-quality development.

Stabilize growth through green transition and ensure short-term security and stability. A win-win situation for energy security and climate mitigation can be achieved through the development of renewable energy and the decarbonization of key economic sectors and urban centres with increased demand-side energy savings, energy and other resource efficiency circular economy action. Detailed investment and green technology roadmaps should be developed, updated, and monitored that align sector-specific policies with carbon-peaking and carbon-neutrality goals. China should adopt three interlinked national strategies for a sustainable food system, Nature-Based Solutions, and climate adaptation. Low-carbon, climate-resilient, and clean development should be integrated into large-scale spatial planning in large river basins and other areas to promote coordinated regional development.

Drive growth through green transition and unleash the momentum of high-quality and innovative growth in the medium and long terms. China should integrate digitalization with sustainable development and promote green technology innovation and green digital governance, and advance the acceleration of green technology deployment in all relevant sectors through direct or blended public-private investment, standards, incentives, green taxes. Engage the public in linking digital platforms with low-carbon, green lifestyles.

Strengthen growth through green transition, improving institutions and mechanisms for governance, deepening green and low-carbon dialogues and cooperation, and laying the foundation for inclusive, green, and healthy global development. Policy coherence should be enhanced. A multi-objective collaborative mechanism to maximize synergies among carbon emissions reduction, pollution prevention, ecological restoration, nature conservation, circular economy, climate adaptation, and economic prosperity should be established. Develop short-, medium- and long-term risk prevention and mitigation plans for industrial and other sectors, regions, and communities affected by the low-carbon transition. Maintain engagements in multi-lateral and bilateral cooperation and concrete exchanges through the Green Belt and Road Initiative and multilateral and regional trade cooperation platforms to achieve the Sustainable Development Goals.

Specific recommendations are as follows.

1. Remain Committed to a Green and Low-Carbon Transition and Ensuring Security and Stability in Key Areas

i. Economic Security

1. *Implement green and low-carbon economic stimulus measures to maintain macroeconomic stability.* Economic recovery plans should prioritize strategic investments toward green and low-carbon development. The expanded use of carbon pricing and other market-based green measures should maximize cost-effective reductions while paying special attention to price stability and investment predictability. Standards should be planned with industry associations to scale up and mainstream green public procurement, accelerate green technology innovation, and increase productivity. Steps to promote green trade in low-carbon, environmental products and services should increase. Further efforts are needed toward the sustainable sourcing of food and other supply chains, including traceability systems, information disclosure, and incentives to promote compliance.

ii. Energy Security

1. *Accelerate investment in renewable energy.* The broad reform of China's electricity power market toward greater market orientation will strengthen the efficiency of market pricing mechanisms that, in turn, will attract additional private sector investments in green electricity generation. The current spot market should be expanded, with additional pilot projects that include interprovincial trading. Increased renewable energy deployment should include land and offshore planning, using best-in-class environmental impact assessments, and respect the ecological redline and spatial planning that protects ecological systems, including migratory corridors. The further scaling up of renewable energy should include the early queuing for initial public offerings (IPOs), targeted loans and equity financing, and lower required reserve ratios. Regional renewable energy pilot projects should focus on correcting poor intra-provincial power consumption and outward grid connectivity, the inadequate development of regional power grids, and lagging price transmission mechanisms. Power grids should become more flexible and interconnected, and complemented with additional power storage to better integrate renewable energy sources.
2. *Stabilize the stock, strictly control the increment, and guide the orderly phase-down of coal power.* Make efforts to peak coal use by 2025 in order to achieve peaking of carbon dioxide emissions before 2030. Short- and interim-term planning should be closely aligned with the dual control low-carbon transition, comprised of a short-term shift in coal power from base-load power generation to peak-management power generation; the elimination of outdated coal generating

capacity while ensuring reasonable operating hours for high-efficiency and low-emission coal power; modernizing the remaining coal power fleet to further cut criteria air pollutants; paying special attention to cutting methane and other short-lived climate pollutants; paying close attention and leading financial risk disclosure related to coal and other fossil-fuel investments, and adjusting investors' expectations for action related to stranded asset risks. An open and competitive auction-based mechanism to replace the guaranteed hours and price of coal-fired power generation units should be established, in conjunction with an efficient electricity-price market to provide economic returns for the flexibility of power.

iii. Food Security

1. *Develop a national strategy for a sustainable agri-food system transition to ensure food security and contribute to carbon peaking and carbon neutrality.* Increase the use of low-till, no-till, cover cropping, rotational cropping, and other proven regenerative and ecological restoration methods. Promote new technologies and applications to increase food production capacity while reducing greenhouse gas emissions within agricultural production chains; protect natural ecosystems and productive agricultural land from conversion to other uses; restore damaged natural ecosystems and degraded agricultural soils; expand the “Clear Your Plate” campaign to further cut food waste and plastic waste; combine mandatory and voluntary product standards to reduce greenhouse gas emissions in the food supply chain; and launch a pilot food label that integrates healthy and low-carbon food consumer information.
2. *Optimize agricultural fiscal incentives and financing measures.* Reform and repurpose environmentally harmful agricultural subsidies toward support systems that increase the harvesting of greener, ecological and carbon-neutral agricultural products. A green tax system covering agri-food should include a carbon tax for large-scale, carbon-intensive aspects of the agri-food system that would catalyze financing and incentives for sustainable production and procurement in the agricultural supply chain, supported by market-oriented innovation of green agri-food technologies. Eco-compensation payments should assist farmers and fishers in the just transition to sustainable food systems.

iv. Climate Security

1. *Integrate climate risk assessment and adaptation strategies into large-scale spatial planning and the design of urban and rural areas to enhance their climate resilience.* A national climate risk map should be developed and updated regularly. A comprehensive climate risk assessment system by zoning and categorization and targeted climate adaptation strategies needs to be developed. A resilient urban and rural spatial planning should be built, and strict climate safety

assessments for project site selection should be conducted. Integrate the use of nature-based solutions and green infrastructure to strengthen the construction of systematic and engineering disaster prevention systems.

2. *Further innovate financial instruments to enhance risk resilience.* The central government and local governments along the Yangtze River and other river basins, coastal, urban, and other areas should jointly establish a pooled risk fund to co-finance risk mitigation actions and accelerate long-term climate-resilient planning. A disaster insurance system that combines policy insurance and commercial insurance should be developed, with a focus on securing insurance coverage in rural areas. Disaster insurance can help increase public awareness about practical and affordable climate risk mitigation actions.

2. Accelerate Green Technological Innovation to Foster New Economic Growth Impetus

1. *Align digitalization with sustainability transformations to enable and accelerate low-carbon technological innovations.* More effort should be made to accelerate the development of digital technologies, explore intelligent solutions for sustainable development, and optimize production and consumption patterns; promote intelligent manufacturing, digitalize cities and infrastructure, and support sustainable transport and climate-smart production; optimize the spatial layout of the digital sector, data centres and IT infrastructure to advance net-zero operations; and accelerate the channeling of more computing resources from the eastern areas to the less-developed western regions to promote the low-carbon and high-quality growth of the digital economy. Pay special attention to the enormous role of young people in using digital apps to accelerate carbon-neutral, zero-waste, and nature-positive lifestyles and consumer choices.
2. *Facilitate the scaling up of low-carbon and zero-carbon innovative technologies.* Maximize the role of new market entrants as the main driver of technological innovation, by emphasizing the role of market-oriented renewable energy actors. Scale up the upgrading and improvement of low-carbon technologies such as heat pumps, the greater use of wooden materials in buildings, net-zero transmission systems, recharging infrastructure, and other steps. Increase the use of applied research funding for emerging green technologies, through direct financing, joint ventures, and public procurement; further develop guidelines, tax, and other incentives for net-zero commercial, institutional, and residential buildings; increase investment in green hydrogen, small-scale carbon capture, utilization and storage, smart grids, and circular economy opportunities.

3. Strengthen a Comprehensive, Green and Low-Carbon System to Bolster Long-Term Endeavours in High-Quality Development

i. Establish a Multi-objective Collaborative Mechanism for Pollution Reduction, Carbon Reduction, Ecological Restoration, Nature Conservation, and Growth

1. *Mainstream Nature-Based Solutions (NbS)*. Establish a standard Chinese system for NbS that aligns with the 2022 UNEA multilateral definition and international standards; integrate NbS into existing policies such as the ecological redline, expand the *Green Bond Endorsed Projects Catalogue* and an updated green finance classification system to include eligible NbS project financing; establish measurement and indicators to establish a multi-disciplinary monitoring and evaluation platform; integrate climate and biodiversity outcomes in NbS financing, including linking emerging climate risk and nature risk disclosure tools.
2. *Develop a sound governance system for green and low-carbon transition and strengthen innovative and flexible institutional capacity building*. Prioritize the development of a dedicated climate change law to set the necessary legal basis for China's climate transition, and explore the inclusion of dual carbon targets and climate adaptation into the scope of public interest litigation by procurators. Create an ongoing working dialogue between financial regulators, supervisors, and others and MEE to develop and ensure ESG standards. Allow consumers to directly purchase green electricity. Establish a green responsibility liability account for governments, enterprises, and individuals. Develop a comprehensive climate data system and standards, and increase the integrity of the national carbon market. Strengthen emissions data quality through capacity building and the clear delineation of responsibilities emitting companies, and set effective deterrents for failure to comply. Expand carbon market coverage to other sectors like steel, aluminum, chemicals and others, improve carbon pricing linked to power market reform, and adopt a national carbon emissions cap with clear annual targets on the cap in relation to the dual control system. Carbon pricing should take account the differing distributional effects on vulnerable groups, including lower-income households and women, with supporting income measures like direct payments to households or other offsetting payments. Specific attention should be paid to regional and sectorial differences, the inter-regional factor flow, and security of industrial and supply chains.

ii. Improve Market-Driven and Government-Led Innovation Mechanisms for Sustainable Investment and Financing

1. *Build a diversified capital investment and financing mechanism.* The use of transition finance to help companies transition from brown to green operations should be based on guidelines and a measurement system that discloses climate, biodiversity, and pollution risks, and sets transition timelines aligned to the 1 + N and dual-control system. Ensure that transition investments do not lead to a net increase in fossil fuels over the mid-term. Additional steps should be taken to encourage public–private partnerships (PPPs) and payments for ecosystem services (PES) to integrate climate, environmental, and ecological financing. A multistakeholder system to track and report annually on ESG-related greenwashing should be established.

iii. Prevent Transition-Related Risks in Key Affected Sectors and Regions

1. *Systematically assess risks from green and low-carbon transition and identify key affected sectors and regions.* Undertake an ongoing, systemic risk assessment of the low carbon green transition, paying close attention to inflationary effects of carbon pricing, stranded asset financial risks, price volatility and default risks in high-carbon sectors. Strengthen risk information disclosure and early warning systems for related regions, sectors, and assets. Create a national climate risk map that can be scaled for use by local authorities, engineers, city planners and others. Support an equitable and inclusive just transition, develop relevant social sustainability frameworks to take into account the needs at the community level, including changing requirements for livelihoods, employment, youth engagement, gender equity, and feasible opportunities for green development. Long-term plans should include providing phased policy safeguards for coal-dependent or high-carbon industrial and other sectors, with social measures that include skills training, re-employment, and local tax adjustments to facilitate a fair and smooth transition.

4. Enhancing Integrated Ecosystem Based Management and Optimizing Low Carbon and Resilient Spatial Patterns

i. Strengthen Integrated Climate-Resilient Management for Low-Carbon and Resilient River Basins

1. *Improve climate resilience in the integrated management of important river basins.* Implement the requirements of the Yangtze River Protection Law and develop a cooperative governance mechanism based on large-scale spatial planning and the co-management of pollution, ecosystem protection, low-carbon development, and climate adaptation. Detailed climate vulnerability assessments should be made throughout the Yangtze River basin, from upstream to downstream areas, major tributaries, key urban and rural agglomerations, river coastlines, estuarine deltas, flood storage areas, and agriculture and natural ecological zones. A risk early warning system should be implemented at the basin level for extreme climate-related weather events, with special attention to flooding, wildfires, drought and heat waves.
2. *Reinforce ecological conservation and restoration of river basins.* Strengthen the control of soil erosion and desertification in mountainous and hilly areas and implement the “returning space to rivers” campaign to restore river and lake basins. Systematically control hydroelectric power, starting with ensuring proposed projects undergo robust, science-informed, and participatory environmental impact assessments, and that all hydropower operations meet the requirements of hydrological integrity and environmental flows. Mitigate negative impacts through ecological compensation areas. Construct fish passages; promote “grain-for-green” in ecologically sensitive areas and strengthen ecological restoration; pay attention to the melting of glaciers at the source of the Yangtze River and strengthen monitoring and early warning; and improve the safety and security mechanisms for vulnerable groups—especially women—in disaster-prone areas such as villages, small towns, and flood storage areas.
3. *Strengthen integrated water and land management of basin and promote the transition of the downstream industrial port shoreline into an ecological shoreline and a shoreline for residents.* Concerted effort should be made to develop and oversee the implementation of the ecological environment zero-development and restricted protected area access list based on the ecological conservation red-line that include setting regulations covering the upper limit of resource utilization and shoreline protection and utilization. Integrate green and low-carbon objectives in the basin-wide law, regulations, standards, and opinions that include thresholds for the optimal utilization and vacating and replacing of the shoreline; reserve land on the shoreline to provide flexibility for future green development in compliance with spatial plans; explore the cultural and economic values of water; and promote shoreline renewal and public space construction.

ii. Ocean Security: Advancing a Sustainable, Low-Carbon Oceans Economy

1. *Strengthen the protection and restoration of marine ecosystems and harness the value of marine carbon sinks.* Extensive measures should be taken to strictly enforce zoning management systems to avoid further destruction of marine habitats and coastal wetlands, and to restore degraded or damaged coastal wetlands and strictly protect critical marine habitats; invest in the creation of resilient, well-connected networks of marine protected areas covering national parks, nature reserves, and marine areas within the ecological conservation red-lines; align large marine protected areas and habitats of major importance with carbon storage; refer to the Intergovernmental Panel on Climate Change (IPCC) guidelines to include oceanic carbon sinks in the national greenhouse gas inventory; and scientifically assess blue carbon in marine and coastal ecosystems under climate-smart integrated management for inclusion in China's updated nationally determined contribution. Anticipate the forthcoming global treaty on tackling plastic pollution by taking early measures that encourage reduction, reuse, recycling, and replacement, and support international cooperation. Initiate pilot projects to tackle plastic pollution before the completion of the global plastics treaty.
2. *Develop green marine industries and climate-smart ports.* Strengthen research and international cooperation in safe and efficient marine carbon sequestration technologies; establish supporting safeguards and incentive mechanisms for marine carbon sinks; explore the development of the application of carbon capture, utilization, and storage in offshore waters; intensify research and development on clean fuel technologies; expand the scale of offshore wind power production, and support the development of green hydrogen and ammonia energy industries; explore the establishment of green marine corridors connecting net-zero marine ports; and initiate further measures to increase the use of renewable fuels in ocean-going fleets.

5. Deepen International Environmental Cooperation to Maintain an Open, Inclusive, and Mutually Beneficial International Environmental Governance Process

i. Strengthen International Climate and Biodiversity Dialogues and Exchanges and Contribute to Global Environmental Governance

1. *Continuously promote bilateral and multilateral climate and biodiversity dialogues.* In the COP 15 process, China should prepare for the implementation of the Post-2020 Global Biodiversity Framework, including updating the National Biodiversity Strategy and Action Plan (NBSAP). Building on positive dialogue mechanisms, such as the EU–China High-Level Climate and Environment Dialogue, and the Ministerial Meeting on Climate Action, China and relevant parties should actively carry out Track 2 and Track 1.5 dialogues to control CO₂ and non-CO₂ greenhouse gases. Building on the China–EU, G20, UNEP, and other initiatives, continue to identify the next steps in green financial mechanisms, including scaling up of Nature-Based Solutions.
2. *Maintain the momentum of linking nature and climate actions and promoting synergies.* Harness climate financing linked to Nature-Based Solutions by formalizing full regulations for China Certified Emissions Reduction (CCER) methodologies, projects, and transactions. Responding to the One Trillion Tree Initiative, forest and other carbon sinks and the maintenance of existing forest resources should be strengthened. Foster participation to incorporate local knowledge and promote ownership for implementation at the local level. It is recommended that discussions on synergistic climate change governance be strengthened at COP 15 Phase II and that further progress be made on synergies between biodiversity and climate change at the UNFCCC COP 27 to promote the integration of global climate and biodiversity governance into global development initiatives.

ii. Pathways Towards a Green and Low-Carbon Belt and Road Initiative (BRI)

1. *Scale up technical cooperation in clean, renewable energy.* Capitalizing on China's first-mover advantage and market experience in the global clean energy market, promoting technology transfer and cooperation in low-carbon and green technologies in partnership with BRI countries, focusing on clean energy infrastructure, power storage, and required grid construction, equipment manufacturing, and technology cooperation and application. Develop a coherent, comprehensive system to coordinate green technical cooperation across partner BRI countries, and support suitable local initiatives through policy and strategy

- alignment, investment and market support, capacity building, and technical assistance.
2. *Guide various market players to improve their green investment and financing service capacity.* Measures should be taken to establish a government capital-led and market-oriented BRI green development fund, explore innovative and multi-channel blended finance, and take further advantage of government and private sector cooperation; set sound ESG standards based on the March 2022 four-ministry green BRI guidelines, with a particular focus on the regular disclosure of risks and impacts of overseas financing; set soft targets to guide policy banks and major investment enterprises to focus on the proportion of investment in green projects; encourage development financial institutions to support the development of renewable energy projects; develop an inter-ministerial coordination and incentive-restraint mechanisms for key investment projects; promote the establishment of an information platform to analyze the implementation of green BRI investment cooperation; and further clarify the endorsed scope, criteria, and good practices of BRI green investment and financing. Develop a pilot BRI green taxonomy in cooperation with partner countries.
 3. *Deepen international cooperation to support green and low-carbon development in BRI countries.* Relying on multilateral cooperation platforms such as the BRI International Green Development Coalition and the Green Investment Principles (GIP) for the Belt and Road, further efforts should be made to strengthen dialogues and exchanges among stakeholders, promote the establishment of green project development platforms under the framework of South–South cooperation, and deeply align with the green and low-carbon development needs of BRI countries. In conjunction with the Belt and Road South–South Cooperation Initiative on Climate Change and the Green Silk Road Envoys Program, China should help enhance the local capacity of BRI countries to address climate change and achieve an inclusive and resilient recovery; strengthen the South–North–South cooperation platform for low-carbon finance.

Annex A

CCICED Scoping Study Report: Digitalization to Advance Sustainability

A.1 Introduction

Digitalization has made its way into many aspects of people's everyday life, significantly changing **economic, societal, and cultural patterns**. At the same time, the commitment to **carbon neutrality, biodiversity protection, and sustainability** requires reimagining the well-established governance models, business practices, and lifestyles. This is especially true for **China**, as the country acts as a role model for emerging economies that strive to innovate and grow sustainably.

China is home to around **1 billion internet users** (more than in the USA and European Union (EU) combined), pioneering companies, and a government that issues future-oriented policies, which together are creating a **multifaceted and cross-industry digital ecosystem** [146]. Such evolution has contributed to the country's growth, reshaped its commercial landscape, and also extended its influence beyond national borders. China's **14th Five-Year Plan (FYP)** also emphasizes pursuing a higher quality, more technologically advanced development model, with specific focus areas including digitalization, telecommunications (5G), artificial intelligence (AI), big data, and quantum computing. Digitalization as an application for existing industries is also a focus with the contribution from the **core digital industries** targeted to **reach 10% of GDP by 2025 in the 14th FYP**. At the same time, sustainability is embodied in the concept of ecological civilization, which is considered an important dimension of this high-quality development. It is therefore important to foster the linkage between digitalization and sustainability.

Today, **digital development and the green economy** are the two megatrends that will serve as the new power to foster economic development in China. Therefore, it is necessary to strategically combine these two fields, which are currently treated separately: as a matter of fact, the digital economy is also vital for China to achieve its development goals and deliver on its **carbon peak and neutrality pledges**. The digital evolution has also strong implications for **sustainable development**, thus

calling for studies on how digital and green technologies can lead the economy and society towards a fair and prosperous future.

In such context, this scoping paper aims to explore the link between digitalization and sustainability; address major challenges regarding the environmental and social impacts of China's digital transformation towards sustainability; provide recommendations and directions for future research. The paper is organized as follows:

Chapter 1 after this introduction, reviews the latest trends regarding digitalization and related public debates in China, analyzes the challenges and opportunities to make digitalization and sustainability mutually supportive, and discusses how digitalization could enhance China's sustainable development.

Chapter 2 briefly reviews the development of China's digital sector, examines the major sustainability challenges connected to it, and emphasizes the need for greening the digital sector.

Chapter 3 suggests the **missing links between** digitalization and sustainability, highlights the relationship of the twin green and digital transition (hereafter "twin transition") with the **achievement of the United Nation's Sustainable Development Goals (UN SDGs), reducing social inequality and improving gender equality**, and calls for the adoption of a **holistic approach that brings together digital innovations and sustainable development**.

Chapter 4 presents Chinese and international perspectives on a range of application scenarios to foster the green and digital transitions.

Chapter 5 describes the **role of the Chinese government** in the digital transition towards sustainability and provides **recommendations for the CCICED to focus on fostering the linkage of digitalization and sustainable development**. Finally, the chapter suggests possible **avenues for future research**.

A.2 Greening the Digital Sector

Digitalization is spreading through all areas of our society and economy. Rapid development in digital technology such as AI, big data, and virtual reality will not only play an ever-greater role in the future economic and social activities but also can be important enablers for the transformation towards sustainability while unleashing also the great potential in greening the digital sector itself. We must consider the potential direct and indirect environmental impact of digitalization and its significance for environmental policy. This section shares insights on the status-quo of greening the digital sector in China and global best practices.

A.2.1 The Digital Sector in China

Over the past decade, rapid digitalization has considerably contributed to productivity enhancement and economic growth in China, at the same time showing many synergies with the effort to achieve pollution reduction and carbon neutrality. The country gained world leadership in several areas, such as e-commerce and mobile payments. As a matter of fact, China has the largest online retail market: in 2020, it represented about 24.9% of the total retail sales in the country—up from 20.7% in 2019—and e-commerce in China accounted for more than 50% of worldwide retail online sales. In comparison, the United States generates 19% of global e-commerce sales, whereas the United Kingdom accounts for only 5%. Furthermore, digital payments represent four out of five transactions in China.

There is no standard definition of the digital economy, and its measurement poses challenges to scholars from all over the world. According to the International Monetary Fund (IMF), in 2008 the size of the so-called “**digitalized economy**”—which includes both digital sectors and digitalized traditional industries—amounted to **15% of the Chinese GDP**. In 2020, the China Academy of Information and Communications Technology (CAICT), a government-affiliated think tank, found that such share **surged to 40%**, and it is projected to grow even further over the next years.

The Chinese government adopted a rather narrow definition of the digital economy. The government issued the classification of digital industry in China in May 2021, which identifies the scope of digital economy industries into five broad categories:

- (1) **Manufacturing Industry for Digital Products**, including the manufacturing of computers, information, and telecommunication technology (ICT) devices, robots and electronic components, etc.
- (2) **Service Industry for Digital Products**, such as the wholesale, retail, rental, and repair of digital products
- (3) **Industry based on the Application of Digital Technology**, such as software development, internet services, telecommunications, etc.
- (4) **Digital Factor Driven Industries**, including internet platforms, e-commerce, e-finance, ICT infrastructures, etc., and
- (5) **Digital Efficiency Enhancement Industry**, including smart manufacturing, smart agriculture, smart mobility, logistics, etc.

Among them, categories 1–4 in this classification are defined as the core industries of the digital economy. The 14th FYP for Digital Economy Development, issued in January 2022, aims to reach the share of the core digital industries to **10% by 2025**. In the classification system, category 5 plays a significant role in the twin transition towards a green and digital society. Therefore, it is suggested to expand the definition of core digital industries by including category 5 and set targets accordingly, in order to promote the efficiency enhancement of many economic sectors. In our scoping study, for the term “digital sector”, we refer to all categories from 1 to 5. China’s digital sector has a significant **environmental footprint** and has therefore received

increased research attention. A 2021 analysis conducted across multiple Chinese regions found that a **1% increase** in the level of development of the digital economy potentially **reduces haze concentration** in the region by approximately **0.2%**. In the same year, another study analyzed data from Chinese provinces and proved the existence of a **positive correlation** between the digital economy and air quality, defined as the level of particulate matter in the air.

Despite these benefits, the **lack of data at the corporate level** hinders a systematic assessment of such effects. In fact, 30% of the top 50 listed companies operating in the digital sector in China **did not issue any Environmental, Social and Governance (ESG) reports** in 2020, and among the companies that published them, some still followed the conventional Corporate Social Responsibility (CSR), **without providing sufficient data** to measure their performance against sustainability indicators.

A.2.2 The Status-Quo of the Green Transition of the Digital Sector

Digital technologies also bring **new challenges** such as environmental issues, labor disruption, e-waste, privacy infringement, emerging oligopolies, and financial risks. Some of them are global, whereas others are more prominent in the Chinese context. The ecological footprint of digitalization is significant. For example, according to a study by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), 4% of the global CO₂ emissions can be attributed to digitalization and the energy consumption of digitalization is rising by around 9% annually. More details of the ecological footprint of digitalization can be found in Fig. A.1.

Data centers are at the heart of the digital sector, playing an important role in driving the digitalization process as they host computing and storage systems that enable the provision of web services. These structures consume vast amounts of energy and are also a major source of greenhouse gas (GHG) emissions worldwide. In 2019, data centers accounted for **more than 80% of Facebook's total emissions**, and data centers worldwide consumed around **1% of global electricity**.

In China, data centers are often called “electricity tigers” due to their huge energy demand. In 2020, they consumed more than **200 billion kWh** of electricity, accounting for **2.7% of China's total consumption**. This share is much higher than at the global level, and such a growing trend is likely to continue in the future. In 2022, the National Development and Reform Commission (NDRC) has **approved a mega-project involving the construction of eight national computing hubs and plans to build 10 national-data center clusters, indicating that its strategy to channel more computing resources from the country's eastern regions to its less developed yet resource-rich western regions is in full swing**. The east-to-west computing resource transfer project enables companies and institutions to utilize

the abundant renewable energy resource in the west while satisfying the computing demand in the developed region in the east. As an example, Huawei already moved part of its data centers to Gui'an New Area, in Guizhou, where it was able to save **over 1 billion kWh** of power and **810,000 tons of carbon emissions** annually. Looking at the big picture, if every data center in China was powered by green energy, emissions could be cut by **320 million tons per year**.

Also, outside China, many governments and companies are helping accelerate the green transition of the digital sector by promoting **sustainable initiatives**. For instance, in 2021, 26 CEOs of ICT companies formed the **European Green Digital Coalition (EGDC)** and signed a declaration to support the green and digital transformation of the EU. With such a document, they committed to investing in the development of solutions that improve the efficiency of the digital sector, as well as to develop effective instruments to measure its environmental impact.

Another example of connecting data centers with renewable energy is, that, some companies, including Google, Microsoft, Green Mountain, and DigiPlex, have moved their server farms into **renewable-based areas**, such as Norway, due to the regulation of the data-center market. In the past years, the Norwegian government has made electricity cheaper for the data center industry, adopting the same tax model used for power-intensive industries like ironwork [147].

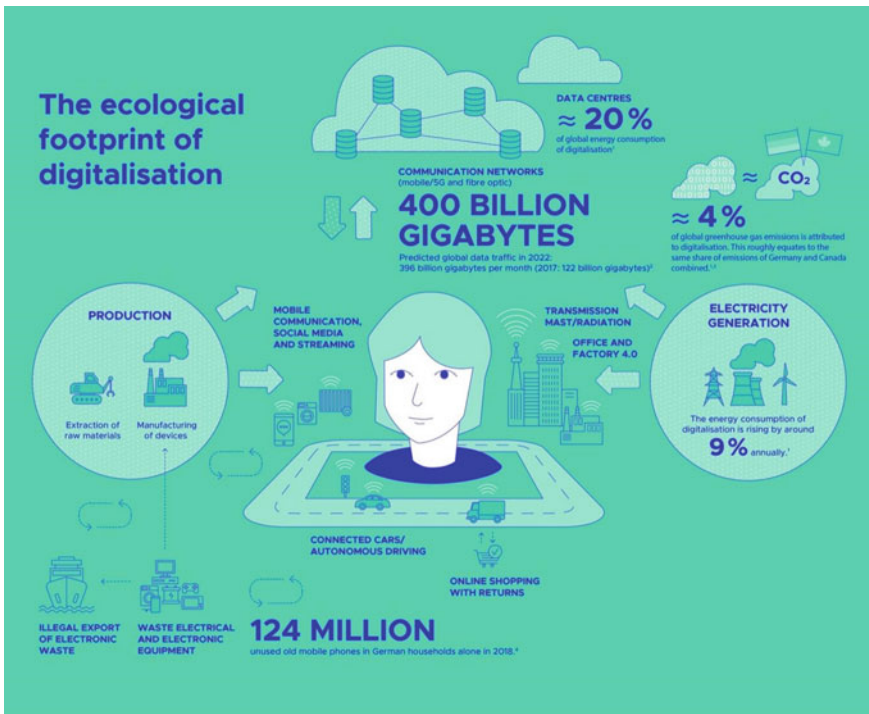


Fig. A.1 The ecological footprint of digitalization

In addition to the benefits already mentioned in Sect. A.2.1, a recent paper found that production factors related to **the (traditional) digital industry had a significant negative effect on embodied carbon emissions in China** from 2002 to 2017. Moreover, a study analyzing energy production from renewable sources in North-western China found that in a 7-year span, the **short-term prediction accuracy** of the energy output coming from renewable sources improved year by year—**from 84.2% in 2012 to 91% in 2019**—thanks to the advancing progress and deeper penetration of digital technologies. As a result, from 2016 to 2019, the use of renewable energy **increased significantly**. In general, the energy transition, the core of the climate actions, is closely linked to the digital technologies, both from the energy demand and supply sides. Apart from improving energy system operational efficiency, digitalization connects the various parts of the energy system and provides enormous potential to transform the energy system from an integrated approach.

Box A.1. Climate Neutral Data Center—Self Regulatory Initiative in Europe

To administer the self-regulatory initiative for climate-neutral data centers, Cloud Infrastructure Service Providers in Europe (CISPE) and the European Data Centre Alliance (EUDCA) created a governance coalition called Climate Neutral Data Centre Pact (the Pact). The **Pact** serves as an initiative among data center operators and trade associations in Europe. It aimed at fulfilling the European Green Deal and at making data centers fully sustainable by 2030.

The Pact has carried out the following actions to achieve its climate-neutral goal:

- (1) **Energy Efficiency:** data centers and server rooms in Europe will meet a high standard for energy efficiency, which will be demonstrated through aggressive power use effectiveness (PUE) targets.
- (2) **Clean energy:** data centers will match their electricity supply through the purchase of clean energy. Data center electricity demand will be matched by 75% renewable energy or hourly carbon-free energy by December 31, 2025 and 100% by December 31, 2030.
- (3) **Water:** by 2022, data center operators will set an annual target for water usage effectiveness (WUE), or another water conservation metric, which will be met by new data centers by 2025, and by existing data centers by 2030.
- (4) **Circular economy:** data centers will set a high bar for circular economy practices and will assess for reuse, repair, or recycling 100% of their used server equipment. Data center operators will increase the quantity of server materials repaired or reused and will create a target percentage for repair and reuse by 2025.
- (5) **Circular energy system:** data center operators will explore possibilities to interconnect with district heating systems and other users of heat to

determine if opportunities to feed captured heat from new data centers into nearby systems are practical, environmentally sound, and cost-effective.

A.3 Fostering the Twin Transformation

A.3.1 *The Missing Links Between Digitalization and Sustainability*

Digitalization offers an enormous range of possibilities for supporting the transformations toward Sustainability. However, up to now, digital resources and projects have been mainly used for conventional growth in established markets characterized by international competition. Sustainability is not the primary purpose of digital progress in these contexts; the dominant aspects are entertainment, convenience, security, and, not least, short-term financial gain. Overall, digitalization processes today tend to act as ‘fire accelerants’, exacerbating existing non-sustainable trends such as the overuse of natural resources and growing social inequality in many countries. The following graphic (Fig. A.2) illustrates the huge spectrum of potential benefits and risks in the context of digitalization and sustainability. Given the broad and disruptive changes that digitalization as a megatrend brings to our age, we must consider questions on how digitalization is changing our societies and the demands of sustainability, and even how it is transforming our concepts of “human development”.

- **First Dynamic:** ‘Digitalization for sustainability’—using digitalization to protect the Earth system and ensure social cohesion: Here, the focus is on the 2030 Agenda and its SDGs. On the one hand, the aim is for digitalization to make valuable contributions towards improving and accelerating solutions to global environmental and development problems. On the other hand, digitalization can also massively exacerbate existing sustainability problems and lead to severe societal distortions if no countermeasures are taken.
- **Second Dynamic:** ‘Sustainable digitalized societies’—realizing a new humanism: This idea focuses on dealing with the fundamental societal upheavals triggered by digital change. Positive and negative development opportunities with corresponding challenges on how to deal with them are also apparent here. In the positive scenario, there is hope that digitalization will bring us closer to a humanist vision of a sustainable world society in the Digital Age. In the negative scenario, however, digitalization entails the risk that digitally empowered inequality and loss of freedom will destroy any previous sustainability achievements.
- **Third Dynamic:** ‘The future of Homo sapiens’—discourses on drawing boundaries: This Dynamic deals with the most fundamental of all sustainability issues: the future viability and identity of the human being itself, embedded in society and in the environment in which it has transformed. Here, the German Advisory

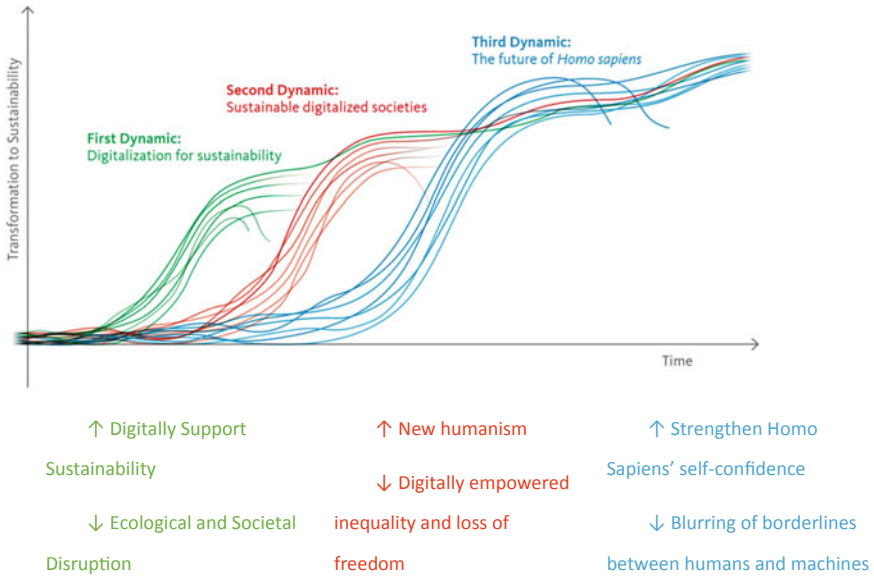


Fig. A.2 Three dynamics of the digital age. *Source* WBGU

Council on Global Change (WBGU) asks questions that sound futuristic, but are already highly topical today.

The three dynamics show the near-, mid-, and long-term impacts of digitalization on society, the economy, and people. For companies, there is a great potential to adopt a cohesive climate strategy backed by AI capabilities. However, in reality, only very few companies have aligned their climate vision and strategy with their AI capabilities, as shown in Fig. A.3.

As AI has become an increasingly ubiquitous topic in the last decade, intergovernmental, national, and regional organizations have developed policies and strategies around AI governance. These actors are driven by the understanding that it is imperative to find ways to address the ethical and societal concerns surrounding AI while maximizing its benefits. Active and informed governance of AI technologies has become a priority for many governments around the world. However, the linkages between the research communities of AI and environment, energy, and sustainability are weak. In 2021, the leading primary topics were Privacy, Safety, and Security; Innovation and Technology; and Ethics (Fig. A.3). Among the AI topics to receive comparatively little attention from tracked organizations are those that relate to energy and the environment, humanities, physical sciences, and social and behavioral sciences (Fig. A.4).

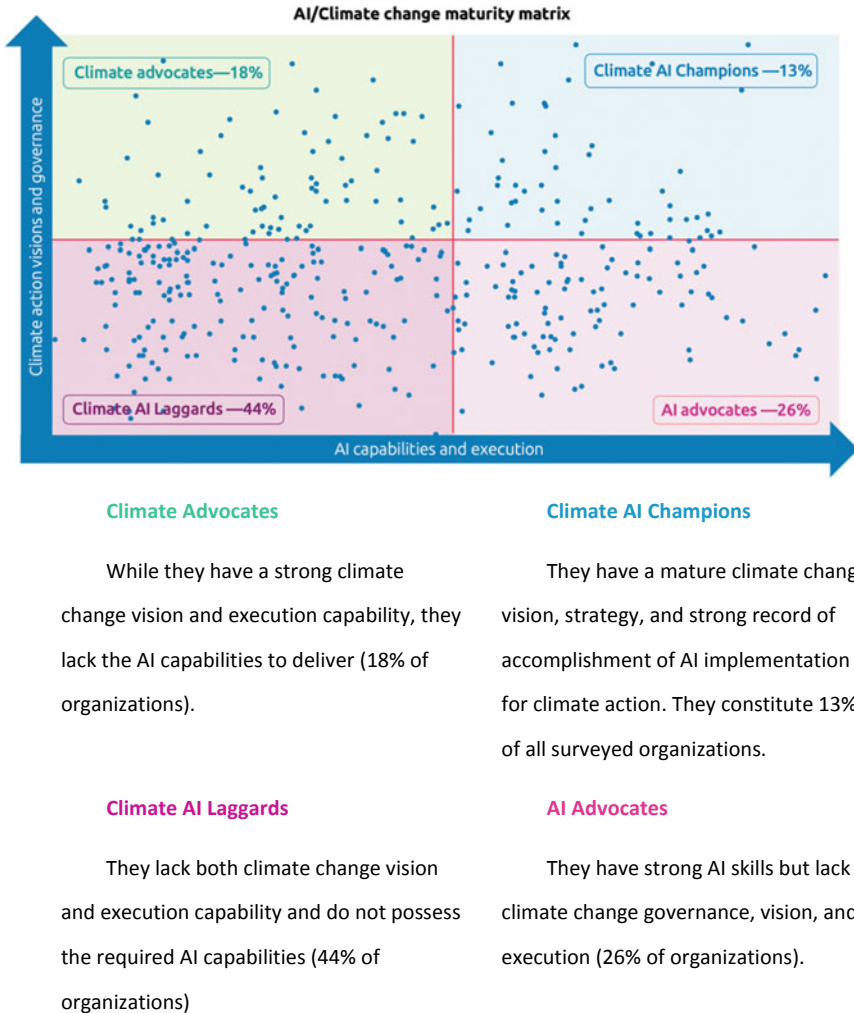


Fig. A.3 Only 13% of organizations combine climate vision and execution with AI capabilities

A.3.2 Social Dimension of the Twin Transformation

The development of smart tools and new technologies could offer great possibilities to increase the inclusiveness of the Chinese society and reduce environmental impact, at the same time booming economic development. A 2019 IMF report showed that digitalization enhances productivity by lowering transaction costs; reducing information asymmetry; better matching demand and supply; enhancing production efficiency.

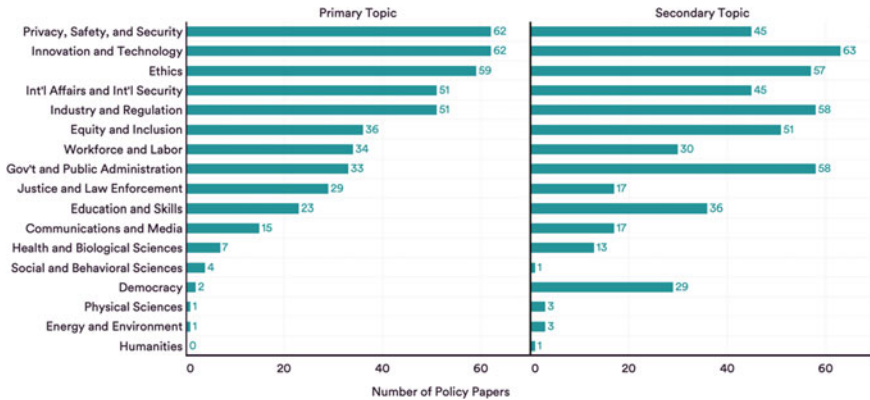


Fig. A.4 Number of AI-related policy papers by the U.S.—based organizations by topic, 2021 [148]

Zooming on the employment landscape in China, one could notice that digital transformation is bringing significant changes. On one hand, technological innovations have led to a so-called “**technical unemployment**”—i.e., a **reduction in the number of employed workers**, especially those involved in the production lines. As a matter of fact, a 2021 paper argued that, in the industrial sector, the number of employed people has fallen by **9 million** since 2012. On the other hand, the digital economy has generated important benefits at the macro level in the last few years. The previously mentioned study by the IMF showed that digitalization **has created several new professions in the e-commerce and sharing economy**—e.g., Alibaba’s platform involves almost 11 million small and medium-sized enterprises (SMEs), which have created over **30 million jobs** over the past decade. Furthermore, digital transformation has **significantly increased the number of flexible job positions**, especially among young people (aged between 16–24), who suffer from the highest unemployment rate in China. Overall, the **net impact** of digitalization on employment is likely to be **positive** in China.

As far as **income inequalities** are concerned, the impact of digitalization is still **unclear**. Digitalization can help reduce poverty by **connecting suppliers in remote regions to consumer markets in city centers**—e.g., Alibaba’s Taobao villages help improve rural interconnection and raise income at the local level. Digitalization can also contribute to increasing financial inclusion in China, by making various financial services easily accessible to rural residents with a smartphone. An empirical research based on data from the “Digital Inclusive Financing Index of Peking University” (2011–2018) showed that **digital empowerment has reduced the urban–rural income gap in China**. Nevertheless, in general, the spread of digitalization could happen at the expense of **low-skilled workers**, and thus potentially widen inequality.

There is a growing concern regarding **workers’ conditions** in the digital economy. In fact, the rapidly growing e-commerce sector and the sharing economy have created millions of jobs, but employment terms are often problematic. For instance, food

delivery platforms require a large number of riders, but the hiring relationship between these two parties is often loose and involves other entities. As a result, the platform may not have to assume the necessary responsibility as an employer. In addition, algorithms may experience problems in calculating the delivery time, sometimes eating up minutes and putting great pressure on riders. Such concerns do not call for a halt in these platforms' operations, but for clearer regulations that balance the stimulus for innovation with the protections of stakeholders' and workers' rights. China has already put a focus on improving the workers' conditions under the digitalization background. In July 2021, the Ministry of Human Resources and Social Security together with seven other departments, recently issued the *Guiding Opinions on Protecting the Labour Rights and Interests of Workers under New Forms of Employment*. The Guiding Opinions stress protecting the labour rights and interests of workers under new forms of employment.

Digital financial services in China have penetrated the excluded and underserved communities, especially the low-income communities, via mobile devices. Digital financial inclusion provides them with access to payments, savings, credit, insurance, etc., which will positively enhance their capacity to benefit from the financial system than others.

In general, digitalization could serve as an enabler for the achievement of SDGs in China, just name a few, Clean Water and Sanitation (SDG 6), Affordable and Clean Energy (SDG 7), Decent Work and Economic Growth (SDG 8), Sustainable Cities and Communities (SDG 11), Responsible Consumption and Production (SDG 12), Climate Action (SDG 13). Digitalization also shows great potential in fostering SDG 5 on Gender Equality.

A.3.3 Gender Perspective of the Twin Transformation

Improving access to digital technologies could help to tackle **gender equality related issues**. As a matter of fact, in China women still lag behind men in labor force participation—the ratio of women to men taking part in labor force activities is **81%**—and an increase in gender equality could generate a **13% growth in GDP by 2025 in China**. In this perspective, e-commerce and gig-economy can foster flexibility in terms of work possibilities, helping women balance work and family commitments. Digital technologies can also enable women to access wider markets and better economic opportunities. For instance, in 2015, **55% of new internet businesses were founded by women**.

Chinese women's digital literacy level could be raised by **public-private partnerships** that organize training and networking events. For example, in recent years **SAP**—a leading business software provider—has partnered with the UN to **train 100,000 female entrepreneurs** in digital technologies and business skills in China, especially in smaller cities.

Box A.2. Digitalization Empowering Women Entrepreneurship

Digital technologies can potentially add **USD 13–18 billion in additional combined annual GDP** just by giving internet access to 600,000 women in developing countries. This can impact gender equality by widening the range of economic opportunities and increasing women’s participation rate in business activities, empowering them to take part in political and social activities as well as to develop their professional skills.

In 2016, Microsoft China launched a series of workshops aimed at inspiring young women interested in science and technology, and at supporting female students graduating in computer science to successfully shift from school to work. The company has held four annual events, plus ten additional Ada Workshop events in Chinese universities, inviting female role models to share their personal stories. As a result, in 2020, more than **1300 students** took part in the annual workshop, which attracted over 6000 total viewers and more than 2900 bullet comments.

A.3.4 Strengthening the Linkage Between Digitalization and Sustainability

The present paper pointed out how **digital innovations could be relevant across all industries** and have an impact on China’s entire **economy, society, and sustainable development**. Nevertheless, digitalization and sustainability often move in different directions and are treated separately, both at the policymaking and corporate strategy levels. That is why, as the scope of this study is expanded, it is necessary to collect evidence on how these two macro-trends could be further connected in three main areas: **governance, business, and research**.

With the aim to strive to bring digitalization and sustainability together, **national and international authorities** should aim at increasing the level of environmental sustainability through the implementation of **ad-hoc policies** that increase the overall level of digitalization of the economy, thus boosting environmental efficiency. For example, the ‘twin transformation: digital and green transition’ supported by the EU and the leading companies committed to integrating the two transformations and also involve actions at the national level (24 EU countries plus Norway and Iceland) had joined the declaration to support the green and digital transformation of the EU.

From the government’s perspective, the following macro-framework to link the digitalization and sustainability can be considered:

- **Shifting innovation visions** and patterns of digital pioneers towards sustainability is of vital importance. These pioneers can influence the ecology of the ICT

sector, thus shifting the narrative of digital development towards the service of sustainability.

- **Mobilizing markets** is another important angle to consider, for example, through green tax reforms. This also includes shifting the roadmaps and goals of the markets to reduce emissions and resource consumption.
- **Modernizing the state** by building digital capabilities as a precondition for governing digital change.
- **Building strong networks** between digital and sustainability research communities.
- **Creating dialogue structures** between civil society, state, private business, and science to shape digital and sustainable futures.

For organizations, there are also opportunities to **build synergies among themselves and within their fields of expertise**. For instance, a paper issued by the World Economic Forum suggests that companies could use digitalization to enhance their green efficiency by setting data-analytics strategies to **collect sustainability data** across business units; enabling process automation to **create measurable efficiency gains** and **improve resources use**; using digital platforms to **collect customer feedback** for environmentally sustainable digital business model innovations.

The choice of analyzing the nexus of digitalization and sustainability is a relatively new trend in the research field. Indeed, as shown by a study, research tends to focus on a specific element of digitization or only addresses one form of sustainability (ecological, economic, or social).

Therefore, in many cases, these two communities of researchers are still **very fragmented**. Connecting these disciplines and fostering direct collaboration enables new perspectives and in-depth insights. In the same direction goes, during the 75th UN General Assembly on the 22nd of September 2020 **President Xi Jinping** announced that China will set up an **International Research Center of Big Data for SDGs**. The center will help UN agencies and the UN Member States implement the 2030 Agenda by playing the roles of public science and technology platform; serving as a think tank for big data and sustainable development; being a hub for developing talent and improving human capacity through education and training. The German Environment Agency (UBA) increases the number of employees with an educational background in IT, AI, or digitalization in general.

Box A.3 Coalition for Digital Environmental Sustainability (CODES)

The **CODES** is an international multi-stakeholder alliance created in March 2021. The main objective of CODES is to reorient and prioritize the adoption of digital technologies in pursuing the UN SDGs to make the 2030 Agenda a reality. As a result of a consultative process, CODES has established an action plan aimed at promoting digital transformation as a positive force for sustainable development. The plan establishes a set of priorities, goals, and timelines to encode social and environmental sustainability into the digital revolution.

It is based on the identification of three shifts that should be addressed simultaneously in order to fulfil the ambitions of the alliance. The first one implies the alignment of visions, values, and objectives of digitalization with those of sustainable development; the second one aims to ensure sustainable digitalization by mitigating the negative impact of digitalization; the third one is focused on steering innovation towards digital sustainability.

A.4 Innovative Digital Solutions to Foster the Green Transformation

The impact of digitalization on sustainability appears to be particularly relevant in China, considering the size of this field in the country. China is the **second-biggest digital economy** after the United States, consolidating its international presence at a rapid pace. This section of the paper offers a glimpse of the **key fields and case studies** on which research should focus in order to understand how digital advancements could help the country achieve its sustainability goals.

A.4.1 Core Digital Capabilities for Low-Carbon Development and Sustainability

Reduction in CO₂ emissions enabled by technologies can help fight the impact of climate change. According to the Global e-Sustainability Initiative (GeSI), digitalization will enable a **20% reduction in global CO₂ emissions by 2030**. Specifically, energy efficiency technologies such as smart grids and integrated energy management systems are projected to generate savings of up to 1.8 gigatons of CO₂e globally by 2030 [149]. As Fig. A.5 shows, the GeSI study estimated that by implementing digital solutions in different sectors of the economy, total global carbon dioxide equivalent (CO₂e) emissions could be reduced by 12 gigatons (Gt) by 2030, providing a path to sustainable growth (Fig. A.5; Table A.1).

A.4.2 Green and Digital Transformations in Various Sectors

This section identifies several areas that can accelerate the transformation process towards more sustainable businesses and societies, describes the benefit that digitalization could generate in those fields, and provides evidence through international

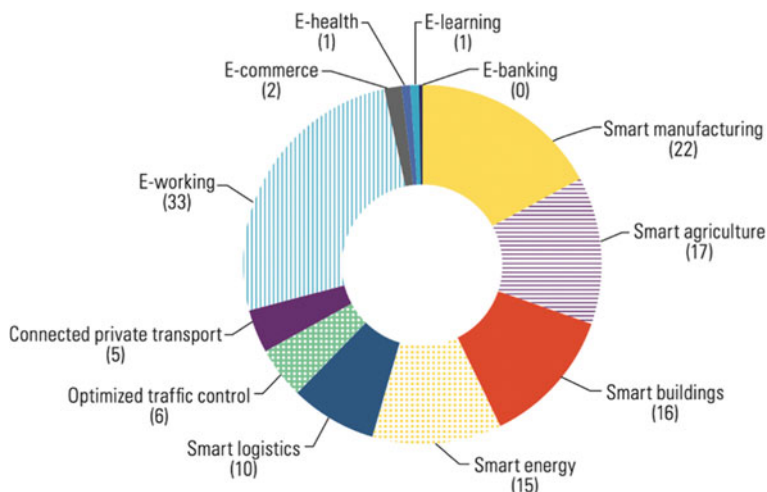


Fig. A.5 Potential for reducing carbon dioxide by 2030, by type of digital solution. Source GeSI

Table A.1 Core digital capabilities for sustainability solutions

Key functions	Technologies	Applications
Map, integrate, analyze, visualize data	AI, Machine Learning (ML), data science, visualization tools ...	Understanding and managing complex systems (VC, cities et al.); databased governance: GHG, ecosystems, resources
Optimize and predict	AI, ML	All economic sectors; ecosystems—improve sustainability governance
Simulate	Digital twins, AI, ML	Smart grids, buildings, value chains, ecosystems
Sense, connect, steer	5G, IoT, sensors, satellites, 5G, AI, ML	Building, understanding and driving high-connectivity systems; automated systems
Track and verify	Blockchain, visualization tools, AI, ML	Monitoring and govern resource flows, green footprints, circular economy
Across sectors	Set of technologies	Green potentials for governance, de-materialization and virtualization

case studies. More specifically, it will explore **smart manufacturing; sustainable mobility; digital transition in cities and infrastructures; climate-smart agriculture; energy and water consumption.**

A.4.2.1 Smart Manufacturing

The application of industry 4.0 technologies in China could lead to a strong **reduction in carbon emissions**. More specifically, **emission reductions** enabled by digital technologies are projected to reach **112 Mt CO₂e per year** by 2030.

According to a 2018 academic paper, the application of digital technologies to industrial processes could enhance sustainability through the following innovations:

- **Real-time data** enables the awareness of resource consumption, allowing for responsive and more efficient changes;
- **Internet of Things (IoT)** enables the acquisition of energy consumption data. The analysis of machine and production line performances improves energy-aware decisions;
- **Optimization software** applied to production processes can generate energy savings;
- **Additive manufacturing** is more resource-efficient than traditional methods due to its ability to reuse waste material, creating objects through 3D printing;
- **Blockchain technology** integrated with industry 4.0 innovations can promote new business models, as it enables the creation of reliable information.

Box A.4 Re-manufacturing for Circular Economy Solutions

Remanufacturing, i.e. the reprocessing and reuse of used (industrial) products, is an important component of the circular economy. One of the greatest challenges of remanufacturing is to reliably identify the industrial products returned from the market and assess their condition. In the EIBA project, Circular Economy Solutions GmbH is working with partners to develop an AI-based identification and assessment system for end-of-life parts. Many industrial products are already suitable for the circular economy. However, until now there has often been a lack of incentives and the necessary know-how in the companies to actually have the corresponding parts recycled and reprocessed. This is where C-ECO's Industry 4.0 business model comes in. It develops services to return the parts to be reprocessed from the market in a structured way at the end of the use phase and to evaluate them. According to its own information, C-ECO returns around three million end-of-life parts annually via a network of 22 logistics bases worldwide. At present, the identification of parts is still mainly done manually.

The biggest challenge is to ensure the same standards and evaluation benchmarks for the individual parts globally. What does a product consist of? What is usable? Which reprocessing strategy is suitable? To answer these questions, products must be clearly identified and evaluated. Experts often only have a few seconds to do this. However, many models differ only slightly from each other, and soiling and wear make the evaluation even more difficult. AI is to

provide support in the future. The project is developing a machine that observes and evaluates the product. Sensors such as depth cameras or a scale identify the old parts and assess their condition.

A.4.2.2 Green Consumption 4.0

In the **USD 1 trillion** markets of global consumer electronics, **less than 20% of electronic waste is recycled**. This lack of recycling practices also causes a loss of USD 57 billion in raw materials. In addition, the production of new Electrical and Electronic Equipment (EEE) causes severe greenhouse gas emissions that could be drastically reduced.

Specific technologies can **improve production and consumption patterns**, enabling the transition towards a circular economy and smart manufacturing—e.g., Industrial Internet of Things (IIOT) technologies, Machine-to-Machine (M2M) devices, data analytics and cloud computing.

Box A.5. Product Digital Passport

The EU is strengthening digital sustainability-oriented product information for consumers through the development and introduction of a digital “product passport” by 2025. At the EU level, that will serve as a basis for Europe-wide information requirements for all products.

The Digital Product Passport is a set of data summarizing a product’s components, materials, chemical substances, and/or information on reparability, replacement parts, and proper disposal. The data originates from all phases of the product life cycle and can be used for various purposes in all these phases (design, manufacture, use, disposal). Structuring data in a standardized, comparable format enables all stakeholders in the value and supply chain to work together towards a circular economy. At the same time, the Digital Product Passport is an important basis for reliable consumer information and sustainable consumer choices in both stationary and online retail.

A.4.2.3 Sustainable Mobility

Research forecasts that digital innovation applied to transportation will save between **161 and 234 Mt CO₂ emissions per year** by 2030 in China. More specifically, **Mobility as a Service (MaaS)** could help **reduce congestion and emissions** by fostering the usage of shared mobility and green transportation solutions. An increase

in the usage of public transport could also lead to the saving of more than **35 Mt of CO₂ emissions** per year—equivalent to the amount of CO₂ absorbed by more than 1.5 billion mature trees.

The implementation of smart traffic-control systems and the increasing usage of optimum route-finding apps, then, will **make traffic flows more efficient and lower distances traveled** per vehicle. GeSI estimates that more efficient routes and traffic control could bring to a yearly reduction of **24 Mt CO₂ emissions**, whereas an increase in smart electric vehicle charging points could lead to a further reduction of nearly **4 Mt CO₂ emissions** per year in the condition that the charging facilities are powered by renewable energies.

In China, the continuous urbanization process, the need for faster and cheaper ways of traveling, and the growing digitalization led to the **spread of shared mobility systems**, such as car- and bike-sharing, and ride-hailing. A survey revealed that **33%** of Chinese preferred shared mobility over other transportation means; this is in line with the findings of another research, which showed that in 2020 shared mobility expenditure in China accounted for **11.3% of urban residents' transportation costs**. In the same year, over **95% of shared cars were new energy vehicles (NEVs)**, making car-sharing a key contributor to sustainable transportation in China.

Currently, China is now largest Electric Vehicle (EV) market in the world: nearly 1.29 million EVs were sold in 2020 alone, with a **40.5% share of global sales** last year, and an 8.3% growth year-on-year. Data proves the importance of this type of car for the country's sustainable future. Xie Chunping, a policy fellow at the London School of Economics, argues that lifetime emissions of electric vehicles are **19–34% lower** than comparable gasoline vehicles. At the same time, it is important to point out that the development of EVs may have significant implications for the global mining industry. It was estimated that **USD 10 trillion** worth of lithium, cobalt, nickel, and copper may need to be mined globally in order to meet the needs of the industry, and the environmental impact in this regard would be relevant.

Box A.6. Autonomous Driving Along Prescribed Local Passenger Transport Routes: Easyride in Munich

Many German cities are currently hosting autonomous mobility system tests for passenger transport. The concepts under investigation range from purely private usage to deployment in local public transport. Fleets of autonomous “robotaxis” and buses (also known as “people movers”) are empowering passenger transport utilities to tailor mobility to the needs of the individual. Right now, there are nearly 40 test routes for autonomous vehicles in local public transport applications. These activities are currently concentrated in three German states: North Rhine-Westphalia, Baden-Württemberg, and Berlin.

One of these pilot projects is “**Easyride—Experience the Future**” in Munich. Here, municipal utility SWM and local passenger transport company MVG are trialing the use of **autonomous shuttle buses** along two predefined routes in the Olympic Park. Shuttle buses of the type e.GO Mover (from e.GO

Moove GmbH, a subsidiary of Aachen-based E.GO Mobile AG, founded in 2018) has been deployed.

During the first pilot test phase, the minibuses are not yet automated and use sensor technology to collect environmental data in anonymized form. Based on this data, autonomous driving will be trialed in the second pilot phase. By the end of 2020, the initial aim was to test automated and connected driving in live practice. Technological development is focused on individualized public transport and automated ride-pooling fleets. The latter is to be controlled by algorithms that have interfaces to existing transportation systems and that therefore facilitate optimal routing and pooling. Beyond this, the hope is that the pilot project will yield insights into customer acceptance of these solutions.

A.4.2.4 Smart Agriculture, Smart Energy and Water Management

As shown by the World Bank in 2021, agriculture employs **25% of Chinese active workers**. According to the ‘**2021 China and Global Food Policy Report**’, in 2018, this sector was responsible for **5.4% of China’s GHG emissions, and agricultural land emissions and enteric fermentation account for more than 60% of the GHG emission from this sector**; in 2017, 28% of agriculture emissions were due to synthetic fertilizers.

According to the State Council of the People’s Republic of China, **autonomous agricultural machinery could increase work efficiency by over 50% and reduce the use of pesticides and fertilizers by over 30%**, playing a very positive role in agricultural production and sustainability. China’s sales of self-driving agricultural machinery equipment and systems reached more than 11,700 units in the first half of 2020, with strong **year-on-year growth of 213%**.

Other **innovative agricultural practices** could help make this sector more sustainable. For instance, big data technologies can enable the analysis of data regarding soil, weather, and production processes, increasing farmers’ ability to **predict crop yields**. Digital tools can improve timing in the farming processes to maximize crop yields. Moreover, by analyzing input and output variables—such as natural disasters, climate, or soil—digital technologies help farmers **select the most appropriate crop** for a specific area.

Digitalization **improves energy efficiency**, gives access to more **affordable energy**, and fosters increases in the generation and use of **renewable sources** thanks to several technologies—e.g., smart grids, sensors, demand-response systems, and predictive analytics. According to GeSI, **digitalization could generate 1.3 billion MWh of energy savings** globally by 2030 [150]. Moreover, the implementation of digitally-enabled measures could lead to **cost savings** in power generation of around **USD 80 billion per year** globally over the period 2016–2040, or about **5%** of total annual power generation costs.

According to the US Energy Information Administration, China is the **world's largest energy consumer**. In 2019, it consumed **150,000 quad BTU** of energy, 50% more than the US consumption and one-quarter of the global energy consumption [151]. In the same year, approximately **602 billion m³** of water were consumed in China—equivalent to around one-sixth of the global water consumption.

Digital tools such as **smart meters** can help reduce energy and water waste by measuring consumption and allowing for more efficient resource utilization. More specifically, smart electricity grids use smart meters to allow for **real-time recording of electricity consumption and off-grid production using renewable sources**. This enhances the possibility to optimize distribution networks with real-time monitoring, automation, and dynamic storage, allowing networks to operate at higher capacities [152]. Smart meters can also be used to **track water usage** and provide more accurate measurements. In this way, they can enable the identification of leaks and accurately measure water consumption, while allowing for more precise billing.

A.5 Policies, Pathways and Potential Elements of a Special Policy Study

A.5.1 Policies and Pathways

Until 2013 the Chinese Government did not intervene much in the digital economy. As a result, internet users were able to access free digital contents in the domestic market, which increased the **penetration of digital services**. The absence of a centralized approach in the early stages of the digitalization process gave innovators plenty of space to experiment solutions [153], which until today has positive and negative impacts.

Governmental institutions have considerably **tightened their oversight of the digital sector**. More attention is paid to the development of the digital economy and the digitalization of the Chinese economy. In the past decade, the government has had an increasingly higher impact by taking **three key roles** as a policymaker, investor, and sustainability sponsor.

With the **13th FYP (2016–2020)**, the government implemented a selection of initiatives to **upgrade the Chinese digital infrastructure**, for example strengthening high-speed transmissions, cross-border cable infrastructure, wireless networks (4G/5G), or developing an “Online Silk Road” in collaboration with Arab countries. The **14th FYP (2021–2025)** further stresses the importance of creating a higher quality digital and integrated economy with a related increase in GDP and at the same time, it promoted sustainability in the concept of an Ecological Civilization. Indeed, the government explicitly states the intention to promote domestic digital industries, encouraging the main economic sectors to adopt new technologies to strengthen China's efficiency and reliability [154]. **There is not yet a clear link between digitalization and sustainability targets, though both are part of the**

14th Five-Year Plan and are important pillars for high-quality development in China.

To become carbon neutral in 2060, the government has introduced various **green initiatives** in the past years. However, China needs an estimated additional USD 6.4 trillion to USD 19.4 trillion to finance the green transition and therefore is looking for additional revenue sources. A **carbon tax** has been imposed to help fund climate-change policies, in addition to the attempts made to attract more **green investments** [155].

China has the potential to reinforce its leadership position in the digital sector by **taking ownership of shaping the nexus of digitalization and sustainability**. A comprehensive and **objective assessment of the environmental and social impacts of the digital sector** is needed to address the **missing links** between domestic priorities and international agendas, public goals and corporate strategies, academic research, and business R&D. **The Scoping Study suggests the CCICED to further explore the following aspects of the nexus of digitalization and sustainability to support the Chinese agenda on the green transition:**

1. Understand the dimensions of the twin transformation, including how digitalization drives economic and social change and how to utilize the potential of digitalization as a tool for a sustainable economy and social development.
2. Create long-term values and benefits through impactful innovations in connecting communities in treating digitalization as a cross-cutting discipline. Communities come from the digital and environmental research fields, but also the public and private sectors and civil society.
3. Study the opportunities of digital-social-environmental transformation, which goes beyond productivity increases. How can digitalization enable sustainable practices, reduce inequalities (digital divide) and improve the well-being of humankind and the environment?
4. How can the foresight of disruptive technologies and an environmental resource perspective reduce negative impacts?
5. How can China make the core of the digital sector, the ICT and ICT infrastructure, less harmful to the environment?

A.5.2 Potential Elements of a Special Policy Study

Based on the findings of the Scoping Study on Digitalization to Advance Sustainability, the German Environment Agency (UBA), the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, and the World Economic Forum (the Forum) would like to propose a Special Policy Study (SPS) which explores, how to put digitalization at the service of sustainability and the construction of an Ecological Civilization, which entails the development of a green, circular and low carbon society and economy. The potential for a digital sustainability transformation is not an automatic process.

In the past two decades, digitalization has worked as an accelerator of economic processes that are still predominantly based on fossil energy and resource extraction. However, **the disruptive impact of digitization on sustainability can be leveraged to accelerate and enhance a sustainability transformation.** Both digital and environmental transformation will increasingly shape our economies and societies. The proposed SPS will examine how the **“missing links” between digitalization and sustainability** can be created, the status quo, the challenges, and opportunities existing in the digital sector itself as well as the traditional industries which undergo the digitalization process. Furthermore, the SPS will focus on the **key emerging innovations and analyze their significance for the environment and development.** Last but not least, the SPS will explore global **best practices** and the enabling environment to support China using its full potential in this respect. The SPS would also provide the attractive possibility to conduct field research together with other SPSs, as digitalization is a crucial cross-cutting issue.

Element 1 Sectors-Perspective: A SPS intends to explore how to accelerate a green transition of the digital sector itself, including greening IT in terms of resource- and energy-use of data centers and blockchain technology, as well as how digital and the “Fourth Industrial Revolution” (4IR) technologies which is characterized by a fusion of technologies that is blurring in lines between the physical, digital and biological spheres, such as AI, IoT, nanotechnologies, materials sciences, etc., could **enable the green transition of traditional sectors**, such as energy, building, mobility, agriculture, manufacturing, etc., including respective value chains. In this regard, the SPS will examine, (1) the status quo, the trends, and challenges these sectors are facing, the emerging green solutions that are enabled by 4IR technologies as well as the enabling environment for **large-scale implementation**; (2) how to **balance** scaling up digitalization for its carbon emission reduction potential while keeping the carbon footprint of digitalization low; (3) the underlining indications of these **disruptive digital innovations in the transition to the green economy**, with a focus on the opportunities and trends for new green products, services, and low carbon business models that resulted from the industrial-, sectoral- and system-level transformation for high-quality economic growth, especially with a cross-cutting perspective for integrated approaches; (4) the **risks** of not doing it right; (5) harnessing the 4IR technologies for environmental and climate governance to **improve policy-making.**

Among other sectors, **manufacturing, which accounts for more than 1/4 of China’s GDP, could be the highlight** of such a SPS. The key issue of the manufacturing sector is to make smart manufacturing and green manufacturing mutually supportive to improve productivity, increase efficiency and reduce environmental impacts, including the green value chain. Firstly, an overview of the total effect of digitalization on the production side of low-carbon development can be analyzed through case studies. For example, we can assess the effect of the incorporation of AI into decision-making on resource management and the burden on the environment. Secondly, a SPS can explore the potential of the digital transformation of the production sector in enabling new management models, new business models, and new production models by selecting inspiring case studies within and outside

China. To be more specific, the digital solutions in production and processing we are focusing on include process automation, digital plant, predictive analysis on demand and production capacity, business-to-business platform, component printing, traceability, etc. Last but not least, product design such as fast prototyping and 3D printing, business-to-consumer platforms for product design cooperation, and its combination with eco-design can be interesting angles to observe as well.

Element 2 Innovations-Perspective: Research on breakthroughs of the recent digital innovations and their significance for the environment, climate, economy, and governance. The SPS can examine the key innovations by (1) identifying the latest digital technological trends and assessing ahead its' possible influence on the environment and development. This includes for example Digital Twins for the meaningful use of environmental data or in the means for a sustainable circular economy; (2) analyzing the specific opportunities and obstacles for deploying innovations e.g., in connectivity, funding, and providing deployment guidance; (3) analyzing the role of digital innovations in an integrated governance and reducing inequality for an inclusive society; (4) identifying and analyzing the key innovations in environmental and sustainability management, where interdisciplinarity is an important quality feature and great potentials exist in interfaces to AI and data science; (5) reskilling to support the digital and green innovation. As application-orientated digital/AI research and environmental and sustainability research are mainly unconnected, the SPS will examine China's potential to link these research communities to show, how and in which fields these communities can target-oriented work well together.

Element 3 Cities-Perspective: the SPS can also extend the scope of research to **the future of cities** that are low carbon, sustainable and resilient through harnessing the digital and 4IR technologies to reduce negative environmental impacts, increase wellbeing, and urban economic activities. In this regard, the SPS will examine (1) the new urban system for production, consumption, mobility, working, and living by harnessing the digital and 4IR technologies to improve health, sustainability, and inclusiveness; (2) the gaps and opportunities in deploying the smart city technologies; (3) the best practices in smart city and enabling environment for upscaling the smart city practices.

Attachment: Twin Transformation Trends

China has experienced a decade of accelerated digitalization driven by heavy Research and Development spending, flourishing entrepreneurial activities, and raising venture capital investments. New business models and technologies emerged and grew at a very high speed, generating innovation in many fields. This section explores **key evolving trends in China**, thus identifying avenues for future research.

All these fields are fully embraced by the **Fourth Industrial Revolution technologies**, which include all those advances “merging the physical, digital and biological worlds in ways that create both huge promise and potential peril [...], forcing us

to rethink how countries develop, how organizations create value, and even what it means to be human”.

Attachment 1. Industry 4.0 to Improve Efficiency and Reduce the Environmental Burden

Industry 4.0 refers to the intelligent networking of machines and processes for industries with the help of information and communication technology. Such digitally-enabled systems allow the optimization of manufacturing productivity by ensuring the convergence of Operational Technology with Information Technology through more efficient, sustainable, and data-driven production processes [156]. Moreover, the adoption of digital technologies and services helps improve industry performance and economic conditions through the upgrade of industrial processes, the optimization of resource allocation, and the creation of higher-quality jobs [157].

There are many ways for companies to use intelligent networking to improve efficiency, thus leaving less burden on the environment and climate. The possibilities include, for example:

- **Flexible production:** In manufacturing a product, many companies are involved in a step-by-step process to develop a product. In being digitally networked, these steps can be **better coordinated** and the machine loads better planned.
- **Convertible factory:** Future production lines can be built in modules and be quickly assembled for tasks. Productivity and **efficiency would be improved**; individualized products can be produced in small quantities at affordable prices.
- **Customer-oriented solutions:** Consumers and producers will move closer together. The customers themselves could **design products** according to their wishes—for example, sneakers designed and tailored to the customer’s unique foot shape. At the same time, smart products that are already being delivered and in use can send data to the manufacturer. With this usage data, the manufacturer can improve his or her products and offer the customer novel services.
- **Optimized logistics:** Algorithms can calculate **ideal delivery routes**; machines independently report when they need new material—smart networking enables an **optimal flow of goods**.
- **Use of data:** Data on the production process and the condition of a product will be combined and analyzed. Data analysis provides guidance on how to make a product more efficiently. More importantly, it’s the foundation for completely **new business models and services**. For example, lift manufacturers can offer their customers “predictive maintenance”: elevators equipped with sensors that continuously send data about their condition. Product wear would be detected and corrected before it leads to an elevator system failure.
- **Resource-efficient circular economy:** The entire life cycle of a product can be considered with the support of data. The design phase would already be able to determine which materials can be recycled.

Box A.7. Industry 4.0

In China: **China Aerospace Science and Industry Corporation (CASIC)** has developed **the INDICS platform**, which targets governments and SMEs in traditional industries and provides them with cloud-based tools and smart manufacturing solutions enabling matchmaking and resource sharing. According to the CASIC, the platform had 1.6 million registered users in 2018, with a total transaction value exceeding USD 64 billion. **SAIC**, a Chinese automotive company, has established a **digital platform that allows buyers to customize their orders via 3D digital car simulations**. Information about the vehicle configuration is then transmitted to suppliers to start production, **reducing the time to market by 35%**. AI tools continuously monitor the production progress to identify errors: as a result, the company increased its order configuration accuracy to 99.8%.

International: The **Global Lighthouse Network**, launched by the World Economic Forum, in collaboration with McKinsey and Company, has demonstrated the true potential of the Fourth Industrial Revolution technologies to transform the manufacturing industry; Out of the 90 lighthouses, 1/3 of them are from China.

In **Germany**, the **platform industry 4.0** is steered and led by the Federal Ministry for Economic Affairs and Climate Action (BMWK) as well as the Federal Ministry of Education and Research (BMBF), and high-ranking representatives from **industry, science, and the trade unions**. Experts from business, science, associations and the trade unions **develop operational solutions** together with representatives from various federal ministries in thematic working groups.

Attachment 2: Smart Cities

In the past three decades, about 600 million people moved from rural areas to cities. As a result, China has become the country with **the greatest number of 1-million population cities** in the world. With other **300 million Chinese people** expected to relocate to urban centers over the next 30 years, this phenomenon will increase the pressure on the environment. The main causes are increased pollution, traffic congestion, and supply and demand of resources. Therefore, China is focusing on the creation of **smart cities**.

Smart cities could improve urban eco-efficiency as a result of three main effects. First, the **technology effect** can boost energy savings and clean production technologies, reducing pollution and resource consumption. Second, thanks to the **industrial structure enhancement effect**, innovation will create new opportunities for R&D,

design, development of software, information, and business services. Finally, the **resource allocation effect**: technological systems can effectively solve the problem of resource management and deploy them where they have the highest impact and efficiency. In conclusion, the concept of Smart City aims at improving urban management, achieving **sustainable city development**, and enhancing residents' **quality of life** with technology.

Nowadays, China is home to around **500 smart cities—half of those present in the whole world**. One of the reasons behind this is the government's active role in providing policies and guidance for their development. The investment in smart cities, which is currently about **USD 26 billion**, is expected to exceed the threshold of **USD 40 billion** in 2023, and there are around **800 Chinese urban centers** ready to make this transition.

In the future, research should concentrate not only on the best tools and technologies to make cities more efficient in terms of energy consumption, water management, and transportation solutions, but also on ways to **identify the urban areas that should be made “smarter”**, and those that do not need to be transformed.

Box A.8. Model Project “Berlin Lebenswert Smart”—5 Pilot Projects

As part of the model project “Berlin lebenswert smart”, the city of Berlin is adopting a new Smart City Strategy—and is working on five concrete pilot projects. These projects are funded as part of the model project and are planned to start in January 2020. Participatory formats will play an important role in both the pre-project phase as well as during the implementation phase.

Smart City Spaces: Hardenbergplatz in Charlottenburg-Wilmersdorf, a typical station forecourt with high usage, is being redesigned smartly and flexibly—i.e., depending on the event, day, weather, and season—for all forms of mobility.

Data Governance and Data-driven Administration: Together with the Einstein Center Digital Future and Siemens AG Data-Governance, the Smart City model project is developing exemplary concepts for pilot areas that integrate municipal and private-sector interests and processes in a way that balances the common good.

Community Budgeting and Smart Participation: In the context of participatory processes, interests tend to be distorted by low participation. Real-labor StadtManufaktur, BBBlockchain, CityLAB, and the mobile CityLAB are supposed to help reach more people with activating, digitally supported participation.

Smart Water—Modelling and Governance: The impact of extreme weather events is obvious, but difficult for decision-makers and the public to comprehend. The project models the effects of spatial heterogeneity and homogeneity on the water cycle and develops a participatory digital wall panel.

Data in everyday life and crisis—Kiezbox 2.0: Local data on climate, air quality, etc. are generally obtained during regular operation. In the event of a crisis (e.g., power failure), solar or battery-powered hotspots for example can form an emergency Wifi network that informs the local population.

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Annex B

CCICED Scoping Study Report: Risk Prevention of Carbon Neutrality Under the New Development Concept

—Scoping Study for a CCICED Special Policy Study

B.1 Research Objectives and Background

This report aims to conduct preliminary research on the risk prevention for carbon neutrality in China from the perspective of new development concept, and provide support for the research of the 7th CCICED. Since President Xi Jinping announced the carbon peak and carbon neutrality goal at the 75th UN General Assembly on September 22, 2020, it has been actively implemented across the country. After a year of trial and practice, the “1 + N” policies such as the Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy has been released in October 2021, which marks a new era for the full-fledged carbon goals. The Working Guidance emphasized that it is the top priority to prevent risks in promoting carbon peak and carbon neutrality, and to strike a balance between pollution prevention and carbon reduction, energy security, industrial chain security, food security and people’s daily life, so as to effectively deal with the economic, financial and social risks that may accompany the green and low-carbon transition, prevent overreaction, and ensure safe carbon reduction.

How to recognize and prevent the risks in the process of carbon neutrality depends on whether the new development concept can be understood and implemented in a full and faithful manner [1]. The prominent problem facing carbon neutrality at present is that in the process of implementing carbon neutrality, we unconsciously fall into the traditional development concept. The consequence of this is the lack of accurate understanding and prevention of risk. Some risks are often overestimated, or underestimated, and some are even neglected. Therefore, the new development concept is an important prerequisite for accurately understanding and preventing risks.

From the perspective of ecological civilization, whether the new development concept is fully and faithfully implemented depends on how to understand the relationship between the environment and development. The traditional industrialization model is based on the perception that the environmental protection conflicts with economic development. It is a model of pollution first and treatment after. If we realize that environment and development can be mutually reinforcing, that is, more environmental protection will spur more development, we grasp the essence of new development concept. Otherwise, it is still a traditional development concept, unable to understand the strategic opportunities it brings to China and its formation mechanism.

Under the new development concept, this report reconsiders and analyzes the transitional risks in the process of achieving the carbon neutrality goal. The report first reveals the essence of carbon neutrality and its implications to China's modernization, then conducts an overall study and judgment on the risks faced by carbon neutrality, and analyzes specific risks, and then analyzes the main risk prevention in key coal areas. In this process, we have conducted literature review from home and abroad. Finally, the report puts forward research directions and ideas for carbon neutrality risk prevention.

Box B.1 Key Policy Nodes for Carbon Peak and Carbon Neutrality

On September 22, 2020, President Xi Jinping announced the carbon peak and carbon neutrality goals (dual carbon goals) at the 75th United Nations General Assembly, which attracted wide attention in the international community and greatly boosted the global confidence in tackling climate change. At the Fifth Plenary Session of the 19th Central Committee of the Communist Party of China at the end of October, the carbon goals were incorporated into the 14th Five-Year Plan and the 2035 Vision. At the Central Economic Work Conference in December 2020, the carbon goals were incorporated into eight key tasks for 2021. At the Two Sessions in March 2021, it has become a hot spot of public opinion.

In March 2020, the ninth meeting of the Central Finance and Economics Committee proposed that carbon peak and carbon neutrality should be included in the overall layout of ecological civilization construction.

On July 30, 2021, the Political Bureau of the Central Committee of the Communist Party of China held a meeting, which required that carbon peak and carbon neutrality be promoted in a coordinated manner. The meeting clearly expressed that we should avoid impulsive carbon reduction, establish the new before abolishing the old, and resolutely curb the blind development of high pollution and emission projects.

On September 21, 2021, President Xi Jinping attended the general debate of the 76th United Nations General Assembly by video, announcing that China will no longer build new overseas coal-fired power plants.

On October 12, 2021, President Xi Jinping issued the initiative to “start a new journey of high-quality development” at CBD COP15 Leaders’ Summit, and announced that China will gradually build “1 + N” policy system for the dual carbon goals.

On September 22, 2021, the Central Committee of the Communist Party of China and the State Council issued the *Opinions on Completely Accurately and Comprehensively Implementing the New Development Concept and Promoting Carbon Peak and Carbon Neutrality*. Subsequently, the Action Plan for Carbon Peak Before 2030 was released, and “1 + N” policies were introduced one after another, which marked a new era in facilitating the work of carbon peak and carbon neutrality. On the eve of UNFCCC COP26, China’s Achievements, New Goals and New Measures for Nationally Determined Contributions was issued.

On December 8–10 in 2021, President Xi delivered an important speech entitled *Accurately Understand China’s Major Development Theoretical and Practical Issues* [1], stressing that we should understand carbon peak and carbon neutrality in a correct way. Many problems still exist. Some places rush to realize carbon goals, some are ap, some take the “one size fits all” approach, some start with carbon reduction campaign, and even switching off to restrict the use of power. All these measures are not in line with the spirit of the Party Central Committee. We should conduct scientific assessment, improve the dual control system of total energy consumption and energy intensity, create conditions to realize the transformation from “dual control” of energy consumption to “dual control” of total carbon emissions and intensity as soon as possible, and accelerate the formation of an incentive and restraint mechanism for reducing pollution and carbon [2].

B.2 Understanding the Major Historical Opportunities and Challenges of Carbon Neutrality

To understand correctly and prevent the risks of carbon neutrality, we must first recognize the major opportunities and challenges of carbon neutrality from a historical perspective. The “dual carbon goals” is a major strategic decision made by the central government after careful consideration, and it is the need for the great rejuvenation and sustainable development of the Chinese nation. The goal of dual carbon is a self-revolution of production and lifestyle, which is essentially a profound change in the development paradigm since the industrial revolution. It is not only an unprecedented challenge, but also a major strategic opportunity for China’s development. When discussing the risks of green transition, we cannot simply discuss risks in terms of risks, but we must jump outside the traditional industrial way of thinking and narrow time and space constraints, and understand the strategic implications and

significance of carbon neutrality in a historical context. Only in this way can we identify: (1) where are the opportunities or benefits from transformation and how big are they, and (2) where and how many risks are there. On this basis, policies can be applied to reduce risks and improve returns, and make objective risk–benefit analysis.

Carbon neutrality is not a multiple-choice question of “whether to do it”, but an applied question of “how to do it”. When discussing the opportunities and risks of carbon neutrality, it needs to be clear that carbon neutrality is not because the opportunities of carbon neutrality outweigh the risks, but because the current development model is unsustainable, and carbon neutrality is a goal with no alternative. The question we face is how to seize opportunities and reduce risks in the process of achieving carbon neutrality, in order to achieve carbon neutrality more effectively.

B.2.1 Global Carbon Neutrality Consensus and Actions Marks a New Era for Green Development

The global consensus and action on carbon neutrality is a revolutionary change in the development paradigm since the industrial revolution. First, more than 130 countries have committed to carbon neutrality. These countries account for about 90% of the world’s carbon emissions and total economic output, and about 85% of the population [3]. Second, about 70% of these countries belong to developing countries. According to the development pathways of the developed countries, carbon emissions must first reach a peak and then decline, showing an “inverted U-shaped” curve as a whole. Now so many developing countries have committed to carbon neutrality and achieved economic take-off through a low-carbon model, which is a subversive change to the traditional development model and development theory, and an epoch-making change [4].

The development paradigm shift in the context of carbon neutrality is different from that discussed in the past. In the past, more emphasis was placed on efficiency improvement, industrial upgrading, and the “smile curve”. It is true that a country can upgrade to the top of the industrial chain and reduce its carbon emissions on the production side by transferring high-emitting industries to other developing countries or regions. However, the carbon emissions on the consumption side affected by the large number of imported high-carbon products will not decrease. For global emission reduction and addressing climate change, this kind of industrial upgrading of a single country is of little substantial significance. Green transformation from the perspective of ecological civilization refers to a comprehensive transformation from development content to development method.

B.2.2 Starting a New Journey of Building Socialist Modernization in an All-Round Way Coincides with the Process of Global Carbon Neutrality

In 2020, China has entered its second centenary period, starting a new journey of building socialist modernization in an all-round way. The second centenary goal is not a simple extension of the first centenary goal, nor is it simply catching up with the modernization of developed countries, but a redefinition of the concept of modernization established since the industrial revolution.

The concept of modernization that is widely accepted in the world is formed after the industrial revolution, and is mainly based on the modernization of a few developed industrialized countries as the standard. Although this kind of modernization based on traditional industrial civilization has greatly promoted the process of human civilization, and China is also one of the biggest beneficiaries of this modernization concept, this kind of modernization based on traditional industrialization mode has its inherent limitations. First, it will inevitably lead to an unsustainable ecological environment; second, it will lead to a departure from the purpose and means of development, and it will be difficult to ultimately achieve the fundamental purpose of development, which is to comprehensively improve human well-being; third, it is impossible to achieve the modernization of the common prosperity of all populations on the earth, not to mention the establishment of a community with a shared future for mankind. Therefore, it is far from enough to just think about how to realize modernization, and it is necessary to deeply reflect and redefine modernization, so as to establish a new discourse of modernization oriented towards the future and universal to the world.

People have also been trying to solve the problems caused by the existing modernization model. However, these ideas are more about seeking solutions to problems under the traditional thinking of green industrial civilization, failing to fundamentally reveal that the essence of these crises lies in the modernization paradigm, so it is impossible to truly overcome these crises. An important feature of Chinese-style modernization is the harmonious coexistence between man and nature. This is a redefinition of the concept of modernization, jumping out of the narrow economic vision and traditional industrial civilization values, starting from the broader vision of human and nature and ecological civilization values, and establishing a new discourse on China's modernization that is future-oriented and globally applicable.

B.2.3 Global Pandemic Facilitates Green Transition

Global carbon neutrality is a correction to the traditional development model established after the industrial revolution, and to a certain extent, the global COVID-19 outbreak is also a correction to the traditional development model and a big test for green development. The development model formed after the industrial revolution is

unsustainable, and the fundamental reason is that this model leads to the destruction of the relationship between man and nature, which is the cause of the COVID-19 crisis. The crisis due to man and nature imbalance may be manifested in the form of global warming, extreme weather, or the spread of virus from nature to human beings.

The correction of the shortcomings of the traditional industrialization model by COVID-19 is manifested in two aspects: one is the change in the concept and content of development. The epidemic has largely reshaped the concept of “good life” shaped by commercial forces in the traditional industrial era. The second is the change in the way of development. Due to the isolation of the epidemic, many economic activities and transactions are conducted online. The epidemic not only shows the direction of green development, but also a big test for the feasibility of green development. When we reflect on the epidemic, we must fundamentally reflect on the shortcomings of the traditional development model formed after the industrial revolution, and find key solutions from ecological civilization.

Therefore, carbon neutrality is not just a simple issue of energy conservation, emission reduction and technological innovation, but the most comprehensive and profound paradigm shift in development since the industrial revolution. Only by understanding carbon neutrality from such historical background can we clearly recognize the historical trend represented by carbon neutrality, and maintain strategic focus and calmly deal with various transitional risks.

B.3 Overall Judgment on the Risk of Carbon Neutrality

Different development concepts determine different understandings of risks and solutions. From the perspective of the new development concept, some of the risk perceptions under the traditional development concept in the past may be overestimated, underestimated, and some are even neglected. When dealing with risks, the solutions with the old and new development concepts are also different. In general, the old development concept is to deal with risks based on the recognition that environment conflicts with development, and the solution is to seek more compromise. While the new development concept is to seek solutions based on the mutually reinforcing relationship between the environment and development.

B.3.1 Research on the Transitional Risks and Problems

Currently, there are two basic views on the perception of carbon neutrality risks. One is pessimistic, arguing that China’s modernization and industrialization have not yet been completed, and it will only take 30 years from carbon peak in 2030 to carbon neutrality in 2060. Compared with about 70 years spent by many developed countries, the challenges and risks are particularly great. The other is optimistic,

arguing that carbon neutrality will bring more than 200 trillion yuan of investment, which will stimulate China's economic growth. Both views are reasonable, but there are a certain bias in the understanding of carbon neutrality. In general, the current research on carbon neutrality risks has the following characteristics.

First, in terms of risk perception, because the traditional development concept is based on the perception of a conflicting relationship between the environment and development, the benefits of transformation are often underestimated and the risks are overestimated. In particular, when economic growth faced difficulties, it began to shake the determination of dual carbon goals, focusing on how to balance the relationship between "dual carbon" and growth. The premise of this discussion is the assumption that "dual carbon" hinders economic growth. Take climate change for example, in standard climate change analysis, the benefits of emission reductions are defined as the losses from climate change [5]. The cost is the investment in emission reduction. In fact, the benefits of emission reductions are not just avoided climate change losses, but more likely to enable the economy to jump to a more competitive structure, thus far greater than "climate change avoided losses". According to the Sixth Assessment Report (AR6) of the United Nations Intergovernmental Panel on Climate Change (IPCC, 2021), even if all countries can achieve the emission reduction targets they have committed to, the global temperature rise will reach 2.4 °C by 2100, and there is still a big gap between the global emission reduction targets of the Paris Agreement [6].

Second, when dealing with risks, our way of thinking are more concerned with the traditional thinking framework which views the relationship of the environment and development as a conflict, and we often fail to see new opportunities for green transformation. We spent a lot of time discussing how to afford the cost of emission reduction [5]. And we go further to discuss how to reduce the impact on specific industries, regions and groups. The way of thinking is more about how to protect vulnerable groups in the process of change, not about compensation for damaged sectors under the framework of the overall Kaldor-Hicks improvement.

Third, there is a tendency to overestimate the risks faced by some specific sectors. Since the premise of achieving the dual carbon goals is to eliminate fossil energy, when discussing the risks of carbon neutrality, people pay more attention to the impact of unemployment, loss, and deterioration of asset conditions caused by the withdrawal of fossil energy, and tend to exaggerate the impact of transformation on the fossil energy industry. According to relevant planning of China, renewable energy will reach 25% in 2030 and 80% in 2060. After the "dual carbon" goal was proposed, people's expectation for fossil energy has changed, and they seemed to regard fossil energy as non-performing asset overnight. However, the replacement of fossil energy by new energy does not mean that the fossil energy industry has become a non-performing asset since then. On the contrary, in the process of removing fossil energy, the fossil energy industry may still be profitable during its existence.

Fourth, the depth and breadth of the impact of carbon neutrality on industries is generally underestimated. Carbon neutrality and carbon peak are two different concepts. Carbon peak can also be achieved under the traditional development model, but carbon neutrality is a paradigm shift in development. It is a process of creative

destruction, which means that many industries will be overturned. For example, when the automobile industry shifts from traditional fuel vehicles to electric vehicles, it does not simply replace internal combustion engines with electric motors, nor does it simply replace drivers with autonomous driving, but redefines the concept of automobiles and reshapes the industrial chain. Just as the function of mobile phones has been greatly expanded from the original single call function to smart phones, and the corresponding industrial ecological chain has undergone tremendous changes, many industries represented by the automobile industry and their industrial ecosystems will also undergo subversive changes. If this is not fully understood and estimated, it will be caught off guard against unexpected risks.

Fifth, in terms of risk, the focus of attention at the global and national level differs. At the global level, the mainstream analysis of climate change in the economics community is more about the uncertainty risk caused by non-transition [7], that is, the risk of acceleration of climate change caused by greenhouse gas emission reaching a tipping point (Tipping point). At the local or national level, the focus is more on the impact of transformation on specific industries, regions and groups.

B.3.2 Overall Judgement on the Green Transition Risks

The Working Guidance pointed out that in the work of carbon peak and carbon neutrality, risk prevention requires us to strike a balance between pollution prevention and carbon reduction and energy security, industrial chain security, food security, and people's daily life, and effectively respond to the economic, financial and social risks accompanied by green and low-carbon transformation, so as to prevent overreaction, and ensure safe decarbonization. We will make an overall judgment on the risks of green transition from the following aspects.

B.3.2.1 Relationship Between Pollution Prevention and Carbon Reduction, and Energy Security

In the age of fossil energy, in addition to the unsustainable risks brought about by carbon emissions from fossil energy, oil and natural gas are highly dependent on imports, which also implies major security risks. At present, China's fossil energy accounts for about 85%, and the energy structure is featured by rich coal, a shortage of oil and natural gas, which makes China's external dependence on oil and natural gas as high as 70% and 40% respectively. From this perspective, energy transition can not only achieve sustainable development in China, but also reduce energy security risks. Potential risks of transition from fossil fuel to renewables are as follows.

The first is the risk of supply instability brought about by the characteristics of new energy. Risk reduction depends not only on technological progress (energy storage technology, grid technology, etc.), but also on new business models (for example, decentralized energy storage systems), electricity price reform to guide the

distribution of energy consumption time points, the combination of new energy and thermal power, and so on. At present, how to maintain the stability of the grid with renewable energy as the main body is still a big technical challenge.

The second is the risk of relying on key metal minerals in the new energy era. The transition from carbon-intensive fossil energy sources to a metal-intensive energy system will witness a surge in demand for key metal minerals, leading to supply chain risks and geopolitical risks.

The third is the risk brought by the speed of energy transition. Energy transformation is not simply to fill the gap between total energy demand and new energy supply, but the transformation of a huge industrial system based on traditional fossil energy. A slow transformation will certainly lead to risks, so does the fast transformation which is similar to shock therapy.

The fourth is the risks caused by the energy price mechanism. The large-scale switch off to limit the use of power in 2020 are related to the lack of a flexible electricity price mechanism and a flexible mechanism to achieve the “dual control” goal as well. It is not directly related to the dual carbon itself.

The fifth is the growth pathway of China’s total energy demand in the future also determines the magnitude of energy risks. China’s energy risks are magnified if energy demand expands unrestrictedly in accordance with the Western way of life. We should always adhere to the principles of saving priority and “dual control” of energy, and cannot simply follow the growth path of total energy demand in developed countries. Even if new energy is extremely cheap in the future, we should always save energy. For example, China’s household electricity consumption and the growth curve of per capita car ownership can no longer follow the traditional pathway of developed countries in Europe and the United States.

Existing energy demand forecast and transition pathway design are more based on the past development experience and the relationship between economic growth and energy demand in developed countries [8]. However, when the traditional industrialization model has to be transformed because it is unsustainable, both the content and method of production will change, and the corresponding energy demand must also be actively adjusted. Under the direction of green development in the future, China’s economic structure, consumption structure, urbanization mode, transportation mode will be quite different from those of developed countries. For example, the number of cars per thousand people in China is less than 200, compared with more than 800 in the United States; the per capita electricity consumption of the household sector in the United States is about 6 times that of China. Obviously, if the American way of life is replicated globally, global development cannot be sustainable. China cannot replicate America’s high dependence on private car consumption patterns and lifestyles. In this way, the future demand for energy will undergo profound changes.

B.3.2.2 Relationship Between Carbon Neutrality and Green Industrial Chain Security

Since China has global competitiveness in terms of renewable energy and new energy vehicles, global carbon neutrality provides a historical opportunity for Chinese industries to outpace others, but it also brings new global supply chain risks. In terms of new energy, China's photovoltaic industry supplies more than 60% of silicon materials, more than 90% of silicon wafers, about 89% of cells, and more than 70% of modules for the global market. At the same time, China is also the world's largest fan manufacturer, accounting for half of the world's output. China accounts for 10 among the market share ranking of the top 15 wind turbine manufacturers in the world. In 2021, China's investment in renewable energy will account for 35% of the world's total, accounting for about half of the total investment in the world's top ten investment countries. In terms of new energy vehicles, China also has great advantages. In 2020 and 2021, China's new energy vehicles will account for 41% and 53% of global sales, respectively. Among the world's top 20 new energy vehicle manufacturers, 12 are from China, 3 are from Germany and 2 are from the United States. In 2021, China's new energy vehicle exports will reach 310,000 units, a year-on-year increase of 304.6%.

First is the risk of international supply chains brought about by competition among major powers. In the past, the risks arising from the global industrial division of labor were controlled by the stable market contract mechanism and the multilateral trade cooperation mechanism (WTO). In recent years, non-market behaviors include trade wars initiated by individual major countries in the name of fair trade, breaking up supply chain in the name of security, and sanctions in the name of human rights issues. These two mechanisms are no longer as effective as in the past. At the same time, the global outbreak of the COVID-19 has a major impact on the supply chain. Under such new conditions, how to establish an effective risk prevention mechanism has become a new challenge.

The second is the supply chain risk brought about by the comprehensive transformation of the energy system. As fossil energy shifts to a new energy system that is dense with key metal minerals, the demand for key minerals will soar, and the corresponding supply chain risks will also increase significantly. According to the forecast of the International Energy Agency, the demand for metal resources of photovoltaic power generation is 5 times that of gas power generation; the demand for metal resources of offshore wind power is 13 times that of gas power generation. The demand for metal minerals in electric fleets is 6 times that of gasoline vehicles. In the next 20 years, the total demand for metal minerals will increase sixfold. Among them, the demand for lithium has increased by 42 times, the demand of graphite has increased by 25 times, the demand of cobalt has increased by 21 times, the demand of nickel has increased by 19 times, and the demand of rare earth has increased by 7 times [9].

At present, the risks China faces in key metal minerals are generally controllable, but the risks continue to increase. Since China has begun to emphasize the full use of both domestic and international markets and the "going global" strategy earlier, it has

already made a good layout in the world's key minerals. At present, China is relatively active in the supply of key minerals, and the supply is generally stable. However, due to global carbon neutrality and technological progress much faster than expected, global demand for key minerals will increase significantly, with corresponding supply risks and uncertainties. In particular, with the rapid expansion of China's new energy and electric vehicles in the global market, many key minerals that currently do not need to rely on imports will become key minerals that are highly dependent on imports and compete with each other.

China's demand for key minerals is not only to meet domestic product demand, but also to meet global demand. At present, China is the world's largest renewable energy market and equipment manufacturer. The photovoltaic industry supplies about 60% of polysilicon, 90% of silicon wafers, 75% of cells, and 70% of modules for the global market. At the same time, China is also the world's largest manufacturer of wind turbines, with more than half of the world's output, and the world's largest producer of smart electric vehicles. China is transforming and upgrading from a world factory in the traditional sense to a global green and intelligent manufacturing factory. Due to China's huge domestic market support and green development strategy, the expansion of the green industry system has unique advantages. It is expected that many products of China's green manufacturing will dominate the world in the future.

The superposition of domestic and foreign demand will bring about rapid growth in China's demand for key minerals, and some minerals will change from self-sufficiency to import dependence. Taking chromium as an example, after 2000, with the rapid expansion of China's global market share of stainless steel, China's demand for chromium has risen sharply. Many key mineral needs related to high technology such as new energy and electric vehicles in China should follow this path to expand rapidly. Therefore, China must take precautionary measures to prepare for import dependence in the event of a substantial increase in demand for key minerals [10].

B.3.2.3 Dual Carbon Goals and Food Security Call for New Thinking

The so-called food security is the guarantee of food supply to meet food demand. However, there are two different criteria for food needs, one for commercial needs and the other for healthy nutritional needs. For a long time, food security has been defined more in terms of commercial needs, especially after basic food and clothing issues have been resolved. The growth path of food demand in developed countries in the past has become the main basis for estimating domestic food demand. However, because the dietary structure and agricultural structure of developed countries are more driven by commercial forces, this standard of total grain demand and structural demand based on commercial forces has brought a lot of health and environmental problems. The food supply and demand have been in a state of imbalance at any time for a long time. The current food security risks are largely embedded in this concept of food demand.

This logic of defining the concept of food security based on business needs is in line with the traditional industrialization logic behind it. The process of agricultural

modernization is a process of being logically transformed by industrialization. If we examine from the two dimensions of production content (what) and production method (how), in the process of agricultural modernization, the production content of agriculture has changed from the past mainly plant-based output to animal-based output. The way is changed from the past ecological agriculture to industrialized agriculture, oil agriculture and single agriculture. The traditional industrialization model is unsustainable, and the agricultural development model formed under the logic of industrialization is also unsustainable.

According to the WHO's health nutrition requirements, the global food supply actually far exceeds the current food demand. However, the demand for food driven by commercial forces not only makes the demand for food continue to expand, but also promotes the transformation of the agricultural structure to the structure of animal products. In this process, the agricultural structure and the dietary structure promote each other, constantly deviate from the structure of healthy nutritional needs, and finally form a vicious circle of "diet structure-health-agricultural structure-environment". That is, a "modern" diet based on animal products brings a lot of health risks and medical expenses, and this modern diet corresponds to the supply structure of animal agriculture. Since the resource and environmental cost of animal products is far greater than that of plant products, this specific dietary structure and agricultural structure correspond to serious problems such as ecological environment resources and climate change. For example, 77% of the world's agricultural land is used directly or indirectly for the production of animal products and about half of the food is used to feed animals [11].

The root cause of these problems lies in the traditional industrialization logic and commercial forces. Modern agriculture is essentially high-carbon petroleum agriculture, and agriculture has become one of the major sources of environmental destruction. In terms of climate change, agricultural greenhouse gas emissions have not only become a driver (carbon source) of climate change, but agriculture itself has also become a victim of climate change. According to the IPCC Sixth Assessment Report [9], agriculture, forestry and other land use emissions accounted for 23%. Since modern agriculture is based on the logic of industrialization, its input, production, processing, sales and other links are highly dependent on the global division of labor and trade, so local agriculture is directly linked to global market risks.

If you compare the food production and health status of China, the United States and India, you can easily understand the vicious circle of "diet structure-health-agricultural structure-environment" [12]. China and India have similar populations, and food production of India is less than half of that of China (food production of India is 308 million tons in 2020 and food production of China is 680 million tons in 2021, see Fig. B.1), however India is a major exporter of food, with rice exports accounting for 1/4 of global level. Since 2004, China has changed from a net exporter of agricultural products to a net importer. According to data from the General Administration of Customs, China will import 165 million tons of grain in 2021, accounting for 24.1% of China's total grain output. The external dependence of food is 19.4%. Among them, soybean imports were 96.518 million tons, and the import dependence was 85.5%. At the same time, although the incidence of

cancer in China is significantly lower than that in the United States, it is higher than that in India and notably on a rapid upward trend (see Fig. B.2). The incidence of cancer in each age group in China is on average several times higher than that in India (see Fig. B.3). The reason behind this is the vicious circle of “diet structure-health-agricultural structure-environment”. The situation in the United States is even worse.

(Share of population with any form of cancer in Figs. B.2 and B.3 is measured as the age-standardized percentage. This share has been age-standardized assuming a constant age structure to compare prevalence between countries and through time.)

Therefore, to solve the problem of food security, it is necessary to redefine the concept of food security, rethink basic issues such as agriculture, diet, health, and the environment, and turn the vicious circle of “diet structure-health-agricultural structure-environment” into a virtuous circle. Under this virtuous circle, the demand

Fig. B.1 Cereal production comparison of China, United States and India

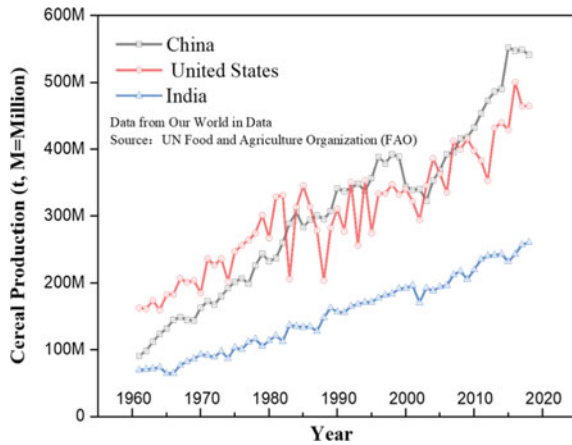


Fig. B.2 Cancer percentage comparison of China, United States and India

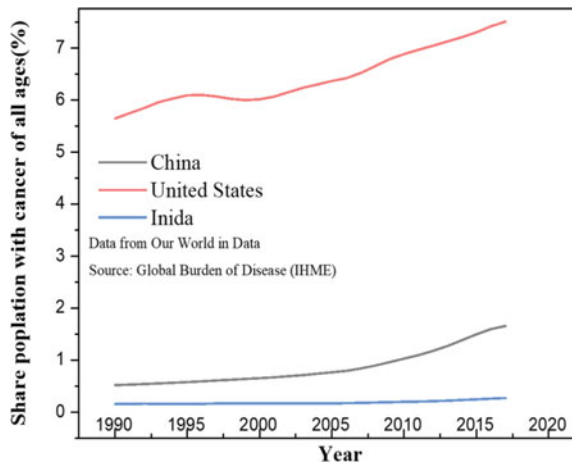
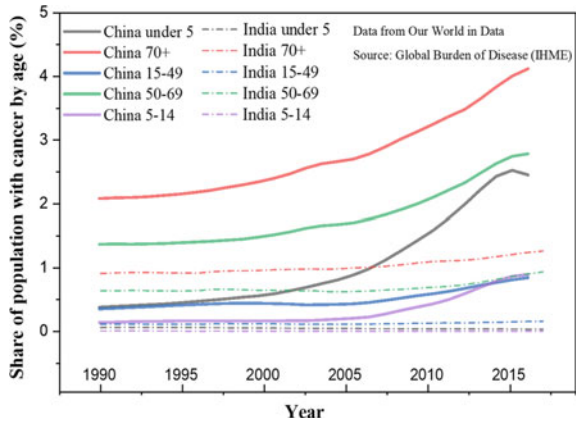


Fig. B.3 Share comparison of population with cancer by age, China and India



for food returns to the normal demand for health, people’s health status is significantly improved, and environmental problems are mitigated. At the same time, the mode of agricultural development shifts from petroleum agriculture to ecological agriculture, and modern agriculture is expected to transform from a carbon source to a carbon sink.

B.3.2.4 Relationship Between the Dual Carbon Goals and People’s Daily Life

The fundamental purpose of dual carbon is to bring development back to the original aspiration that is, to improve people’s well-being. “Dual carbon” requires a profound transformation of production methods and lifestyles. In the process of this transformation, people’s daily life should be continuously improved. However, the transformation process of this development paradigm may have different effects on the production and life of specific groups of people at specific stages.

First, the direct content of the dual carbon goals is the transformation of the energy system. With the substantial reduction in the cost of new energy, the total energy cost will continue to decrease in the long run, thereby improving people’s quality of life.

Second, since carbon neutrality is a process of reducing the proportion of fossil energy, it will impact some areas, industries and groups which are intensive in fossil energy. However, the reduction in the proportion of fossil energy does not necessarily mean that fossil energy has become a sunset industry or a non-performing asset. In the process of removing fossil energy, due to the controllable total energy supply, under the target of “2030 and 2060” roadmap, fossil energy companies can still gain reasonable profit, thereby promoting the development of new energy. This means that the impact of carbon neutrality on some specific groups of people can be hedged through effective policy and mechanism design.

Third, about the argument that “dual carbon” affects people’s daily life. Some people attribute the power cut in some areas in 2021 to “dual carbon”, but in

fact, it is mainly due to unreasonable coal power prices, resolving excessive coal capacity, export-driven, and high pollution and high emission projects launched locally, weather, and a lack of flexible implementation mechanism for the “dual control” goal. It has no direct link with the “dual carbon” work.

Fourth, in the process of implementing the “dual carbon” work in some places, they adopted a simple and rude “one size fits all” approach, such as closing factories at will, which affected the lives of some people. These are caused by the failure to fully and faithfully understand and implement the new development concept, and it is exactly what the central government wants to correct in the Working Guidance.

B.4 Carbon Neutrality and Key Risk Prevention

B.4.1 The Biggest Strategic Risk is the Misunderstanding of Carbon Neutrality

Global carbon neutrality is the result of scientific consensus. It is not a multiple-choice question of “do it or not”, but an applied question of “how to do it”, which is also a major strategic opportunity for China. The key to recognizing and seizing this opportunity is to fully and faithfully understand and implement the new development concept. The essence of the new development concept is to establish the understanding and mechanism of mutually reinforcing environment and development; the traditional development concept regards environment and development as a conflict, which is a development model of pollution first and treatment later. Without a deep understanding of the essence of carbon neutrality, it will be seen as a burden of development, or be reduced to a technical or energy issue, or even simply pursue carbon reduction for the purpose of carbon reduction, which will bring strategic risk.

B.4.2 The Risk of Absence of Carbon Neutrality in the Overall Planning of Ecological Civilization

Carbon reduction has double dimension, and it can be positive and negative to ecological environment protection and resource conservation. For example, reducing fossil energy can improve air quality and is good for health, but new energy will greatly increase the demand for key metal minerals, the entire life cycle of which, such as mining, smelting, processing, manufacturing, transportation, installation, maintenance, and end-of-life treatment, will cause a lot of pollution. If carbon reduction is for carbon reduction itself, without considering other dimensions of risk, a single act of reduction may exacerbate ecosystem damage. Therefore, “dual carbon” should be

incorporated into the overall layout of ecological civilization construction to achieve co-benefits of carbon reduction and ecological protection [13].

B.4.3 The Impact of Carbon Neutrality on the Key Coal Areas

Specifically, it includes the impact on the economy, employment, and finance. The development model of these coal-rich regions has two typical characteristics. First, in the past, it has always relied on the traditional path of industrialization to do coal mining and set up factories”. Second, it not only relies heavily on resource endowment advantages, but also the economy lies in a high-carbon, low-value-added link in the industrial chain of the traditional industrialization model. Not only facing the problem of energy transformation, coal-rich regions require systematic transformation for the entire industrial base (including manufacturing, service), financial base, employment structure, etc. all of which are based on energy endowment. Take Inner Mongolia (IM) as an example, more than 80% of its industries are energy and raw materials, and the six high-energy-consuming industries account for about 90% of industries of IM. The energy consumption and the carbon emissions per unit of GDP is three times and four times the national average, respectively. At the same time, its scenery and other new energy resources and ecological culture and other resources are also very rich, but these have not been fully developed so far [14].

B.4.4 The Impact of Carbon Neutrality on the Key Industries

Manufacturing has been the most important engine of China’s rapid growth over the past 40 years and a major cause of China’s environmental problems. The total industrial carbon emissions still account for more than 70% of the total carbon emissions of the whole society (about 40% of which are industrial electricity emissions), and the energy consumption accounts for more than 60% of the total energy consumption of the whole society. China acts like the world’s factory, and about 20–30% of its carbon emissions are contained in exported products. Fossil energy industry should achieve carbon neutral first. The most prominent industries are electricity, steel, building materials, non-ferrous metals, petroleum and chemical industries with high energy consumption, whose carbon emissions account for about 80% of industrial carbon dioxide emissions. Considering that electricity accounts for about 40% of industrial carbon emissions, and that the output of these industries has reached or is close to peak, achieving industrial carbon peak by 2030 is not a difficult problem, but the biggest challenge is to achieve carbon neutrality goals. Carbon neutrality is a process of creative destruction, meaning a comprehensive reshape of economy. Many industries are facing the problem of transformation or even elimination. This in turn will bring about a large number of transitional justice issues, including re-employment, local taxation and other issues.

B.4.5 The Impact of Carbon Neutrality on Asset Repricing

As the dual carbon goals has profoundly changed market expectations, under new constraints and development concepts, concepts such as cost, benefit, and optimal behavior have undergone profound changes, triggering the market to re-price assets in specific industries, especially fossil energy and its related industries. This will bring about major changes in the capital market, stock market, enterprises, households and the country's balance sheet, which will have a systematic impact on the economy [15]. This process, in particular, requires careful handling and risk management. However, we need to distinguish two different concepts, the sunset industry and the non-performing asset industry. It is true that carbon neutrality means the process of removing fossil energy, but this does not mean that the fossil energy industry will become a non-performing asset industry. Under the target of "2030 and 2060" roadmap, the proportion of fossil energy will continue to decline, but the fossil energy in the market (and overall energy prices) may remain relatively high. This can not only speed up the development of new energy, but also reduce the state's burden of supporting the transformation of the fossil energy industry.

B.4.6 The Risks of Green Structural Reform

A green transition is a jump from one structure to another, for example, jumping from traditional cars to electric cars, from traditional taxi mode to network platform sharing car rental mode, from chemical agriculture to Internet ecological agriculture. Although the returns will be higher under the new structure, since this jumping process may fail, if there is no corresponding risk aversion mechanism, the transformation will be difficult, and the economy will be locked in the traditional economic structure. Therefore, a "green insurance" mechanism needs to be established to facilitate this "0 → 1" structural jump. This mechanism can be similar to agricultural insurance, government subsidy, and new capital venture capital mechanism.

B.4.7 The Risks of Climate Adaptation

Addressing climate change includes mitigation and adaptation. Agricultural scientists usually simulate the impact of climate change on agricultural yields based on crop models, while economists introduce the concept of a "smart farmer", revealing that farmers change their cropping patterns to adapt to climate change [16]. However, due to the complex price feedback mechanism in the market, changing the planting pattern will not necessarily increase income, and without doing so will not necessarily reduce income. Therefore, in many cases, decentralized market mechanisms are the most effective way for climate risk aversion.

B.5 Challenges and Risks of Green Transformation in Key Coal Regions

The dual carbon goals is a major historical opportunity for China's development, but it will also have a certain impact on some regions, industries, and groups. Inner Mongolia and Shanxi are major energy provinces in China, with coal output exceeding 1 billion tons, accounting for 30.71% and 35.27% of the national coal output respectively. For a long time, the two places have formed an economic structure, employment structure, fiscal and taxation income based on coal resource endowment. But at the same time, these two regions are rich in new energy resources, ecological and cultural resources, and have unique green development advantages. According to the 2021 Corporate Social Responsibility Report of the Coal Industry by China Coal Association, there will be nearly 2.85 million employees in the coal industry in 2020, including 2.1 million employees in large coal enterprises, accounting for 74%. Taking these two typical regions as examples, we conduct an overall study and judgment on the challenges faced by green transformation, and briefly reveal the main risks they face in terms of "establishment" and "breakdown".

B.5.1 Introduction

Inner Mongolia

Due to the advantages of coal resource endowment, Inner Mongolia has taken an unsustainable traditional resource-based development path to a large extent in the past, which has brought a lot of ecological and environmental problems while bringing economic development. Inner Mongolia emits 7.2% of the country's carbon dioxide to produce 1.7% of the country's total economic output. Energy consumption accounts for 5.2%, which is three times the national average. The per capita carbon emission level is nearly four times the national average. At present, the energy and raw material industries in Inner Mongolia still account for 82% of the increase in industries above designated size, and traditional high-energy-consuming industries such as electric power, chemicals, steel, nonferrous metals, petrochemicals, and building materials still account for 89% of industries above designated size. Inner Mongolia's external coal transportation volume is maintained at 550 million to 600 million tons, accounting for 1/3 of the country's inter-provincial coal transfer volume. Inner Mongolia's coal transportation to the whole country and the installed capacity of coal-fired power are the first in the country. The power transmission channel has always ranked first in the country, accounting for nearly 20%. At present, the overall pattern of Inner Mongolia's economic development over-reliance on energy-intensive industries has not been fundamentally reversed. In 2020, investment in high-energy-consuming industries in the region will still account for more than 64% of manufacturing investment [14].

At the same time, the green resources of Inner Mongolia are also very prominent. Its wind energy, photovoltaic resources and ecological resources are quite rich. As an ecological security barrier in northern China, Inner Mongolia has a unique advantage in taking the transformation path of ecological first and green development. Inner Mongolia has 1.3 billion mu of grassland, 350 million mu of forest, more than 60 million mu of water surface and wetland. The area of grassland and forest ranks first in the country. It has the largest and most complete ecosystem in the north, is the source of many river systems, and the place where the northern continental monsoon pass through. It is an important ecological security barrier for this core area. In addition, Inner Mongolia is also rich in cultural resources.

Shanxi

Shanxi Province has coal reserves of 50.725 billion tons, accounting for 1/3 of the national total, making it the largest coal province in China. Accordingly, its economy is also based on coal. High energy-consuming industries account for about 70% of Shanxi's total energy consumption, and most of the energy products are transported outside the province. In 2021, Shanxi's external coal transfer will account for about 60% of the province's output, the power transfer will account for more than 30% of the province's power generation, and the external transfer of coke will account for 80% of the province's output. Regarding the status quo of Shanxi's coal-based industrial structure, it is especially necessary to "establish first and then break down" and seek progress while maintaining stability. The pressure of coal removal on the transformation of traditional industries must be properly handled to avoid affecting the national industrial chain and supply chain, and affecting the stable development of Shanxi's economy. Local fiscal revenue in coal-related fields accounts for more than 30%, and the stability of fiscal revenue must be fully considered. At the same time, Shanxi is rich in new energy resources and cultural resources, and has unique advantages in green development.

B.5.2 The Challenge of Breaking Down

In terms of "breakdown", the common challenges in these places are mainly the impact of coal and coal-based industries, which will have impacts on employment, industry, local finance, social security, ecological environment, and asset re-pricing. However, since coal has not really entered the downward channel at present, the coal industry generally remains profitable at this stage. The difficulty of coal power is mainly due to factors such as the price mechanism, as well as the influence of its own operation.

Coal and coal-based industries (including coal chemical industry and coal power) have high debt ratios due to their high capital intensity and historical debt. Once shut down or limited production, it will bear greater debt risk. At the same time, due to the long service life of coal mines and coal-fired power units, high-input assets will be idle and wasted. However, since coal removal is an orderly and gradual process,

rather than an industry-wide shutdown overnight, the actual risk release of the coal removal process is also a gradual process. In the process of coal removal, it is actually possible and necessary for coal prices to remain at a reasonable and relatively high level. As for the high asset-liability ratio of the coal-based industry, it is not directly related to the “dual carbon” goal. The “dual carbon” target only further exposes corporate risk. The coal industry and coal-based industry are major taxpayers in Inner Mongolia and Shanxi, accounting for more than 1/3 of local fiscal revenue. However, this effect is also not released immediately. Therefore, although these key coal provinces face great challenges in the process of achieving dual carbon” goals, as long as the “2030 and 2060” roadmap is steadily advanced, various challenges can be overcome.

B.5.3 The Challenge of Establishment

- The echelon of key coal regions in the national “2030 and 2060” roadmap.
- Further coordination is needed between new energy construction and national land and space planning.
- The issue of clean energy output remains to be resolved.
- Green investment has not yet formed a market-oriented approach and investment model, and the corresponding technology and talents are also lacking.
- The compensation mechanism for connotative emissions needs to be improved. Inner Mongolia and Shanxi are both major coal and coal-fired power exporting provinces. Although the production side has high carbon emissions, a large proportion of it is exported energy for the whole country. How to define the emission reduction responsibilities of connotative emission exporting provinces such as Inner Mongolia and Shanxi, and establish a regional cooperation mechanism for carbon peak and carbon neutrality, has become an important issue.
- In terms of green transformation, how to accurately define the functions of the central and local governments, including public investment, fiscal expenditure responsibilities, etc., need to be defined.

B.6 Future Research Topics and Policy Implications

There has been a lot of research on the risks of the “dual carbon” goals. What is most needed now is to jump outside the traditional industrialization thinking, reconsider and evaluate relevant risks under the new development concept, and put forward new risk prevention ideas and policy recommendations.

B.6.1 Research on the New Discourse System and Policy Discourse

Some of the current cognitions on carbon neutrality have largely failed to establish a discourse system and policy discourse to promote carbon neutrality. We should recognize the disadvantages of non-transition and the advantages of transformation, and have a better understanding of the severity and urgency of the global climate change crisis. In particular, we should reveal the harm of global climate change to China. It must be recognized that the biggest risk lies in no transition, and transition offers a historical opportunity for China to outpace others. In a complex and severe situation, policymakers should maintain a strategic focus on carbon neutrality.

B.6.2 Re-evaluate the Transitional Risks

Many of the transitional risks discussed so far do not actually come from green transition, but rather from the inherent disadvantages of the traditional development model. Transition only exposes what has been temporarily masked. Therefore, the fundamental solution to these risks is to completely change the way of development, rather than not transforming or delaying the transformation. Without transformation, these risks will break out and be even more destructive. In particular, existing so-called transitional risks need to be reassessed. Many of the so-called transitional risks that we are worried about have basically nothing to do with “dual carbon” goals. For example, power cut is not caused by “dual carbon”. Attributing these risks to “dual carbon” goals would have a profound negative impact on China. Some risks are overestimated, or underestimated or even neglected.

B.6.3 Research on the Transformation of Government Functions in the Context of Carbon Neutrality

The current standard definitions of government functions are all defined under a market economy based on an industrialized model. When the traditional industrialization model must undergo green transformation because it is unsustainable, the corresponding market and government functions must also undergo transformation.

B.6.4 Research on the Market Mechanism to Reduce Risks

A well-functioning market mechanism is one of the most effective means to avoid “dual carbon” risks. An effective market mechanism can not only reduce the

occurrence of risks, but also diversify risks when they occur, improving economic resilience.

B.6.5 Research on Pressing Issues, Policy Roadmap and Mechanism Design for Green Transition

The current “1 + N” policy system needs a lot of in-depth and meticulous work in the implementation, including how to further put forward specific policy recommendations, how to make early warning to problems that may arise in the implementation process, and how to summarize experiences and lessons learned in a timely manner. In particular, risks arising from improper administration should be avoided, such as “one size fits all” approach for all regions and industries.

B.6.6 Key Research on Incorporating Dual Carbon Goals into the Overall Planning of Ecological Civilization

On the one hand, since the realization of the “dual carbon” goals is a systematic work, if it is not incorporated into the overall layout of ecological civilization, it will be difficult to achieve [3]. On the other hand, the current simple thinking of reducing carbon for the purpose of carbon itself fails to coordinate carbon reduction with ecological and environmental protection, and even exacerbates unsustainability in some cases.

B.6.7 Research on the Incentives for Green Technological Innovation

Green transformation is a “0 → 1” process, and new technologies face thrilling jumps both in technology and in the market during the process of Research and Development and promotion. If there is no effective risk sharing mechanism, such as capital market mechanism design, insurance mechanism, social security mechanism, etc., green transformation will not be realized due to high risks.

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Annex C

CCICED Scoping Study Report: Sustainable Trade and Investment¹

C.1 Trade and Environment Synergies

Trade continues to make a significant contribution to GDP growth in many countries and has been vital to the economic recovery of many countries, particularly in the Asia–Pacific region, following the initial economic shocks of the coronavirus pandemic.

Trade has helped support common prosperity objectives such as expanded employment, higher wages, poverty alleviation, and recurring inequity gaps. For example, data strongly suggest a positive correlation between trade openness and higher wages: for example, participation in global supply chains shows higher average wage levels of 4%. Trade openness can indirectly contribute to improved social conditions such as working conditions. However, social benefits never happen automatically as a consequence of trade, underscoring the vital importance of strong domestic or behind-the-border measures to be sequenced with trade openness.

The same is true in tracking the complex and indirect interaction between trade, innovation, and total factor productivity. Trade in services can be an important generator of net employment growth, including higher rates of income growth in some sectors, such as financial services, telecommunications, or engineering-related services. Importantly, embodied services in many higher-value-added traded goods are a growing source of employment in some countries.

¹ Scott Vaughan is the leading author of this scoping report.

Trade and Gender: An important development objective is closing the gender inequality gap. A growing body of evidence confirms that closing gender inequality gaps makes compelling economic sense: for example, greater gender equality is associated with higher rates of GDP. Ongoing initiatives like Aid for Trade have included programs to increase the participation of women entrepreneurs in trade, close wage gaps between men and women, and support women’s leadership roles in trade. In 2020, the World Trade Organization (WTO) Informal Working Group on Trade and Gender was launched to improve data tracking women in trade, measuring the effects of trade policies and patterns on women’s employment and wages, and assess how trade-related price effects of goods and services affect the most vulnerable. The Buenos Aires Joint Declaration on Trade and Women’s Economic Empowerment, signed in December 2017 by more than 125 WTO members, has underscored the importance of improved gender-based analysis (GBA+) to assess trade effects on women and identify concrete options for women in the areas of greater empowerment, entrepreneurship, and wage parity, among others. However, women face persistent barriers, including limited access to trade finance and more general financing due to restrictive laws, lack of collateral and training, and other barriers. The World Bank International Finance Corporation estimates the capital gap for female entrepreneurs is USD 300 billion.

Green Trade: 2022 marks the 30th anniversary of the United Nations (UN) Conference on Environment and Development, held in Rio de Janeiro, wherein governments pledged to ensure a “mutually supportive” relationship between trade and the environment in sustainable development.

Trade continues to play an important role in the global distribution, at scale, of a widening basket of green, low-carbon goods and services. For example, trade plays a vital role in increasing the availability and affordability of solar photovoltaics and other renewable energy goods and related services. In the past decade, the price of solar panels has dropped by roughly 80%, with tariff levels for most components at around 2%, helping to spur global renewable energy trade.

Green trade extends well beyond low-carbon, renewable energy. For example, markets for low-carbon, zero-deforestation, pollution-free goods and services are estimated at around USD 200 billion per year. Most forecasts expect green markets for hundreds of traded goods and services—from steel and automobiles to coffee and tourism—to expand. For example, the International Energy Agency reports sales of electric vehicles tripled between 2018 and 2021, representing 10 percent of global sales. Markets for green hydrogen (see below) are expected to increase sharply in the coming decade.

Green Hydrogen: An important emerging area of green trade involves green hydrogen. Many national net-zero plans prioritize green hydrogen—that is, hydrogen produced with renewable energy—as a route to carbon neutrality. The first bulk shipment of liquefied hydrogen occurred in 2021 using a new purpose-built bulk container. As trade expands, trade policy can help differentiate between categories of hydrogen (brown, grey, and green) through certification standards and promote greater cooperation between exporting and importing markets.

Recent ministerial statements by WTO members reflect the breadth of linkages connecting trade and the environment, with work underway examining the role of trade in net-zero transition pathways, plastics pollution, zero-deforestation supply chains, disciplining fossil fuel subsidies, and other areas.

Scoping study experts noted multiple opportunities for trade and green goals to work in synergy, as well as several conceptual differences that pose underlying challenges. Both trade rules and climate and ecosystem protection initiatives, such as natural capital accounting, prioritize the need to correct market and pricing failures. Both systems, in theory, support the internalization of environmental externalities. However, in practice, perspectives on how to implement internalization vary widely. For example, an estimated USD 1.8 trillion in environmentally harmful subsidies were provided by many of the same governments that were using carbon and other pricing to reduce externalities.

Study experts noted that trade has allowed for narrow and time-limited exceptions for some green subsidy support—notably, the prior use of the temporary WTO green box for agriculture. Given the scale of subsidy reform needed to support the goals of Kunming and Glasgow biodiversity and climate outcomes, permanent approaches to green subsidies need to be reinstated, while existing disciplinary rules to curb harmful subsidies must be enforced.

Other differences between trade and environmental governance were noted. While the WTO and most regional or bilateral trade agreements are based on a relatively homogenous set of rules—like those based on trade without discrimination, which include principles such as “most-favoured nation” and “national treatment”, and the prohibition of export restrictions—the Paris Climate Agreement governance architecture is based on bottom-up, heterogeneous approaches established through nationally determined contributions (NDCs). Differences between NDCs are often significant, in terms of both differing targets and timetables related to greenhouse gas (GHG) emissions reductions and the choice of measures used, such as market-based carbon pricing, regulations, mandatory standards, green procurement, green financing, carbon capture utilization and storage, green infrastructure investments, research and development innovation financing, and other measures.

Given that these differences in policy choice are likely to increase throughout 2030, scoping study experts emphasized the importance of international cooperation, dialogue, and trust-building to avoid friction. The WTO system of notification

in supporting transparency offers lessons for international cooperation around carbon pricing. Beyond transparency, heterogeneous climate mitigation measures are likely to lead to trade friction, notably through the proposed use of border carbon adjustments, market access bans, sanctions, and other tools. Again, current WTO practices to help determine the comparability and equivalency of differing regulations and standards are useful: for example, the WTO Technical Barriers to Trade Agreement's conformity assessment rules coupled with international standards provides a framework to compare and build convergence among different carbon mitigation measures.²

A similar bottom-up approach will likely characterize the outcome of the Kunming Conference of the Parties (COP) negotiations, in which the Global Biodiversity Framework will be implemented at the domestic level through updated National Biodiversity Strategic and Action Plans. With the growing importance of the sustainable use of biodiversity, coupled with the growing actions of some private sector agricultural commodity companies, green financial services, and action taken to identify and reform environmentally harmful agricultural subsidies,³ many trade and climate issues are likely to also involve global biodiversity targets.

Green Standards: Nowhere is the heterogeneity of nature-related domestic measures more evident than in the area of sustainability sourcing standards. There are now hundreds of mandatory and voluntary standards at play in global markets, all intended to promote green development outcomes. Such standards differ widely, both in the criteria used to define green, low-carbon, low-pollution, sustainability, or other characteristics and in the different auditing standards used to measure implementation and outcomes. Since most green standards focus on changing how products like steel, electricity, cement, agricultural commodities, and other goods are produced or priced through measures like carbon taxes, they also create tension with the trading system's primary focus on differentiating produced goods.⁴

² One example of a carbon tax with planned increased stringency is Canada's national carbon price, introduced in 2019 at a rate of CAD 20/tonne, rising to CAD 50/tonne in 2022, and then at yearly intervals to reach CAD 170/tonne by 2030. Among the interesting features of the Canadian example is the use of equivalency between federal- (state-)level pricing and different provincial market-based approaches—notably, the provinces of Quebec and Nova Scotia, which use cap-and-trade rather than carbon pricing.

³ In 2021, an estimated USD 1.8 trillion in environmentally harmful subsidies were provided by governments, including subsidies for fossil fuels, agriculture, and other areas. An important report prepared by the Nature Conservancy, the Paulson Institute, and Columbia University set out a financing proposal that included eliminating environmentally harmful agricultural and other subsidies that undermine conservation objectives. Following work in the CCICED Green Finance Special Policy Study (SPS) that recommended China tackle harmful agricultural subsidies, the 2022 CCICED scoping study on innovative finance has identified subsidy reform as a priority for future CCICE work.

⁴ Recent work to build convergence in green financing taxonomies and standards, such as the creation of the new International Sustainability Standards Board of the IFRS Foundation, illustrates efforts to reduce gaps among dozens of major standardization bodies.

Regional Trade Agreements: Early models like the North American Free Trade Agreement have helped guide subsequent bilateral and regional free trade agreements in setting out environmental provisions in stand-alone chapters, as well as, in some cases, building an international environmental cooperation program. The early NAFTA model has influenced the Comprehensive and Progressive Transpacific Partnership (CPTPP), which includes a chapter on the environment. China applied to become a CPTPP member in September 2021.

The 2019 agreement of the Regional Comprehensive Economic Partnership (RCEP) marks a significant achievement. While RCEP contains no environmental provisions, it is linked to a wider Association of Southeast Asian Nations (ASEAN) institutional structure that has several ongoing areas of work related to climate change, the Sustainable Development Goals (SDGs), biodiversity protection, and other areas.

Green Belt and Road Initiative (BRI): The BRI is among the largest sources of trade finance ever and provides a significant platform to advance green trade. The World Bank estimates that BRI financing has the potential to increase global trade between 1.7% and 6.2% and to increase global real income by between 0.7 and 2.9%. CCICED continues to work to green new BRI investments through financing standards and safeguards and prohibiting financing in important areas like overseas coal power. In March 2022, the National Development and Reform Commission issued new comprehensive, ambitious guidelines to further advance green BRI outcomes. Among the priority areas of this new guidance is green trade, specifically calling for BRI to “continue to optimize the trade structure and vigorously develop high-quality, high-tech, high-value-added green product trade. [It also calls for BRI to] [s]trengthen the import and export of energy-saving and environmentally friendly products and services”.

C.2 Green Industrial Policy

There have been multiple efforts to define and classify industrial policies, although, given their wide differences, a more useful approach is to examine the composition and effects of government policies through case studies.⁵

Following the 2008 global financial crisis that exposed extensive market failures and weak government oversight, interest in industrial policy has steadily increased. The United Nations Conference on Trade and Development’s (UNCTAD’s) World Investment Report 2018 estimates that 84 countries accounting for 90% of global GDP have adopted formal industrial policies in the past 5 years. An influential 2019 economic study by the International Monetary Fund (IMF), entitled The Return of

⁵ The Organisation for Economic Co-operation and Development’s (OECD’s) Production Transformation Policy Review has set up a peer review process to examine different approaches to industrial policies. Its 2018 assessment of Shenzhen, for example, showed that the city of 18 million, today, grew from a fishing village in the 1970s to a global finance, technology, and innovation hub.

the Policy That Shall not be Named, examined what it called “true industrial policy”, which revolves around government support that concentrates less on picking industrial “winners”—which governments generally do badly—in favour of providing support for technological innovation.

The IMF title reflects the tainted reputation of industrial policy among many economists and trade experts. However, a new generation of industrial policies focuses on setting large, mission-oriented objectives—or what the economist Mazzucatto⁶ calls moonshot missions—supported by enabling measures like front-end financing or tax incentives to de-risk innovative start-ups or establish what Dani Rodrik calls an ongoing institutional process within which companies work with governments to unclutter regulations that impede innovation.

The IMF argues that successful industrial policies rely less on the invisible hand of the market than on what it calls the “leading hand of the state”. In examining the reasons behind the success of Asian economies in economic growth, the IMF concludes that technology- and innovation-focused industrial policy is based on state intervention that facilitated a shift in domestic firms toward more sophisticated sectors beyond their existing comparative advantage. They observe that trade, in general, and export-oriented policies, in particular, play a key role in innovation by exposing companies to external competition and, in turn, prompting further innovation.

This export-led focus contrasts with earlier versions of industrial policies—for example, those pursued in the 1980s and earlier—that were based on import substitutions that led to inefficiencies, stifled innovation, and created ongoing reliance on imported inputs in supply chains. This system impeded a shift to higher-value-added outputs and sectors.

Whole-of-Government Net-Zero Plans: Against this background of recent industrial policies, there has been a surge in green industrial policies in recent years, notably in emphasizing the role of green technological innovation in achieving net-zero climate goals, a circular economy, and alternatives to pollution-intensive manufacturing. Green industrial policies are defined as “government intervention to hasten the restructuring of the economy towards environmental sustainability”. By its nature, low-carbon and green transition planning is complex, covering economy-wide measures like taxation; government investments in green technologies; sector-specific plans covering energy, transport, agriculture, industry, buildings, and other

⁶ Mazzucato’s report to the EU’s Horizon has characterized industrial policy as a “mission-oriented” approach to tackle grand societal challenges. Instead of beginning with stating the problem one is trying to solve, such as sluggish productivity rates of low levels of high-value clean power patents, Mazzucato favours identifying the mission or objective that needs to be reached, arguing that missions embed five criteria: (i) boldness and inspiration with wide societal relevance; (ii) a clear direction with goals that are targeted, measurable, and time-bound; (iii) ambitious goals that entail realistic research and innovation actions; (iv) objectives that are cross-disciplinary and cross-sectoral, and that involve cross-actor innovation; and (v) objectives that drive multiple bottom-up solutions.

sectors; and demand-side measures like energy efficiency. Net-zero plans generally highlight specific areas of innovation like e-vehicles, the development of large-scale battery storage, or what the International Renewable Energy Agency (IRENA) recommends in developing green hydrogen.

Ensuring coherence and coordination among these different measures will be immensely challenging. Cambridge economist Ha-Joon Chang has argued that industrial policies should take a more holistic approach to ensure that links across different sectors are clearly understood and mapped with clear plans.

This focus on a comprehensive or holistic approach to green industrial policies is especially timely, given the similarity of most national plans in their goal to achieve carbon neutrality. For example, in March 2022, Canada released its updated net-zero plan, which consists of 79 different implementation plans comprising combined climate funding programs worth CAD 29 billion to advance green technology innovation, regulations, a national carbon-pricing mechanism, and other measures. Similarly, the United Kingdom's 2020 *Ten Point Plan for the Green Industrial Revolution* envisions the United Kingdom being the world leader in green technology and green finance. The United Kingdom plan includes various quantitative targets, like creating 250,000 new green jobs, planting 30,000 ha of trees annually by 2025, quadrupling offshore wind capacity by 2030, and re-wilding 30,000 parcels of land the size of football fields, along with other goals in 10 clusters.

The 2020 EU industrial strategy positions its net-zero targets within its Twin Transition Pathways of green development and digitization. The details of the EU's climate plan are set out in its updated 2021 Green Deal, which sets out sector-specific targets and pathways similar to the United Kingdom and many other government low-carbon plans. In the case of the EU, these comprise sustainable transport, green industrial transformation, clean energy, green buildings, protecting nature, and building multilateral cooperation, with details set out in its Fit for 55.⁷

Recent updates of the EU plan reflect the importance of adaptability—which has been noted by the IMF. In 2021, an updated EU industrial strategy was released in light of the ongoing COVID-19 pandemic. In March 2022, the EU dramatically moved up the timetable for its shift away from imported oil and gas, calling for a “lightning speed” shift to renewable energy in light of the Ukrainian crisis.

⁷ There are many other examples of green industrial policies. For example, the France 2030 strategy calls for the “re-industrialization” of the economy, with EUR 30 billion in financing to develop small-scale nuclear energy facilities, develop the world's first low-carbon aircraft, produce 2 million electric or hybrid automobiles annually, and be a world leader in green hydrogen. The Biden Administration has released several climate plans to reach its net-zero targets, including whole-of-government approaches that include industrial strategy investments, plans for green procurement, and other targets. In 2020, Singapore released its whole-of-government Green Plan to coordinate net-zero carbon and green development implementation, building on previous highly successful industrial policies to attract financial service, processing, marine, and other business investments. In addition, Singapore has typically offered generous fiscal and financial incentives to attract investors. For example, this industrial strategy helped leverage the industrial agglomeration in the Jurong Island Export Processing Zone (EPZ) to diversify investments along the value chain, including in refining, storage, and shipping, supported by diversified financial and service sector clusters.

Trade Dimensions of Green Industrial Policies: Given the economy-wide and sectoral coverage of most green industrial policies, it is not surprising they have various trade dimensions as well as concerns. For example, the British plan calls for batteries to be made in the Midlands, while the proposed Biden Administration net-zero automobile strategy envisages electric cars made in America, raising concerns about national treatment, non-discrimination, or the trade effects of subsidies and incentives.

A further dimension involves the use of various performance requirements that investors are required to meet. Local content and other performance requirements vary widely but typically include measures to support local labour markets or require joint ventures in which the government takes an equity stake or stipulates management participation targets. Other provisions include technology transfer provisions, investments in local infrastructure, the provision of local public health services, local procurement contracts, gender equity, and other objectives. Local content requirements can also contain blunter trade instruments like export restraints, including export licences, taxes, and other measures intended to increase local higher-value-added content.

While local content practices vary widely, many are strongly linked to socio-economic and human capital goals like employment, wage and income security, closing equity gaps, and other objectives set out in SDGs, in particular SDG 8, which pledges to “promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all”.

C.3 Zero Deforestation

Each year, between 3 and 4 million hectares of primary tropical forests are lost, and with them, the enormous ecosystem and climate services they provide, in addition to livelihood sources for Indigenous and local communities. Since 1990, roughly 80 million hectares of forests have been destroyed.

Rates of deforestation differ widely between countries. For example, deforestation in Indonesia has declined since 2016, largely as a result of that government’s moratorium on new forest concessions coupled with other measures. However, as that moratorium will be lifted in 2022, experts will monitor deforestation rates.

By contrast, deforestation rates in Brazil’s tropical Amazon region reached their worst level in more than a decade in January 2022. Data from Brazil’s national forestry service reported a 400% increase in monthly deforestation compared to January 2021. Government data show that 3235 km² (5110 square miles) of rainforest were cleared in the Brazilian Amazon between August 1, 2020, and July 31, 2021. Since one third of the earth’s total tropical rainforests are located in Brazil, these losses have global implications, with the Brazilian portion of the Amazon flipping from a net sink to a net source of carbon dioxide in 2021.

By far the single biggest cause of deforestation is agriculture: the UN estimates that 90% of global deforestation is driven by agricultural extension, roughly evenly

divided between burning forests for croplands and livestock grazing. Accordingly, there have been a number of initiatives by companies, governments, philanthropy organizations, and others to tackle the underlying causes of deforestation by focusing on the production, export, and consumption of crops and livestock products that have led to deforestation and displaced local communities.

The 2021 CCICED SPS on green supply chains highlighted China's important role in supply chains: China is among the world's largest importers of soft commodities. The 2021 study recommended the following concrete steps to reduce deforestation linked to soft commodity trade: (i) ensure that all imported soft commodities are legally sourced in the country of origin; (ii) advance international sustainable sourcing standards through contracts with companies that import soft commodities; and (iii) apply the tools needed to support sustainable sourcing—including third-party certification, traceability, and the use of digital tools like blockchain.

Moreover, the CCICED SPS recommended that the government develop a strategic, comprehensive, and robust system to support the sustainability of soft commodity imports.

This emphasis on the role of government in working with private companies to implement zero-deforestation soft commodity supply chains is becoming more important, as is raising trade dimensions. Three recent developments underscore the growing role of governments in using regulations or other measures to condition market access to commodities.

First, at the UN COP 26 meeting in 2021, 141 governments signed the Glasgow Leaders' Declaration on Forests and Land Use to collectively halt and reverse forest loss and land degradation by 2030. Trade is specifically identified as one of the main instruments to reach this 2030 goal:

Facilitate trade and development policies, internationally and domestically, that promote sustainable development, and sustainable commodity production and consumption, that work to countries' mutual benefit, and that do not drive deforestation and land degradation.

Second, several governments have adopted or proposed domestic trade measures intended to stop imports within their jurisdictions of soft commodities that may be linked to deforestation. Examples of this approach include proposals by the EU, United Kingdom, and France, and policies enacted by Norway and others. While such measures are in keeping with the spirit of the above Glasgow declaration regarding the use of domestic trade policies to support the 2030 goals, questions persist about how such actions align with the WTO and other trade agreements.

There are various data issues, including reliable means to differentiate between legally and illegally harvested timber, traceability, and due-diligence steps that can account for the source and chain of custody of imported commodities, and the cost these and other efforts may pose to consumer products.

Third, there have been a number of new private sector pledges to tackle deforestation. These new promises should be seen in the context of past pledges. In 2014, the New York Declaration on Forests set the goal of cutting deforestation rates by one half by 2020; meanwhile, over 440 companies made over 700 pledges through

the Consumer Goods Forum to curb deforestation in their supply chains and cut deforestation. Those earlier voluntary targets have not been met.

The question is whether these new voluntary pledges will fare any better. Among the lessons from past voluntary deforestation pledges is the need to provide financing to local farmers, communities, and Indigenous groups to address complex systemic drivers of deforestation and land degradation. These drivers can include the reform of land-tenure laws, providing access to farm-level credit to support sustainable land-management approaches like non-commercial mixed cropping, agroforestry, or other approaches generally frowned upon by commercial credit providers that favour high commercial crop yields. Roughly USD 36 billion in funding from donors, multilateral agencies, and philanthropic organizations has been committed to advancing these and other objectives.

Rather than tackling deforestation-free and legally harvested trade by relying on either mandatory regulations or voluntary private sector initiatives, study experts identified the need for private–public sector cooperation. Lessons from green industrial policy can help identify specific forms of cooperation, for example, in providing incentives for private-company traders, importers, and retailers to use blockchain and other tools to strengthen due-diligence traceability.

The need for new, robust, transparent tools is especially pressing.

C.4 Plastic Pollution

In March 2022, at the UNEA-5 meeting in Nairobi, 175 countries endorsed the resolution regarding marine plastics, prompting the United Nations Environment Programme’s (UNEP’s) Executive Director to call this the most important multilateral agreement since Paris.

The resolution text authorizes an international negotiating committee (INC) to begin work immediately to develop an international, legally binding agreement on plastic pollution. Among the objectives of this new treaty will be.

- A comprehensive approach that addresses the full life cycle of plastics
- The promotion of the sustainable production and consumption of plastics
- The use of national and international cooperative measures to reduce plastic pollution in the marine environment
- The coordination of regional and international conventions⁸

⁸ The conventions and international agreements noted in the plastics resolution are the International Convention for the Prevention of Pollution from Ships and its 1978 Protocol, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, the Stockholm Convention on Persistent Organic Pollutants, the Rotterdam Convention on the Prior Informed Consent Procedure for certain Hazardous Chemicals and Pesticides in International Trade, the United Nations Convention on the Law of the Sea, the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters and its 1996 Protocol, the Strategic Approach to International Chemicals Management, the United Nations Framework Convention on Climate Change, and the Convention on Biological Diversity. They also recognize international

- The encouragement of the private sector to participate, and other actions.

In addition to the diverse risks of marine plastic pollution, the UNEA discussion also identified the link between plastics and climate change, including the production of GHG emissions—notably methane emissions—as a result of manufacturing plastics.

The INC mandate includes trade by way of reference to international cooperative measures and the reference to the Basel Convention. Work is underway on determining what types of trade measures may be needed to tackle plastics. For example, the 2021 Ministerial Statement circulated among roughly 30 WTO members references the extent to which plastics are traded, referencing data by the United Nations Conference on Trade and Development (UNCTAD) estimating global trade in plastics by value at USD 1 trillion per year, or an astonishing 5% of total merchandise trade.⁹

The WTO initiative, which China has been instrumental in putting in place, identifies several options, including the transition to more circular plastic economy models, improving the environmentally sound management, recovery, and recycling of plastics; improving access to green technologies; expanding trade in more sustainable plastics substitutes; and other options.¹⁰ The WTO group also notes the need for improved international standards to benchmark practices, notably through the International Organization for Standardization (ISO) or differentiating products with specific green tariff codes through the World Customs Organization.

This list of trade policy options underscores the possible role of trade in supporting the expanded trade in goods and services that are defined as being greener than or environmentally preferable to standard goods and services. Various regional trade agreements have included trade preferences for green goods and services, which, once defined, would benefit from lower tariff and non-tariff barrier levels. The WTO has struggled to reach its own Environmental Goods Agreement.

organizations and regional instruments and programmes, as well as efforts led by nongovernmental organizations and the private sector.

⁹ Data show primary forms of plastics comprise 56% of this total, followed by intermediate forms at 11%, intermediate manufactured goods at 5%, final manufactured products at 21%, and waste at 2%. In some categories—notably synthetic textiles and rubber tires—the UNCTAD report estimates as much as 60% of the total volume of global production is traded internationally.

¹⁰ The most significant trade measure related to a circular economy and plastics remains China's changes to its import licensing in 2017 and 2018 that bans the import of waste, including plastic waste.

C.5 Carbon Pricing, Competitiveness, and Border Carbon Adjustment

Carbon pricing has long been identified as the first-best pathway to tackle carbon pollution. By leveraging markets, carbon pricing can affect economy-wide changes, incentivize behavioural changes toward less carbon-intensive options among consumers, and provide a powerful catalyst to internalize environmental externalities. Leading economists like Nobel-prize winner William Nordhaus have argued that putting a price on carbon pollution provides signals to consumers about the carbon footprint of their consumption, induces producers to move toward lower-carbon options, incentivizes innovators and financiers to scale up low-carbon investments, and economizes information and data needed to implement these changes.¹¹ International organizations as diverse as the IMF, WTO, OECD, World Bank, UNEP, and others have long argued in favour of market-based instruments like carbon emissions trading systems (ETSs) or carbon taxes.

Jurisdictions are listening to this evidence. According to the World Bank's Carbon Pricing Dashboard, 65 carbon-pricing initiatives have been implemented across 45 national jurisdictions in 2021. While this uptake is welcome, the global average price of GHG emissions remains very low, at USD 3/tonne.

China has introduced the world's largest carbon market, measured by coverage. Following almost a decade of pilot carbon market projects, in late 2020, China's Ministry of Ecology and Environment introduced the ministerial regulation covering the legality of its national ETS. The national ETS was launched in 2021, covering 2200 power sector companies.

The first ETS trade occurred in July 2021 at the Shanghai carbon market exchange with an opening price of RMB 48 per tonne, or USD 7.4 in late 2021, rising to roughly USD 9/tonne in the first quarter of 2022.

Competitiveness Issues: An ongoing concern of companies subject to taxation involves their competitiveness relative to other companies in the sector located in jurisdictions with lower tax levels. Compliance carbon markets are no exception.

For Chinese businesses, a proxy measure of potential competitiveness concerns relates to expectations about the price of ETS credits. Results of a 2021 survey of businesses found that the majority of respondents anticipated a gradual increase in the price of carbon credits over the coming decade, with expectations varying from RMB 139/tonne by 2029, to higher-level expectations of nearly RMB 200/tonne by 2029.

Interestingly, a majority of respondents expected their investment decisions to be increasingly affected by the ETS system, with 53% expecting those investment decisions to be strongly affected and another 31% moderately affected by 2030. While investment decision options are not identified in the survey, one can assume these involve capital and operating investments needed to avoid the rising costs of ETS pricing.

¹¹ Nordhaus [1].

Border Carbon Adjustments proposals are one policy option to address both competitiveness issues linked to carbon pricing and possible leakage issues (that is, companies relocating to jurisdictions with low or no carbon taxes).

Proposals regarding border carbon adjustment are not new. The WTO has examined different proposals for several decades. In 2009, the Waxman-Markey Bill proposed a carbon adjustment measure, which died with the overall bill. However, interest in border carbon adjustment has been greatly rekindled with the 2021 release of the EU's Carbon Border Adjustment Mechanism (CBAM proposal). This is the most detailed border carbon adjustment proposal ever made, and some version very likely will come into effect as early as 2023, with full implementation by 2029. The proposed CBAM covers iron and steel, cement, aluminum, fertilizers, and electricity—and its proposed structure and operations.

An analysis by leading expert Aaron Cosbey from IISD traces the evolution of the border carbon adjustment concept, its alignment with the goals of the Paris Agreement, details of the EU CBAM proposal, and provides an initial analysis of what this could mean for Chinese exports of these industrial and other goods. This analysis references work by UNCTAD and others, suggesting a material effect on Chinese exports.

Modelling analysis of CBAM by E3G and the research group Sandbag finds that, while effects on Chinese exports like steel are likely to be negative at the aggregate level, the effects on sub-categories of exports like direct-reduced-iron steel are likely to result in net pricing benefits, reflecting the modern Chinese manufacturing capacity in this area compared to European counterparts.

Another quantitative assessment of CBAM using the GTAP 10 global trade database was co-authored by Drs. He Xiaobei, Zha Fan, and Ma Jun. Among the conclusions of their March 2022 study is that CBAM will have different but important spillover effects in several emerging economies and developing countries, leading to macro-economic impacts, including income-related effects. Given these macro-economic dimensions, the authors propose that the IMF should be more involved in helping smooth CBAM-related price spikes that will likely affect some exporting countries. They also propose that the revenue generated by CBAM be managed through a new IMF fund to assist developing and emerging economies buffer the price effects of, and help finance, green technology and other low-carbon transitions.

C.6 Recommendations

Recommendation One: CCICED should examine how to support the implementation of the March 2022 NDRC green BRI guidelines with a specific focus on how to increase the overall proportion of green trade among BRI partners. This work can include ways to expand trade in high-tech green goods and services, phase out trade finance linked to coal and other fossil fuels, and increase green trade among BRI partners in sustainably sourced soft commodities.

Recommendation Two: Green industrial policies are needed to meet urgent climate, biodiversity-related sustainable use and circular economy objectives. Within its ongoing work, CCICED should track emerging and leading practices in green industrial policy, drawing on lessons and case studies of how to design and implement public–private sector partnerships that prioritize innovation and technology as tools to increase productivity in meeting performance outcomes.

Recommendation Three: CCICED should continue its work related to green value chains, with a specific focus on research and recommendations on trade and other measures coupled with voluntary instruments that can help China fulfill the Glasgow Forestry and Land Use Pledge before 2030.

Recommendation Four: CCICED should examine how green trade can close gender inequality gaps and contribute to broader common prosperity outcomes linked to jobs, wage parity, skills training, and other areas.

Recommendation Five: CCICED should identify ways in which trade can support the INC’s work toward a new global plastics treaty. CCICED’s contribution can include further work on trade preferences for environmental goods and services, beginning with a technical analysis of the current level of plastics trade in China; an analysis of substitute products/services that would reduce the environmental harm of plastics; an analysis of tariff and, more importantly, non-tariff barriers to greener plastics substitutes; and an analysis of the likely impacts of green tariff preferences. This work could expand to other areas of trade, notably sustainably sourced soft commodities, with an analysis of how trade preferences could reduce deforestation and other harmful impacts.

Annex A: Scoping Study Team Structure

<i>Chairs</i>	
Scott Vaughan	CCICED International Chief Advisor
Bernice Lee	CCICED Special Advisor; Research Director, Futures, Chatham House
John Hancock	Senior Policy Advisor, World Trade Organization
<i>Core experts</i>	
Nathalie Bernasconi	Senior Director, Economic Law and Policy, International Institute for Sustainable Development
Aaron Cosbey	Senior Associate, International Institute for Sustainable Development
Ana Toni	Executive Director of Instituto Clima e Sociedade (iCS)
Carolyn Deere Birkbeck	Director, Forum on Trade, Environment, Graduate Institute of International and Development Studies Geneva
Nicolas Lockhart	Lawyer, Sidley Austin LLP
Kimberley Botwright	Head, Sustainable Trade, World Economic Forum
Daniela Garcia	DPR Mission of Ecuador, World Trade Organization

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Vicky Chemutai	Economist, World Bank
Wang Yi	CCICED Member; Member of Permanent Committee of the 13th National People's Congress; Former Vice President of Institutes of Science and Development, Chinese Academy of Sciences
Zou Ji	CCICED Special Advisor; CEO and President, Energy Foundation China
<i>Participating experts</i>	
Adrien Assous	Executive Director, Sandbag
Ieva Barsauskaite	Senior Policy Advisor, International Institute for Sustainable Development
Christophe Bellmann	Head of Policy Analysis and Strategy, Forum on Trade, Environment and the SDGs (TESS)
Dimitri de Boer	CCICED Special Advisor; Chief Representative for China ClientEarth, Team Leader of EU—China Environment Project
Madelaine Bowen	Policy Analyst, Environment and Climate Change Canada
Dong Ke	China-Global Engagement Director, The Nature Conservancy
Jackson Ewing	Senior Fellow, Duke University, Nicholas Institute for Environmental Policy Solutions
Peter Govindasamy	Director, International Trade Cluster, Singapore Ministry of Trade and Industry
Jennifer Hillman	Senior Fellow, Council on Foreign Relations; ex-Appellate Body member; ex-ITC member
Marianne Kettunen	Senior Policy Advisor and Head of Partnerships, Forum on Trade, Environment and SDGs (TESS)
Harris Kuemmerle	Freelance Policy Analyst
Pascal Lamy	Former European Commissioner for Trade and Former Director-General of the WTO
Cristina Larrea	Lead, Sustainability Standards, International Institute for Sustainable Development
Li Daoji	Professor of State Key Lab. of Estuarine and Coastal Research and director of Plastic Marine Debris Research Centre, East China Normal University
Li Jinhui	Executive Director of Basel Convention Regional Center for Asia and the Pacific and professor in the School of Environment of Tsinghua University
Michael Mehling	Deputy Director, MIT Center for Energy and Environmental Policy
Sebastien Paquot	Head of Section, Counselor Climate and Environment—EU Delegation to China
Jonny Peters	Senior Policy Advisor, E3G
Isabelle Ramdoo	Deputy Director, IGF, International Institute for Sustainable Development
Alice Tipping	Lead, Sustainable Trade and Fisheries Subsidies, International Institute for Sustainable Development

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Tu Kevin	Managing Director, Agora Energy Transition China
Tu Xinquan	Dean, China Institute for WTO Studies, University of International Business and Economics
Wang Guosheng	Forestry and Grassland Inventory and Planning Institute, National Forestry and Grassland Administration
Zhang Xiliang	Executive Director of the Institute of Energy, Environment and the Economy at Tsinghua University
<i>Report lead author</i>	Scott Vaughan, CCICED International Chief Advisor

Reference

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Annex D

CCICED Scoping Study Report: Innovative Green Finance¹²

D.1 Overview

Green financing has increased dramatically in recent years and now covers the full spectrum of financial services, from consumer and corporate banking to asset management, pension funds, and insurance, among others. This scoping study, launched in early 2022, examined some recent developments in innovative green finance. Given the widening and dynamic advances in green finance, coupled with the degree of technical details within individual areas, this report is intended to illustrate the kinds of green finance issues CCICED should examine in Phase VII.

China remains a global source of innovative green finance. Momentum continues at the state, provincial, and municipal levels and across different areas of the private sector, particularly in enabling carbon peaking, carbon neutrality, and other green transition implementation. The 2021 26th Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change in Glasgow, the expected Kunming Conference on Biodiversity (CBD) COP, and other multilateral initiatives (such as the China-hosted November 2022 RAMSAR Convention meeting) are all drivers of expanded green finance, while the 14th Five-Year Plan emphasized the critical role of green finance in moving toward high-quality, green development and ecological civilization. Accordingly, China has issued a number of important guidelines and opinions in recent months covering domestic actions, as well as putting a spotlight on international green finance linked to Green Belt and Road (BRI) priorities.

Green finance has two main characteristics. The first comprises top-down, mandatory compliance markets such as China's national carbon market, emerging rules like mandatory climate risk disclosure, the reform of subsidies, incentives, and taxes to advance green development, and a wide range of public investments. The second

¹² Scott Vaughan is the leading author of this scoping report.

comprises bottom-up, market-driven voluntary green financing instruments like environment, social, and governance (ESG) products, private sustainability supply chains for green goods and services, voluntary carbon offset markets, the growing demand for green consumer goods and services, and many other initiatives.

A key goal is to build synergies between top-down guidance and bottom-up application and innovation in order to create synergies that unleash the full potential of green finance. The green finance journey can further be accelerated with supporting regulations, such as recent steps by China to create a unified energy market,¹³ within which green objectives such as linking emerging carbon emissions markets and water rights trading markets are expected to play a role.

Leveraging private and public partnerships to drive innovation in green finance and integrating climate and natural asset financing are the two overarching objectives of the 2022 CCICED scoping study. The study stresses the vital importance of integrating climate and biodiversity finance. While science unambiguously concludes that climate and ecological risks are deeply interconnected, climate and nature financing are not.¹⁴ Instead, climate and ecological financing are largely moving on separate tracks, with private sector engagement in climate finance continuously rising, while ecological and biodiversity financing are still dominated by public finance. The study examines how these gaps can be closed.

The international co-chairs of the CCICED scoping study are **Violante di Canossa**, Development Economist, Head of Research and Policy Team, United Nations Development Programme (UNDP) China, and **Andrew Deutz**, Director of Global Policy, The Nature Conservancy. The scoping study benefited from the opinions and advice of Chinese and international experts, who met several times between January and April 2022.

The 2022 scoping study drew on a number of recent and current CCICED works, including the *2021 CCICED Special Policy Study on Green Finance*, the *2021 Scoping Study on Nature-Based Solutions*, the *2022 Special Policy Study on Nature-Based Solutions*, and the *2022 Special Policy Study on Sustainable Food Supply Chains*.

The study focused on three key areas:

The benefits of integrating climate and nature finance.

¹³ The April 2022 guidelines from the Central Committee of the State Council, intended to create a single, unified and consolidated national energy market, set out steps to integrate market-oriented, industry-based standards with government direction and guidance. The guidelines cover areas like market access and fair competition rules, social credit, procedures to ensure the interconnectivity of energy supply chains, greater standardization of energy infrastructure, and improved energy trading markets guided by market-oriented reforms.

¹⁴ Economic evidence of the growing risks of climate change, measured both in short-term extreme weather events and longer-term GDP losses, is well established. There is also a growing body of evidence showing that the loss of biodiversity and ecosystems similarly poses immediate and longer-term cascading macroeconomic risks. Conversely, evidence shows that investing in nature is an investment in future economic prosperity. For example, recent modeling using *GTAP economic data* shows the global GDP losses due to the loss of forests, clean water systems, and agricultural lands.

Tools, policies, and institutions to advance integrated climate-nature finance.
 Reforming environmentally harmful subsidies and implementing green subsidies.

This report is organized as follows: Part One highlights some of the many recent trends in climate and nature finance, particularly in the context of the Glasgow Climate COP and negotiations toward the Kunming Biodiversity COP. Part Two examines the three key areas noted above. Part Three identifies short-, medium-, and longer-term solutions to climate and nature finance. Part Four makes several recommendations to CCICED as it begins Phase VII of its work.

Overall Recommendation: CCICED should prioritize green finance as a cross-cutting and stand-alone research theme throughout Phase VII, with a particular emphasis on two areas: how to integrate climate and nature finance and how to maximize innovation through market-oriented and public sector alignment. Future CCICED work should examine developments in specific areas of green finance such as ESG standards, transparency, auditing and accountability practices, financing nature-based solutions (NbS), sustainable food and green supply chains, voluntary carbon and biodiversity markets, mandatory climate and nature-risk disclosure, greenwashing, and other areas. Future CCICED work should further include identifying how to leverage and increase green finance in the BRI to help meet SDG and the Paris Climate Agreement and Kunming Goals. As an overarching theme, CCICED should identify how to integrate and amplify common prosperity goals, including green jobs and stable wages and household income, as well as closing gender, income, and other inequality gaps.

D.2 Part One

Context: Financing levels, sources, gaps, and options: Both climate and nature finance have increased in the past decade, albeit at different rates of growth. **Global climate finance** in 2019–2020 was estimated at USD 632 billion annually. **Global biodiversity finance** in 2019 was estimated at USD 143 billion annually. These levels are insufficient to meet the Paris Climate Agreement target of a temperature rise of only 1.5 °C, advance carbon peaking and carbon neutrality, and implement the forthcoming Global Biodiversity Framework of the Kunming CBD process.

The Climate Policy Initiative estimates a global climate finance gap of USD 3.6 trillion to USD 4.1 trillion annually. A January 2022 McKinsey Report estimates an investment increase of USD 3.5 trillion yearly will be needed to achieve net-zero transition goals (with a net investment of USD 9.2 trillion), while the 2020 Financing Nature Report estimates a biodiversity financing gap of USD 598 billion to USD 824 billion per year.

Through numerous government opinions, guidelines, and other measures, China continues to emphasize the importance of green finance. For example, in 2021 the Ministry of Finance issued preferential tax rates for enterprises based on energy savings, resource efficiency, and circular economy criteria. In November 2021,

the People's Bank of China (PBOC) established a new climate financing facility to provide low-interest loans via financial institutions to support company-based low-carbon investments. Other instruments, like PBOC's updated 2021 *Green Bond Endorsed Projects Catalogue*, green taxonomy work, and many others, are examined below. Between 2021 and 2022, an estimated 80 climate-related initiatives, from amendments to the green bond catalogue to carbon sequestration financing, have been issued at the state level and by provinces and municipalities, as well as sector-specific directives.

As in other jurisdictions, China's national emissions trading scheme is an important source of climate finance: as China's ETS compliance carbon market expands from the power sector to other sectors, as well as undergoing the transition from an intensity-based to emission cap system, so too will the revenues generated from these trades. China has also underscored the importance of carbon sequestration linked to NbS.

Biodiversity Financing: The October 2021 *Kunming Declaration* noted that “*urgent and integrated action is needed, for transformative change*”, calling for greater coherence between the UN CBD and the United Nations Framework Convention on Climate Change, as well as other international agreements. The March 2022 Geneva Conference of the CBD made progress toward an eventual Kunming COP outcome, although significant square brackets remain. However, there have been a number of national commitments to increase international biodiversity financing, including the 2021 announcement by China of a new Kunming Biodiversity Fund and announcements by France, the EU, and others in increasing the proportion of overseas development assistance directed toward biodiversity protection.

In addition to increasing public financing of biodiversity, experts underscored the increasing engagement of the private sector. In September 2021, 78 institutions endorsed the CERES *Financial Institutions Statement Ahead of the Convention on Biological Diversity*, which called for a stronger Global Biodiversity Framework and National Biodiversity Strategies and Action Plans (NBSAPs), mandatory national regulations to implement the recommendations of the Task Force for Nature Risk Financial Disclosures (TNFD) covering nature-risk disclosure by financial institutions, and the reform of subsidies that are harmful to biodiversity and ecosystems.¹⁵

Also in 2021, roughly 30 financial institutions signed the *Financial Sector Commitment Letter on Eliminating Commodity-Driven Deforestation*, promising to assess their exposure to deforestation risk by 2022, disclose that risk in 2023, and by 2025 announce concrete measures to eliminate agriculture-related deforestation risk. The Business for Nature Organization, an alliance of hundreds of companies, has called for increased action to halt ecosystem destruction and increase restoration.

¹⁵ These action areas complement the recommendations of the 2021 CCICED green finance report, which comprise the adoption of TNFD disclosure and the redesign of China's system of agricultural subsidies and farm-support programs away from environmentally harmful outcomes toward systems that protect, restore and regenerate key ecosystems.

Storebrand Asset Management, based in Norway, is a signatory to both the CERES and Commodity-Driven Deforestation commitment, in addition to many other green finance initiatives. With US 120 billion in assets, it has a three-part strategy to green finance: exert influence to make companies greener and sustainable through its active ownership of some 4000 companies; an exclusion list of companies that fail to meet their investment standards covering conduct-related standards and product-based standards like tobacco, cannabis, coal, and palm-oil. The current exclusion list comprises 257 companies. In addition, an observation list is maintained to monitor specific companies. In February 2022, Storebrand placed two of the world's largest soybean traders on their observation list because of the probable effects of deforestation attributed to their soft-commodity supply chains.

In 2021, the Axa Investment Manager Group announced before the 2021 Kunming meeting that it would strengthen its zero deforestation and green supply chain standards in its investment, insurance, and operations and committed EUR 1.5 billion to sustainable forest management. BNP Paribas Asset Management announced that by 2025 it would invest EUR 3 billion in terrestrial-related biodiversity protection, as well as EUR 250 million for start-ups to mobilize green development. In 2022, the company was ranked as the first of 150 financial institutions in protecting forests. Following its announcement in 2021 to become a regenerative company, Walmart released a comprehensive row crop position statement that sets out supplier standards covering climate change impacts, deforestation, and environmental sustainability.

While these and many other private sector commitments to protect and sustainably use biodiversity are important, they pale by comparison with the growing number of climate finance commitments made around the Glasgow COP to advance net-zero carbon neutrality goals. Under the Glasgow Financial Alliance for Net Zero, roughly 450 financial institutions with a reported asset value of USD 130 trillion have joined a number of sector-specific initiatives like the Net Zero Banking Alliance, Net Zero Asset Managers Banking Alliance, Net Zero Insurance Alliance, and the Paris-Aligned Investment Initiative. A critical challenge remains to translate these and other private sector commitments into concrete actions: financing of oil, gas, and coal has increased in the fourth quarter of 2021, while the effects of the crisis in Ukraine have caused chaos in global energy markets in the first quarter of 2022.

Aligned and Integrated Green Finance: 2021 marked an important step at the multilateral level in moving away from separate or silo climate and biodiversity finance. The Glasgow Leaders' Declaration on Forests and Land Use is a promise by 141 governments to “halt and reverse forest loss and land degradation by 2030”. At the country level, a growing number of nationally determined contributions (NDCs) include forest landscape restoration, related land use, land-use change and forestry, and water management as part of climate mitigation and adaptation goals. One of the strongest bridges between climate and nature involves NbS: the early 2022 UNEA-5 resolution on NbS marks the first multilateral definition of NbS, which is expected to increase NbS-related transparency and comparability and, as a result, may unlock additional private sector financing.

Financial Sector Enablers: Among the stark conclusions of the April 2022 Intergovernmental Panel on Climate Change (IPCC) Working Group III is the characterization of the financial sector as a “critical enabler” of carbon pollution. The IPCC report noted that over half of the world’s largest financial institutions have no restrictions on financing oil and gas, reflecting a “systematic underpricing” of climate risk. Other analysis found that two-thirds of the world’s largest banks and asset managers have no plans to reduce climate financing, and 83% of the world’s largest polluting companies have no roadmap towards net-zero targets. In 2020, large commercial banks invested an estimated USD 750 billion in coal, oil, and gas while making Paris-related net zero pledges.

Study experts noted the extremely dynamic scope of recent private sector-led initiatives linking nature and climate. For example, HSBC Pollination Asset Management, a specialized investment firm, intends to invest in regenerative agriculture, sustainable forestry, NbS, and other areas. The dairy company Danone North America—among the founding members of the One Planet Business for Biodiversity—announced in 2021 that it would co-finance with U.S. National Fish and Wildlife Foundation, research and technical support to farmers in regenerative soil management. The U.S. food giant General Mills has made commitments to support the regenerative soil and land use of its wheat and grain farmers.

Misalignment Risk: Despite top-level multilateral signals and many examples of individual private sector initiatives, climate and nature finance are not currently aligned and risk growing further apart. This misalignment creates risks to both carbon neutrality and biodiversity goals.

Study experts stressed the science-based, inextricable connection between the climate and biodiversity systems. Risks related to one tend to affect the other—for example, the concurrent, cascading, and non-linear impacts of climate-related extreme weather events pose increasingly acute risks to biodiversity and ecosystems, that in turn are affecting critical food security, human security, and wider macroeconomic security. The Working Group II report of the IPCC Sixth Assessment identifies the pervasive negative impacts and future risks to natural ecosystems because of global warming, from ocean acidification and increased forest species mortality to changes in species range and disease vectors.

Critically, these risks are considered material economic and financial risks. The groundwork has been laid out clearly, from economic assessments of ecosystem and natural capital losses in the 2020 Dasgupta Review, the growing operationalization of the TCFD recommendations to the financial sector, and growing work by central banks in this area—including the 2019 Bank of England Global Financial Risk Forum, 2020 report of Central Bank of The Netherlands that concluded that ecosystem risk is a widening financial risk, to the 2020 Green Swan Report and 2021 high-level exchanges facilitated by the Bank for International Settlements—to technical advances among national statistical agencies in implementing more standardized environmental and ecosystem accounting within national statistical agencies that go beyond GDP income flow measurement to include broader asset values of inclusive wealth comprising human capital, natural capital, and produced capital.

As the late Thomas Lovejoy noted at a 2021 CCICED meeting on NbS, climate change is part of a wider ecosystem imbalance of global dimensions. Many of these technical areas, from better risk disclosure to wider natural capital accounting, comprise the hundreds of initiatives currently underway and are a welcome solution to correcting current deficiencies. An illustrative description of some of these many initiatives is noted below. A more comprehensive as well as more focused technical assessment should be part of CCICED's future green finance work.

D.3 Part Two

D.3.1 Section One: Opportunities for NbS

Financing for NbS: The term Nature-Based Solutions captures a wide range of definitions, project applications, and underlying values and assumptions. While the term *nature-based solutions* was for the first time formally adopted through multi-lateral consensus at the early 2022 Fifth session of the United Nations Environment Assembly, UNEA-5, the term remains sensitive.

Increased policy attention on NbS is attracting diverse sources of financing. For example, the UNDP *Human Development Report 2020* provides case studies in which private insurers are partnering with government agencies to provide coral reef insurance in Mexico, a collective financing mechanism to develop green infrastructure in support of freshwater management in Ecuador, high-resolution ecosystem mapping in Costa Rica to guide development, and other initiatives.

The February 2022 UNEA-5 resolution marks the first time a multilateral body has adopted by consensus a universal definition of Nature-Based Solutions. This adoption of an international definition, drawing on the work of the International Union for the Conservation of Nature and others, marks an important step toward common international definitions, project classification, and social and other safeguards and standards that can attract international investors on a greater scale. The recent report, *The State of Finance for Nature in the G20 Report* of the United Nations Environment Programme (UNEP) and others underscores the importance of making the financial case for NbS.

Nature-based solutions (NbS) is a category of assets in which businesses, governments and citizens can invest in order to work with nature ... Through the improvement of carbon sequestration on agricultural lands and peatlands, defence from flooding by restoring mangrove populations, and the protection of global biodiversity through forest and other land conservation, nature-based solutions can help improve society today and in the future.

Greater engagement by private investors is needed to close financing gaps currently affecting NbS. Estimates by the 2021 *State of Finance for Nature report* suggest USD 133 billion is invested annually in NbS. Of this total, 86% or USD 115

billion is public financing related to conservation, regeneration of forests, peatlands, agriculture, water conservation, and natural pollution control systems.¹⁶

The report estimates that private sector NbS financing is much lower, at 14% of total annual financing—or USD 18 billion per year—with investments dominated by biodiversity offsets, sustainable supply chains, impact investment, and private philanthropy investments. The report identifies five priorities to increase financing for NbS:

- Increase Overseas Development Assistance.
- Reform agricultural subsidies.
- Mandate Multilateral Development Banks (MDBs) to increase NbS financing.
- Link developing country debt relief with NbS investments.
- Support results-based NbS public financing linked to green bonds.

In 2021, UNDP's BIOFIN in China began work to reduce the biodiversity financing gap by delivering what is available, reallocating resources from where they harm to where they help, acting early to reduce the need for future investments, and generating additional resources. In addition to these four areas, numerous other solutions have been proposed to close financing gaps. For example, a recent Third World Network piece on post-Glasgow financing noted China's use of capital controls to de-link domestic climate financing costs from international trends.

Public–Private Sector/Blended Finance: In addition to private and public financing scaling up nature investments, study experts emphasized the importance of public–private partnerships (PPPs) and blended finance to increase NbS financing. Various standards, guidelines, and projects underscore the potential of PPPs and blended finance, including the role of Development Finance Institutions (see below) in providing front-end concessional financing to help de-risk private sector investments, the willingness of some public finance sources to take on first-tranche losses in de-risking, and the use of guarantees, equity financing, and other approaches, which have been examined and deployed by the World Bank International Finance Corporation, the Organisation for Economic Co-operation and Development (OECD), and others.

An international PPP example is the 2020 agreement between France's AfD and Blackrock to create a USD 500 million Climate Finance Partnership for climate infrastructure in developing countries.

¹⁶ Similar estimates by the Coalition of Private Investment in Conservation (CPIC) indicate that conservation-related investments in 2021 remain overwhelmingly dominated by private debt and equity, followed by real assets. By contrast, tools like publicly traded instruments are rarely used in biodiversity-related finance, compared to renewable energy financing, for example. The CPIC report notes that the main revenue sources associated with conservation finance are dominated by sustainable commodities, which comprise more than half of all private sector investments, followed by returns from carbon and biodiversity credits. The report notes various barriers to scaling up biodiversity finance: a lack of project-ready investments, gaps in international design and measurement standards, and small-scale projects of around USD 5 million. CPIC estimates that 99.7% of investors are in Australia, Germany, the Netherlands, South Korea, Switzerland, the United Kingdom, and the United States.

Gender Equity and BIOFIN A priority of UNDP’s BIOFIN initiative in advancing gender equity through financing and financial instruments to support women and nature, including through special projects, specialized project workshops, gender balance in teams and other tools. One example of this work is in Costa Rica, which is among the world’s leaders in NbS and Payment for Ecosystem Services (PES). Three innovative financial instruments initiated in Costa Rica with the support of BIOFIN are a private capital rural women’s credit mechanism, a PES financing mechanism for women working in the forestry sector, and a women’s agro-forestry PES credit fund. The impact of these funds is expected to lower financing barriers women face in protecting nature.

The *UNDP Strategic Plan 2022–2025* prioritizes gender equity as one of its six signature solutions to confront structural obstacles to gender equity and build women’s economic empowerment and leadership. An important outcome of the Geneva Conference of the Kunming CBD negotiations in March 2022 was progress in adopting a gender framework for the pending global biodiversity framework that will integrate best practices in gender equity in biodiversity practices. A useful summary of leading gender-nature practices was released by Women4Biodiversity in late 2021.

D.3.2 Section Two: Initiatives and Tools

Business Investment Roadmaps: The January 2022 report *Seizing Business Opportunities in China’s Transition Towards a Nature-Positive Economy* identifies key transition investment opportunities for businesses in important systems like food and ocean use, energy and natural resources, and infrastructure and the built environment, in which increased nature financing can benefit the economy, create jobs, and support sustainability. The report estimates that investments in China’s nature-based economy could add USD 1.9 trillion in business value and 88 million new jobs by 2030. The report sets out an important framework and roadmap that should guide CCICED’s future work in this area.

Natural Asset Class: In September 2021, the New York Stock Exchange and the Intrinsic Exchange Group launched a new asset class based on nature and the ways that nature provides benefits to people, strengthens economic productivity, and takes into account multiple intrinsic values. This natural asset class was examined in the 2021 British Government’s *Economics of Biodiversity: The Dasgupta Review*. The Intrinsic Exchange Group announced work to develop standards to measure and report on the flows of ecosystem services needed to measure this new asset class.

National Green Development Fund: The Fund was launched in 2020 with a capitalization of CNY 88 billion or USD 14 billion to provide equity financing in support of decarbonization. The first equity financing deal was announced in the first quarter of 2022, under a joint arrangement with China's largest steelmaker Baowu, to finance the decarbonization of steel production. This green financing tool is seen as an important market-oriented instrument that can help close gaps in green equity financing. Emerging lessons from the fund should be followed, including the evidence it provides for how similar models could close equity financing gaps in nature-related financing.

Ecological Environment-Oriented Development Reserve Bank: China's Ministry of Ecology and Environment (MEE) released new guidelines on March 8, 2022, based on lessons from a series of pilot green financing projects in 2021. The new guidelines link several green financing funds and reserve banks at the project level—notably, funds for environmental protection, sewage and wastewater treatment, soil remediation, freshwater and marine estuary environmental protection in the Bohai Sea, Yangtze River Estuary-Hangzhou Bay and Pearl River Estuary, ecological restoration of soils, forests, lakes, and grasslands, agro-environmental projects, and other areas outlined in the guidelines. Projects in the reserve banks will help finance ecological environment-oriented development outcomes based on joint PPPs and are intended to help leverage and attract greater private sector financing in areas like contaminated soil remediation that have had difficulty attracting private sector finance. MEE shared data on ecological environment-oriented development financing of 36 pilot projects already initiated, which have since been expanded.

The Shandong Green Development Fund is a leading example of an innovative financial mechanism designed to attract and catalyze private investors in climate-friendly infrastructure and related green technology investments. The Shandong Fund establishes a comprehensive climate investment framework with clear outcome-based interim and longer-term targets. For example, the fund estimates that by 2027, climate investments will reduce carbon emissions by 3.75 million tons annually, while climate resilience investments will benefit over three million people. It is also among the first financing mechanisms in China that prioritize effective gender mainstreaming. The fund is managed by a top-tier fund manager, CICC Capital Management, the subsidiary of a leading investment bank, China International Capital Corporation, which is publicly listed on the Hong Kong Stock Exchange. Lessons from the fund could be applied to broader climate-ecological integrated project financing.

Green Infrastructure Finance: Following the launch of the first batch of Real Estate Investment Trusts (REITs) on the Shanghai and Shenzhen stock markets in 2021, roughly CNY 30 billion (USD 4.7 billion) was quickly raised. As in other markets, China's REITs are backed by real assets. As of April 2022, a total of 12 public-offering REITs have been issued, with unit prices increasing by 20%. It appears this pilot REIT program will soon expand to cover a wider range of infrastructure categories. As flagged in the CCICED 2021 Special Policy Study (SPS) on Green Finance, REITs include several green financing areas, notably feeding into China's National Green Development Fund, the Yangtze River Green Development Fund,

and green industry investment funds initiated and established by local governments. At the same time, the report noted several challenges in scaling up green REIT funds, including a lack of tax incentives, insufficient liquidity, low yields, and poor franchise and ownership transfer channels. Based on the overall success of China's REITs and their expected growth, CCICED made a number of recommendations to increase ecological-environmental REIT financing, including through widening PPP cooperation, improved environmental measurement and transparency, and other steps.

Standards, Reporting, and ESG: There are hundreds of major private sector non-financial reporting standards that measure products and services, operational processes, and, less frequently, combined performance impacts. For example, there are over 400 product-related sustainability standards, with roughly half measuring agricultural products like coffee, tea, palm oil, soy, rice, wheat, and other soft commodities. Standards exist for a range of services, including electricity, tourism, and green finance. The scope of private standards is expanding in light of net-zero pledges, with coverage including steel, cement, green hydrogen, and other areas.

The financial sector has been following the proliferation of green standards that has characterized agricultural and other sectors. The International Monetary Fund (IMF) has counted over 200 standards for climate finance alone. This proliferation risks creating market confusion among competing standard bodies.

In response, several international initiatives are underway to bring about greater coherence, comparability, convergence, and, if possible, standardization to unite varying standards. The newly launched **International Sustainability Standards Board** (ISSB) of the International Financial Reporting Standards (IFRS) Foundation is expected to build greater convergence among major climate-related standards bodies. These include **TCFD, SASB, CDSB, CDP, IIRC, GRI, PRI, Science-Based Climate Targets, IMP**, and the **Capitals Coalition**. It is too early to tell how smoothly the ISSB work will progress. In a hopeful sign, the heads of IIRC and SASB jointly wrote to the IFRS in 2021, committing to work together. While few expect the ISSB's task to be smooth or quick, the eventual outcome will affect dozens of major Chinese standardization and accreditation entities, given the importance of IFRS standards in major Chinese companies.¹⁷

As noted, there are numerous ESG standards. One example is the UN-related **Principles for Responsible Investment** (PRI), which are intended to help investors, asset managers, and others benchmark ESG standards and reporting. In late 2020, PRI issued **guidance linking ESG with negative carbon options**, notably related to forestry conservation, afforestation, and avoided deforestation. This work complements other PRI guidance—for example, its principles relating to forestry and science-based biodiversity targets. In addition, in order to move responsible investment from process and business conduct to real-world impacts contributing to the SDGs, PRI has outlined a **five-part framework** for tangible SDG outcomes. With

¹⁷ Study experts noted that most green finance standards are process-oriented—for example, setting up climate risk assessment strategies and processes to assess climate risk—as opposed to outcome-based standards.

the same purpose, UNDP has also developed the **SDG Impact Standards for Bond Issuers**—a set of decision-making tools helping investors and enterprises integrate impact management and contributing positively to the SDGs into their strategy, management approach, disclosure, and governance practices.

An important recent example of cooperative work between public and private sector standard bodies is the agreement between the EU's European Financial Reporting Advisory Group and GRI to co-develop a new biodiversity reporting standard. The advisory group is working toward a draft standard in mid-2022, and GRI is working to update its current biodiversity standard under the **Global Sustainability Standards Board** before the end of 2022. This cooperation has the potential to align the EU's biodiversity standards with wider/global standards under the GRI and may prove to be a useful blueprint for aligning Chinese-based biodiversity standards with international ones.

The relationship between private green financial standards and ESG-related markets and regulations is complex: regulatory supervisors seek to ensure markets are innovative and responsive to evolving demand and supply conditions while at the same time ensuring market actors follow various rules governing transparency, solvency, auditing, and truthful product claims, among others. One example of regulatory-led action to further green financial markets is the EU rules covering sustainability-related disclosure in the financial services sector, which will require all asset managers to classify their portfolios as either sustainable or non-sustainable, referencing the EU Taxonomy.

Shades of Green: Following the release of new EU rules in 2022, there have been discussions regarding the possible expansion of categories beyond the current green taxonomy, reflecting predictable worries among investors that not falling within a green category means they fall into a non-green, brown, or environmentally destructive category. Similar debates have occurred pertaining to products and services certified as green, sustainable, or low carbon. Study experts noted the potential usefulness of other categories, notably red or brown, no-go, high-risk or classification categories—essentially a negative list of high-risk financing. The Traffic Light System MEE has introduced in its BRI project financing is a useful model to inform decision making based on three environmental risk categories: red as high risk, yellow as no environmental risks, and green indicating no environmental risks and environmental benefits.

Recently, PBOC called for increased research into green transition finance; that is, identifying ways for carbon- or pollution-intensive firms like steel, cement, or chemical companies that are ineligible to access green financing—like green bonds or other ESG products—can access transition finance. PBOC has put a spotlight on the role of financial institutions in helping companies currently excluded from green financing opportunities but with green transition plans and commitments to access bridge or transition financing—for example, through the use of sustainability-linked bonds or financing arrangements designed around longer timelines, with interim performance targets that include the gradual lowering of GHG emissions.

This focus on transition finance is important in widening the scope of many green financing products—which often remain a small segment of the overall financial sector—to include plans to green the finance sector more comprehensively by planning the transition away from current brown or grey financing to overall, systemic green goals.

Transparency and Accountability: Market and investor confidence hinges on transparency and accountability: if investors lack confidence in the robustness and independent verification or auditing of market data, they will eventually exit those markets. Green markets are no exception. On the contrary, given the still novel and emerging dynamics of carbon, biodiversity, and other green markets, investors arguably are looking for even greater transparency and accountability compared to more established and familiar markets. Transparency narrowly includes financial accounting standards and compliance, as well as a growing range of non-financial reporting standards and market expectations.

More broadly, transparency also includes the design and delivery of both domestic public policies—for example, through national audit offices and independent statistical agencies, to international Development Finance Institution (DFI) financing. Recommendations from recent reviews of DFIs point to the need for robust, independent transparency and accountability mechanisms that include predictable procedures through which local complaints can be received, reviewed through compliance investigations, and settled using dispute resolution procedures, followed, if necessary, by financing to correct harmful practices and compensate local communities.

Greenwashing Risks: 2021 saw record levels in ESG investments, with asset managers creating a record number of new ESG products. The market analysis group Morningstar Analytics reported an all-time peak in ESG investments in 2021: as of September 2021, sustainable fund assets were more than USD 330 billion. (By comparison, **ESG assets** in the third quarter of 2020 were USD 183 billion.) The majority of these investments are linked to renewable energy.

This growth is welcome, provided green claims lead to actual, measurable green performance outcomes. However, the risk that green ESG claims are exaggerated, weakly founded, or based on nothing is real and growing. In late 2021, China cautioned against the risk of greenwashing, and with good reason. A February 2022 ***Nature* article** notes significant gaps in corporate carbon mitigation plans—often omitting entirely Scope Three emissions in their reporting or relying on carbon offsets to meet net-zero pledges. Such weaknesses are partly explained by weak climate governance within private sector corporate boards: for example, a 2021 **survey by NYU’s Stern School of Business** showed extremely weak board governance capacity related to climate and ESG matters.

A good practice is the EU’s annual “sweep”—mandated by law under consumer protection regulations—to expose greenwashing. In early 2021, the results of the EU’s first sweep of websites concluded that 40% of green claims lacked evidence, while a subsequent EU report that examined 344 green claims concluded that over 50% lacked evidence to back green claims, of which an astonishing 37% were based on vague, misleading, or false claims.

In late March 2022, the UN Secretary-General launched the High Level Expert Panel on the Net-Zero Emissions Commitments of Non-State Entities to examine net-zero markets claims in ESGs, climate and carbon disclosure standards, securities and accounting regulators, regulatory and other bodies supervising the global financial system, and others. The panel, chaired by former Canadian environment minister and former CCICED vice-chair Catherine McKenna, is expected to make recommendations in late 2022 or early 2023. CCICED follows the work of the panel and invites members to brief them on their ongoing work and eventual recommendations that should be adopted by China's relevant supervisors.

Green Taxonomies: Under the EU International Platform on Sustainable Finance, the China–EU Common Ground Taxonomy initiative issued its first assessment of Climate Change Mitigation taxonomies in November 2021. The purpose of the platform's China–EU working group is to build greater comparability and interoperability among different national taxonomies, in order to support common or converging practices of green bond issuers and verifiers; company-level low-carbon roadmaps; banks and other financial institutions aligning their portfolios with low-carbon roadmaps; development finance institutions and reporting entities interested in benchmarking the Common Principles for Climate Mitigation Finance Tracking (see below); and international standard-setting bodies. By 2022, all EU financial products that list some green claims must cross-reference how they align with the EU green taxonomy.

China's green taxonomy focuses mainly on providing guidance for green bond issuers and covers three main areas: environmental improvement, climate change measures, and the efficient use of natural resources. China's green taxonomy is based on the 2021 joint PBOC, NDRC, and CSRC Green Bond Endorsed Projects Catalogue, which identifies several major activities and specific sectors. For conservation and NbS-related finance, the “ecology and environment related sector” is the most relevant and comprises “ecological agriculture” and “ecological protection and construction”. Given the importance of standards to support green markets, the Chinese taxonomy also includes green services such as auditing, inspection, and evaluation of projects.

The 2021 CGT report identifies common areas between the EU and China green taxonomies that have the highest impact. Critically, the EU green taxonomy forestry sector and China taxonomy ecology and environment sector are earmarked as “high priority”, thus underscoring the opportunity to increase investments in NbS. That report notes that principles like “do no significant harm”, various social and human rights issues, and other areas have yet to be addressed, while differing terminology, standards, and safeguards make detailed comparisons difficult.

Do No Significant Harm: The legal principle is defined by UNEP as the duty of a state to prevent, reduce, and control the risk of environmental harm to other states. The principle has been included in numerous international treaties and agreements, especially covering water resource management. As negotiations to complete Article 6 continued, in 2018 the Sustainable Development Dialogue group was formed to

examine safeguards to be considered in Articles 6.2, 6.4, and 6.8 related to the “do no harm” principle.

DFIs: Study experts highlighted the role of DFIs in integrating public and private sector climate and biodiversity investments. Most of the estimated 450 DFIs that make up 10% of global annual investment have the dual mandate of supporting economic development through job creation, public health and education, gender equity, or rural electrification and making a return on investments comparable with prevailing markets.

In recent years, many DFIs have taken a more proactive role in SDG financing, including financing climate change mitigation and adaptation: for example, between 2015 and 2020, European DFIs have committed EUR 8 billion in climate finance. One example of DFI helping to leverage PPPs is the German BMZ partnership with the InsurReliance Global Partnership to help underwrite climate risk affecting poor and vulnerable households and communities. In order to better coordinate DFI-related climate financing, European DFI entities agreed in late 2020 to increase comparable climate disclosure measurement and reporting.

Gender Lens Investments and Development Finance Institutions: In 2018, G7 countries promised to mobilize USD 3 billion in DFI and private sector investments to support gender equity, by improving women’s access to finance, skilled jobs, and leadership opportunities. As of early 2021, approximately USD 4.6 billion investments has been committed under the 2XChallenge, which has expanded well beyond the G7-based DFI to include the European Investment Bank, pension funds, private equity funds, and institutional investors. Part of the success in exceeding their financing targets has been the progress made in implementing comparable criteria to measure the impact of gender equity financing in women’s entrepreneurship, leadership, employment, consumption, and intermediate investment.

Overseas Development Assistance: The revised 2021 Common Principles for Climate Mitigation Finance Tracking serves as the basis for MDBs (including ADB, AIIB, and the New Development Bank) and IDFC members to classify climate finance in a comparable manner via the annual Joint Report of Multilateral Development Banks on Climate Finance. Of the total amount tracked in the joint report (USD 66 billion), the majority consists of investment loans (USD 50.4 billion), with much lower levels comprising policy-based lending (USD 4.8 billion) and grants (USD 3.3 billion). Other forms of climate finance are lines of credit (USD 2.1 billion),

guarantees (USD 1.9 billion), equity finance (USD 1.4 billion), and results-based finance (USD 1 billion).¹⁸

An important outcome of the Glasgow COP was the Climate Finance Delivery Plan on how to meet the Paris Climate Agreement pledge of USD 100 billion a year. While noting disappointment that the USD 100 billion has not been met, the plan expressed confidence it will be met by 2023, based on tracking and scenarios prepared by the OECD that point to the need for both MDBs and Export Credit finance to shift current financing and increase climate financing.

Risk Disclosure: There have been significant steps following the 2017 release of the **TCFD report**, notably in adopting management rules covering climate-related risks and opportunities. Of note, in June 2021, the G7 agreed to **mandatory climate risk reporting** based on the TCFD recommendations.¹⁹ In July 2021, the G20 agreed to adopt a **“baseline global reporting standard”**.

In July 2021, PBOC released its Guidelines on Environmental Information Disclosure for Financial Institutions. The PBOC guideline notes,

Financial institutions shall report on their environmental objectives, visions, strategic plans, policies, actions and key outcomes during the year, such as their own operating activities generated by carbon emission controlling targets and achievements, resource consumption, pollution and prevention, climate change mitigation and adaptation, etc.²⁰

For example, among the recommendations of the 2021 Board Statement of the Institute of International Finance on climate finance is the need to harmonize international risk disclosure rules, as well as support the convergence of green taxonomies, data standards, metrics, and other enabling tools.²¹

As noted, the 2021 CCICED Green Finance SPS recommended China adopts TNFD risk disclosure practices. Given the inherent connection between climate and nature risk, consideration should be made to coordinate the release of TCFD and TNFD disclosure at the same time, acknowledging that the phased-in introduction of mandatory risk disclosure will be complex.

¹⁸ The tracking report provides various categories to track MDB investments, notably related climate adaptation financing that includes the “crop and food production” and “other agricultural and ecological services”, and in the climate mitigation category under “agriculture, aquaculture, forestry and land-use”.

¹⁹ There are different approaches to mandatory climate disclosure within the G7. For example, in July 2021, the U.S. Securities Exchange Commission announced it was developing new rules for all public companies, thereby differing from the EU’s Sustainable Financial Disclosure Regulation’s more narrow coverage of asset managers and financial advisors. The EU regulation came into force in 2021. A related example of central bank guidance on climate risk is the November 2021 Principles for the Effective Management and Supervision of Climate-Related Financial Risks of the Bank for International Settlements.

²⁰ In addition to carbon-related risks, TCFD has important consequences from a climate resilience and adaptation lens, since it also covers the disclosure of physical risks from climate-related events like flooding, drought, coastal inundation, etc.

²¹ Chinese members of the institute are Agricultural Bank of China, China Merchants Bank, Bank of Communications, Industrial and Commercial Bank of China, China Construction Bank, China Everbright Bank, CITIC, China Development Bank, Industrial Bank, and China Guangfa Bank.

In April 2022, PBOC and six ministries introduced an important draft law intended to strengthen and build greater comparability regarding how financial risk will be measured, managed, and reported across its financial services sector through a common risk framework. As this important new legislation emerges, opportunities to include climate, ecological, and environmental financial risks could be considered.

Voluntary Carbon Markets: One of the strongest market signals of NbS investment trends is the growing interest in voluntary carbon markets, through which investors purchase carbon offset credits. Market projections vary widely, with PRI estimating investments in reforestation and afforestation reaching USD 800 billion in annual revenues by 2050, reflecting assets of over USD 1.2 trillion. Less spectacular forecasts from the January 2021 final report of the ***Task Force on Scaling Voluntary Carbon Markets*** estimated carbon offset markets at between USD 5 and USD 50 billion by 2030. **2021 recorded voluntary carbon markets** of USD 1 billion in trades, with forestry and land use constituting over 60% of all investment. Within China, there are over 20 major carbon offset certifying bodies, such as the China Quality Certification Center. Given recent work to ensure carbon offsets are not subject to greenwashing, initiatives like the **Voluntary Carbon Markets Integrity Initiative**, which issued clear initial recommendations in late 2021, present an opportunity to align Chinese domestic market practices with evolving international standards and best practices.

Recent guidelines and opinions issued by China's State Council, PBOC, and MEE emphasize the central role of carbon sequestration markets as a part of China's carbon peaking and neutrality transition pathways, examined in a recent CCICED background note on carbon offset markets.

Attention is growing around nature markets. Narrowly, these cover voluntary NbS markets that include various outcomes like climate adaptation, sustainable agriculture, freshwater management, and climate mitigation. More broadly, markets draw from years of work around natural capital-based markets, as examined in the 2021 *UK Dasgupta Review*, or ongoing work on payment for ecosystem services. In April 2022, the Finance for Nature launched a new global task force to examine nature markets.

Corporate NbS Funds: In the past year, there has been a flurry of company-led funds related to supply chains and NbS. Examples include

Apple Restore Fund of USD 200 million, launched in April 2021, to finance forestry projects that will remove up to 1 million metric tons of carbon annually.

L'Oreal: Fund for Nature Regeneration, a EUR 50 million fund to restore degraded ecosystems and capture 15–20 million metric tons of CO₂.

Amazon Right Now Climate Fund of USD 100 million for NbS investments.

Orange Nature Climate Fund of EUR 50 million to purchase high-quality carbon credits.

Kering Regenerative Fund for Nature to support NbS linked to responsible and green supply chains, with a goal of restoring 1 million ha by 2025 and supporting regenerative agriculture.

The LEAF Coalition, a coalition of the U.S. and British governments and 19 major companies, including Walmart, Bayer, and Unilever, announced it had reached its USD 1 billion target for tropical forest protection in late 2021.

These initiatives complement a substantial increase in nature finance from private philanthropy organizations like the Bezos Earth Fund commitment at the Glasgow COP to USD 2 billion in financing to help stop deforestation, as part of a broader Protecting our Planet Challenge to support 30 × 30 conservation goals.

Deforestation-Free Supply Chains: The 2021 CCICED green value chain SPS report examined the strong causal link between the sourcing of various soft commodities, such as soy and palm oil, and deforestation, specifically tropical deforestation.

More than a decade ago, hundreds of companies signed onto a zero-deforestation pledge by 2020 under the Consumer Goods Forum. In 2014, the New York Declaration on Forests promised to halve global deforestation rates by 2020. Both targets have been missed by a wide margin, prompting various assessments to map complex supply chains and prioritize a systems-based approach to sustainable sourcing, including designing inclusive governance systems that deliver financing to local farmers.

Financing local farmers will be critical in meeting new sustainable supply chain promises as well as meeting the new global deforestation Glasgow pledge. Typically, small-scale farmers face higher production costs in meeting sustainable sourcing standards and third-party certification criteria while being hampered by a lack of access to affordable credit, especially in meeting upfront costs.

In the past year, there have been numerous new financing initiatives to implement sustainable supply chain sourcing. For example, the Responsible Commodities Facility was recently established with the collaboration of WWF, TNC, UNEP, WEF Tropical Forest Alliance, and others, to help finance farmers producing sustainable soy in Brazil.

Other examples of NbS-focused financing initiatives include the Nature + Accelerator Fund, launched by IUCN and the GEF, which is intended to scale up NbS financing toward an eventual goal of USD 160 million from 70 NbS projects by 2030.

At the first meeting of the UN CBD COP 26 in October 2021, China announced a new USD 230 million Kunming Biodiversity Fund, inviting other countries to contribute to the fund.

With the Glasgow Leaders' Declaration on Forests and Land Use, signed by China and 140 other countries committed to stopping deforestation within their jurisdictions by 2030, the responsibility to ensure deforestation-free supply chains has shifted to the government's steps to augment private sector actions. A number of jurisdictions, including Norway, France, the EU, the United Kingdom, and others, have introduced regulatory measures to restrict market access for goods that cannot prove they have been harvested legally or meet certain sustainability standards. Opposition from various food importers regarding the proposed law of due-diligence procedures is one reason the British bill is delayed.

From a financial reporting perspective, this renewed focus on supply chains now includes climate risk considerations. In announcing its climate risk disclosure draft rules in 2021, the U.S. Securities Exchange Commission indicated it would likely include Scope 3 GHG emissions linked to upstream and downstream supply chains. An Opinion issued in late 2021 by China's State Council indicated the need to undertake a climate risk assessment to align China's supply chains with carbon peaking and carbon neutrality goals.

D.3.3 Section Three: Reforming Environmentally Harmful Subsidies

The 2021 Financing Nature report highlights the extent to which many agricultural and other harmful subsidies contribute to biodiversity loss on either the production or consumption side. Examples from that report include subsidies that contribute to freshwater pollution, land degradation, forest and other ecosystem habitat loss, preferential output-based support of single-crop outputs, ineffective waste management, and other impacts. Citing OECD estimates tracking 53 countries, the report notes annual agricultural subsidies in 2016–2017 of USD 703 billion and estimates total “biodiversity-harmful subsidies” in 2019 of between USD 274 and USD 542 billion.

There have been numerous efforts over the past three decades to identify, reduce, and reform environmentally harmful subsidies. Past work has focused on national farm-support programs like the U.S. Farm Bill or the EU Common Agricultural Policy, with some success in carving out different kinds of farm support. For an interim period, the World Trade Organization (WTO) allowed green box subsidy support for some agricultural subsidies. Study experts suggested these temporary measures be made permanent.

As noted, a major conclusion of the *Financing Nature* report is the urgent need to reform environmentally harmful subsidies. A joint FAO-UNDP-UNEP report from September 2021 recommended repurposing most forms of agricultural subsidies due to their pervasive price distorting and nature-destructive effects, in addition to negative climate, public health, equity, and trade effects.²² The report recommends six steps to estimate harmful agricultural subsidies at the national level as the basis for repurposing them. Similarly, UNDP's BIOFIN has developed a methodology to estimate domestic farm subsidy levels that are harmful to nature, with case studies underway in numerous countries (such as this case study in Mongolia). There is an opportunity to highlight subsidy reform during COP 26.

²² The FAO-UNDP-UNEP report estimates global farm support is projected to increase to almost USD 1.8 trillion in 2030 under a business-as-usual scenario that takes into account the expected economic recovery. About 73% of this (USD 1.3 trillion) would be in the form of border measures, which affect trade and domestic market prices. The remaining 27% (USD 475 billion) would be in the form of fiscal subsidies that support agricultural producers and could continue to promote overuse of inputs and overproduction.

Among the recommendations of the CCICED 2021 green finance SPS is the importance of reforming China's subsidy program. Specific recommendations include.

Increase subsidies of a universal nature to reduce the damage of subsidies to biodiversity while ensuring that farmers' income and agricultural output do not decline. This would entail a shift in the structure from direct to indirect subsidies.

Integrate environmental targets into the criteria for determining subsidies. Environmental targets should be included in the identification criteria of more subsidy policies, including targets to support ecological protection.

Subsidy reform has also been an important focus of climate action. For example, in 2009, the G20 pledged to identify and eliminate "inefficient fossil fuel subsidies". Actual progress has been limited either in defining what "inefficient" means or bringing about lasting reductions to support levels.²³ Initiatives like Friends of Fossil Fuel Reform, established in 2010, and ongoing analytic work by the IMF, OECD, the World Bank Energy Subsidy Reform Facility, the Global Subsidies Initiative, and others helped provide the context for reference in the 2021 Glasgow declaration of a commitment to reduce fossil fuel subsidies. Given the increased role of market-based instruments in advancing carbon neutrality goals, study experts noted that among the distortionary effects of fossil fuel subsidies is a weakening of the intended price effect of carbon markets.

Reforming environmentally harmful subsidies has been the topic of ongoing work at the WTO and its predecessor, the GATT, for three decades, with little progress. The 20-year WTO negotiations toward an agreement on reforming fish subsidies underscore the inability of trade policy to reach a consensus to condition and reduce environmentally harmful subsidies.

D.4 Part Three

D.4.1 Short-Term and Medium-Term Implementation Opportunities.

Green Taxonomy: Identify how the current green taxonomy can scale up NbS investments by tracking taxonomy categories of "Ecological Agriculture" and "Ecological Protection and Construction".

Financial Risk Disclosure: Identify how China's newly announced mandatory climate risk disclosure can track physical risks related to climate-related extreme weather events (for example, flooding), as well as track how various climate resilience

²³ A 2021 assessment for the G20 concludes nominal levels of subsidies remain unchanged from 2010 to 2019.

27% (USD 475 billion) would be in the form of fiscal subsidies that support agricultural producers and could continue to promote overuse of inputs and overproduction.

investments, with a special category for NbS-related climate adaptation investments, can be included in the new disclosure framework.

Economics of Nature Loss: Deepen analysis by financial regulators around risks of biodiversity losses and financial exposure to biodiversity losses, domestically and in overseas engagement, and incorporate, for example, the ongoing work of the Network of Central Banks and Supervisors for Greening the Financial System.

Data Supporting Carbon Markets: In support of carbon market approaches to carbon peaking and neutrality, CCICED can examine options in the design of China's recent commitment to create a comprehensive climate data system to make data related to NbS carbon sequestration systems available to investors, as well as track the development of new ISSB standards as they relate to climate and nature finance.

Article 6 Rules: Following the completion of the Paris Rulebook, review the current portfolio of eligible post-2013 CDM projects, and retain those carbon credits that align with the new Article 6.2 and Article 6.4 rules regarding double-counting, additionality, permanence, and transparency.

Financing Sustainable Sourcing of Supply Chains: CCICED should help identify existing rural financial support programs, such as eco-compensation programs, to include direct payments to farmers (for example, through well-established financing programs like China's Eco-Compensation Scheme, preferential loans, or other rural payment schemes to integrate NbS payments). CCICED's SPS on Sustainable Food Systems is relevant in this regard.

Climate Risk Assessment of China's Value Chains: As work begins in assessing the climate risk of China's domestic supply chains, CCICED can help identify risks associated with the potential degradation of forests, wetlands, peatlands, grasslands, and others in terms of their carbon stocks, as well as the extensive de-risking benefits of NbS in relation to climate adaptation and resilience.

Corporate NbS Funds: CCICED can examine how tax incentives and tax treatment, together with other practices, can encourage more company expenditures in NbS projects, with tax incentives linked to both investment levels and actual income flows generated from NbS funds, and with credits tied to income revenue that benefits local farmers, communities, and others.

Closing Inequality Gaps: CCICED should identify how NbS financing can help address income, labour, gender, and other inequalities, as this is an integral part of China's green transition commitment as well as commitments in the 14th Five-Year Plan and more recent economic goals of closing China's income inequality gaps.

D.4.2 International and South–South Cooperation

Biodiversity Resource Mobilization: The completion of the CBD Kunming COP 15 is expected in the second half of 2022. CCICED should prioritize how to implement the decisions of the Kunming summit to increase financing for biodiversity, with a priority focus on scaling up green finance from the private sector and coordinating and leveraging multilateral development bank financing to advance 30 × 30 and sustainable use objectives.

Green BRI: In late March 2022, NDRC issued new Opinions on Promoting the Green Development of the Belt and Road Initiative. At the core of this new Opinion is the requirement to advance green development throughout BRI cooperation. Among the priority areas identified is green finance, based on the work of the UN and G20, which includes promoting voluntary guidelines and best practices related to green investments and financing, leveraging loans from international financial institutions and private green investment, and encouraging financial institutions to implement the Green BRI Investment Principles. The Principles, signed by over 35 major Chinese and other banks, set out steps to embed sustainability in corporate governance, assess and disclose environment-related risks, use green financing instruments like ESG products, use green supply chains, and raise public awareness. CCICED’s Phase VII work should identify the means to implement the new Opinions, through research, case studies, and recommendations.

DFI/MDB De-Risking Financing: MDBs and DFIs should step up coordination to de-risk carbon transition and increase blended/PPP finance to help de-risk private sector financing.

D.4.3 Medium-Term Opportunities

Green Taxonomy: Update China’s green taxonomy to include additional and specific categories for conservation finance and NbS investments.

Nature-Risk Disclosure: In the next ten years, adopt the TNFD standards to disclose nature-related risks among all financial sector actors, including asset managers.

Sustainable Supply Chains: Set annual financing levels to support farmers, fishers, and others in ensuring sustainable, nature-positive supply chains. Diversify financing to include grants, equity, and lines of credit to finance the enabling tools needed for the traceability of supply chains.

Subsidy Reform: Implement domestic actions to reduce fossil fuel subsidies in support of China’s dual control targets and increase subsidy support for net-zero agriculture, land use, and forestry management goals. Implement pilot projects to restructure agricultural subsidies to an indirect system that supports rural livelihoods.

It would be useful for CCICED to examine and draw lessons from past attempts at reforming environmentally harmful subsidies.

D.5 Part Four

D.5.1 Recommendations

In addition to the overall recommendation that CCICED prioritize learning how to integrate nature and climate financing. Additional recommendations are as follows:

Recommendation one: CCICED should identify policies, case studies, standards, and partnerships to scale up financing in high-quality NbS, including forests, mangroves, grasslands, wetlands, regenerative land management and green/sustainable food systems, green and climate-resilient infrastructure, marine and coastal resilience, and other areas.

Recommendation two: CCICED should identify roadmaps for the private sector to increase climate and nature financing, with the aim of ensuring that *overall* financial flows reduce negative impacts on nature/climate. Work can include analysis of emerging standards, safeguards, disclosure practices, green taxonomies, ESG financial products, auditing standards, monitoring and verification standards, and other initiatives, including evolving from the G20 Working Group on Sustainable Finance. Synergies between digitization and sustainability are examined in a complementary CCICED 2022 scoping study.

Recommendation three: CCICED should identify opportunities to increase and leverage public sector finance both within China—including involving state-owned enterprises—as well as via international public finance involving bilateral, regional, or MDB finance, export finance, and other areas.

Recommendation four: CCICED should examine opportunities for public–private partnerships and related blended nature and climate finance, including options to integrate compliance and voluntary carbon markets.

Recommendation five: CCICED should deepen its analysis of options for systemic, comprehensive reform of environmentally harmful subsidies in support of integrated nature-climate finance. Special focus should be placed on addressing jobs, income, and other inequalities in fiscal policy reform.

Recommendation six: CCICED should help support and strengthen international cooperation in green finance through ongoing exchange at the strategic policy and regulatory levels and in relation to product and other areas in support of shared efforts to support global green development goals.

Report authored by Scott Vaughan, CCICED International Chief Advisor.

Annex A: Scoping Study Meetings for 2021–2022 Research Year

January 26—Scoping Study Introductory Meeting.

February 17—Core Expert Inception Meeting.

March 24—Scoping Study Workshop: Innovative Green Finance.

April 21—Scoping Study Workshop: Sovereign Debt Linked to Biodiversity, Climate and SDGs: An opportunity for China?

Annex B: Scoping Study Team Structure

<i>Chairs</i>	
Scott Vaughan	CCICED International Chief Advisor
Violante di Canossa	Development Economist, Head of Research and Policy Team, UNDP China
Andrew Deutz	Director of Global Policy, The Nature Conservancy
<i>Core experts</i>	
Christoph Nedopil	Associate Professor and Director Green Finance and Development Center, Fudan University
Margaret Kuhlow	Global Finance Practice Leader, WWF International
Jill Dauchy	CEO, Potomac Group
BAI Yunwen	Director of Center for Financing NbS, Institute of Finance and Sustainability
SUN Tianshu	Institute of International Development Cooperation, CAITEC
Tracey Cumming	UNDP, Technical Advisor on Environmental Finance for the Biodiversity
Swarnim Waglé	Chief Economic Advisor, UNDP Regional Bureau for Asia and the Pacific
Mark Halle	Co-Founder, BetterNature
Paul Steele	Chief Economist, International Institute for Environment and Development
Renata Rubian	Policy Advisor, UNDP Regional Bureau for Asia and the Pacific
<i>Consulting experts</i>	
Bob Tansey	Senior Policy Advisor, The Nature Conservancy
Knut Alfsen	International Chief Advisor Support Team
Wang Yali	SDG Finance Specialist, UNDP China
Stewart Maginnis	Deputy Director General, International Union for Conservation of Nature; Co-Team Lead, Special Policy Study on Nature-based Solutions
Du Hongxia	Senior Manager, Green Finance, WWF China

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Zhang Chenghui	Former Director-General of the Research Institute of Finance, Development Research Center of the State Council
Erik Berglöf	Chief Economist, Asian Infrastructure Investment Bank
Ye Yanfei	Inspector of the CBIRC's Policy Research Bureau
Eric Usher	Head, UNEP Finance Initiative
Zhang Jianping	Director, Center for Regional Economic Cooperation, CAITEC
Xu Jiajun	Executive Deputy Dean, Institute of New Structural Economics at Peking University
Rodolfo Lacy	Director for Climate Action and Environment for Latin America, OECD
Zhang Yumei	Researcher, Institute of Agricultural Economics and Development, Chinese Academy of Agricultural Sciences
Farooq Ullah	Strategist, The B Team
Rose Niu	Chief Conservation Officer, Paulson Institute
Gianni Ruta	Lead Environmental Economist, World Bank
Jess Ayres	Director, Climate Change, Children's Investment Fund Foundation
Yue Qi	Manager, Climate, Children's Investment Fund Foundation
WEI Yuan	IFC/SBN Asia Coordinator
Dimitri de Boer	Chief Representative, China, ClientEarth
Fan Danting	Legal Researcher, ClientEarth
Fu Xiaotian	Food And Natural Resources Program Director, World Resource Institute (China)
Sonja Sabita Teelucksingh	Adviser to the CEO, Global Environment Facility
Carolina Rojas	Advisor, Strategic Environmental Dialogues, GIZ
Maxim Kenens	Junior Advisor for Sustainable Finance, Long-Term Strategies and NDC Implementation, GIZ
Ulrich Volz	Director of the Centre for Sustainable Finance and Professor of Economics at SOAS, University of London
Zhang Jianyu	Executive President, BRI Green Development Institute (BRIGI)
Rebecca Ray	Senior Academic Researcher, Boston University Global Development Policy Center
Simon Zadek	Chairman, Finance for Biodiversity
Jean-Paul Adam	Director for Technology, Climate Change and Natural Resources Management in the United Nations Economic Commission for Africa
Catherine Phuong	Deputy Resident Representative, UNDP Lao PDR
Carlos Larrea Maldonado	Professor, Universidad Andina Simón Bolívar, Ecuador
Hannah Ryder	CEO, Development Reimagined
Xiong Wanting	Chinese Academy of Social Sciences
Kirthisri Wijeweera	Advisor on Nature Performance Debt Instruments, UNDP
David Boland	Global CEO, EvolveGroup

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Adam Starr	Technical Specialist, SAFE Ecosystems Project at UNDP Lao PDR
Thome Xaisongkham	Programme Analyst, UNDP Lao PDR
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Annex C: China’s Terrestrial Carbon Sink Potential—A Review of Literature

Author: Kalifi Ferretti-Gallon.

Link to Full Report.

D.5.2 Executive Summary

The impacts of climate change over the last decade have intensified worldwide. In 2021, the global disruptions of the COVID-19 pandemic were compounded by extreme weather and climate disasters. Devastating climate-related events over the last year included heatwaves, hurricanes, floods, and droughts experienced by countries across the world, amounting to well over 170 billion dollars of damage. As climate change impacts continue to add environmental, social, and economic pressures to a global system already under stress, it is becoming increasingly important to reduce greenhouse gas emissions.

By the end of COP26, 151 countries revised or submitted new nationally determined contributions (NDCs) to a global reduction of emissions. China revised its NDC to include new goals for its emissions peak and net-zero targets. However, there is concern that the revised objectives and climate strategies of the world’s largest emitting country might not be sufficient to reduce global temperatures to 1.5 °C above pre-industrial levels. Fortunately, recent efforts to restore and protect China’s terrestrial biomes have improved the country’s capacity to reduce its net emissions.

This report provides a review of literature on the capacity of China’s terrestrial ecosystems to store carbon and remove carbon dioxide for each major terrestrial biome: forests, grasslands, croplands, shrublands, and wetlands. This analysis concludes with a list of policy recommendations and opportunities for each biome to enhance China’s capacity to store carbon and exceed its current targets.

Based on the review of literature, four key takeaways are identified.

Carbon sequestration plays a significant role in China’s carbon peaking and carbon neutrality. The degree to which different biomes offer carbon storage and sequestration potential varies greatly, with China’s forests providing the majority of soil and vegetation carbon storage (38%), followed by grasslands (30%), croplands (19%), shrublands (8%), and wetlands (5%).

China’s forests shifted from source to sink; currently representing about 56% of total terrestrial sequestration. Existing programs incentivizing afforestation and

reforestation in China is expected to increase forests capacity to remove and store carbon, and substantially expanding these initiatives to could significantly offset the countries predicted annual emissions.

Managing in China to improve yields could also enhance sequestration potential. Croplands in China store about 1/5th of its terrestrial carbon. Sequestration through sustainable soil management to improve annual yields could also function to significantly increase carbon uptake.

Grasslands and shrublands don't hold as much vegetation carbon relative to forests but still play a vital role. Both biomes have diminished in area due to conversion to other land uses but have a high potential of carbon sequestration and retention of properly restored.

Protecting wetlands will be important for mitigating major GHG releases. While wetlands represent the smallest proportion of China's terrestrial carbon storage, they are an important storage for carbon dioxide as well as methane and are vulnerable to climate impacts and land-use change that could prompt their release.

A comprehensive system to track trends in China's terrestrial carbon storage and sequestration rates is strongly recommended. China's terrestrial biomes are important for offsetting the country's emissions and contributing to global efforts to mitigate climate change. However, their capacity to remove and store carbon is influenced by variables specific to each biome. A system that tracks these trends will improve analysis and inform better land sector policies in China.

Annex E

Progress on Environment and Development Policies in China and Impact of CCICED's Policy Recommendations (2018–2022)

E.1 Environmental and Development Planning

E.1.1 Building Systems for an Ecological Civilization and Building a Beautiful China

The year 2018 is of particular importance, as it is the first year of implementing the task of “Speeding up Reform of the System for Developing an Ecological Civilization, and Building a Beautiful China” as proposed at the 19th CPC National Congress, the first year of exploring the modernization of China’s governance system and the first year following the reform of Party and government institutions. In the history of China’s eco-environmental protection, each major change has injected new vitality into the environmental protection cause, which moves forward amidst further reforms.

The National Ecological and Environmental Protection Conference was held on May 18–19, 2018 in Beijing. This conference was unprecedentedly high-profile since it was attended by General Secretary Xi Jinping and other NPC Standing Committee members in addition to Li Zhanshu, chairman of the Standing Committee of the 13th National People’s Congress (NPC). In his important speech at the conference, Chinese President Xi Jinping stated the six principles that should be upheld in the efforts to build an ecological civilization in the new era, including that man and nature live in harmony, that our natural environment is precious, that there is no welfare more universally beneficial than a sound natural environment, that our mountains, rivers, forests, farmlands, lakes and grasslands together form a biotic community, that the strictest regulations and laws should be applied in protecting the environment and that joint efforts should be made in building a global ecological civilization. By moving faster to building systems for an ecological civilization, we will see that by 2035, fundamental improvements are made in environmental quality, that the goals of the Beautiful China Initiative are essentially met. By the middle of the century, we will complete all-round improvements in the material, political,

intellectual, social and ecological domains. At that time, environmentally friendly ways of living and developing will be fully formed, humans and nature will coexist in harmony, modernization of our national governance system and capacity in the environmental field will be fully realized, and our efforts to build a beautiful China will be successful.

Since 2018, China has won the battle against pollution, preliminarily addressed the weaknesses in ecology and environment, and basically built the systems for an ecological civilization. Since the beginning of the 14th Five-Year Plan (FYP) period, China has been advancing the battle against pollution, thoroughly implementing central environmental protection inspections and exploring how to put into practice the concept that “lucid waters and lush mountains are invaluable assets”, with environmental quality significantly improved and green development becoming the basic feature of high-quality development in the new era.

E.1.2 All-Round Green Transition Driven by the 13th FYP

During the 13th FYP period, China was committed to the building of an ecological civilization by focusing on the goal of “winning the battle against pollution” in line with the Five-sphere Integrated Plan to promote coordinated progress in the economic, political, social, cultural and ecological fields. This had led to marked changes in China’s energy, industrial, transportation and land use structures, over-fulfilment of the nine binding environmental targets as set forth in the 13th FYP, and a new landscape of promoting high-quality economic development through ecological and environmental protection. Achievements have been made in the following five spheres:

1. **Fruitful results have been achieved in ecological and environmental legislation.** Since the 13th FYP period, 13 laws, including the Environmental Protection Law and the Yangtze River Protection Law, and 17 administrative regulations, including the *Regulations on the Administration of Pollutant Discharge Permits* and the *Regulations on the Administration of Environmental Protection in Construction Projects*, have been established or revised. There are 15 environmental laws enforced mainly by the Ministry of Ecology and Environment (MEE), taking up nearly 1/20 of all the laws currently in force, and 84 regulations established by the MEE. As of November 2021, there were 32 environmental administrative regulations. In addition, there are more than 40 intra-Party disciplines and rules closely relate to ecology and environment. A system of ecological and environmental laws and regulations has basically taken shape, providing a legal basis for nearly all areas of ecology and environment.
2. **Major progress has been made in the construction of a system of ecological and environmental standards.** During the 13th FYP period, 673 national ecological and environmental standards were revised and released. In recent years, MEE has amended and enacted the *Measures for the Administration of*

Eco-environmental Standards and Rules for the Formulation and Revision of National Eco-environmental Standards, further improving the top-level design of the ecological and environmental standards management system and setting the direction of future work on the formulation and implementation of ecological and environmental standards.

3. **The reform of the system of compensation for ecological and environmental damage has been in full swing.** Case practice has made positive progress. As at the end of November 2021, over 7600 cases of ecological and environmental compensation had been handled nationwide, which involved more than RMB 9 billion of compensation, pushing forward the management and remediation of damaged environment. A system of compensation for ecological and environmental damage has been incorporated into 19 local environmental protection regulations at the provincial level.
4. **Intra-Party regulations and normative documents have played a key leading role.** A number of intra-Party environmental regulations, such as provisions on central environmental protection inspections and the measures for holding Party and government leaders and cadres accountable for ecological and environmental damage, have been formulated or revised successively, which have not only promoted the fulfillment of the political duties for ecological progress and environmental protection, but also effectively facilitated the process of rule of law in environmental protection.
5. **Rules and regulations have been put in place for law-based pollution control.** A series of documents have issued for law-based governance in all dimensions, such as a law-based country, government and society, and the awareness about the rule of law. MEE has issued the *Guiding Opinions on Deepening Eco-environmental Administration and Continuously Strengthening Pollution Control in accordance with the Law*, which is a comprehensive document for promoting law-abiding pollution control in the ecological and environmental protection system.

E.1.3 Improvement of Environmental Governance Propelled by Green Urbanization

Urban and rural development is an important vehicle for driving green development and building a beautiful China. The 13th FYP period was vital to promoting the implementation of green urbanization and fully achieving the national new urbanization targets for 2020. Early in 2015, the CPC Central Committee and the State Council released the *Guideline on Accelerating the Building of an Ecological Civilization*, which proposes to energetically advance green urbanization, protect natural landscapes and speed up the building of beautiful countryside.

In terms of laws and regulations, a legal framework for green urbanization has been established. This covers laws and regulations such as the *Energy Conservation Law of the People's Republic of China* (Amended in 2018), the *Law of the People's Republic*

of China on the Prevention and Control of Atmospheric Pollution (Amended in 2018), the Regulation on Energy Conservation in Civil Buildings, and the Regulation on Energy Conservation in Public Institutions; and comprehensive policies such as the Guideline of the General Office of the State Council on Scientific Greening (GBF [2021] No. 19), the Master Plan for Creating Green Lifestyles (FGHZ [2019] No. 1696) and the 14th Five-Year Plan for the Development of a Circular Economy (FGHZ [2021] No. 969).

In terms of assessment mechanisms, an accounting system for green urbanization has been established. The Guideline of the CPC Central Committee and the State Council on Supporting Shenzhen in Building a Pilot Demonstration Area of Socialism with Chinese Characteristics, which was issued in August 2019, explicitly proposes to “explore the implementation of an accounting system for the value of ecosystem services”. Later, the Guideline of the CPC Central Committee and the State Council on Supporting Zhejiang’s High-quality Development and Construction of a Demonstration Zone for Common Prosperity promulgated in June 2021 proposes to “explore how to improve the gross ecosystem product (GEP) accounting and application system with Zhejiang’s characteristics”. The Guideline of the State Council on Supporting Guizhou in Blazing New Trails in the Development of the Western Region in the New Era introduced in January 2022 proposes to explore the inclusion of GEP in relevant performance appraisal systems and put into effect the assessment of both economic development and GEP. So far, Zhejiang and Guizhou have both issued their own technical specifications for GEP accounting. Provinces (autonomous regions and municipalities directly under the central government) such as Qinghai, Hainan and Inner Mongolia, 23 cities (prefectures and leagues) including Shenzhen and Lishui, and more than 100 counties (county-level cities and districts) including Arxan and Chishui, have conducted pilot programs for GEP accounting. MEE has enacted several GEP accounting standards, including the *Ecosystem Assessment: Technical Specification for Accounting Gross Ecosystem Product (GEP)*, thereby laying a foundation for the implementation of GEP accounting.

In practice, local governments have pushed for green urbanization with local characteristics in light of their respective development realities. China-Singapore Tianjin Eco-City emphasized job-housing balance and mixed land use, established an economical, efficient and circular energy system, and paid attention to waste collection and recycling. Xiong’an New Area in Hebei Province created a national land and space pattern that gives priority to ecological protection within 1770 km², with blue and green spaces accounting for no less than 70%, and formed urban forms that conform to nature. Chongqing energetically upgraded urban and rural infrastructure, built the Yulu Avenue, improved the environment around the native Yueyin Lake, and advanced regional iconic eco-housing projects including Luneng Star City by upholding the principle of “weighing protection over development”.

Moreover, the General Office of the State Council issued the *Work Plan for Pilot Construction of “Zero-Waste Cities* in February 2018 and later the MEE published a list of 11 pilot “zero-waste” cities on April 30, 2019. In June 2021, 15 ministries including the Ministry of Housing and Urban–Rural Development

(MOHURD) issued the *Opinions on Strengthening Green and Low-Carbon Development in Counties*, so as to peak carbon dioxide emissions and achieve carbon neutrality. On October 24, 2021, the State Council issued the Action Plan for Carbon Dioxide Peaking Before 2030, which requires peaking carbon emissions in urban and rural development, promoting green and low-carbon development of urban and rural areas, and implementing green and low-carbon development requirements. In February 2022, the State Council approved the *Guiding Opinions on Accelerating the Construction of Environmental Infrastructure in Cities and Towns*, which proposes to build an environmental infrastructure system that integrates waste disposal facilities and monitoring and supervision capabilities by 2025 and establish a modern environmental infrastructure system that is systematic and complete, efficient and pragmatic, intelligent and green, safe and reliable by 2030.

On the whole, eastern coastal provinces such as Guangdong, Jiangsu, Shandong and Zhejiang have a higher level of green urbanization, and are all at the forefront across the country. Central provinces like Henan, Hubei and Hunan are in the middle; while western remote provinces including Tibet and Gansu generally lie at the bottom and lag far behind in terms of green urbanization.

E.1.4 High-Quality Development Fueled by Major River Basin Development Plans

The Yellow River and the Yangtze River, two “mother rivers” of the Chinese nation, are the cradles of Chinese civilization. For historical reasons, the two river basins have suffered from problems such as ecological damage and environmental pollution to varying degrees, seriously containing the sustainable development of the two regions. The Yellow River basin sees outstanding problems with water ecology and water resources exploitation and utilization, with the shrinkage of wetlands in the source region yet to be fundamentally curbed. The Yangtze River basin is faced with numerous problems including water loss and soil erosion, lake eutrophication and soil salinization, depletion of fish resources, and severe water pollution in some areas.

Since the 18th CPC National Congress, issues regarding the green development and long-term healthy and sustainable development of the two river basins have been put on the national agenda. The CPC Central Committee has put forward in succession major national strategies for regional development in the new era, including “development of the Yangtze River Economic Belt (YREB)” and “ecological protection and high-quality development of the Yellow River basin”. Over the past five years, relevant provinces, autonomous regions and municipalities within the two river basins have actively practiced the ecological civilization concept that “lucid waters and lush mountains are invaluable assets”, further implemented the new development philosophy and advanced ecological protection and high-quality development of the river basins, with significant progress made.

E.1.4.1 High-Quality Development of the Yellow River Basin

On September 18, 2019, Chinese President Xi Jinping chaired and addressed a symposium on the ecological protection and high-quality development of the Yellow River basin in Zhengzhou. In his speech, Xi emphasized that we should adhere to the concept that lucid waters and lush mountains are invaluable assets, give priority to ecological protection and green development, take into account the conditions of the upper, middle and lower reaches, the main stream and tributaries, and both banks of the Yellow River, and strengthen coordinated protection and harnessing of the river to ensure the long-term stability of the Yellow River, promote high-quality development of the river basin and turn the river into a happy river that benefits the people. On January 3, 2020, Xi stressed at the sixth meeting of the Central Committee for Financial and Economic Affairs that the Yellow River basin should make great efforts to protect and harness the river in a coordinated manner, and take the path of ecological protection and high-quality development. In August 2020, the Political Bureau of the CPC Central Committee deliberated the *Outline of the Plan for the Ecological Protection and High-Quality Development of the Yellow River Basin*, and required improving the ecological environment in the Yellow River basin by adjusting measures to local conditions and conforming to the laws of nature, and striving to make significant progress during the 14th FYP period.

On February 1, 2021, MEE issued the *Key Tasks for Promoting Ecological and Environmental Protection in the Yellow River Basin in 2020*. Later, 18 provinces (municipalities) released and put into force their respective “three lines and one list”. In August 2021, the National Development and Reform Commission (NDRC), together with the MOHURD, issued the *Implementation Plan for Municipal Sewage and Garbage Treatment in the Yellow River Basin during the 14th Five-Year Plan Period* to guide the orderly implementation of urban sewage and waste treatment, promote high-quality construction and high-level operation and maintenance of facilities, and facilitate ecological protection in the basin.

Provinces and autonomous regions in the Yellow River basin have taken corresponding actions. On November 29, 2019, Sichuan specified 17 key tasks with respect to environmental protection and ecological restoration of the Yellow River. In April 2020, Shaanxi issued and enacted the *Key Work Points for Promoting Ecological Protection and High-quality Development of the Yellow River Basin in 2020*, which specifies 22 key tasks. In January 2022, Shanxi laid down a list of key tasks for ecological and environmental protection for 2022. In March 2022, Gansu issued the *Plan for Ecological Protection and High-quality Development of the Yellow River Basin* and other related documents. At this point, the dynamics of ecological protection and high-quality development in the upper, middle and lower reaches of the Yellow River basin have taken shape. Shandong also prepared a provincial plan for ecological protection and high-quality development of the Yellow River basin and formulated policies and measures for the protection and harnessing of the Yellow River, supporting high-quality development of the Yellow River basin and preserving, inheriting and carrying forward the intangible cultural heritage within the basin.

On June 5, 2020, the Supreme People’s Court promulgated a guideline on providing judicial services and guarantees for ecological protection and high-quality development of the Yellow River basin. The guideline explicitly proposes to punish environmental pollution and other crimes by adhering to the strictest rule of law.

E.1.4.2 High-Quality Development of the Yangtze River Basin

In April 2018, President Xi Jinping stressed at a symposium on further promoting the development of the YREB that “The key to promoting the development of the YREB in new circumstances is to correctly understand the relationship between comprehensive advance and breakthroughs at key points, between environmental protection and economic development, between overall planning and unremitting efforts, between eliminating old drivers of growth and fostering new ones, and between self-development and coordinated development”.

In order to implement General Secretary Xi Jinping’s important instructions of “stepping up conservation of the Yangtze River and stopping its overdevelopment”, the CPC Central Committee and the State Council issued the *Outline of the Plan for the Integrated Regional Development of the Yangtze River Delta* in December 2019. In July 2020, the General Office of the State Council distributed the *Notice on Effectively Carrying out the Fishing Ban in the Yangtze River Basin*. In response to this, the Ministry of Agriculture and Rural Affairs (MARA), the Ministry of Public Security (MPS) and the State Administration for Market Regulation (SAMR) took the lead in formulating the Implementation Plan for Further Strengthening the Resettlement of Fishermen in Key Areas of the Yangtze River where Fishing is Prohibited and Fishermen are Retired, the Action Plan for a Special Campaign on Combating Illegal Fishing in the Yangtze River and the Special Action Plan for Cracking down on Market Sales of Illegal Catches in the Yangtze River respectively. The Yangtze River Protection Law, which was put into force on March 1, 2021, is China’s first legislation on a specific river basin. In 2021, MEE deliberated and adopted in principle the *Action Plan for Deepening the Protection and Restoration of the Yangtze River*, the *Action Plan for the Ecological Conservation and Governance in the Yellow River*, the *14th Five-Year Action Plan for the Control of Urban Black and Odorous Water Bodies and Environmental Protection*, the *Action Plan for the Comprehensive Improvement of Key Marine Areas*, and the *National Plan on Marine Dumping Areas (2021–2025)*, and put into effect the *Law of the People’s Republic of China on the Protection of the Yangtze River*.

After five years of green development, the YREB is becoming the main force of high-quality economic development in China and contributing a growing share to China’s GDP. The YREB has been integrated into initiatives such as the Belt and Road Initiative (BRI), the Western Region Development and the New Western Land-Sea Corridor, and provinces and cities along the Yangtze River have continued to advance green transition of project financing and industrial orientations, and spare no efforts to build new economic growth poles. The YREB has undergone major changes in three areas: first, fundamental changes in the ideas and concepts of cadres and the

masses; second, significant changes in the water quality of the Yangtze River; third, marked changes in the ecological environment. The improvement of the Yangtze River shoreline has been promoted on all fronts, with green ecological corridors basically formed on both sides of the river.

E.1.5 CCICED Policy Recommendations

Over the past five years, CCICED has put forward a whole raft of constructive policy recommendations such as biodiversity conservation, improvement of living conditions, and pollution control, mainly covering the following three areas.

E.1.5.1 Ecological Progress

With ongoing concerns about the building of an ecological civilization, CCICED proposed in 2020 once again that in terms of development concepts, China should unswervingly promote ecological conservation, implement the concept that “lucid waters and lush mountains are invaluable assets, promote a comprehensive green transition of the economy and society, and realize people-centered green and high-quality development. In terms of policy objectives, China should maintain the strategic focus on making ecological progress and align the green development targets in the 14th FYP with the United Nations 2030 Agenda for Sustainable Development.

E.1.5.2 Green Urbanization

With respect to the greening of cities and towns, CCICED proposed in 2018 to change traditional mindsets and fully integrate green standards into urban and rural planning; advance energy conservation, emission reduction and industrial upgrading; and come up with innovative solutions in light of local conditions. It provided systematic policy recommendations in 2019, including that the 14th FYP should contain a strategy for reshaping China’s urbanization based on ecological conservation, seek endogenous growth and turn green urbanization into an important driver of high-quality economic development in China; that a new understanding of the urban–rural relationship should be developed; that under the new development philosophy, we should go beyond the traditional knowledge of “agriculture, rural areas and farmers” and expand new green supplies in rural areas by making full use of the Internet and other new technologies as well as unique natural, environmental, cultural and other advantages of the countryside.

The 2020 and 2021 CCICED Policy Recommendations proposed to push ahead with green transition of cities with the goal of green prosperity, low carbon and intensiveness, recycling, fairness and inclusiveness, safety and health. Besides, China should step up efforts to build green and low-carbon infrastructure in cities, perfect county-level green development strategies, combine efficiently using land resources

with the transformation and upgrading into modern green agriculture, industrial layout adjustment, farmers' employment and continuous income increases, and stick to the "one-pole, multi-wing" integrated rural development model which is dominated by green development and supported by diversified development forms.

E.1.5.3 Green Development of Major River Basins

With respect to the green development of the two river basins, CCICED put forth policy recommendations for a Yangtze River protection law early in 2005. In the new stage, CCICED put forward the following recommendations in 2018: (1) strategically, China should give priority to specific areas having a significant impact on the health of the entire river basins, especially solid waste pollution, in the environmental governance and ecological restoration. (2) China should accelerate the legislation on Yangtze River protection, which should reflect systematic, differentiated and targeted protection of the river basin. (3) China should guide the participation of multiple stakeholders, scientifically identify and address the negative impacts of environmental pollution and ecological damage on the production and life of community residents. (4) Both mandatory and voluntary mechanisms should be established to ensure active engagement of commercial capital in ecological and environmental protection. (5) Existing government projects should be expanded to open up financial channels for commercial capital investment, for example, setting up an ecological fund for the Yangtze River.

In the 2019 Policy Recommendations, CCICED proposed from a long-term perspective to make the YREB a strategic priority in the 14th FYP and build it into a model and benchmark for green development of river basins. Relevant policy recommendations include quickening the formulation of an ecological and environmental protection strategy for the YREB, accelerating the establishment of a basin-wide ecological compensation mechanism involving a vertical compensation option and multiple horizontal compensation options, and strengthening the hard constraints on ecological protection in the YREB, among others.

E.2 Environmental Governance and Rule of Law

E.2.1 Exploring the Further Reform and Modernization of National Environmental Governance System

Xi's Report to the 19th CPC National Congress sets forth the strategic arrangements such as speeding up reform of the system for developing an ecological civilization, promoting green development and building a beautiful China. The report also states that China will strengthen overall planning, organization and leadership for

building an ecological civilization, establish regulatory agencies to manage state-owned natural resource assets and monitor natural ecosystems, and improve environmental management systems. Over the past five years, the country has provided safeguards for the building of an ecological civilization by deepening the reform of the management systems for natural resources and the ecological environment, implementing the strictest ecological and environmental protection system and establishing an environmental governance system in which government takes the lead, enterprises assume main responsibility and social organizations and the public also participate.

The first session of the 13th NPC approved the *Institutional Reform Plan of the State Council* to set up the MEE and the Ministry of Natural Resources (MNR). MEE is mainly responsible for establishing and improving the fundamental systems with respect to the ecological environment, coordinating, supervising and regulating major ecological and environmental issues, and supervising and administering to ensure the attainment of national emission reduction targets. It also supervises the work of nuclear and radiation safety, takes the leading role in the regulation of ecological environment access and in eco-environment monitoring, initiates the Central Government's supervision over the protection of the ecological environment, guides and coordinates educational campaigns over eco-environmental protection. MNR is mainly responsible for coordinating the conservation of mountains, rivers, forests, farmlands, lakes and grasslands, unifying the power over national land and space utilization and ecological protection and restoration, and solving problems such as omission committed by the owners of natural resources and overlapping spatial planning.

In November 2018, the *Guideline on Comprehensively Strengthening Ecological and Environmental Protection and Resolutely Putting up the Uphill Battles against Pollution* revealed the connotations of the environmental governance system and key directions of reform, and proposed a framework consisting of five systems such as the environmental supervision system, the economic policy system, the rule of law system, the capacity assurance system and the social action system. This provides an important institutional guarantee for achieving milestones in the battle against pollution.

In November 2019, the *Decision of the CPC Central Committee on Some Major Issues Concerning Upholding and Improving Socialism with Chinese Characteristics and Modernizing National Governance System and Capacity* defined the important position of the system of institutions for ecological progress in China's national governance system, making the environmental governance system a key part of the national governance system.

On March 3, 2020, the *Guiding Opinions on Building a Modern Environmental Governance System* set the target of establishing a sound system of leadership responsibility, corporate responsibility, universal action, regulation, market, credit and laws, regulations and policies for environmental governance by 2025, and forming an environmental governance system featuring clear orientation, scientific decision-making, efficient execution, effective incentives, multi-party engagement and benign interactions.

In September 2021, the General Office of the State Council issued the *Opinions on Deepening the Reform of the Compensation System for Ecological Protection*, which aims to improve the classified compensation system that targets ecological elements, determine the level of compensation according to the economic and social development of the ecological protection areas and the performance in ecological protection, provide appropriate compensation for the protection costs of diverse ecological elements, and implement a comprehensive compensation system that takes into account ecological space functions.

The *Opinions of the CPC Central Committee and the State Council on the Complete and Accurate Implementation of the New Development Concept to Peak Carbon Emissions and Achieve Carbon Neutrality* was issued on September 22, 2021. The guideline states that to achieve carbon dioxide peaking and carbon neutrality, we should place strict control over fossil energy consumption, accelerate coal reduction, actively develop non-fossil fuels, turn to renewable energy alternatives and deepen the reform of energy systems and mechanisms in the principle of “overall planning by the central government, conservation first, dual-wheel drive, coordination of domestic and international energy resources, and risk prevention”.

The *Opinions of the CPC Central Committee and the State Council on Deepening Pollution Prevention and Control* issued on November 2, 2021 lays down the general requirements, main objectives, major tasks and safeguard measures for furthering the battle against pollution. According to the guideline, the structural, fundamental and tendency pressures on ecological and environmental protection in China have not yet been eased, and pollution problems are still acute in key regions and industries, indicating a long way away from achieving carbon dioxide peaking and carbon neutrality and from building an ecological civilization.

The *Measures for Special Inspections on Ecological and Environmental Protection* was brought into effect on May 10, 2021. It regulates and guides the special inspections by inspection teams by defining the targets and priorities of inspection, standardizing the procedures and authority of inspection, tightening up the disciplines and requirements for inspection and further regulating the special inspections on ecological and environmental protection, thus facilitating the resolution of outstanding environmental issues and the fulfillment of environmental responsibilities.

Environmental information disclosure is a social responsibility of enterprises and an important means of eliminating market failures caused by information asymmetry. On May 24, 2021, the General Office of the MEE issued the *Reform Plan for the Law-based Environmental Information Disclosure System*, which sets forth the general idea and key tasks of the reform and provides the top-level design for a law-based environmental information disclosure system, which focuses on enterprises' responsibility for ecological and environmental protection. The aim is to establish a law-based environmental information disclosure system that features corporate self-regulation, effective management, strict supervision and strong support.

E.2.2 Judicial Support for Environmental Governance

The enforcement of a sound legal system entails a powerful judicial system, and standardized and strict judicial action is an integral part of environmental governance and an important tool that ensures the effective implementation of systems and regulations. The *Catalogue for Guiding Integrated Administrative Law Enforcement Matters for Eco-environmental Protection*, which was issued on March 9, 2020, provides for the requirement of unifying law enforcement for ecological and environmental protection, specifies the comprehensive administrative law enforcement functions in this regard, and lays down the administrative penalties and administrative mandatory items for ecological and environmental protection in accordance with relevant laws and administrative regulations. On January 7, 2021, MEE promulgated the *Guiding Opinions on Optimizing the Way of Law Enforcement for Eco-environmental Protection to Improve the Effectiveness of Law Enforcement*, which points out the general direction and path of the current work for environmental law enforcement teams nationwide, systematically sums up the law enforcement systems and mechanism, and provides the clear direction and specific systems for the enforcement work across the country.

In 2021, MEE organized the review of typical cases of environmental violations and crimes with respect to hazardous waste across provincial administrative regions, including the case of illegal collection of waste motor oil and suspected illegal disposal of hazardous waste by a waste oil recovery company in Ningbo, Zhejiang Province, the case of illegal dumping of waste mineral oil across administrative regions in Linyi, Shandong Province, and the case of illegal collection and transfer of waste mineral oil and disturbance of social administration order in Changde, Hunan Province. In these cases, some offenders illegally dumped, landfilled and disposed of hazardous waste across provinces, some sold simply disposed hazardous waste as quality products or mixed the same with products, and some related to the criminal gangs that had been long engaged in the dark industrial chain of illegal disposal of hazardous waste to pollute the environment. Local environmental authorities worked closely to ensure the smooth operation of the joint law enforcement mechanism for trans-provincial crimes, collaborated with public security and procuratorial organs to form synergies, and organized inter-provincial investigations based on the clues from the public and grassroots grid service managers, effectively deterring environmental violations and criminal acts related to hazardous waste.

On April 27, 2020, MEE announced the first case where illegal use of ozone depleting substances (ODS) constituted the crime of environmental pollution and was subject to criminal punishment in China. The person held liable was sentenced to 10 months' imprisonment by the local court for polluting the environment. On October 29, 2021, MEE launched a special ODS-related enforcement campaign, with each of the four illegal producers fined RMB 1 million.

E.2.3 Introducing Pollutant Discharge Permits

On January 24, 2021, the State Council unveiled the *Regulations on the Administration of Pollutant Discharge Permits* (hereinafter referred to as the “*Regulation*”). As the core system that administers stationary pollution sources, the Regulation concerns the building of a system of institutions for ecological progress and an environmental governance system, and lays a legal basis for improving the environmental quality and the stationary pollution source management system.

The *Regulation* specifies that pollutant discharging units are primarily responsible for controlling pollutant discharge. Pollutant discharge permits are legal instruments whereby pollutant discharging units undertake the obligations and responsibilities for pollutant discharge control, which are legally binding and mandatory and return the responsibilities for controlling pollutant discharge to enterprises. The *Regulation* stipulates the scope of responsibilities of pollutant discharging units for controlling pollutant discharge, information recorded on a pollutant discharge permit, requirements for outlet setting and standardized management of outlets, as well as specific requirements for monitoring, environmental management ledger records, executive reports on pollutant discharge permits, among others.

The *Regulation* strengthens the responsibilities of competent environmental authorities for ongoing and ex-post oversight, and requires competent environmental authorities to establish a nationally unified information platform for the management of pollutant discharge permits, thus creating conditions for routine law enforcement and supervision on pollutant discharging units for the purpose of optimizing their environmental protection performance levels. It also provides a nationally unified information platform for the disclosure of discharge information and regulatory information by introducing social supervision, establishes a mechanism for sharing information on environmental compliance and integrity of enterprises, and enhances the credit constraints of pollutant discharge permits.

E.2.4 Continuing to Improve Environmental Laws and Placing Climate Legislation on the Agenda

Environmental laws are an important and essential way of maintaining the environmental governance order, and regulate the environmental protection behaviors of the public and enterprises. Sound environmental laws can lead to more scientific, normative and well-grounded environmental governance work, with clearly defined responsibilities of polluters to promote the improvement of the environmental governance system. Below lists some environmental laws issued or revised between 2018 and 2022, which provide important support for the administration and management of environmental protection and escort the reform and development of environmental protection in China.

The *Nuclear Safety Law of the People's Republic of China* (the “Nuclear Safety Law”) came into force on January 1, 2018. It is of great significance to guaranteeing nuclear safety, preventing and dealing with nuclear accidents, safely using nuclear energy and protecting the safety and health of the public and those engaged in the nuclear sector.

The *Law of the People's Republic of China on Prevention and Control of Soil Pollution*, adopted on August 31, 2018, aims to strengthen the concept of prevention from the source and reduce pollution generation, establish a sound soil pollution liability mechanism, impose severe punishments on pollution and achieve innovation in multiple systems: risk control and classified management; clear responsibilities and strict supervision; meticulous regulation and thorough control; special management of sensitive land uses.

On October 26, 2018, the sixth meeting of the Standing Committee of the 13th NPC adopted the *Decision on Amending 15 Laws Including the Law of the People's Republic of China on the Protection of Wildlife*, under which the *Environmental Protection Tax Law of the People's Republic of China* was amended, greening the tax system and accelerating the green reform of the tax system. The *Law of the People's Republic of China on the Prevention and Control of Desertification* was amended to better prevent and control land desertification, and promote sustainable economic and social development. The *Energy Conservation Law of the People's Republic of China* was amended to promote society-wide energy saving, improve the energy utilization efficiency and boost coordinated and sustainable economic and social development. The *Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution* was amended to protect and improve the environment, prevent atmospheric pollution, strengthen the responsibilities of local governments with respect to environmental protection and improvement of air quality with the aim of improving ambient air quality, with the supervision over local governments intensified.

According to the second amendment to the *Law of the People's Republic of China on Environmental Impact Assessment* adopted on December 29, 2018, China will implement a sustainable development strategy to prevent environmental pollution and ecological damage, curb the adverse impacts of the implementation of planning and construction projects on the environment, and advance coordinated development in economic, social and environmental spheres.

On December 28, 2019, the *Forest Law of the People's Republic of China* was amended to uphold four principles: (1) giving priority to ecology and protection and promoting sustainable development; (2) respecting and conforming to nature and following the laws of forest protection, cultivation and utilization; (3) ensuring sustainable use of forest resources through classification and scientific management; (4) sticking to the principles while being flexible, having in place strict management and protection systems in line with national conditions while leaving room for the formulation of specific measures and further reforms.

The *Law of the People's Republic of China on the Prevention and Control of Environmental Pollution Caused by Solid Wastes* was amended on April 29, 2020. It is an important foundation and the main basis for the environmental management

of solid waste in China. With the law in place, China has established sound systems for the prevention and control of pollution from solid waste.

Adopted on December 26, 2020, the *Yangtze River Protection Law* is the first law on a specific river basin in China.

The third amendment to the *Grassland Law of the People's Republic of China* was adopted on April 29, 2021, which aims to protect, develop and make rational use of grasslands, improve the ecological environment, maintain biodiversity, modernize animal husbandry and promote the sustainable development of the economy and society.

Adopted on December 24, 2021, the *Law of the People's Republic of China on the Protection of Wetlands* protects the ecological environment of wetlands through institutions and regulations. Committed to making wetlands shared green spaces for the people, the law is a guideline for society at large to strengthen wetland protection and restoration, and a key move for China to lead global ecological governance.

In order to better cope with climate change and support the attainment of the carbon peaking and carbon neutrality targets, MEE issued the *Guideline on Coordinating and Strengthening Climate Change Response and Ecological and Environmental Protection* on January 7, 2021. The guideline specifies the main areas and key tasks for coordinating and strengthening climate change response and ecological and environmental protection, and defines the tasks for promoting the coordination of regulations and policies in five areas: laws and regulations, standards, environmental and economic policies, synergies between pollution abatement and carbon reduction, and coordination between climate change adaptation and ecological protection and restoration.

E.2.5 Deepening the Green Financial System

Marked by the *Guideline on Building a Green Financial System* jointly issued by the People's Bank of China (PBOC), the Ministry of Environmental Protection (MEP) and five other ministries and commissions in August 2016, China has initiated the building of a green financial system across the board. In June 2017, PBOC, CBRC, the Standardization Administration of China (SAC) and other departments jointly issued the *Development Plan for the Construction of a Standardized System for the Financial Sector (2016–2020)*, listing the “green financial standardization” as a priority in the standardization of the financial sector.

After several years of continuous efforts, the development of green finance in China has achieved remarkable results: first, the green financial products and market system have basically taken shape. By the end of 2021, the balance of China's green loans in domestic and foreign currency had reached nearly RMB 16 trillion, a YoY increase of 33%, ranking first in the world in terms of stock size. 2021 saw the issuance of over RMB 600 billion of green bonds in China, a YoY increase of 180%, with a balance of RMB 1.1 trillion, ranking among the top in the world.

Second, the framework and organizational structure of green financial standards have been basically established. In January 2018, according to the *Development Plan for the Construction of a Standardized System for the Financial Sector (2016–2020)* jointly issued by PBOC and four other ministries and commissions, the China Financial Standardization Technical Committee (CFSTC) approved the establishment of the Working Group on Green Finance Standards led by PBOC. In September 2018, the first plenary meeting of the Working Group was held in Beijing, and the organizational structure for the development of green finance standards was established. The six major categories of green finance standards studied by the Working Group are general basic standards on green finance, green financial products and service standards, green credit rating and assessment standards, green finance information disclosure standards, green finance statistics and sharing standards, and green financial risk management and protection standards. Based on this, China's framework system for green finance standards has also basically formed.

Third, a sound incentive and constraint mechanism for green finance has been gradually developed. The carbon-reduction supporting tool and the special refinancing loan to support the clean and efficient utilization of coal created by PBOC have driven more social capital to invest in green and low-carbon areas. In the meantime, PBOC has also carried out a comprehensive evaluation on green finance in banking financial institutions, and has included green loans and green bonds in the scope of quantitative evaluation, guiding financial institutions to increase green asset allocation in an orderly manner.

Fourth, regional green finance standards are gradually being established and improved. The pilot zones for green finance reform in six provinces and nine regions have been vigorously developing green finance in the past few years, and local green finance standards have been introduced. At present, Huzhou, Quzhou, Guangdong Huadu District, Ganjiang New Area and Gui'an New Area, as pilot zones for green finance reform, have all made great progress in the construction of green finance standards systems. In addition, there are increasing innovative standards for financial instruments, products and services. Among them, work related to the certification standards for green enterprises, project standards for green project libraries and evaluation standards for green banks has been actively carried out in the pilot zones, and the regional green finance standards systems have been increasingly improved. For example, the Huzhou Pilot Zone for Green Finance Reform and Innovation released four local green finance standards in June 2018, including the *Evaluation Standards for Green Financing Projects*, the *Evaluation Standards for Green Financing Enterprises*, the *Evaluation Standards for Green Banks*, and the *Construction Standards for Green Finance Franchise Institutions*.

Fifth, international cooperation on green finance has been deepened. In September 2018, ISO officially established the Technical Committee on Sustainable Finance (ISO/TC322). According to the *China Green Finance Progress Report (2018)* released by PBOC, TC322 will develop a framework guide for sustainable finance management, clarifying relevant concepts, terminology, principles and practical guidelines. In March 2019, the first meeting of TC322 was held in London, which elected Ma Jun, Director of the Green Finance Committee, China Society for Finance

and Banking as the vice-chair of TC322, and unanimously approved to launch the project of Sustainable Finance Terminology Standards. In 2021, PBOC chaired and drafted the *G20 Sustainable Finance Roadmap* and the *G20 Sustainable Finance Synthesis Report*. PBOC also participated in and launched the Central Banks and Supervisors Network for Greening the Financial System (NGFS), which is becoming one of the most influential international cooperation platforms for green finance.

The “three functions” of green finance (i.e. resource allocation, risk management and market pricing) are emerging. Firstly, through monetary policy, credit policy, regulatory policy, mandatory disclosure and green evaluation, financial resources have been guided and leveraged towards low-carbon projects, green transition projects, CCS and other green innovation projects. Secondly, the financial system’s ability to manage climate change-related risks has been enhanced. Thirdly, a national carbon trading market is under construction, and carbon futures and other derivative products have been developed, with reasonable carbon price set through trading. The “five pillars” (i.e. green financial standards system, regulation and information disclosure requirements for financial institutions, the incentive and restraint mechanism, green financial products and market system, and international cooperation in green finance) have also taken initial shape, and are playing an increasingly important role in supporting China’s low-carbon transition and high-quality development. China’s multi-level green financial products and market system has basically taken shape.

On April 21, 2021, PBOC, NDRC and CSRC jointly issued the *Notice on Printing and Distributing the Green Bond Endorsed Project Catalogue (2021 Edition)*, with which the *Green Bond Endorsed Project Catalogue (2021 Edition)* (hereinafter referred to as the “2021 Edition Catalogue” or the “New Edition Catalogue”). This is the first update to China’s Green Bond Endorsed Project Catalogue and an important document marking the harmonization of green bond taxonomy.

On May 27, 2021, PBOC issued the *Green Financial Evaluation Program for Banking Financial Institutions*. The *Program* has revised the 2018 program and upgraded from green credit to green finance: firstly, it has expanded the business coverage for assessment, taking into account the development of green loans and green bonds in an integrated manner, and reserving space for further assessment of new business models such as green equity investment and green trusts; secondly, it has revised the corresponding evaluation indicators based on the expanded assessment scope; thirdly, it has expanded the application scenarios of evaluation results, and incorporated the results of green finance performance evaluation into the rating of financial institutions by PBOC.

On November 4, 2021, the International Platform of Sustainable Finance (IPSF), a joint initiative of China, Europe and other economies, held its annual meeting during the UN Climate Change Conference (COP26), and released the *Common Ground Taxonomy: Climate Change Mitigation*. The Common Ground Taxonomy, jointly released by China and the EU, marks the gradual convergence of green finance standards between countries. On October 15, 2021, the Sub-forum themed “Financial Sector Supporting Biodiversity” was held during the Ecological Civilization Forum of the first part of the 15th meeting of the Conference of the Parties to the Convention

on Biological Diversity (COP15), launching a global phase of biodiversity finance development. In October 2021, 13 institutions including the Asian Infrastructure Investment Bank (AIIB), Industrial Bank, the International Finance Forum (IFF), the United Nations Environment Programme (UNEP) and the World Bank (WB) launched the “Global Joint Initiative on the Partnership of Biodiversity and Finance” in Beijing, calling on financial institutions to incorporate biodiversity conservation into their business strategies, decision-making processes and financing policies; and encouraging financial institutions to work with environmental protection organizations in developing more financial instruments and financing products, and in mobilizing more financial resources to support biodiversity conservation. In April 2022, the joint research group set up by the Central Banks and Supervisors Network for Greening the Financial System (NGFS) and the International Network for Sustainable Financial Policy Insights, Research, and Exchange (INSPIRE) released a report titled “Central Banking and Supervision in the Biosphere: An Agenda for Action on Biodiversity Loss, Financial Risk and System Stability”, calling upon central banks and financial regulators all over the world to take action to address the risks associated with nature and biodiversity.

The deepening of the green financial system can help push the development of green finance, thereby accurately guiding the allocation of resources, controlling the flow of capital, safeguarding the market order, preventing market risks, accurately energizing the development of key areas such as environmental protection, pollution prevention and control and clean emission reduction, reducing the pressure on resources and the environment, and contributing to ecological progress.

E.2.6 Incorporating Carbon Emission Impact Assessment (CEIA) into Environmental Impact Assessment (EIA)

On May 31, 2021, MEE issued the *Guiding Opinions on Strengthening Prevention and Control from the Source in Energy-Intensive and High-Emission Projects for Ecological and Environmental Protection* (hereinafter referred to as the *Guiding Opinions*, HHP [2021] No. 45). Article 7 of the *Guideline* requires incorporating CEIA into EIA. Environmental authorities and administrative approval departments at all levels should actively advance the pilot EIA program for these “two-high” projects, and align and implement carbon dioxide peaking action plans for relevant regions and industries and policy requirements such as clean energy alternatives, clean transportation and total coal consumption control. In the EIA process, identification of the source items of pollutants and carbon emissions, source intensity accounting, analysis of the feasibility of pollution abatement and carbon reduction measures and comparison of different solutions should be carried out in a coordinated manner, with a view to bringing forth the optimal solution to coordinated control. Eligible localities and enterprises are encouraged to explore and implement pilot

projects for coordination between pollution abatement and carbon reduction, and carbon capture, utilization and storage (CCUS).

E.2.7 Improving the Environmental Credit System

In order to “improve our systems for credibility assessment based on environmental protection performance, for mandatory release of environmental information, and for imposing severe punishment for environmental violations” as set forth in the Report to the 19th CPC National Congress, MEE and NDRC have continuously improved the system for credibility assessment based on environmental protection performance, actively built an environmental credit information sharing platform and guided localities to develop new approaches to application of assessment results, with positive results achieved.

First, improving the system for credibility assessment based on environmental protection performance. MEE, together with NDRC and other ministries, issued in succession the *Measures for Assessing Corporate Environmental Credit (for Trial Implementation)* and the *Guideline on Strengthening the Construction of the Corporate Environmental Credit System*, to regulate the information collection, rating, release and application of the results with respect to enterprises’ environmental credit. In 2020, MEE and NDRC drafted and submitted to the General Office of the CPC Central Committee and the General Office of the State Council for the issuance of the *Guiding Opinions on Building a Modern Environmental Governance System*, which clearly proposes to “improve the environmental credit assessment system and implement hierarchical supervision based on the assessment results”.

Second, promoting the construction of an environmental credit information platform. NDRC has completed and put into operation a national credit information sharing platform, and launched creditchina.gov.cn, a website that provides the public with “one-stop” credit information inquiries. MEE has completed the environmental credit information sharing system, a task assigned to it under the “National Credit Information Sharing Platform (Phase II)” project, and set up sub-portals for environmental credit information sharing, so that it can guide local environmental authorities at all levels to collect, push and share environmental credit information and then push complete environmental credit assessment results and information on enterprises’ environmental violations to the national credit information sharing platform. Moreover, MEE and NDRC have worked together to build ministerial data.

Third, strengthening the application of environmental credit assessment results. MEE has actively coordinated with departments concerned to apply the environmental credit assessment results to areas such as green finance, market supervision and price regulation. In 2021, MEE, in conjunction with the General Administration of Customs (GACC), verified the environmental violations of 91 dishonest enterprises subject to integrated punishment for serious breach of laws over the past three years, and studied the continued implementation of punishment for dishonesty on enterprises with environmental violations in accordance with the law. Anhui has

encouraged banking financial institutions to provide enterprises with high environmental credit ratings with simplified credit procedures and preferential interest rates, and Jiangsu has limited the maximum increase in interest rates for loans to enterprises with good environmental credit ratings and above to 15%.

Fourth, promoting and applying the experience in environmental credit assessment management. MEE and NDRC have actively guided localities to promote an apply experience in environmental credit assessment management, and established a three-level assessment system that covers provinces, cities and counties. Environmental authorities in more than 20 provinces, 80 cities and 230 counties across the country have carried out environmental credit assessment among enterprises, with over 30,000 enterprises assessed, including key enterprises under state monitoring, heavily polluting enterprises and enterprises in industries with serious overcapacity. Some localities have gradually expanded the ranks of enterprises to be assessed as necessary. Provinces including Guangdong, Chongqing and Zhejiang have included enterprises and public institutions engaged in EIA, environmental inspection and testing and third-party control of environmental pollution in the scope of mandatory assessment. Some localities have adjusted their environmental credit assessment models in time. Hebei, Henan and Fujian have put into practice dynamic management of environmental credit, and have all realized real-time assessment and facilitated the application of assessment results to green credit, financing through listing, tax refunding, awarding of honorary titles and application for research projects.

E.2.8 Promoting Green and Low-Carbon Lifestyles

For the first time, the *Outline of the 14th Five-Year Plan (2021–2025) for National Economic and Social Development and the Long-Range Objectives Through the Year 2035* elaborates on green development in a separate chapter and sets the targets for promoting green production and consumption: by 2025, remarkable results will be achieved in a shift towards eco-friendly work and lifestyle; by 2035, eco-friendly work and lifestyle will be advanced to cover all areas of society.

On April 29, 2021, the 28th meeting of the NPC Standing Committee adopted the *Law of the People's Republic of China on Food Waste*. This law sets out clear requirements for relevant departments of the State Council, people's governments at all levels and relevant units, as well as penalties for breaking the law. The adoption of the law is of great importance, as it has raised food waste from a moral and public order constraint to a legal one.

On September 22, 2021, the CPC Central Committee and the State Council issued the *Guideline on Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy*. The *Guideline* proposes to accelerate the development of green modes of production and lifestyles; expand the supply and consumption of green and low-carbon products, advocate green and low-carbon lifestyles; include green, low-carbon development in the national education system; launch demonstration campaigns to build a green and low-carbon society;

build social consensus and accelerate the formation of a good pattern of universal participation.

On October 24, 2021, the *Action Plan for Carbon Dioxide Peaking Before 2030* was published. The *Action Plan* proposes to advocate green and low-carbon living patterns. It states that we should curb luxury, waste, and unnecessary consumption, put a resolute stop to wasteful behaviors, and work tirelessly to reduce food waste in the catering industry; promote energy conservation throughout whole society, launch demonstration campaigns to build a green and low-carbon society, intensify initiatives to promote eco-friendly living patterns, select and publicize a group of role models, and foster new trends for green and low-carbon living patterns; vigorously expand green consumption, promote green and low-carbon products, and improve the system for green product certification and labeling; and increase the proportion of green government procurement.

In January 2022, NDRC and other ministries issued the *Implementation Plan for Promoting Green Consumption*, which proposes that by 2025, the concept of green consumption will gain ground, extravagance and waste will be effectively curbed, the market share of green and low-carbon products will be raised sharply, marked results will be achieved in green transformation of consumption in key sectors, green ways of consumption will be generally adopted and a consumption system for green, low-carbon and circular development will take shape. By 2030, green consumption will become a conscious option of the public, green and low-carbon products will be mainstreamed in the market, a green and low-carbon development model for consumption will be substantially formed in key sectors, and green consumption systems, policies and mechanism will be basically established.

E.2.9 CCICED Policy Recommendations

E.2.9.1 Deepening the Reform of Environmental Systems

The 2019 CCICED Policy Recommendations proposed to invite public participation and feedbacks before final decision-making for a project and renew the understanding of the urban–rural relationship. The 2020 CCICED Policy Recommendations stated that in terms of implementation mechanisms, comprehensive measures should be adopted to align short-term targets with mid- and long-term goals and ensure coordinated systems and mechanisms. Efforts should be made to create synergies among legislative, judicial and administrative organs in promoting ecological progress, establish a sound modern environmental governance system, and improve coordination and efficiency in green governance.

E.2.9.2 Judicial Support for Ecological and Environmental Governance

In 2016, CCICED proposed to strengthen the construction of judicial support systems and mechanisms for ecological and environmental protection in the following ways: (1) by giving citizens, enterprises, communities and social organizations access to justice with regard to environmental affairs; (2) by reforming environmental justice systems across administration regions; (3) by advancing public interest litigation over ecological and environmental damage. It recommended improving the public interest litigation system for environmental protection, relaxing restrictions on plaintiff qualification, encouraging citizens and environmental social organizations to take an active part in environmental public interest litigation, and increasing public participation and judicial publicity in trials over the environmental and resources; promoting the establishment of an environmental public interest litigation fund system; advancing the alignment between environmental litigation and non-litigation procedures, and supporting people's procuratorates in filing environmental public interest lawsuits in accordance with the law.

E.2.9.3 Constantly Improving Environmental Laws

In 2018, CCICED proposed to strengthen the legal protection of marine and coastal ecosystems. The legislation on Yangtze River protection should be accelerated, which should reflect systematic, differentiated and targeted protection of the river basin. In 2019, CCICED proposed to amend the government procurement law; revive the carbon market; further improve the total emission control target, speed up the legislation and enhance the binding force of the national carbon trading system; promote allowance auctioning while increasing the industries and sectors covered and establishing a "carbon price" mechanism, so as to build a robust carbon market with effective execution mechanisms. In 2021, CCICED proposed to put into action the *Law on Food Waste*, raise public awareness, change eating habits and reduce food waste; formulate operable implementation rules and schemes in accordance with specific provisions; and establish a coordination mechanism where government takes the lead, industry associations and social governments play a guiding role, catering enterprises set the pace, and consumers are self-disciplined.

E.2.9.4 Deepening the Green Financial System

In 2020, CCICED proposed to improve the green standards system, green fiscal and taxation system, and green financial system, form policy incentives that are commensurate with green development, and promote the implementation of these policies through policy compliance, regulation and enforcement. The value accounting methods and realization mechanisms for ecological capital services should be perfected to promote the high-quality development of the Yangtze and Yellow River

basins. Biodiversity conservation indicators should be integrated into the green finance framework to promote the mainstreaming of conservation finance.

The 2021 CCICED Policy Recommendations put forward three important suggestions on deepening the instrumental role of green finance. First, it is suggested to expand investment and financing related to biodiversity conservation, make ecological conservation, restoration and regeneration an important area of green finance, and further identify necessary initiatives to advance pilot ecological conservation finance; secondly, it is proposed to give play to the role of green finance instruments in the traceability of fisheries sustainability; thirdly, it is recommended to support the sustainable development and post-epidemic green and low-carbon recovery in BRI countries, and promote cross-sectoral cooperation in green energy, green infrastructure and green finance.

E.2.9.5 Improving the Environmental Credit System

In 2019, CCICED proposed to implement market incentives, establish a scientific and coherent green labeling and certification system, and build a statistical indicator system for green consumption and a national green consumption information platform. Market-based means and mandatory regulations on green products should be combined, differentiated tax and market credit incentives should be brought into force, and subsidies that discourage or even hinder the circulation of green products should be phased out. Environmental safeguards and EIA mechanisms should be established to reduce the environmental risks of projects to be built. Green investment principles should be put into action and risk information associated with the environment and climate should be disclosed.

E.2.9.6 Advocating Green and Low-Carbon Lifestyles

In 2018, CCICED proposed to guide multi-stakeholder participation, and identify and address the negative impacts of environmental pollution and ecological damage, among others, on community residents' production and life. Gender issues should be integrated into good ESG (Environmental, Social and Governance) practices through multi-stakeholder participation. Public environmental awareness should be raised via publicity and educational campaigns.

In 2019, CCICED proposed to incorporate green consumption into the 14th FYP as one of the important tasks to build an ecological civilization, and initiate green life campaigns. The demand for green products should be boosted and the exemplary role of celebrities in green consumption should be brought into full play, so that green consumption can become a social fashion.

In 2020, CCICED recommended improving the systems and mechanisms for promoting green consumption, establishing economic incentives and market-driven systems, especially in terms of price, taxation, credit, regulation and market credit, and guiding the supply of green ecological products and services and residents'

green consumption choices. Priority areas for green consumption should be established. Priority should be given to increasing the effective supply of green products and services in key areas such as clothing, food, housing, transportation (and communication), daily necessities and tourism.

In 2021, CCICED suggested to establish a unified national green consumption information platform to publish information on green products and services; and raise public awareness of low-carbon, biodiversity-friendly consumption through capacity building and training related to green consumption and the establishment of a network of interested parties.

E.3 Energy, Environment and Climate

E.3.1 Building a New Power System Dominated by New Energy

On March 15, 2021, Chinese President Xi Jinping pointed out at the ninth meeting of the Central Committee for Financial and Economic Affairs that the 14th FYP period would be a critical window period for carbon dioxide peaking and that the reform of the power system should be deepened to build a new power system with new energy as the mainstay.

To realize the goal, national energy authorities and relevant enterprises and institutions have carried out a large amount of work. In September 2021, NDRC and the National Energy Administration (NEA) issued an official reply to State Grid Corporation of China (SGCC) and China Southern Power Grid (CSG) to promote the pilot program for green electricity trading.

In November 2021, the 22nd meeting of the Central Commission for Comprehensively Deepening Reform deliberated and adopted the *Guiding Opinions on Accelerating the Construction of a National Unified Power Market System*. According to the meeting, China will improve the multi-level unified power market system, build a national power market at a quicker pace, establish unified rules and technical standards for electricity trading, and push for a diversified and competitive electricity market pattern. China will advance the establishment of a power market mechanism that is compatible with its energy transition, orderly promote the participation of new energy in market transactions, scientifically guide power planning and effective investment, and give play to the role of the power market in supporting clean and low-carbon energy transition. SGCC also officially issued the *Inter-provincial Electricity Spot Trading Rules (for Trial Implementation)*, resulting in orderly preparations for the trial operation of inter-provincial electricity spot trading. The launch of inter-provincial electricity spot trading will motivate market players to regulate power surplus and deficiency throughout the grid by market-based means, drive large-scale clean energy accommodation, facilitate the building of a new power

system dominated by new energy, and help achieve carbon dioxide peaking and carbon neutrality.

In January 2022, NDRC and NEA released the *Guiding Opinions on Accelerating the Construction of a National Unified Power Market System*, which states that by 2025, a national unified power market system will be preliminarily established, the national market and provincial/regional markets will operate collaboratively, with integrated design and joint operation of mid- and long-term, spot and auxiliary service markets of electric power and significant improvements in cross-provincial and cross-regional market allocation of resources and green power trading scale, and market trading and pricing mechanisms that are conducive to the development of new energy and energy storage will take shape. By 2030, the national unified power market system will be basically completed.

In achieving the carbon peaking and carbon neutrality targets, energy is the main battlefield, where electricity plays a key role. With new energy flooding power grids, the power system will need to strike a balance between randomly fluctuating load demand and power supply, resulting in fundamental changes in its structure, operation control mode, and planning, construction and management. Then, a new generation power system with new energy power production, transmission and consumption as the mainstay will be formed. Building a new power system dominated by new energy is a complicated task, which requires government leadership, enterprise participation and the concerted efforts from all parties as opportunities and challenges coexist.

E.3.2 Continuously Adjusting and Optimizing the Energy Structure

Continuing to promote the optimization of the energy structure is vital for reducing pollution and emissions, winning the battle against air pollution, and peaking carbon emissions and achieving carbon neutrality.

On June 27, 2018, the State Council issued the *Three-Year Action Plan for Keeping Skies Blue*, which proposes to optimize the energy structure, advance key initiatives such as saving energy and resources across the broad, and effectively promote clean heating in northern China, implement total coal consumption control, launch comprehensive upgrading of coal-fired boilers, accelerate the development of clean and new energy, and develop a green transportation system in key regions including the Beijing-Tianjin-Hebei (BTH) region and surrounding areas, the Yangtze River Delta and the Fen-Wei Plain.

A sound industrial system should be established for biogas. On November 5, 2019, NDRC unveiled the *Catalogue for Guiding Industrial Restructuring (2019 Edition)*, in which biomass power generation and biogas are repeatedly highlighted in the part concerning new energy. On December 6, 2019, 10 ministries including NDRC jointly issued the *Guiding Opinions on Promoting the Industrialization of Bio-Natural Gas*, which sets the goal for the country's annual biogas output at over 10 million cubic

meters by 2025. On June 18, 2020, the *Circular on Addressing Overcapacity in Key Areas in 2020* was issued, which proposes to accomplish all the tasks for cutting coal overcapacity during the 13th FYP period by the end of 2020, address the issue of “zombie enterprises” proactively yet prudently, classify and dispose of coal mines with a capacity of less than 300,000 tons/year and accelerate the phase-out of coal mines that fail to meet relevant environmental requirements. From May 9 to August 16, 2020, State Grid Qinghai Electric Power Company supplied clean energy power to the Sanjiangyuan region for 100 consecutive days, setting a new world record for 100% power supply through clean energy and reducing coal consumption by 61,000 tons and CO₂ emissions by 166,000 tons.

In the past five years, China’s installed renewable energy capacity has grown at an annual average rate of about 12%, and ranks first in the world in terms of installed hydro, wind and photovoltaic power capacity. As of 2021, China’s non-fossil energy installed capacity exceeded that of coal power for the first time and the total installed capacity of non-fossil energy power generation reached 1.12 billion kilowatts. The energy supply system is shifting from a coal-based one to a diversified one, and renewable energy is gradually becoming the main source of new installed capacity.

E.3.3 Continuing to Promote Energy Conservation and Energy Efficiency Improvement

Continuing to promote energy conservation and energy efficiency improvement is an important long-held policy whereby China can fundamentally remove resource and environmental constraints and bottlenecks, build an ecological civilization, promote high-quality development and achieve carbon dioxide peaking and carbon neutrality.

1. **Promote energy-efficient technologies and products.** On June 27, 2018, the State Council issued the *Three-Year Action Plan for Keeping Skies Blue*, which proposes to improve energy use efficiency; further implement the control over both total energy consumption and energy intensity; and encourage the development of county-level biomass cogeneration of heat and power, biomass briquette boilers and biogas in places where resources permit. The Central Economic Work Conference on December 8, 2021 proposed to promote clean and efficient utilization of coal, enhance the new energy consumption capacity, optimize the mix of coal and new energy and concentrate on breakthroughs in green and low-carbon technologies, taking into account the situation that coal still prevails in China.
2. **Accelerate low emission transformation and advance energy conservation in industry and the energy sector.** In 2018, NEA and MEE introduced the *Notice on Issuing the 2018 Targets and Tasks for Coal Power Ultra-Low Emission Renovation and Energy Efficiency Renovation in Each Province (Region and City)*, which sets the national target of improving 48.68 million kilowatts of coal-fired power generators to achieve ultra-low emissions and 53.905 million kilowatts energy conservation. As at the end of 2018, about 810 million kilowatts

of coal-fired power generators had been renovated for ultra-low emissions, and 689 million kilowatts for energy conservation, with the target for 2020 beaten ahead of schedule.

In December 2020, the Ministry of Industry and Information Technology (MIIT) proposed at the National Work Conference on Industry and Information Technology to encourage and guide industrial enterprises to improve the quality of electric power, strengthen the transformation and IT-based development of electric equipment, and comprehensively improve energy efficiency and demand response capability. On November 17, 2021, the State Council executive meeting decided to set up another special refinancing loan of RMB 200 billion to support the clean and efficient utilization of coal, on top of previous financial instruments for carbon emission reduction, thus forming a policy scale to drive green and low-carbon development.

3. **Focus on energy conservation and environmental protection to mobilize green upgrading.** According to the *Guiding Opinions of the State Council on Accelerating the Establishment and Improvement of a Green and Low-Carbon Circular Economic System*, which was issued on February 22, 2021, establishing a sound green and low-carbon circular economic system and promoting green transition in all areas of economic and social development is the fundamental solution to the problems in the field of resources and the environment in China. On September 12, 2021, the General Office of the CPC Central Committee and the General Office of the State Council issued the *Opinions on Deepening the Reform of the Compensation System for Ecological Protection*, which mentions the implementation of preferential tax policies for energy conservation and environmental protection, new energy and ecological construction.
4. **Accelerate the revision of relevant laws and regulations, and establish energy conservation and efficiency improvement mechanisms.** On October 9, 2021, a National Energy Commission meeting deliberated the plan for a modern energy system during the 14th FYP period, the implementation plan for carbon dioxide peaking in the energy sector, and the guideline on improving the systems and mechanisms as well as the policies and measures for green and low-carbon energy transition, among others.

E.3.4 Enhancing Climate Action and Adaptation

In the past years, China incorporated climate adaptation as an important component of its climate strategy, and has achieved positive outcomes. In particular, President Xi Jinping put forward the decarbonization targets (carbon peaking and carbon neutrality). It signifies that climate action has been incorporated, as a significant part of the development of ecological civilization and a community of shared future for mankind, into the *Outline of 14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through the Year 2035*. With

the guidance of the carbon peaking and carbon neutrality targets, China has raised the importance of climate action and climate adaptation to an unprecedented level.

In 2018, China initiated the institutional reform, transferring the responsibility of climate actions to the MEE, which facilitated the coordinated management of climate action, environmental governance and ecological governance at the institutional level.

On September 22, 2022, Chinese President Xi Jinping solemnly pledged, in the general debate at the 75th United Nations General Assembly, that China will strive to achieve carbon peaking by 2030 and carbon neutrality by 2060. During the two sessions of 2021, Carbon Peaking and Carbon Neutrality were officially included as an important component of the *14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives through the Year 2035*. In January 2021, MEE issued the *Guideline on Optimizing the Ways of Ecological and Environmental Protection Law Enforcement to Improve the Efficiency of Law Enforcement*, which defines the main tasks and scope for coordinating and enhancing climate actions and ecological protection.

On September 23, 2021, Chinese President Xi Jinping announced, at the 76th United Nations General Assembly, that China would no longer increase overseas thermal power projects.

On February 18, 2022, MEE reviewed and in principle approved the *National Climate Strategy for 2035*. The strategy is of great significance in preventing risks and adverse impacts of climate change, safeguarding social and economic development and ecological safety, and illustrating China's role as a major responsible country to build a community of shared future for mankind.

E.3.5 Initiating the Building of a National Carbon Market

MEE is working to accelerate the building of a national carbon emissions trading market by establishing and improving complete system and strengthening the foundation of carbon emission data, stepping up push for building a basic support system and enhancing capacity building.

The building of national carbon credit registry system and carbon emissions trading system has been advanced steadily. The *Notice on Doing a Good Job in the Formulation of 2018 Carbon Emission Report and Verification and Emission Monitoring Plan* was issued in January 2019, which requires governments at provincial, municipal and district levels to urge major carbon emitters to continuously monitor, report and verify carbon emission data. In May 2019, MEE published the *Circular on Doing a Good Job in the List of Key Emitters in the Power Generation Industry and the Submission of Related Materials in the National Carbon Emissions Trading Market*, urging provincial supervising departments to submit lists of key emitters in the power generation industry to be included in the national carbon market and their account-opening materials, in order to lay solid foundation for registering in the carbon credit registry system and carbon trading system, carbon quota allocation, carbon market testing and operation, as well as online carbon emissions trading.

On December 25, 2020, MEE held a ministerial executive meeting, deliberated and adopted the *Measures for the Administration of Carbon Emissions Trading (for Trial Implementation)*, which officially took effect on February 1, 2021. On July 16, 2021, the national carbon market was officially put into operation, signifying the launch of the largest carbon market in the world.

On September 12, 2021, the General Office of the CPC Central Committee and the General Office of the State Council issued the *Opinions on Deepening the Reform of the Compensation System for Ecological Protection*, in a bid to expedite the construction of national energy rights and carbon emissions trading market.

The national carbon market is both a major institutional innovation and complex, systematic project. It should be supported by a complete legal system, a sound management mechanism, effective market mechanism and solid carbon emission data. On December 31, 2021, the national carbon emissions trading market officially closed with a satisfactory conclusion in that year. From its initiation on July 16 to December 31, the cumulative volume of carbon emission allowances (CEA) traded was 179 million tons, with a cumulative turnover of RMB 7.661 billion. The successful operation of national carbon market has played a key role in carbon abatement of power industry, while offering helpful experience for inclusion of other industries into the market. Overall, the national carbon market has begun to fulfill its role as an important policy tool in controlling and reducing greenhouse gas emissions, promoting the realization of carbon peaking and carbon neutrality.

E.3.6 CCICED Policy Recommendations

In recent years, energy, environmental and climate issues have received widespread attention from the international community. CCICED put forward many policy recommendations for development of the energy sector, such as building a new energy-oriented electricity system, continuously optimizing energy structure, continuously promoting energy conservation and improving energy efficiency, facilitating climate actions and adaptation, as well as launching the national carbon market.

E.3.6.1 Continuously Optimizing Energy Structure

The 2019 CCICED Policy Recommendations advised to achieve synergistic advancements in economic development and energy reform, eco-environmental protection and climate change tackling. To achieve, that, it is suggested to further curb use of coals by developing national long-term zero-emission strategy, gradually eliminating the use of coals and increasing subsidies and financial supports for renewable energies.

The 2020 CCICED Policy Recommendations advised to roll out hydrogen economy policies at the national level, promote fuel cells in transportation and co-generation, and increase the proportion of sustainable biomass gas production in the energy structure.

The 2021 CCICED Policy Recommendations advised to accelerate decarbonization in the manufacturing industry, strictly control the new production capacity in energy-intensive and high-emission industries, and facilitate net-zero emission technology innovation and the application of sci-tech achievements in steel, non-ferrous metal, cement, chemicals, petrochemicals and other industries where it is hard to reduce emissions.

E.3.6.2 Continuously Promoting Energy Conservation and Improving Energy Efficiency

Energy conservation and energy efficiency has attracted ongoing attention from CCICED. The 2018 CCICED Policy Recommendations proposed to “promote energy conservation, emission reduction and industrial upgrading; and taking economically viable and high-impact green technologies as a breakthrough, unleash the potential for energy conservation, emission reduction and industrial upgrading through institutional and policy innovation”. With regard to energy saving in indoor air conditioning, it is proposed to “strengthen control of coal use, promote renewable energy, and expand energy efficiency gains; play a leading role in the implementation of the *Kigali Amendment to the Montreal Protocol* and develop world-leading energy efficiency standards for air conditioning”.

The 2019 CCICED Policy Recommendations stressed to promote innovative technologies in urban infrastructure and energy systems; expand nature-based urban green areas and green infrastructure; develop high-standard green buildings and clean, low-carbon energy systems; and introduce strict energy efficiency standards applied to consumer areas such as refrigeration and lighting systems, etc.

The 2020 CCICED Policy Recommendations proposed to promote green buildings, comprehensively promote the design, construction and operation of green and healthy buildings, strengthen the environmental labeling of green household products, especially low carbon and energy efficiency certification, and expand the effective supply of energy-efficient green household products. For the “new infrastructure” to support green development, it is proposed to cover renewable energy, low-carbon and resilient infrastructure, and building energy efficiency improvements, etc.

The 2021 CCICED Policy Recommendations emphasized urban renewal as a major opportunity to transform green urbanization. To this end, it is necessary to strictly control large-scale demolition and construction, and attach importance to brownfield restoration; and enhance green renovation of older blocks and buildings, including the use of green and recycled building materials, and energy efficiency improvements.

E.3.6.3 Strengthening Climate Actions and Adaptation

In 2018, CCICED proposed that China should redouble efforts to mitigate climate change, make more contributions to global climate governance, take coordinated actions against climate change, and become more coordinated in tackling climate change and addressing other environmental problems. In 2019, CCICED advised to strengthen researches and capacity building with regard to climate adaptation and nature-based solutions. In 2020, CCICED proposed to focus on energy transition and upgrading to actively tackle climate change and build a low-carbon society. In 2021, CCICED recommended to conduct climate risk assessments related to extreme weather events caused by climate stressors such as floods, heat waves, coastal storms and droughts, and further enhance adaptive capacity at the scale of the Yangtze and Yellow River basins; and develop sustainable partnerships on the basis of South–South Cooperation Initiative and the Green Silk Road Envoys Programme under the Belt and Road Initiative.

E.3.6.4 Initiating the National Carbon Market

In 2019, CCICED proposed to activate the carbon market by further refining the goals for emission cap control, strengthen the binding force of national carbon emission trading system by accelerating the establishment of legal framework, and set up a carbon pricing mechanism to build robust carbon market with an effective enforcement mechanism. In 2021, CCICED proposed to accelerate incorporating industries with high emissions into the carbon market, and improve the establishment of the trading system. It was suggested to adopt incentive measures based on different realities in different regions as early as possible, and take opportunities to build a blended carbon pricing system.

E.4 Pollution Prevention and Control

E.4.1 Achieving Major Victory in Air Pollution Prevention and Control

Pollution control is a complex, systematic project which requires unremitting and strenuous efforts. The year 2013 saw an important milestone as the *Circular of the State Council on Issuing the Action Plan on Air Pollution Prevention and Control* was unveiled and implemented.

In June 2018, the CPC Central Committee and the State Council released the *Guideline on Comprehensively Strengthening Ecological and Environmental Protection and Resolutely Putting up the Uphill Battles against Pollution*. It proposed to focus on the BTH region and its surrounding areas, the Yangtze River Delta and

the Fen-Wei Plain as the main battle field to promote industrial, energy, transportation and land structuring. It also advised greater efforts to strengthen regional joint control, tackle heavily polluted weather, and further reduce PM_{2.5} and days of heavy pollution, in order to improve air quality and make people benefit from the blue sky and clean environment.

For three consecutive years, MEE has continued to conduct enhanced monitoring for prevention and control of air pollution in three key regions, including and “2 + 26” cities surrounding the BTH region. The air quality of the three key regions has seen continuous improvement thanks to the actions for comprehensive governance of air pollutions in autumns and winters. In the autumn and winter of 2020, the PM_{2.5} of the BTH region and the Fen-Wei Plains declined by 37.5% and 35.1%, and the days of heavy pollution dropped by 70% and 65%, respectively, compared with the same period in 2016.

In 2020, days with good air quality in municipal and above cities reached 87%, up by 5.8% (target: 3.3%) over 2015; the average concentration of particulate matter in cities failing to meet PM_{2.5} target dropped by 28.8% (target 18%) compared to 2015. In the course of three years, the enforcement of various policies and measures has greatly facilitated the fulfillment of pollutants goals and decoupling of economic growth from air pollutions, which allowed us to outperform the binding targets for air quality improvement during the 13th FYP.

The *Outline of the 14th Five-Year Plan (2021–2025) for National Economic and Social Development and the Long-Range Objectives Through the Year 2035* was adopted on March 11, 2021. The document proposes to fight the battle of pollution prevention and control, enhance coordinated control and management of multiple pollutants across regions, in order to basically eradicate days of heavy pollutions. The *Guideline of the CPC Central Committee and the State Council on Moving forward the Battle against Pollution* issued on December 2, 2021 states that attention should be focused on eradicating days of heavy pollution, facilitating prevention and control of o₃-zone pollution, and advancing governance of pollution from diesel trucks.

E.4.2 Accomplishing Remarkable Results in Water Pollution Prevention and Control

Over the past years, China has unveiled a series of policies and regulations on water pollution, signifying the strategic role of water pollution control industry in the country.

On January 1, 2018, the *Decision on Amending the Law of the People’s Republic of China on Water Pollution Prevention and Control* (Second Amendment) was officially put into enforcement. The document further specifies the responsibilities of governments at various levels for water environment quality, intensified efforts for prevention and control of agricultural pollution and strict punishment on illegal activities. In addition, the new amendment also added and revised contents regarding

public health and impacts of ecological environment, illegal pollution discharge activities and data fraud, operation of urban sewage treatment plants, prevention and control of livestock and poultry pollution, as well as protection and management of drinking water sources.

Dealing with dark and fetid bodies of water is the first task among the five battles against water pollution. MEE cooperated with MOHURD to launch the special action against dark and fetid bodies of water. Tours of inspection were initiated in September and October, 2018, and those haven't addressed issues identified during the tours would be held accountable under the central environmental inspection. Water bodies located at sources of drinking water will be held as the first priority in prevention and control of pollution of the Four Water Bodies. MEE cooperated with MWR to initiate a special environmental campaign for protecting drinking water sources.

2020 marks the final year of the critical fight against water pollutions, and it is also a crucial year to usher in the 14th FYP period. In the year, significant progress has been achieved in the battle to keep water clear. 2804 drinking water sources and 10,363 ecological problems have been rectified nationwide, improving the safety of drinking water for around 770 million residents. 95% of municipal and above built-up regions across the country have eradicated black and odorous water bodies. Sewage outlets at estuaries of the Yangtze River and the Bohai Sea were screened. Rivers of the Yangtze River Basin and the Bohai Sea estuaries which have been incorporated in the Campaign to Eradicate Inferior Water Bodies have been removed from the Inferior V category. Efforts have been intensified for governance of rural domestic sewage and black and smelly water bodies. During the 13th FYP period, environments of 136,000 administrative villages have been renovated. The water pollution control industry has reached a mature stage, with a market size of 1.06913 trillion yuan.

As China's environmental protection industry gradually focuses on systematic governance, the water pollution treatment sector will transition towards comprehensive environmental governance which focuses on water governance with comprehensive governance of multiple segments. That means to change the segmented, rough treatment methods, take into consideration of the circular logic of water, air, solid waste and soil pollution, and respect the evolutionary process of the nature. That's how we realize comprehensive governance of multiple segments.

In 2021, a series of documents, such as the *Outline of the 14th Five-Year Plan (2021–2025) for National Economic and Social Development and the Long-Range Objectives Through the Year 2035* and the *Water Eco-environmental Protection Plan for Key River Basins (2021–2025)* were successively released, which clarifies the requirements for continuous improvement of ecological environment and the future development direction of the industry. That symbolizes the coordinated transition of the industry from prevention and control of water pollution to governance of water environment, water ecology and water resources.

On March 1, 2021, the *Law of the People's Republic of China on the Protection of the Yangtze River* officially took effect. As China's first law for watershed protection, the document ushers into a new era of legally protecting the Yangtze River. According to the law, vessels carrying toxic materials and dangerous chemicals are

prohibited from traveling in the Yangtze River, and a ten-year long fishing ban will be implemented.

In November 2021, the *Opinions of the CPC Central Committee and the State Council on Deepening Pollution Prevention and Control* proposed to consolidate and maintain the achievements of pollution prevention and control during the 13th FYP period, and deepen efforts to secure victory in a range of iconic battles, such as the Fight to Keep Water Clear, Black and Smelly Water Body Governance, Critical Battle for Restoration of Yangtze River, the Critical Battle for Protection and Governance of the Yellow River, as well as the Critical Battle for Comprehensive Governance of Key Sea Areas. In addition to that, a series of regulations, such as the *Joint Protection Planning of Regional Ecological Environment in the Yangtze River Delta*, the *Outline of the Plan for the Ecological Protection and High-Quality Development of the Yellow River Basin* and the *Regulations on the Management of Groundwater*, were successively promulgated, which further specifies the definition of collaborative governance of water pollution and clarifies the strategy for watershed governance. In particular, the promulgation of the *Yellow River Protection Law* is being accelerated according to relevant procedures.

Promoting ecological progress is a long-term, arduous task, and the demands of the water governance market are to be further released. The policy principles, such as Pollution Control and Carbon Reduction for Synergetic Effects and Curb Pollution in a Scientific and Targeted Way, will guide the development of sewage treatment technologies.

E.4.3 Continuously Strengthening Soil Pollution Prevention and Control

Soil is the final victim of atmospheric and water pollution and solid wastes. Once the soil is polluted, the restoration and governance is difficult and takes long time and huge costs. In recent years, the problem of soil environment has become increasingly prominent, arousing wide concern in the society. Since 2013, CCICED has been, in its policy recommendations, calling for targeted measures for preventing and controlling soil pollution, and concentrated force to effectively resolve prominent environmental issues, such as air, water and soil pollutions. In June 2018, the CPC Central Committee and the State Council issued the *Guideline on Comprehensively Strengthening Ecological and Environmental Protection and Resolutely Putting up the Uphill Battles against Pollution*. According to the document, work should be done to comprehensively implement the action plan for prevention and control of soil pollution, with a focus on key areas, industries and pollutants, while effectively controlling the environmental risks of agricultural lands and lands for urban construction. In August, the *Law of the People's Republic of China on Prevention and Control of Soil Pollution* was promulgated, which fills the gap for laws of pollution control, especially in terms of soil pollution, and further improves the legal

framework for environmental protection. The document specifies basic framework and principles for planning and risk control standards, general survey and monitoring of soil pollution, as well as prevention, protection, risk control and restoration of soil pollution. Its enforcement signifies China has reached a higher level in soil governance and will gradually promote the restructuring of the industry. Since 2020, Hunan, Shanghai, Sichuan, Jiangsu, Henan and other regions have further refined the directory of and policies regarding agricultural lands and lands for urban construction. The requirements for construction lands, information of pilot programs, as well as engineering requirements, have been made clearer, and the requirements for monitoring and comprehensive governance have been continuously refined.

On June 3, 2020, the *Guidance on Overall Planning for Pandemic Prevention and Control and Ecological and Environmental Protection for Economic and Social Development* was introduced, which requires classified and enhanced measures for soil pollution control and restoration and prevention of solid waste pollution. According to the document, cooperation should be conducted to facilitate the inspection of enforcement of the *Soil Pollution Control Law*. Guidance should be provided to local governments to establish a directory of risk control and restoration for soil pollution. The *Ban on the Entry of Foreign Garbage to Promote the Reform of Solid Waste Import Management System* should be well implemented, and efforts should be continued to slash the imports of solid wastes, in order to basically realize zero import of solid waste by the end of 2020.

2021 marks the start of the 14th FYP period. We will endeavor to protect our clean lands and take full launch of the campaign to control pollution in agriculture and in rural areas. On December 29, 2021, the *14th Five-Year Plan for the Protection of Soil, Groundwater and Rural Ecological Environment* (HTR[2021] No. 120) was issued. The Plan has put forward a series of goals: by 2025, the quality of soil environment and groundwater environment should keep stable, and safe utilization of polluted agricultural lands and key construction lands should be improved; agricultural pollution should be preliminarily controlled, and construction of environmental infrastructure in rural areas should be steadily promoted, and rural ecological environment should be continuously improved. By 2035, the quality of soil environment and groundwater environment should be steadily improved, and safety of soil environment in agricultural land and key construction land should be effectively guaranteed, and risks of soil pollution should be held under comprehensive control; agricultural pollution should be curbed, and environmental infrastructure in rural areas should be upgraded, and rural ecology should be fundamentally improved.

E.4.4 Prevention and Control of Marine Pollution

Since the 13th FYP period, China has made remarkable accomplishments in protecting marine environment. The phased targets for the crucial battle of comprehensive governance of Bohai Sea have been fulfilled. Efforts have been continued to prevent and control the pollution in offshore areas, in order to promote land and

marine development in a coordinated way. The Blue Bay rectification action and the coastal zone protection and restoration project have been well implemented. As a result, the overall quality of marine environment has been improved, and the roles of local sea areas in the ecological system of have been significantly enhanced.

The top-level planning for protection of marine environment during the 14th FYP period has been gradually strengthened. The *Implementation Opinions on Strengthening Supervision and Management of Outlets into Rivers and Sea*, the *14th Five-Year Plan for Marine Eco-environmental Protection*, the *Action Plan for the Battle for Comprehensive Management of Key Sea Areas*, the *Opinions on Strengthening the Supervision of the Ecological Environment of Mariculture* and the *National Plan for Marine Dumping Sites (2021–2025)* were issued and put into implementation. The amendment of *Marine Environment Protection Law* has been initiated. The timeline and roadmap for marine environment protection during the 14th FYP period have become clear.

On January 11, 2022, MEE, NDRC, MNR, MOT, MARA and the China Coast Guard (CCG) jointly issued the *14th Five-Year Plan for Marine Eco-environmental Protection*. The document explicitly states that the construction of beautiful bay should be taken as the priority and focus of the protection of marine environment during the 14th FYP period, with the bay (bay area) as an important unit. Besides, it also proposes to build a cascaded bay governance pattern at national, provincial and municipal levels. Besides, systematic planning should be conducted based on actual realities to promote comprehensive governance of the ecological environment at the bay area and facilitate the construction of beautiful bay by breaking down the key tasks during the 14th FYP period and implementing them into 283 bay areas.

On February 10, 2022, MEE, NDRC, MNR, MOHURD, MOT, MARA and CCG jointly issued the *Action Plan for the Battle for Comprehensive Management of Key Sea Areas*, which specifies the overall requirements, main objectives, key tasks and guarantee measures for the comprehensive management of three key sea areas (including coastal areas of the Bohai Sea, the Yangtze River-Hangzhou Bay, and the Pear River). According to the *Action Plan*, by 2025, the proportion of three key seas areas with good water quality should be increased by around 2% compared to 2020. The rectification of sewage outlet at estuaries should be steadily promoted. Estuaries of main rivers should be basically removed from the Inferior V category. Coastal wetlands and shorelines should be effectively protected. The marine environment risk prevention and emergency response capacities should be significantly improved. The purpose is to build a beautiful bay bearing values for national demonstration.

On March 2, 2022, the State Council released the *Implementation Opinions on Strengthening Supervision and Management of Outlets into Rivers and Sea*, which made systematic deployments for strengthening and regulating the supervision and management of outlets through outlets identification and tracking, classification and rectification, and strict supervision and management, etc., and put forward the phase-based objective of “completing the investigation of outlets into key bays and the rectification of outlets into the Bohai Sea by 2023”.

In the past years, the principle of promoting land and marine development in a coordinated way and restricting land activities to protect the marine environment

has been well implemented, which has been supported by the deepening of reform and administration by law. Besides, the strictest ecological protection system has been executed. As a result, remarkable achievements have been accomplished in the battle for marine pollution control, and the quality of marine environment has been gradually promoted.

E.4.5 CCICED Policy Recommendations

Research on air, water and soil pollution control has been the primary work of CCICED. Over the past 5 years, CCICED has carried out plenty of researches and proposed numerous constructive policy recommendations which have been accepted by the Chinese government. These efforts have promoted, to varying degrees, the introduction of action plans for prevention and control of air, water and soil pollution in the new era, thus accelerating the green transition in China.

E.4.5.1 Prevention and Control of Air Pollution

Over the past few years, CCICED has focused heavily on the priority issue of air pollution prevention and control, but the focus has been on synergies between air pollution control and combating climate change. The 2018 CCICED Policy Recommendations advised to strengthen coal use controls, promote renewable energy, and expand energy efficiency gains; eliminate quota systems or long-term contracts, control industrial coal use, and increase support for the economic transition of coal-dependent provinces (regions and cities).

The 2019 CCICED Policy Recommendations proposed that to achieve high-quality development, China should accelerate climate actions and coordinate air quality improvement and GHG emission reduction. Besides, it also advised to advance the optimization of utilization structure of industrial, energy, transportation and land resources under the guidance of the crucial battle against pollution. In addition, efforts should be made to coordinate the objectives of economic development, energy reform, ecological protection and climate actions, and promote sustainable development.

The 2020 CCICED Policy Recommendations stressed to maintain the strategic focus on ecological civilization and align the green development goals in the 14th Five-Year Plan with the UN 2030 Agenda for Sustainable Development, center on energy transition and upgrading, actively address climate change, and build a low-carbon society.

The 2021 CCICED Policy Recommendations stated that a climate-friendly strategy for air pollution control should be implemented to realize the carbon peaking and carbon neutrality targets in a coordinated and orderly way.

E.4.5.2 Prevention and Control of Water Pollution

From 2018 to 2022, CCICED has put forward many recommendations to the Chinese government for water pollution control. The 2019 CCICED Policy Recommendations proposed to establish strict energy efficiency standards in refrigeration, lighting systems and other consumer areas, and build a circular economic system covering solid waste disposal, water treatment and garbage disposal. The 2020 CCICED Policy Recommendations advised to establish an innovative ecological compensation mechanism so as to accelerating horizontal ecological compensation of river basins from the standpoint of water resources, water environment and water ecology. The 2021 CCICED Policy Recommendations advised to improve the joint technology breakthrough mechanism to enhance science-based marine management, including tackling point-source and non-point source pollutions. Besides, it also advised to enhance pollution control for coordinated land and marine development, strengthen analysis, monitoring and source-tracing of mercury pollutants, and tighten the control of marine plastic pollution and sources of micro-plastic, so as to reduce plastic pollution, and improve waste management and disposal capacities.

E.4.5.3 Prevention and Control of Soil Pollution

The 2019 CCICED Policy Recommendations stated that high-quality afforestation and measures such as investing in the protection of mangroves, coastal wetlands and watershed can all enhance carbon sequestration and biodiversity, and achieve more ecosystem benefits such as flood control and soil and water conservation. The 2020 CCICED Policy Recommendations advised to implement labor-intensive ecological public works such as afforestation, wetland and coastal area restoration, soil and water body restoration, green buildings and renovation to houses. Besides, it also advised to compile and release a list of major innovative green technologies in key fields, such as waste management, land utilization and planning, and restoration of pollution sites.

E.4.5.4 Protection of Marine Ecology

In 2018, CCICED summarized global ocean governance experiences, and proposed to strengthen legal protection for marine and coastal ecosystems, and formulate a national action plan to restore the functions and services provided by marine ecosystems. The 2019 CCICED Policy Recommendations advised to continue to promote integrated ocean governance and launch a network of protected areas including marine ecosystem protection red lines and the national park system. The 2020 CCICED Policy Recommendations proposed to step up the protection and restoration of coastal wetlands and rebuild key habitats; and delineate marine ecosystem protection red line areas and marine protected areas to help with marine biodiversity conservation and fishery development. The 2021 CCICED Policy Recommendations

advised to conduct a baseline study on the accounting of the value of marine ecosystems, step up the protection and restoration of important marine species and their habitats, and improve the quality and stability of marine ecosystems.

E.5 Protection of Ecological System and Biodiversity

E.5.1 Ecological Redlines and Compensation

As two basic systems for China's ecological protection, the ecological redline system and the ecological compensation system play important roles in protecting the ecological system and biodiversity.

E.5.1.1 The Ecological Redline System

The ecological redlines are not only the bottomline and lifeline for protecting China's ecology security, but also the basis for constructing spatial layout system. In the report to 19th CPC National Congress, it is explicitly stated that "We will complete work on drawing redlines for protecting the ecosystems, designating permanent basic cropland, and delineating boundaries for urban development". In January 2017, the CPC Central Committee and the General Office of the State Council jointly issued the *Several Opinions on Delineating and Strictly Observing Ecological Red Lines*, which proposes to designate ecological protection redlines for the provinces (municipalities directly under the central government) along the BTH region and the Yangtze River Economic Zone by the end of 2017 and complete the delineation of the redlines for national ecological protection before the end of 2020.

In August 2019, MEE and MNR published the *Notice on Issuance of the Technical Specification for Delineating Boundaries of Ecological Protection Redlines*, which requires further efforts to promote the designation of the ecological protection redlines. In November 2020, MEE approved 7 documents, including the *Technical Specification for Supervision of Ecological Conservation Redline-Baseline Investigation (Trial)*, as national environmental protection standards, in order to deepen the implementation of the *Several Opinions on Delineating and Strictly Observing Ecological Red Lines*.

On December 23, 2021, the "Three Line and One List" project (ecological protection redline, environmental quality bottomline, resource utilization upperline and Ecological Environment Entry List, covering all provinces and municipalities), was completed, and a region-specific ecological governance system has been basically established.

Currently, the designated ecological redlines cover more than 2.4 million km², around one fourth of Chinese mainland area.

E.5.1.2 Ecological Compensation

In order to further promote ecological protection, the General Office of the State Council and the State Council issued the *Reform Plan of Compensation System for Ecological Damage* in December 2017. According to the document, the system would be put into trial operation from January 1, 2018, and it was required to basically build an ecological compensation system with clearly defined responsibilities, smooth channels, technical specification, strong supports, sound compensation measures and effective restoration measures by 2020.

In the end of 2018, NDRC and other 8 ministries issued the *Action Plan for Building a Market-oriented, Diversified Ecological Compensation Mechanism*. The *Action Plan* proposes to improve the mitigation and compensation system for resource exploitation, reduction of pollutants discharge, water conservation and carbon emission rights, in order to guide ecological beneficiaries and investors to compensate ecological protectors.

In September 2021, the General Office of the CPC Central Committee and the State Council released the *Opinions on Deepening the Reform of the Compensation System for Ecological Protection*. According to the document, an ecological compensation system consistent with the social and economic development status should be basically established by 2025; a categorized compensation system based on ecological protection costs should be improved; a comprehensive compensation system aimed at improving steady delivery of public services should be improved; and a market-oriented, diversified compensation landscape based on the “Beneficiary Pays” principle should be basically formed. Besides, it also proposes that an ecological compensation system which aligns with the requirements for ecological civilization in the new era should be basically completed by 2035.

At present, relevant ministries and commissions are working actively to promote the formulation of the *Ecological Compensation Ordinance*. It is planned that on the basis of the *Guideline on Improving the Ecological Compensation Mechanism* published by the State Council General Office in 2016, the Ordinance will summarize China’s experience in ecological compensation in the past two decades and incorporate effective principles and practices as legal rules, in order to provide legal basis for promoting ecological compensation at larger scales.

E.5.2 Success of the CBD COP15 (Part 1)

On October 12, 2021, the High-level Segment of the United Nations Conference on Biological Diversity was convened in Kunming, China. At the leaders’ summit during CBD COP15, President Xi Jinping delivered a keynote speech titled “Ecological Civilization: Building a Shared Future for All Life on Earth”. President Xi pointed out that biodiversity makes Earth full of vigor vitality, and lays the foundation for human survival and development. Protecting biodiversity helps protect Earth, our common homeland, and contributes to humanity’s sustainable development.

The *Kunming Declaration* was unanimously adopted at COP15. It put forward 17 commitments such as to develop, adopt and implement an ambitious and transformative post-2020 global biodiversity framework. The purpose is to put biodiversity on a path of recovery by 2030 at the latest, move the world toward the 2050 Vision of “Living in harmony with nature”, and send out a message of biodiversity conservation to the whole world. To show the spirit of COP15, China took the initiative to invest 1.5 billion yuan in building the Kunming Biodiversity Foundation, in an effort to support developing countries to contribute to biodiversity conservation work. China calls for and welcomes financial supports from various parties to the Foundation.

If we do not fail Nature, Nature shall never fail us. COP15 marks a new beginning for global biodiversity governance. At this point, the international community should unite as one to build a beautiful planet for the mankind.

E.5.3 An All-Round Protection System Has Been Basically Formed

In 2018, MEE and MNR were formally established, which provides institutional guarantee for the coordinated and systematic governance of mountain, water, forest, land, lake and grass environments and for the unified ecological protection and restoration.

The Ministry of Finance, in collaboration with MEE and MNR, initiated the trial program of Protecting and Restoring Mountains, Waters, Forests, Farmlands, Lakes and Grasses. In 2018 and 2019, a total of 10 billion yuan was distributed to support 10 trial programs in key regions. In 2019, leveraging the natural resources satellite remote sensing technologies, an all-round all-factor monitoring system was built for protecting mountains, waters, forests, lakes, farmlands and grasses.

In June 2020, the *Master Plan for the Major Projects for the Protection and Restoration of Ecosystems (2021–2035)* was released. The *Plan* includes 9 key restoration projects, including the Qinghai-Tibet Plateau ecological shield area, key ecological areas along the Yellow River, and key ecological areas along the Yangtze River, involving the protection and restoration of all natural ecosystems such as mountains, waters, forests, fields, lakes, grasses and oceans. In October, the Third Plenary Session of the 12th CPC Central Committee further stressed the importance of “promoting green development and harmonious coexistence of human and nature.

On February 9, 2021, the General Office of the Ministry of Finance, MEE and MNR jointly issued the *Circular on Organizing and Applying for Central Finance to Support the Integrated Protection and Restoration Project of Mountains, Waters, Forests, Farmlands, Lakes, Grasses and Sands*, in a bid to coordinate and promote the comprehensive, systematic and source-oriented governance and integrated protection and restoration of these environments. Besides, it has also been incorporated into the *Resolution of the Central Committee of the Communist Party of China on the Major Achievements and Historical Experience of the Party over the Past Century*.

Mountains, waters, forests, farmlands, lakes and grasslands are part of a community of life. From the proposal to practice of this concept, its connotation has been continuously extended. From constant release of documents and planning to the involvement in pilot programs for ecological protection and restoration by various departments, China has made remarkable progresses in this regard, and has basically formed an all-round ecological protection and restoration system.

E.5.4 Exploration of Realizing Values of Ecological Products

On February 19, 2021, the 18th Meeting of the Central Commission for Comprehensively Deepening Reform adopted the *Opinions on Establishing a Sound Mechanism for Realizing the Value of Ecological Products*. According to this document, establishment of such mechanism is a key pathway for implementing the concept of “lucid waters and lush mountains are invaluable assets”, but it is also a necessary action for modernizing national ecological governance system and governance capacity, and bears profound significance for green transition of social and economic development.

In April 2021, the General Office of the CPC Central Committee and the State Council issued the *Opinions on Establishing a Sound Mechanism for Realizing the Value of Ecological Products*. In the document, it is required that by 2025, a framework of system for realizing the values of ecological products should be basically formed; a relatively scientific system for calculating the values of ecological products should be basically established; the policy system for ecological protection compensation and ecological damage reparation should be improved; the government assessment mechanism for realization of values of ecological products should be basically formed; the ecological problems, such as being hard to measure, pledge, trade and liquidate, should be largely resolved; a benefit-oriented ecological protection mechanism should be basically established; and the capacity of converting ecological advantages into economic advantages should be significantly strengthened. Besides, it also proposes that by 2035, the system for realizing the values of ecological products should be improved, and a new mode for ecological civilization development with Chinese characteristics should be formed, and a green production and living mode should be universally built, as strong support to attain the goal of Building a Beautiful China.

Focusing on the *Opinions on Establishing a Sound Mechanism for Realizing the Value of Ecological Products*, various localities have gradually been engaged in exploration and practices in this regard. In April 2022, the *Implementation Plan for Establishing a Sound Mechanism for Realizing the Value of Ecological Products in Tianjin* was published and enforced. Jinnan District of Tianjin promoted the construction of main battle field for green ecological defense, which covered 25% of forestry area and 65% of the blue and green space. Besides, the District also advanced the demonstration area for carbon peaking and carbon neutrality by approving a series of zero-carbon or low-carbon innovative high-tech enterprises, in a bid to diversify the pathways. In the same period, Jiangsu Province published the *Implementation Plan*

for Establishing a Sound Mechanism for Realizing the Value of Ecological Products in Jiangsu. The document specifies several goals: By 2025, an initial institutional framework for the realization of the value of ecological products will be formed; and by 2035, a comprehensive mechanism for the realization of the value of ecological products will be fully established. Regions such as Liyang worked actively to build such mechanism, and constructively proposed to build an ecological products trading market, in order to build a government-led model of ecological protection with the participation of multiple entities.

E.5.5 Effectively Enhancing Protection of Wild Animals

China is one of the countries with the most diversified wild animal species, including more than 7300 vertebrates. Among them, more than 470 terrestrial vertebrates, such as giant panda and golden monkey, are species which only live in China. China is taking a leading position in terms of wild animal protection. By now, China has established 11,800 natural habitats of various types, covering 18% of the Chinese land territory, which allows effective protection of more than 85% of national protected wild animal species.

On June 5, 2018, MEE, the Office of the Spiritual Civilization Development Steering Commission, the Ministry of Education, the Central Committee of the Communist Young League, the All China Women's Federation jointly issued the *Code of Conduct among Citizens for the Protection of the Ecological Environment (for Trial Implementation)* at the main venue of June 5 National Environment Day. The document advocates simple, moderate, green and low-carbon lifestyles. In particular, Article 7 "Caring for the Natural Ecology" explicitly proposes to protect wild animals, avoid damaging habitats of wild animals, refrain from stepping into natural reserves, avoid buying or using products made of rare wild species, and reject to eat wild animals.

On February 24, 2020, the 16th Meeting of the Standing Committee of the 13th National People's Congress adopted by vote the *Decision on a Complete Ban of Illegal Wildlife Trade and the Elimination of the Unhealthy Habit of Indiscriminate Wild Animal Meat Consumption for the Protection of Human Life and Health*, in a bid to completely ban and punish illegal wildlife trade, eradicate the unhealthy habit of indiscriminate wildlife meat consumption, maintain bio-security and ecological safety, effectively prevent major public health risks, safeguard human life and health, strengthen ecological progress, and promote the harmonious coexistence of mankind and nature. From May to June of the same year, the inspection group of the National People's Congress Standing Committee went to Guangxi, Jiangxi, Fujian, Yunnan and other regions to inspect the protection of wild animals; and the Standing Committee of the People's Congress of Hebei carried out field inspection on wild animal protection.

In February 2021, the National Forestry and Grassland Administration and MARA published the newly updated *List of National Key Protected Wildlife*. Relevant departments of China are required to implement the work identified in the List according to relevant laws and regulations, and step up efforts to protect wild animals. Besides, it is also required to define the responsibilities of governments of different regions based on the species in the List, in order to ensure the safety of the species and their habitats, and avoid indiscriminate capturing or killing of wild animals and damages of their habitats. The rules should be strictly enforced, in order to severely punish illegal activities, and prohibit eating or illegal trade of wild animals.

E.5.6 The National Park Management System Begins Producing Good Results

In June 2019, the General Office of the CPC Central Committee and the State Council published the *Guiding Opinions on the Establishment of a Nature Reserve System Dominated by National Parks*. The document proposes to build a nature reserve system with national parks as the main body, promote the scientific setting of the nature reserves, and build a new institution, new mechanism and new mode for the natural ecological system to ensure healthy, stable and efficient operation of the system.

In October, 2020, the Third Plenary Session of the 19th Central Committee of the Chinese Communist Party put forward the Major Project for Biodiversity Conservation. It is suggested to initiate a national park institutional trial program and build a nature reserve system with national parks as the mainstay. In October 2021, the General Office of the CPC Central Committee and the State Council issued the *Opinions on Further Strengthening Biodiversity Conservation*. According to the document, efforts should be continued to advance the investigation and assessment of the biodiversity conservation prioritized areas and national strategic areas by 2025, so that the area of nature reserves with national parks as the mainstay account for 18% of the territorial land area; by 2035, typical ecological systems, national key protected wild animal species, endangered wild animals and plants and their habitats should be well protected.

At the UN CBD COP15 in October 2021, Chinese President Xi Jinping pointed out that in order to strengthen biodiversity conservation, China is accelerating the construction of a nature reserve system with national parks as the mainstay, and gradually incorporating into the national park system the areas with the most important natural ecosystems, the most unique natural landscapes, the best natural heritage and the richest biodiversity. Since the pilot national park system was implemented in 2015, 10 national parks have been constructed, including the Northeast China Tiger and Leopard, Qilian Mountain, Giant Panda, Sanjiangyuan, Hainan Tropical Rainforest, Wuyishan, Shennongjia, Pudacuo, Qianjiangyuan and Nanshan. In October 2021, the first national parks such as Sanjiangyuan, Giant Panda, Northeast China

Tiger and Leopard, Hainan Tropical Rainforest and Wuyishan were officially established. In 2022, China will advance the construction of three national parks, including the Asian Elephant National Park. By now, China has established more than 11,800 protected areas, covering 1/4 of the territorial land area.

E.5.7 CCICED Policy Recommendations

Over the past years, CCICED has proposed many valuable policy recommendations for ecological system and biodiversity conservation.

E.5.7.1 Ecological Red Lines, Restoration and Compensation

The 2021 CCICED Policy Recommendations advised to expand investment and financing related to biodiversity conservation, which means to include ecological conservation, restoration and regeneration as an important area of green finance; carry out pilot ecological protection finance, risk disclosure, reporting and stress testing, and defining responsibilities of the private sector for public investments so that public and private sectors' financial flows are aligned with biodiversity goals; and expand the application of fintech in biodiversity conservation by such ways as launching "Fintech + Biodiversity Conservation" pilot demonstrations.

In addition, CCICED also suggested to actively implement the post-2020 global biodiversity framework, set up goals for construction of ecological corridor targeted towards ecological redline and protected areas, establish an efficient, stable ecological safety network, and protect the integrity of the ecological system. Besides, it also advised to adopt transformative ecosystem-based approaches to support high-quality and green development.

E.5.7.2 CBD COP15

The 2018 CCICED Policy Recommendations advised China to leverage strong leadership to facilitate the realization of the five goals at CBD COP 15, including the establishment of the post-2020 biodiversity framework and of an effective mechanism, timely fulfillment of strategic goals of the convention, and enhanced biodiversity conservation in overseas investment and trade. The 2019 CCICED Policy Recommendations advised, based on the experience of Paris negotiation on climate actions, to leverage the political wills accumulated through green diplomacy to enhance the green BRI construction, and promote the biodiversity conservation. The 2020 CCICED Policy Recommendations called for building on the success of CBD COP15 in 2021 to stimulate ambitious multilateral cooperation, and strengthen national actions to protect nature and human well-being. The 2021 CCICED Policy

Recommendations advised to promote the mainstreaming of biodiversity conservation in different economic sectors; integrate nature conservation and nature-based solutions into public and private sectors' investment plans; set scientifically based, quantifiable, ambitious and pragmatic biodiversity targets with indicators to track progress, and pay attention to the pressures on biodiversity, the current status and the impact and effectiveness of solutions.

E.5.7.3 National Park Management System and Wild Animal Protection

By reviewing the experience in building national park management system and wild animal protection, the 2021 CCICED Policy Recommendations advised to step up the construction of national parks and protected areas; identify cost-effective priority areas of protection, and improve the effect of protection based on their respective capabilities; vigorously safeguard the integrity of the ecosystems of national parks and protected marine areas and wilderness areas; assess the overall potential of carbon sequestration in ecological protection red line areas, and identify areas with greater carbon sequestration potential.

In terms of wild animal protection, CCICED Policy Recommendations advised to promote the protection and management of productive landscapes, such as those in the field of agriculture, forestry and fishing; incorporate avoiding alien species intrusion as a national priority and in the post-2020 biodiversity framework; make efforts to expand the forestry, wetland and grassland areas to enhance climate resilience; impose strict ban on illegal trade of wild animals, illegal production and use of pesticides, illegal fishing activities, and illegal change of purpose of land uses; endeavor to eliminate the behavior of eating wild animals and enhance control of wild animal products for medical purposes; and mobilize the whole society to protect the health of livestock, wildlife and plants, safeguard ecosystem integrity, carry out disease prevention, and develop early warning systems under the framework of "One Health".

E.6 Regional and International Engagement

E.6.1 Leading the Way in International Climate Change Governance

The Chinese government attaches great importance to tackling climate change. In the past few years, China has continued to play a constructive role in this regard, and stepped up its efforts with unprecedented intensity to promote international cooperation on addressing climate change.

On May 20, 2018, at the 26th BASIC Ministerial Meeting on Climate Change, the joint statement of the BASIC countries included "building a community with a

shared future for mankind, in terms of climate resilience and low greenhouse gas emissions development” under the advocacy of China. This is the first time that the concept of “building a community with a shared future for mankind” is reflected in a multilateral international document in the field of climate change.

In 2019, at the UN Climate Action Summit, China and New Zealand co-led the establishment of the Nature-Based Solutions Coalition and released the widely supported *Declaration on Nature-Based Solutions for Climate*. During the Summit, China also released the *Policy Proposal on Nature-Based Solutions*, suggesting the establishment of a Group of Friends for Nature-Based Solutions (NBS).

On September 22, 2020, President Xi Jinping announced at the general debate of the 75th session of the UN General Assembly that China would increase its nationally determined contributions (NDCs) and adopt stronger policies and measures to peak carbon dioxide emissions by 2030 and achieve carbon neutrality by 2060. This was the first time China had proposed to achieve the carbon peaking and carbon neutrality targets, which drew great attention from the international community. On December 12, President Xi Jinping further improved the new target of the NDCs at the Climate Ambition Summit, saying that by 2030, China’s carbon dioxide emissions per unit of GDP will drop by more than 65% compared to 2005, non-fossil energy will account for about 25% of primary energy consumption, forest stock will increase by 6 billion cubic meters compared to 2005, and total installed capacity of wind and solar power will reach over 1.2 billion kilowatts. This is the most ambitious emission reduction target for 2030 in the world, and fully demonstrates China’s significant role in addressing global climate change and achieving the world’s 2050 target of zero carbon emission.

In January 2021, the Ministry of Ecology and Environment (MEE) issued a policy prioritizing “nature-based solutions” (NBS) as a means to address climate change and form synergy in the areas of climate, nature and pollution control. China’s afforestation program has increased the country’s forest coverage from 21.37% to 22.96%, making China the largest contributor to the growth of green space globally.

At the Leaders Summit on Climate on April 22, 2021, Chinese President Xi Jinping proposed that “we should be committed to harmony between man and Nature, green development, systemic governance, people-centered approach, multilateralism and the principle of common but differentiated responsibilities”. On June 17, 2021, China decided to ratify the *Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer* and will make new contributions to the protection of the global ozone layer and to the response to climate change. China not only played a key role in the reaching of the *Paris Agreement*, but also led its implementation.

On September 21, 2021, Chinese President Xi Jinping proposed at the general debate of the 76th session of the UN General Assembly that China will vigorously support the green and low-carbon development of energy in developing countries and will not build any new coal power projects outside China, demonstrating China’s sense of responsibility as a major power.

In October 2021, Chinese President Xi Jinping attended the Leaders’ Summit of the 15th meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD COP15) and delivered a keynote speech, emphasizing that in

order to help achieve the carbon peaking and carbon neutrality targets, China will issue implementation plans and a series of supporting measures for peaking carbon emissions in key fields and key sectors, and build up a “1 + N” policy framework for carbon peaking and carbon neutrality; vigorously develop renewable energy and accelerate the planning and construction of large-scale wind power and photovoltaic base projects in deserts and Gobi areas. Since 2015, China’s domestic climate mitigation actions have become more aligned with global governance goals. On October 28, 2021, the Chinese government officially submitted *China’s Achievements, New Goals and New Measures for Nationally Determined Contributions*, which injected a strong impetus for the international community to actively address climate change.

On November 1, 2021, President Xi Jinping delivered a written message to the 26th session of the Conference of the Parties (COP26) to the UN Framework Convention on Climate Change, proposing to uphold multilateral consensus, focus on concrete actions and accelerate the green transition, in response to some major issues of the era, such as tackling climate change and promoting world economic recovery. On November 16, 2021, China and the United States released the *Joint Glasgow Declaration on Enhancing Climate Action in the 2020s* at the UN Climate Change Conference UK 2021 in Glasgow. The *Declaration* mentions that in addition to its recently communicated NDC, China intends to develop a comprehensive and ambitious *National Action Plan* on methane, aiming to achieve a significant effect on methane emissions control and reductions in the 2020s. The *Declaration* also states that the United States and China intend to convene a meeting in the first half of 2022 to focus on the specifics of enhancing measurement and mitigation of methane, including through standards to reduce methane from the fossil and waste sectors, as well as incentives and programs to reduce methane from the agricultural sector.

On November 16, 2021, Chinese President Xi Jinping had a virtual meeting with U.S. President Joe Biden. On the issue of climate change, Xi noted that China and the United States had worked together to facilitate the reaching of the *Paris Agreement* to address climate change, and that climate change can well become a new highlight of China-U.S. cooperation as both countries are transitioning to green and low-carbon economy. Xi said all countries need to uphold the principle of common but differentiated responsibilities, and strike a balance between addressing climate change and protecting livelihoods. He pointed out that what the world needs is less finger-pointing or blame game, but more solidarity and cooperation, and that actions speak louder than words. He called on developed countries to earnestly fulfill their historical responsibilities and due obligations and maintain policy consistency.

E.6.2 Promoting South–South Cooperation

In international cooperation for development, China sees North–South cooperation as the main platform and South–South cooperation as a supplement. China strives to drive developed countries to increase development assistance to developing countries

and construct a new type of global development partnership that is more equal and balanced to create a favorable external environment for poverty reduction.

In January 2018, in promoting cooperation among BRICS countries, China Council for BRICS Think Tank Cooperation (CCBTC), the Chinese coordinator for the BRICS think tank cooperation, held the 2018 CCBTC Annual Meeting and Wanshou Forum to facilitate the exchanges and cooperation of think tanks of BRICS countries. In September 2018, the Beijing Summit of the Forum on China-Africa Cooperation (FOCAC) was held, at which the *Beijing Declaration-Toward an Even Stronger China-Africa Community with a Shared Future* and the *Beijing Action Plan* were adopted, pushing China-Africa relations to a new height marked by a stronger community with a shared future. In 2018, a new round of government institutional reform saw the establishment of a new agency directly under the State Council, the China International Development Cooperation Agency (CIDCA), which consolidates the foreign assistance coordination and other responsibilities of the Ministry of Commerce and the Ministry of Foreign Affairs, and unveils a new chapter for China to conduct South-South cooperation.

China has actively carried out South-South cooperation on climate change with the large number of developing countries. Since 2011, China has allocated a total of RMB 1.2 billion for South-South cooperation on climate change, signed 40 cooperation documents with 35 countries, and helped related countries improve their capacity to cope with climate change by building low-carbon demonstration areas and providing meteorological satellites, photovoltaic power generation systems and lighting equipment, new energy vehicles, environmental monitoring equipment, cleaner cooking stoves and other materials as assistance. At the same time, China has trained about 2000 officials and technicians in the field of climate change for nearly 120 developing countries.

At a time when de-globalization and COVID-19 pandemic are posing a significant impact on the development cooperation pattern, China is sharing its governance experiences and applicable technologies, bringing more developing countries into the international division of labor and cooperation system, and boosting the confidence and determination of the world to participate in the supply of public goods and achieve win-win results through sharing. On September 4, 2021, the 2021 International Forum on South-South Cooperation and Trade in Services, with a theme of “Digital Economy for South-South Cooperation”, was held, proposing that the large number of developing countries should make full use of the opportunities in digital economy, actively address the challenges, and mobilize all parties to form a development synergy to bridge the digital divide.

E.6.3 Greening the “Belt and Road Initiative” at a Deeper Level

Guided by the concept of green BRI, China has continuously reinforced the foundation of cooperation with countries along the Belt and Road on the basis of the achievements made in green and low-carbon development, in a bid to make green development a common feature in the development of BRI countries. The CCICED policy recommendations in recent years have encouraged to promote green BRI.

At the end of 2018, the electric buses, the Chinese Red, produced by Chinese companies BYD and Yutong became a unique sight on the streets of Santiago, and were highly praised by Chilean President Pinera. On April 16, 2019, the Industrial and Commercial Bank of China (ICBC) issued the world’s first green bonds focusing on Belt and Road inter-bank regular cooperation (BRBR), and the funds raised will be used to support green BRI.

In Adama City, Ethiopia, the second largest wind farm in Africa built by China has been put into operation, supplying a total of 2.6 billion kilowatt hours of power to the power grid, equivalent to reducing consumption by 810,000 tce and reducing the emission of soot, sulfur dioxide and nitrogen oxides by 2158 tons. In Thailand’s Sirindhorn Reservoir in Ubon Ratchathani Province, there is also a blue “island”, which is the Sino-Thai hydro-floating solar hybrid project at Sirindhorn Dam, in which the floating solar farm and the hydropower equipment generate electricity alternately or simultaneously, reducing about 47,000 tons of greenhouse gas emissions per year.

In 2020, against the backdrop of the spread of the COVID-19 pandemic, the downward pressure on the world economy, and a complex and changing international situation, the BRI became the biggest highlight of international cooperation. BRI countries stepped up trade and economic cooperation, through which a large quantity of supplies and products were sent to the related countries to combat the pandemic as the trade volume continued to expand. A total of 6354 China–Europe freight trains departed, a year-on-year increase of 41%. The trains played an important role in ensuring smooth flow of goods and stable supply of materials amid the pandemic. Studies show that the BRI will lift 7.6 million people out of extreme poverty and 32 million people out of moderate poverty in the related countries.

In April 2021, President Xi Jinping noted at the Boao Forum for Asia that a closer partnership on green development would be built. Xi called for efforts to strengthen cooperation on green infrastructure, green energy and green finance, etc. Xi also called for improving the BRI International Green Development Coalition, the Belt and Road Green Investment Principles and other multilateral cooperation platforms to make green a defining feature of Belt and Road cooperation.

On March 16, 2022, four departments including the National Development and Reform Commission jointly issued the *Opinions on Promoting the Green Development of the Belt and Road Initiative*. The *Opinions* puts forward 15 specific tasks in three respects, which are promoting green development cooperation in key areas, promoting the green development of overseas projects, and improving the

supporting system for green development, covering key areas such as connectivity of green infrastructure, green energy, green transportation, green industry, green trade, green finance, green science and technology, green standards, and addressing climate change.

It can be said that in the past ten years, the BRI green development partnership has become stronger, which is reflected in the joint initiation of the Initiative for Belt and Road Partnership on Green Development with 28 countries, the facilitation of the construction of the BRI International Green Development Coalition and the BRI Environmental Big Data Platform, the implementation of the Belt and Road South–South Cooperation Initiative on Climate Change, and the establishment of the Belt and Road Energy Partnership. Belt and Road cooperation will become a model for international cooperation on green development in the new era.

E.6.4 New Advances in Global Ocean Governance

China has always attached great importance to international ocean governance and strengthened international ocean cooperation with relevant countries. In 2018, the State Oceanic Administration released the *National Marine Eco-environmental Protection Plan (2017–2020)*. In November 2018, China and Canada jointly released the *Joint Statement of the Government of the People’s Republic of China and the Government of Canada on Marine Litter and Plastics*, underlining that both sides agree to reduce the unnecessary use of disposable plastic products and enhance the capacity to control the entry of plastic waste into the ocean from the source. In March 2019, China and France issued a joint statement, proposing to strengthen existing multilateral mechanisms such as the *Basel Convention*. As part of the country’s “ecological protection red line” program, China will work to identify about 30% of its coastal waters as completely development-forbidden.

China is deeply involved in international ocean governance. In the *Outline of the 14th Five-Year Plan (2021–2025) for National Economic and Social Development and the Long-Range Objectives Through the Year 2035* adopted in March 2021, it is explicitly stated that China should “deeply participate in the formulation and implementation of international ocean governance mechanisms and related rules, promote a just and reasonable international maritime order and a maritime community with a shared future”. China is actively engaged in international negotiations on ocean-related issues, such as the UN consultations on an international agreement on the sustainable use of marine biodiversity in areas beyond national jurisdiction, as well as negotiations and consultations under the UN Regular Process for World Ocean Assessment, the *Convention on Biological Diversity*, the International Seabed Authority and other mechanisms. 2021 also marks the start of the UN Decade of Ocean Science for Sustainable Development, to which China gives active responses by participating in the research of cutting-edge scientific issues such as sci-tech innovation for comprehensive understanding of oceans, conservation of marine ecology and biodiversity, ocean solutions to carbon neutrality targets, and

the discovery of special habitats in the deep sea, in order to help achieve sustainable ocean development.

On March 2, 2022, heads of state, environment ministers and other delegates from 175 countries adopted a historic resolution at the resumed 5th session of the UN Environment Assembly (UNEA-5.2) in Nairobi: End plastic pollution: Towards an internationally legally binding instrument by 2024. This resolution considers prevention and control from an entire life cycle perspective, including the production, design and disposal of plastics.

China is actively involved in global marine litter control. In January 2020, China issued the *Opinions on Further Enhancing Plastic Pollution Control*; Hainan Province, Fujian Province and Dalian City of Liaoning Province, among others, explored the implementation of a sea cleaner system. At the regional level, under the framework of the mechanisms such as the Trilateral Summit Meeting among China, Japan and the Republic of Korea, the ASEAN-China Summit, the G20 Summit, and the Asia-Pacific Economic Cooperation (APEC), China has actively cooperated with neighboring countries to enhance regional capacity to deal with marine plastic litter through joint scientific expedition, scientific and technological research and development, technical assistance, academic conferences, etc. In addition, China has also cooperated in a deep-going manner with the UN Environment Programme and other international institutions to create demonstration projects, share governance experiences and promote practical experiences; it has conducted exchanges and cooperation with nearly 50 countries in marine environmental protection, disaster prevention and mitigation, climate change response, blue carbon, ocean acidification and marine litter management, and signed more than 30 bilateral cooperation agreements and constructed 8 institutions and platforms of international organizations in China.

E.6.5 CCICED Policy Recommendations

The mission of CCICED is to push forward the international exchanges and cooperation between China and other countries on environment and development. Whether it is on climate change, South-South cooperation or the BRI, the research work conducted by CCICED has integrated leading international and domestic experts and promoted two-way policy exchanges and interactions between China and the wider world. The details are summarized as follows.

E.6.5.1 Strengthening International Cooperation on Climate Change

The 2018 CCICED Policy Recommendations proposed to step up climate change mitigation actions and enhance China's contribution to global climate governance.

The 2020 CCICED Policy Recommendations suggested that as the global outbreak of the COVID-19 pandemic highlights the importance of integrated measures, China should address environmental challenges in an integrated manner,

actively respond to climate change with energy transition and upgrading at the core, and build a low-carbon society. Moreover, efforts should be made to strengthen the economic evaluation of coal power and develop a roadmap for its gradual reduction and eventual phase-out; and enhance multilateral climate cooperation with Europe and other developing countries through the Ministerial Meeting on Climate Action and other initiatives to forge new global climate leadership.

The 2021 CCICED Policy Recommendations proposed to uphold the holistic nature of the global ecosystem; promote the mainstreaming of climate change, biodiversity conservation, pollution prevention and control; and strengthen cross-sectoral and cross-regional policy convergence; and explore the establishment of green responsibility accounts through ecological capital accounting to consolidate the micro-foundation of green and low-carbon development and guarantee the comprehensiveness, smoothness and universality of the transition.

E.6.5.2 Advancing South–South Cooperation

The 2019 CCICED Policy Recommendations proposed to support sustainable trade and to take joint actions to strengthen green supply chains and push forward South–South cooperation. The 2020 CCICED Policy Recommendations advised to study the establishment of a traceability system for commodity trade and related due diligence standards, and to support the related countries in transitioning to sustainable production methods through South–South cooperation. The 2021 Policy Recommendations proposed to make use of the Belt and Road South–South Cooperation Initiative on Climate Change to publicize the advantages of green solutions to the countries involved in BRI cooperation, and to create a closer partnership on green and sustainable development.

E.6.5.3 Promoting Green BRI

CCICED has continued to pay attention to and study the greening of the BRI. The 2018 CCICED Policy Recommendations proposed to jointly build the BRI International Green Development Coalition and to align the BRI with the *Paris Agreement*, the global biodiversity goals and the UN 2030 sustainable development goals. The 2019 CCICED Policy Recommendations advised to promote the alignment of the sustainable development strategies of the countries involved in the cooperation for green BRI. The 2020 CCICED Policy Recommendations proposed to push forward green BRI and global green supply chains, strengthen green international cooperation and achieve a green prosperity globally. The 2021 CCICED Policy Recommendations proposed to expand the BRI to cover a wider scope of green development and align the BRI with the UN 2030 Agenda for Sustainable Development, incorporate climate mitigation and adaptation, affordable and applicable clean energy, biodiversity conservation and other sustainable development goals into the construction of the Green Silk Road, and strengthen the synergy among the goals. CCICED also advised

to strengthen multilateral cooperation platforms such as the BRI International Green Development Coalition, the BRI Environmental Big Data Platform, and Belt and Road Green Investment Principles.

E.6.5.4 Striving for New Advances in International Ocean Governance

The 2018 CCICED Policy Recommendations stated that China should cooperate with other countries to tackle plastic pollution. China should intensify the research on emerging ocean environmental issues of global concern, including the priority issues of ocean acidification, plastics and microplastics in oceans, oxygen-deficient hot spots and other emerging ocean environmental issues that have an impact on the globe. The 2019 CCICED Policy Recommendations advised China to strengthen comprehensive ocean governance, actively participate in global ocean governance, and enhance its capacity in marine ecosystem protection and governance. The 2020 CCICED Policy Recommendations advised China to actively work with the international community to establish clear and quantifiable targets for the conservation and restoration of the global terrestrial and marine ecosystems. The 2021 CCICED Policy Recommendations proposed to diversify global marine public goods and participate in global marine environmental governance in a deep-going manner.

E.7 Conclusions

The past five years have witnessed several major achievements in the sustainable development process of China. China has implemented the Five-sphere Integrated Plan to promote coordinated progress in the economic, political, cultural, social and eco-environmental fields. With the overriding purpose of building a beautiful China and realizing a harmonious coexistence between human beings and nature, China strives to build a national governance system for ecological progress, and has pushed forward the reform of the systems and mechanisms for eco-environmental management in a deep-going manner, organized the refining and revision of the relevant laws and regulations, and implemented special campaigns for the improvement of the atmosphere, water and soil. In addition, China has constructed a green financial system and tightened the regulation of corporate environmental credit, and worked to drive the comprehensive green transition of the economy and society. In the meantime, focused efforts have been made to carry out global climate and environment cooperation, develop green BRI, facilitate the fulfillment of the UN 2030 Agenda for Sustainable Development, and build a community with a shared future for mankind.

On the whole, the past five years have been a decisive period for China's eco-environmental governance, a turning point for the improvement of the country's ecological environment, and a critical period for its economic and social development to transition to a high-quality and green one. The past five years witnessed the fundamental formation of the Xi Jinping thought on ecological civilization, the

basic establishment of a modern national environmental governance system under the framework of ecological civilization, the full establishment of laws, regulations and policies for eco-environmental governance in line with the national situation, the successful dissemination of the new development concept and the idea that lucid waters and lush mountains are invaluable assets, and the comprehensive green transition in economic and social sectors as a general trend. In the past five years, the system of major function-oriented zoning in China has been gradually improved, and the national park system has been actively piloted; comprehensive resource conservation has been effectively implemented, with the intensity of energy and resource consumption significantly reduced; major ecosystem protection and restoration projects have progressed smoothly, with forest coverage continuously increased; eco-environmental governance has been significantly strengthened, with the environment improved. China has participated in and led international cooperation on climate change, and has become an important player, contributor and leader in the cause of global ecological progress.

In the past five years, the global spread of the COVID-19 pandemic has once again sounded the alarm to mankind that we should get rid of the old models of production and lifestyle that over-consume energy and resources and destroy the ecological environment. Instead, we should work together to cope with climate change, protect the eco-environment, protect the Earth and foster the harmony between man and nature. The global ecosystems are an interrelated whole, and no country or region can stay intact alone. The world needs to unite immediately. There is only one Earth for mankind. Despite the differences in national situations, achieving sustainable development has always been a common goal of all countries. Currently, the comprehensive agendas for achieving carbon neutrality, protecting nature, reducing waste and pollution, and supporting holistic health, as well as the commitment to achieving social equity, are penetrating into different countries and various social levels. China, while addressing domestic environment and development challenges, has also worked with the international community to tackle global challenges. It is dedicated to building green BRI and global green supply chains, deepening international cooperation on sustainable development, and facilitating stronger, green and healthy global development.

Over the past five years, CCICED has maintained its development orientation as a strategic, early-warning and forward-looking international high-end think tank, and carried out research in line with domestic needs and the new situation of international governance. CCICED has achieved a wide range of outcomes with various highlights, and its influence has continued to expand. CCICED's policy recommendations have been highly valued by the Chinese government, and many of the policy recommendations have been translated into documents issued by the central and local governments and into active social actions through various forms. CCICED has fully played its key supporting role as a think tank. The past five years also witnessed the continuous development, growth and expansion of CCICED. In the 30 years of development since its establishment in 1992, CCICED has never forgotten its original aspiration. It has always paid close attention to China's environmental and development issues with an internationally leading perspective. It is always thinking about

how a large developing country should deal with the relationship between environment and development, and is always coordinating the relationship between China's domestic eco-environmental governance process and the international sustainable development agenda.

In the past three decades, China's development has benefited from international cooperation; in the next three decades, China's development will still be inseparable from international cooperation. As a platform for two-way international exchanges and cooperation, CCICED will, in light of the changing domestic and international situation, summarize and share China's unique sustainable development path, especially the country's explorations and achievements under the framework of ecological civilization, and contribute Chinese wisdom and solutions to building a clean and beautiful world.

Appendix: Overview on the Relevance of China's Environmental and Development Policies and CCICED Policy Recommendations During 2018–2022

Field	Time of release of policy	Policy progress (2018–2022)	Content
Environmental and development planning	<p>June 2018</p> <p>December 2018</p> <p>March 2019</p> <p>December 2020</p> <p>June 2021</p> <p>October 2021</p> <p>November 2021</p> <p>February 2022</p> <p>December 2019</p> <p>July 2020</p> <p>August 2020</p> <p>December 2021</p>	<p>In June 2018, the Central Committee of the Communist Party of China and the State Council issued the <i>Opinions on Comprehensively Strengthening Ecological and Environmental Protection and Securing a Decisive Victory in Pollution Prevention and Control</i>.</p> <p>The General Office of the State Council issued the <i>Work Plan for Pilot Construction of “Zero-Waste Cities”</i>.</p> <p>The National Development and Reform Commission released the <i>Key Tasks for New Urbanization Construction in 2019</i>.</p> <p>The Ministry of Ecology and Environment revised and released the <i>Measures for the Administration of Eco-environmental Standards and Rules for the Formulation and Revision of National Eco-environmental Standards</i>, which further improved the top-level design of the management system of eco-environmental standards and clarified the future direction of the formulation and implementation of eco-environmental standards.</p> <p>15 departments including the Ministry of Housing and Urban-Rural Development issued the <i>Opinions on Strengthening Green and Low-Carbon Development in Counties</i> to strengthen green and low-carbon development in counties and help achieve carbon peaking and carbon neutrality targets.</p> <p>The State Council issued the <i>Action Plan for Carbon Dioxide Peaking Before 2030</i>, which requires urban and rural areas to take actions to achieve carbon peaking, promote green and low-carbon development, and implement the relevant requirements for green and low-carbon development.</p>	<p>1. Ecological civilization</p> <p>In terms of development concept, the 2020 CCICED Policy Recommendations proposed to resolutely strive for ecological progress and implement the idea that lucid waters and lush mountains are invaluable assets, promote a comprehensive green transition in the economy and society, and achieve people-oriented green and high-quality development. In terms of policy goals, the Recommendations proposed to maintain the strategic focus on ecological civilization and align the green development goals in the <i>14th Five-Year Plan</i> with the UN 2030 Agenda for Sustainable Development.</p> <p>2. Green cities and towns</p> <p>The 2018 CCICED Policy Recommendations advised to change the traditional thinking and fully integrate green standards into urban and rural planning; promote energy conservation, emission reduction and industrial upgrading; innovate solutions with full consideration of the local realities.</p> <p>The 2019 CCICED Policy Recommendations advised to reshape the urbanization strategy and re-examine urban-rural relations.</p> <p>3. Green development of major river basins</p> <p>The 2018 CCICED Policy Recommendations advised to promote the green development of the Yangtze River Economic Belt and advance the legislation process for the protection of the Yangtze River.</p> <p>The 2019 CCICED Policy Recommendations advised to make the Yangtze River Economic Belt a strategic priority in the <i>14th Five-Year Plan</i>, and build it into a model and benchmark for green development of river basins.</p>

(continued)

(continued) Field	Time of release of policy	Content
	Policy progress (2018–2022)	<p>The Ministry of Ecology and Environment issued the <i>Guiding Opinions on Deepening Eco-environmental Administration and Continuously Strengthening Pollution Control in accordance with the Law</i>. This is a comprehensive document for the eco-environmental protection authorities to promote pollution control in accordance with the relevant laws and regulations.</p> <p>The State Council agreed to the <i>Guiding Opinions on Accelerating the Construction of Environmental Infrastructure in Cities and Towns</i>, which proposes to build an environmental infrastructure system that integrates waste treatment and disposal facilities and monitoring and supervision capabilities by 2025.</p> <p>The Central Committee of the Communist Party of China and the State Council issued the <i>Outline of the Plan for the Integrated Regional Development of the Yangtze River Delta</i>.</p> <p>The General Office of the State Council issued the <i>Notice on Effectively Carrying out the Fishing Ban in the Yangtze River Basin</i>.</p> <p>The Political Bureau of the CPC Central Committee deliberated the <i>Outline of the Plan for the Ecological Protection and High-Quality Development of the Yellow River Basin</i>.</p> <p>The Ministry of Ecology and Environment deliberated and adopted in principle the <i>Action Plan for Deepening the Protection and Restoration of the Yangtze River</i>, the <i>Action Plan for the Ecological Conservation and Governance in the Yellow River</i>, the <i>14th Five-Year Action Plan for the Control of Urban Black and Odorous Water Bodies and Environmental Protection</i>, the <i>Action Plan for the Comprehensive Improvement of Key Marine Areas</i>, and the <i>National Plan on Marine Dumping Areas (2021–2025)</i>.</p>

(continued)

(continued) Field	Time of release of policy	Policy progress (2018–2022)	Content
Governance and rule of law	February 2018 September 2018 March 2020 January 2021 October 2021 January 2021 June 2018 January 2020 September 2021 October 2021 March 2020 May 2021 2018–2022 January 2021 October 2020 October 2020 May 2021 September 2021	<p>Policy progress (2018–2022)</p> <p>The <i>National Marine Eco-environmental Protection Plan (2017–2020)</i> was released</p> <p>Provisions were made on the functions, internal bodies and staffing of the Ministry of Ecology and Environment</p> <p><i>Catalogue for Guiding Integrated Administrative Law Enforcement Matters for Eco-environmental Protection</i></p> <p>The Ministry of Ecology and Environment issued the <i>Guiding Opinions on Optimizing the Way of Law Enforcement for Eco-environmental Protection to Improve the Effectiveness of Law Enforcement</i></p> <p>The General Office of the State Council issued the <i>Opinions on Deepening the Reform of the Compensation System for Ecological Protection</i></p> <p>The General Office of the State Council prepared the <i>Outline of the Plan for the Ecological Protection and High-Quality Development of the Yellow River Basin</i></p> <p>The General Office of the State Council issued the <i>Opinions on Promoting Green Development in Urban and Rural Areas</i></p> <p>The State Council issued the <i>Three-Year Action Plan for Keeping Skies Blue</i></p> <p>The State Council issued the <i>Guiding Opinions on Reforming and Improving the Working Mechanism on Complaints and Proposals to Promote the Settlement of Acute Eco-environmental Problems for the People</i> was released</p> <p>The General Office of the CPC Central Committee and the General Office of the State Council issued the <i>Guiding Opinions on Building a Modern Environmental Governance System</i></p> <p>The General Office of the Ministry of Ecology and Environment issued the <i>Reform Plan for the Law-based Environmental Information Disclosure System</i></p> <p>On January 1, 2018, the <i>Nuclear Safety Law of the People's Republic of China</i> (hereinafter referred to as the <i>Nuclear Safety Law</i>) was officially implemented</p>	<p>1. Deepening the reform of environmental mechanisms</p> <p>The 2019 CCICED Policy Recommendations suggested that a preventive mechanism for green finance be established</p> <p>The 2020 CCICED Policy Recommendations suggested that the legislative, judicial and administrative authorities conduct cooperation and form a synergy for achieving ecological progress, and that a sound modern environmental governance system be established to improve the coordination and efficiency of green governance</p> <p>2. Exploring modern environmental governance</p> <p>The 2018 CCICED Policy Recommendations advised to step up innovation in all respects including policy, planning and technology to realize green urbanization in China in an era of digital and green development</p> <p>The 2020 CCICED Policy Recommendations proposed to improve the accounting methods and realization mechanisms for the value of services provided by ecological capital to promote the high-quality development of the Yangtze River Basin and the Yellow River Basin</p> <p>The 2021 CCICED Policy Recommendations proposed to pay attention to digital technology innovation and empowerment, coordinate sustainable production and consumption, build a global green value chain, and remove the impediments in the green “dual circulation” development pattern</p> <p>3. Change of lifestyle</p> <p>The 2018 CCICED Policy Recommendations advised to guide multi-stakeholder participation to scientifically identify and address the negative impacts of environmental pollution and ecological damage on the work and life of community residents</p> <p>The 2019 CCICED Policy Recommendations advised to launch a green lifestyle campaign to stimulate the demand for green products. Celebrities could be invited to play a demonstration and leading role in terms of green consumption so as to make green consumption a social trend</p>

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(continued) Field	Time of release of policy	Policy progress (2018–2022)	Content
		<p>On August 31, 2018, the 5th Meeting of the Standing Committee of the 13th National People's Congress adopted the <i>Law of the People's Republic of China on Prevention and Control of Soil Pollution</i></p> <p>On December 28, 2019, the 15th Meeting of the Standing Committee of the 13th National People's Congress amended the <i>Forest Law of the People's Republic of China</i></p> <p>On April 29, 2020, the 17th Meeting of the Standing Committee of the 13th National People's Congress amended the <i>Law of the People's Republic of China on the Prevention and Control of Environmental Pollution Caused by Solid Wastes</i> for the second time</p> <p>On December 26, 2020, the 24th Meeting of the Standing Committee of the 13th National People's Congress adopted the <i>Law of the People's Republic of China on the Protection of the Yangtze River</i></p> <p>On December 24, 2021, the 32nd Meeting of the Standing Committee of the 13th National People's Congress adopted the <i>Law of the People's Republic of China on the Protection of Wetlands</i></p> <p>The State Council promulgated the <i>Regulations on the Administration of Pollutant Discharge Permits</i>, which took effect on March 1, 2021</p> <p>The 45th Meeting of the Standing Committee of the 6th People's Congress of Shenzhen adopted the <i>Regulations on Green Finance in Shenzhen Special Economic Zone</i> (hereinafter referred to as the <i>Regulations</i>)</p> <p>The Ministry of Ecology and Environment, the National Development and Reform Commission, the People's Bank of China, the China Banking and Insurance Regulatory Commission and the China Securities Regulatory Commission jointly issued the <i>Guiding Opinions on Promoting Investment and Financing to Address Climate Change</i></p> <p>The Ministry of Ecology and Environment issued the <i>Guiding Opinions on Strengthening Prevention and Control from the Source in Energy-Intensive and High-Emission Projects for Ecological and Environmental Protection</i>, which clearly states in Article 7 that carbon emission impact assessment will be incorporated into the environmentThe CPC Central Committee and the State Council issued the <i>Opinions of the CPC Central Committee and the State Council on the Complete and Accurate Implementation of the New Development Concept to Peak Carbon Emissions and Achieve Carbon Neutrality</i></p> <p>mental impact assessment system</p>	<p>The 2020 CCICED Policy Recommendations advised to focus on people and promote green models of production and lifestyle by pushing forward green technology innovation, sustainable production and consumption, and green urban development</p>

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(continued)	Field	Time of release of policy	Policy progress (2018–2022)	Content
	Energy, environment and climate	September 2021 June 2018 August 2018 December 2019 February 2021 November 2020 December 2020 January 2021 September 2021 January 2022	<p>The General Office of the CPC Central Committee and the General Office of the State Council issued the <i>Opinions on Deepening the Reform of the Compensation System for Ecological Protection</i>.</p> <p>The State Council issued the <i>Three-Year Action Plan for Keeping Sixes Blue</i>.</p> <p>The National Energy Administration and the Ministry of Ecology and Environment issued the <i>Notice on Issuing the 2018 Targets and Tasks for Coal Power Ultra-Low Emission Renovation and Energy Efficiency Renovation in Each Province (Region and City)</i>, proposing the national targets of 48,68 million kilowatts of coal power ultra-low emission renovation and 53,905 million kilowatts of energy efficiency renovation.</p> <p>Ten departments including the National Development and Reform Commission jointly issued the <i>Guiding Opinions on Promoting the Industrialization of Bio-Natural Gas</i>, proposing that China's annual production of biogas will exceed 10 billion cubic meters by 2025.</p> <p><i>Guiding Opinions of the State Council on Accelerating the Establishment and Improvement of a Green and Low-Carbon Circular Economic System</i>.</p> <p>The State Council issued the <i>Plan for the Development of the New Energy Vehicle Industry (2021–2035)</i>.</p> <p>The Ministry of Ecology and Environment held a ministerial executive meeting, which deliberated and adopted the <i>Measures for the Administration of Carbon Emissions Trading (for Trial Implementation)</i>, which took effect on February 1, 2021.</p> <p>The Ministry of Ecology and Environment held a briefing on the management policy of carbon emissions trading, at which it was proposed that the CPC Central Committee and the State Council attach great importance to the work of addressing climate change, and that China will strive to peak its carbon dioxide emissions by 2030 and achieve carbon neutrality by 2060, fully demonstrating China's confidence and determination to actively address global climate change.</p> <p>The General Office of the CPC Central Committee and the General Office of the State Council issued the <i>Opinions on Deepening the Reform of the Compensation System for Ecological Protection</i> to accelerate the construction of a national energy rights and carbon emissions trading market.</p> <p>The National Development and Reform Commission and the National Energy Administration issued the <i>Guiding Opinions on Accelerating the Construction of a National Unified Power Market System</i>, aiming to realize the sharing and optimal allocation of power resources in a wider scope, improve the stability and flexibility of the power system, and promote the formation of a new power system with stronger new energy consumption capacity.</p>	<p>1. Continuous energy restructuring</p> <p>The 2019 CCICED Policy Recommendations advised to achieve synergistic advancements in economic development and energy reform, eco-environmental protection and climate change tackling.</p> <p>The 2020 CCICED Policy Recommendations advised to formulate a national-level hydrogen energy economic policy, promote fuel cells in transportation and co-generation, and increase the proportion of sustainable biomass gas production in the energy structure.</p> <p>The 2021 CCICED Policy Recommendations advised to accelerate decarbonization in the manufacturing industry and strictly control the new production capacity in energy-intensive and high-emission industries, and facilitate net-zero emission technology innovation and the application of sci-tech achievements in steel, non-ferrous metal, cement, chemicals, petrochemicals and other industries where it is hard to reduce emissions.</p> <p>2. Continuous energy conservation and energy efficiency improvement</p> <p>The 2018 CCICED Policy Recommendations proposed to push forward energy conservation, emission reduction and industrial upgrading.</p> <p>The 2020 CCICED Policy Recommendations proposed to strictly implement the system in which government departments purchase energy-efficient products in priority or on a compulsory basis, and clarify the binding provisions on green procurement by government departments.</p> <p>The 2021 CCICED Policy Recommendations advised to encourage innovation in climate investment and financing products and instruments, launch local pilots, develop an applicable, efficient and advanced classification standards system for climate investment and financing, and actively push for the elimination of fossil fuel subsidies.</p> <p>3. Launch and operation of the national emissions trading system</p> <p>The 2021 CCICED Policy Recommendations proposed to incorporate high-emission industries into the carbon market as soon as possible; provide long-term, clear and consistent market expectations and an effective price conduction mechanism; improve the national carbon emissions trading system.</p>

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(continued) Field	Time of release of policy	Policy progress (2018–2022)	Content
Pollution prevention and control	<p>June 2019 March 2020 November 2021 March 2019 2021 July 2019 December 2021 November 2018 January 2022 February 2022 March 2022</p>	<p>The Ministry of Ecology and Environment issued the <i>Plan for Comprehensive Control of Volatile Organic Compounds in Key Sectors</i> The General Office of the CPC Central Committee and the General Office of the State Council issued the <i>Guiding Opinions on Building a Modern Environmental Governance System</i> <i>The Opinions of the CPC Central Committee and the State Council on Deepening Pollution Prevention and Control</i> was issued The Ministry of Ecology and Environment, together with the Ministry of Natural Resources, the Ministry of Housing and Urban–Rural Development, the Ministry of Water Resources and the Ministry of Agriculture and Rural Affairs, issued the <i>Notice on Issuance of the Implementation Plan for the Prevention and Control of Groundwater Pollution</i> <i>The Outline of the 14th Five-Year Plan (2021–2025) for National Economic and Social Development and the Long-Range Objectives Through the Year 2035; the Water Eco-environmental Protection Plan for Key River Basins (2021–2025)</i> and other documents were successively issued, making important deployments for the continuous improvement of the ecological environment and the future development direction of the industry, marking China's transition from water pollution prevention and control to the coordination of water environment, water ecosystem and water resources The Ministry of Ecology and Environment, the Ministry of Agriculture and Rural Affairs and the Ministry of Natural Resources jointly issued the <i>Implementation Opinions on Enforcing the Soil Pollution Prevention and Control Law and Promoting the Settlement of Acute Soil Pollution Problems</i> <i>The 14th Five-Year Plan for the Protection of Soil, Groundwater and Rural Ecological Environment</i> was issued The Ministry of Ecology and Environment, the National Development and Reform Commission and the Ministry of Natural Resources jointly issued the <i>Action Plan for the Integrated Management of the Bohai Sea</i>, which sets out the timeline and roadmap for the action The Ministry of Ecology and Environment, the National Development and Reform Commission, the Ministry of Natural Resources, the Ministry of Transport, the Ministry of Agriculture and Rural Affairs, and the China Coast Guard, among other departments, jointly issued the <i>14th Five-Year Plan for Marine Eco-environmental Protection</i></p>	<p>1. Atmospheric pollution prevention and control The 2018 CCICED Policy Recommendations advised to strengthen climate change mitigation actions and enhance China's contribution to global climate governance. The potential in energy conservation, emission reduction and industrial upgrading may be unleashed by making use of green technologies that are economically viable and have a big influence and through institutional and policy innovation The 2019 CCICED Policy Recommendations proposed that to achieve high-quality development, China should accelerate climate actions and coordinate air quality improvement and GHG emission reduction The 2020 CCICED Policy Recommendations advised to maintain the strategic focus on ecological civilization and align the green development goals in the <i>14th Five-Year Plan</i> with the UN 2030 Agenda for Sustainable Development, center on energy transition and upgrading and actively address climate change, and build a low-carbon society The 2021 CCICED Policy Recommendations stated that the integration of low-carbon development, nature conservation and pollution prevention and control should become a strategic priority for the current economic recovery. The integrity of global ecosystems should be kept in mind 2. Water pollution prevention and control The 2018 CCICED Policy Recommendations advised to promote the green development of the Yangtze River Economic Belt and accelerate the legislation process for the protection of the Yangtze River The 2019 CCICED Policy Recommendations advised to establish strict energy efficiency standards in refrigeration, lighting systems and other consumer areas, and build a circular economic system covering solid waste disposal, water treatment and garbage disposal 3. Soil pollution prevention and control The 2018 CCICED Policy Recommendations proposed to set up a collaborative management system for achieving ecological progress The 2019 CCICED Policy Recommendations stated that high-quality afforestation and measures such as investing in the protection of mangroves, coastal wetlands and watershed can all enhance carbon sequestration and biodiversity, and achieve more ecosystem benefits such as flood control and soil and water conservation The 2020 CCICED Policy Recommendations advised to implement labor-intensive ecological public works such as afforestation, wetland and coastal area restoration, soil and water body restoration, green buildings and renovation to houses The 2021 CCICED Policy Recommendations stated that integrating low-carbon development, nature conservation and pollution prevention and control should be a strategic priority for the current economic recovery</p>

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(continued) Field	Time of release of policy	Policy progress (2018–2022)	Content
		<p>The Ministry of Ecology and Environment, the National Development and Reform Commission, the Ministry of Natural Resources, the Ministry of Housing and Urban–Rural Development, the Ministry of Transport, the Ministry of Agriculture and Rural Affairs and the China Coast Guard jointly issued the <i>Action Plan for the Integrated Management of Key Marine Areas</i> (hereinafter referred to as the <i>Action Plan</i>), which sets out the overall requirements, main objectives, key tasks and safeguard measures for the integrated management action on three key marine areas, the Bohai Sea, the Yangtze River Estuary–Hangzhou Bay and the Pearl River Estuary adjacent sea areas during the 14th Five-Year Plan period</p> <p>The General Office of the State Council issued the <i>Implementation Opinions on Strengthening Supervision and Management of Outlets into Rivers and Sea</i>, which made systematic deployments for strengthening and regulating the supervision and management of outlets through outlets identification and tracking, classification and rectification, and strict supervision and management, etc., and put forward the phase-based objective of “completing the investigation of outlets into key bays and the rectification of outlets into the Bohai Sea by 2023”</p>	<p>4. Marine ecosystem protection</p> <p>In 2018, CCICED summarized global ocean governance experiences and proposed to strengthen legal protection for marine and coastal ecosystems, and formulate a national action plan to restore the functions and services provided by marine ecosystems</p> <p>The 2019 CCICED Policy Recommendations advised to continue to promote integrated ocean governance and launch a network of protected areas including marine ecosystem protection red lines and the national park system</p> <p>The 2020 CCICED Policy Recommendations proposed to step up the protection and restoration of coastal wetlands and rebuild key habitats; delineate marine ecosystem protection red line areas and marine protected areas to help with marine biodiversity conservation and fishery development</p> <p>The 2021 CCICED Policy Recommendations advised to conduct a baseline study on the accounting of the value of marine ecosystems, step up the protection and restoration of important marine species and their habitats, and improve the quality and stability of marine ecosystems</p>

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(continued)	Field	Time of release of policy	Policy progress (2018–2022)	Content
	Conservation of ecosystem and biodiversity	<p>November 2020 September 2021 January 2022 October 2021 June 2020 April 2021 June 2018 June 2019 September 2021 October 2021 February 2022</p>	<p>In order to implement the <i>Environmental Protection Law of the People's Republic of China</i> and <i>Several Opinions on Delimiting and Strictly Observing Ecological Red Lines</i>, the Ministry of Ecology and Environment approved and released seven standards, including the <i>Technical Specification for Supervision of Ecological Conservation Redline-Base/line Investigation (on Trial)</i> as national standards for environmental protection.</p> <p>The General Office of the CPC Central Committee and the General Office of the State Council issued the <i>Opinions on Deepening the Reform of the Compensation System for Ecological Protection</i>.</p> <p>The <i>Opinions of the CPC Central Committee and the State Council on Comprehensively Advancing the Key Work for Rural Revitalization in 2022</i> proposed to implement hard and fast measures for arable land protection. The Party organs and the government departments will both be responsible for the protection of arable land, in a bid to safeguard the red lines of 1.8 billion mu (about 120 million hectares) of arable land.</p> <p>The high-level meetings at the 2020 UN Biodiversity Conference kicked off in Kunming, Yunnan Province. The theme of the conference is Ecological Civilization—Building a Shared Future for All Life on Earth.</p> <p>The <i>Master Plan for the Major Projects for the Protection and Restoration of Ecosystems (2021–2035)</i> was released. The <i>Plan</i> includes 9 key restoration projects, including the Qinghai-Tibet Plateau ecological shield area, key ecological areas along the Yellow River, and key ecological areas along the Yangtze River, involving the protection and restoration of all natural ecosystems such as mountains, waters, forests, fields, lakes, grasses and oceans.</p> <p>The 18th Meeting of the Central Commission for Comprehensively Deepening Reform deliberated and adopted the <i>Opinions on Establishing a Sound Mechanism for Realizing the Value of Ecological Products</i>.</p> <p>Five departments, including the Ministry of Ecology and Environment, the Office of the Central Steering Commission for Spiritual Civilization Development, the Ministry of Education, the Central Committee of the Communist Youth League and the All-China Women's Federation, jointly released the <i>Code of Conduct among Citizens for the Protection of the Ecological Environment (for Trial Implementation)</i> (referred to as the <i>Ten Articles on Citizens' Conduct</i>) at the National Event on World Environment Day, advocating a simple, moderate, green and low-carbon lifestyle.</p> <p>The General Office of the CPC Central Committee and the General Office of the State Council issued the <i>Guiding Opinions on the Establishment of a Nature Reserve System Dominated by National Parks</i>.</p> <p>The Ministry of Natural Resources approved the establishment of the Sanjiangyuan (Three-River-Source) National Park. In 2022, the creation of 3 national parks, including the Asian Elephant National Park, will be pushed forward.</p>	<p>1. Ecological red lines, ecological restoration and compensation</p> <p>The 2021 CCICED Policy Recommendations advised to expand investment and financing related to biodiversity conservation; include ecological conservation, restoration and regeneration as an important area of green finance; further identify necessary initiatives and carry out pilots of ecological protection finance, risk disclosure, reporting, stress testing, and responsibilities of the private sector for public investments to ensure public and private sector financial flows are aligned with biodiversity goals.</p> <p>2. Biodiversity Conference</p> <p>The 2021 CCICED Policy Recommendations advised to promote the mainstreaming of biodiversity conservation in different economic sectors; integrate nature conservation and nature-based solutions into public and private sectors' investment plans; develop science-based, quantifiable, ambitious and pragmatic biodiversity goals, and establish related indicators to track the progress; pay attention to the pressure on biodiversity, the current situation and the impact and effectiveness of response measures.</p> <p>3. National park management system and wildlife protection</p> <p>The 2021 CCICED Policy Recommendations advised to step up the construction of national parks and protected areas; identify cost-effective priority areas of protection, and improve the effect of protection based on their respective capabilities; vigorously safeguard the integrity of the ecosystems of national parks and protected marine areas and wilderness areas; pay special attention to green connectivity, in cross-regional biodiversity hot spots; assess the overall potential of carbon sequestration in ecological protection red line areas and identify areas with greater carbon sequestration potential.</p> <p>4. Marine ecosystem protection</p> <p>The 2020 CCICED summarized global ocean governance experiences and proposed to strengthen legal protection for marine and coastal ecosystems, and formulate a national action plan to restore the functions and services provided by marine ecosystems.</p> <p>The 2019 CCICED Policy Recommendations advised to continue to promote integrated ocean governance and launch a network of protected areas including marine ecosystem protection red lines and the national park system.</p> <p>The 2020 CCICED Policy Recommendations proposed to step up the protection and restoration of coastal wetlands and rebuild key habitats; delineate marine ecosystem protection red line areas and marine protected areas to help with marine biodiversity conservation and fishery development.</p> <p>The 2021 CCICED Policy Recommendations advised to conduct a baseline study on the accounting of the value of marine ecosystems, step up the protection and restoration of important marine species and their habitats, and improve the quality and stability of marine ecosystems.</p>

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(continued) Field	Time of release of policy	Policy progress (2018–2022)	Content
		<p>The General Office of the CPC Central Committee and the General Office of the State Council issued the <i>Opinions on Further Strengthening Biodiversity Conservation</i>. The 16th Meeting of the Standing Committee of the 13th National People's Congress adopted by vote the <i>Decision on a Complete Ban of Illegal Wildlife Trade and the Elimination of the Unhealthy Habit of Indiscriminate Wild Animal Meat Consumption for the Protection of Human Life and Health</i>, in a bid to completely ban and punish illegal wildlife trade, eradicate the unhealthy habit of indiscriminate wildlife meat consumption, maintain bio-security and ecological safety, effectively prevent major public health risks, safeguard human life and health, strengthen ecological progress, and promote the harmonious coexistence of mankind and nature</p>	

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Field	Time of release of policy	Policy progress (2018–2022)	Content
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Regional and international engagement	<p>April 2019</p> <p>June 2021</p> <p>September 2021</p> <p>September 2021</p> <p>December 2021</p> <p>April 2019</p> <p>April 2021</p> <p>July 2021</p> <p>January 2018</p> <p>September 2019</p> <p>March 2022</p>	<p>At the Second Belt and Road Forum for International Cooperation held in Beijing, China announced that it will implement the Belt and Road South–South Cooperation Initiative on Climate Change together with the relevant countries</p> <p>The Permanent Mission of China to the United Nations deposited with the Secretary-General of the United Nations an instrument of ratification by the Chinese government of the <i>Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer</i></p> <p>President Xi Jinping proposed at the general debate of the 76th session of the UN General Assembly that China will vigorously support the green and low-carbon development of energy in developing countries and will not build any new coal power projects outside China, demonstrating China’s sense of responsibility as a major power</p> <p>The 2021 International Forum on South–South Cooperation and Trade in Services, with a theme of “Digital Economy for South–South Cooperation”, was held at the China National Convention Center</p> <p>The Council for Promoting South–South Cooperation (CPSSC) convened the 2021 Annual General Meeting and the 4th Meeting of the 2nd Board</p> <p>The Thematic Forums of the Second Belt and Road Forum for International Cooperation were held in Beijing</p> <p>President Xi Jinping delivered a keynote speech via video at the opening ceremony of the Boao Forum for Asia Annual Conference 2021. He proposed to improve the BRI International Green Development Coalition, the Belt and Road Green Investment Principles and other multilateral cooperation platform, and to build a closer partnership on green development</p> <p>The Ministry of Commerce and the Ministry of Ecology and Environment issued a notice on the issuance of the <i>Guidelines on Foreign Investment and Cooperation for Green Development</i></p> <p>The State Council Information Office published a white paper on <i>China’s Arctic Policy</i></p> <p>The International Ocean Governance Workshop was held in Beijing on September 29, 2019</p> <p>On March 16, 2022, four departments including the National Development and Reform Commission jointly issued the <i>Opinions on Promoting the Green Development of the Belt and Road Initiative</i>. The <i>Opinions</i> puts forward 15 specific tasks in three respects, which are promoting green development cooperation in key areas, promoting the green development of overseas projects, and improving the supporting system for green development, covering key areas such as connectivity of green infrastructure, green energy, green transportation, green industry, green trade, green finance, green science and technology, green standards, and addressing climate change</p>	<p>1. Promoting international cooperation on climate change and highlighting the historical responsibility</p> <p>The 2018 CCICED Policy Recommendations proposed to strengthen climate change mitigation actions and enhance China’s contribution to global climate governance</p> <p>The 2019 CCICED Policy Recommendations stated that to achieve high-quality development, China should coordinate air quality improvement and GHG emission reduction. To this end, China needs to formulate a clear low-carbon development strategy to achieve synergy between economic development and energy reform, eco-environmental protection and climate change tackling</p> <p>The 2020 CCICED Policy Recommendations suggested that as the global outbreak of the COVID-19 pandemic highlights the importance of integrated measures, China should coordinate public health, economic activities, ecosystem changes (including climate, oceans and rivers) and other areas, implement the concept of “holistic health”, promote the alignment of terrestrial-marine actions, achieve synergy between climate response and biodiversity conservation, and address environmental challenges in an integrated manner</p> <p>The 2021 CCICED Policy Recommendations advised to make concerted efforts to achieve the carbon peaking and carbon neutrality targets; implement a climate-friendly air pollution prevention and control strategy; and carry out integrated and coordinated governance with the implementation of the carbon peaking and carbon neutrality targets as the work direction in the coming years</p> <p>2. Promoting South–South cooperation</p> <p>The 2018 CCICED Policy Recommendations proposed that there is still a huge gap between the existing global actions after the execution of the <i>Paris Agreement</i> and the global actions that should be taken to avoid catastrophic climate changes. With the challenges far greater than expected, governments of countries should strengthen domestic measures and international cooperation</p> <p>The 2019 CCICED Policy Recommendations proposed to support sustainable trade and to take joint actions to strengthen green supply chains, with a focus on building green supply chains for bulk commodities such as soybeans, palm oil, fish and beef, and timber, so as to push forward the South–South cooperation</p> <p>The 2020 CCICED Policy Recommendations advised to study the establishment of a traceability system for commodity trade and related due diligence standards, and to support the related countries in transitioning to sustainable production methods through South–South cooperation</p> <p>The 2021 CCICED Policy Recommendations advised to further implement capacity building projects in conjunction with the Belt and Road South–South Cooperation Initiative on Climate Change and the Green Silk Road Envoy Program, publicize the advantages of green solutions to the countries involved in BRI cooperation, and create a closer partnership on green and sustainable development</p>

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Field	Time of release of policy	Policy progress (2018–2022)	Content
			<p>3. Promoting green BRI</p> <p>The 2018 CCICED Policy Recommendations proposed to promote green BRI, jointly build the BRI International Green Development Coalition, and align the BRI with the <i>Paris Agreement</i>, the global biodiversity goals and the UN 2030 sustainable development goals</p> <p>The 2020 CCICED Policy Recommendations advised to push forward green BRI and global green supply chains, strengthen green international cooperation and achieve a green prosperity globally</p> <p>The 2021 CCICED Policy Recommendations proposed to expand the BRI to cover a wider scope of green development and align the BRI with the UN 2030 Agenda for Sustainable Development</p>

Annex F

Report on Gender Mainstreaming in SPS for the Period 2021–2022

In 2018, the CCICED Executive Committee identified gender equality as a cross-cutting theme and research priority. To support the integration of gender considerations as part of the Special Policy Studies for the period 2020–2021, the CCICED Secretariat International Support Office prepared this report.

The purpose of this report is two-fold: first, to highlight some of the research findings and recommendations of CCICED’s 2020–2021 research work specific to gender, drawing on the final research papers from the Special Policy Studies; second, to provide recommendations for mainstreaming gender perspectives in the forthcoming phase of the research.

As exemplified in CCICED’s recent work, gender equality is increasingly recognized as imperative to expediting progress on environmental sustainability and climate change. Not only is ensuring women have access to their rights an objective in itself, but enabling women’s equitable access to and control of environmental resources and their participation and leadership in environmental decision making expedites progress toward sustainable environmental outcomes. The importance of implementing gender-responsive and inclusive approaches and practices that engage women as well as diverse groups in environmental and climate change initiatives, by hearing their perspectives, understanding their unique needs, and drawing on their capacities, is clear. Many of this year’s CCICED Special Policy studies introduce gender concepts and demonstrate their practical application in progressing gender equality and women’s rights in tandem with progressing sustainable development outcomes throughout the diverse range of environmental topics they address. The 2022 scoping studies²⁴ on innovative green finance and sustainable trade provided additional examples of gender initiatives.

²⁴ The scoping studies were not reviewed as part of this report.

F.1 Gender Equality and the International Framework

China and most countries have signed on to international commitments that obligate them to promote gender equality, eliminate discrimination, and mainstream gender throughout legislation, policies, and programs, including within environment and climate change programs. China's domestic and international commitments to gender equality and sustainable development include

- Convention on the Elimination of all Forms of Discrimination Against Women (CEDAW 1979)
- United Nations Conference on the Environment and Development and Agenda 21 (UNCED 1992)
- United Nations Conference on Women and Platform for Action (Beijing 1995)
- 2030 Agenda for Sustainable Development (SDGs)
- China National Program for Women's Development (2021–2030)
- United Nations Framework Convention on Climate Change (UNFCCC)
- United Nations Convention on Biodiversity (CBD).

The UNFCCC's *Gender Plan of Action* has identified the following gender-based priority areas, which member states are encouraged to advance: capacity building, knowledge management, and communication; gender balance, participation, and women's leadership; coherence; gender-responsive implementation and means of implementation; and monitoring and reporting. These priorities are reinforced in the *Climate Change and Gender Outcomes resulting from COP 26*, and they represent areas with which research objectives and approaches can be aligned to help further a gender-responsive sustainable development agenda. Similarly, the CBD also has a gender action plan with which research can be aligned.

Gender equality is recognized as integral in making progress toward the SDGs. It is not only a stand-alone goal to achieve gender equality and the empowerment of women and girls but is recognized as cross-cutting across all SDGs, including those related to the environment and climate change. As a stand-alone goal, it promotes women's access to natural resources and enabling technologies and their increased participation and leadership in environmental decision-making processes. Importantly, it also calls on reforms to give women equal rights to economic resources, including ownership of and control over land and other forms of property, financial services, inheritance, and natural resources. As a cross-cutting priority, gender equality can accelerate progress toward the other goals, including those associated with energy, ecosystem management, environment, climate change, disaster risk reduction, oceans, and forests.

The increasingly recognized intersections between gender, the environment, and climate change and emerging good practices and case studies in these areas create opportunities for China to leverage this learning for integration into its own approaches and policies. Opportunities are also enabled for China to contribute to these growing fields by offering innovative approaches that, enable women's participation and leadership in the design and implementation of approaches that

are responsive to their needs and those of other marginalized groups, including for example, supporting women entrepreneurs and business ownership, which can have a multiplier effect on sustainable development.

F.2 CCICED’s 2021 Gender-Related Work Through Special Policy Studies: Key Observations

This section presents key observations on the importance of gender equality within each SPS research area and identifies opportunities to further advance gender equality within environmental and climate change policy development and governance.

F.2.1 Climate Change

The intersections of climate change and gender equality are well-recognized within the international community. China’s international commitments include the UNFCCC and its Gender Action Plan, as well as the SDGs, in which the issues of gender equality are a stand-alone goal and crosscut environmental and climate change goals. Gender equality considerations within climate change frameworks and approaches relate to women’s and men’s traditional roles within society and the economy and how these impact their access to and control of resources, such as land, climate change solutions, and clean energy investments; their participation and leadership in decision making, including as it relates to the transition to a green economy and climate financing; and their access to their rights, including access to land rights. Such commitments encourage the identification of gender-based barriers and gender-responsive measures to address them in order to leverage women’s capacity to contribute to climate change initiatives, promoting both gender equality and sustainable development.

Reflecting the important intersections between gender equality and climate change, the *Carbon Emissions Peaking and Carbon Neutrality Policy Measures and Implementation Pathways* SPS effectively integrates gender considerations. References to gender are included in the paper’s introduction and executive summary, and a section of the SPS is dedicated to gender mainstreaming within climate and energy transition-related work, complete with recommendations. The paper recognizes that strengthening the integration of gender considerations in climate change will promote China’s progress toward gender equality and sustainable development, while also improving China’s international image, given the global community’s recognition of the imperative of addressing gender equality within climate change and environmental approaches. It also recognizes the importance of enabling women’s participation as facilitators and leaders in climate work, acknowledging climate change’s

disproportionate impact on them and the importance of considering their perspectives and leveraging their capacities to address it. It also advocates for a just, low-carbon energy transition, in which women are enabled to participate equally and access opportunities in an evolving job market. Finally, the paper encourages greater consideration of social impacts, particularly related to gender equality, within overseas green investments and aids, and promotes greater engagement in international cooperation on gender equality, including leveraging China's leading role in global climate governance to promote the integration of gender equality.

Future research could focus on providing analysis of specific initiatives that demonstrate the importance of women's engagement as participants and leaders within the design and implementation of climate change initiatives, showcasing and potentially comparing the results against gender-neutral initiatives. Future research could also provide explicit details on how existing green investment initiatives have integrated gender equality and climate change objectives, and could make recommendations for the development of such initiatives in the future.

F.2.2 Value Assessment of Nature-Based Solutions

Though international best practices specific to gender equality and nature-based solutions (NbS) are not yet well documented, there are many gender dimensions of NbS and wider environmental initiatives. Gender considerations within NbS approaches relate to the ways in which women's and men's different traditional roles and positions in society impact their access to and control of resources related to NbS, their participation and leadership in NbS decision making, and their access to their rights, including to the benefits of NbS. Unless gender-based barriers related to NbS are identified and gender-responsive measures are incorporated in NbS design and implementation, women are often excluded from contributing their unique perspectives and insights to the development of solutions due to gender-discriminatory norms that inhibit their participation and leadership. Design and implementation processes that expressly integrate gender considerations enable women as well as men to contribute to and benefit from NbS, ensuring these solutions are representative of the societies they are intended to serve.

The *Value Assessment of Nature-Based Solutions* SPS effectively integrates gender considerations at key points in the paper. It emphasizes the importance of gender and inclusion in the prototype database for NbS, by suggesting that gender-responsive and inclusive approaches be highlighted in categorized case studies, particularly within criteria five, six, and seven, which are closely aligned with inclusive approaches. The sub-paper *Prototype Database of Nature-based Solutions Cases* provides an excellent introduction to how gender and inclusion considerations are incorporated into and relevant to the prototype framework. The main paper also encourages the collection and analysis of relevant data in the SEEA EA, which enables measuring and tracking of benefits from NbS in a comprehensive manner, by encouraging ecosystem accounts to include data disaggregated by gender and

ethnicity to better understand the distribution of NbS outcomes across demographic groups. Notably, the SPS dedicates a section to *gender dimensions of NbS in China*, providing short case studies illustrating gender dimensions of ecosystem provisioning services, ecosystem cultural services, and ecosystem regulating services. Importantly, at its conclusion, the report includes a discrete recommendation emphasizing the role of women in NbS development and implementation, ensuring that their needs and perspectives are considered in NbS design, implementation, and monitoring; that they are enabled to participate and share in NbS benefits; and that governance processes are inclusive. In the appendix, the relevance of gender considerations to the IUCN global standard is illustrated in the categorization of a case study on sustainable aquaculture and innovative seaweed farming in Zanzibar, providing an effective model to replicate in integrating gender.

The integration of gender and inclusion considerations into the case studies appears to have been limited by an absence of existing data disaggregated by sex, ethnicity, and other factors. Future research efforts, then, could showcase additional case studies that feature and analyze such data, thus demonstrating the utility of its collection and analysis to measuring equitable outcomes (i.e., for women and Indigenous Peoples) for the wider NbS community. Research to improve global standards for NbS could also consider a more explicit focus on gender and inclusion considerations within the various criteria, to increase understanding and uptake of the systematic integration of gender considerations.

F.2.3 Global Ocean Governance

Gender equality is recognized as essential for the effective protection of oceans, the sustainable management of ocean and marine resources, and the accomplishment of the SDGs. The different roles of women and men in using and managing marine ecosystems and women’s lesser access to their rights, decision making, and resources—reinforced by gender-discriminatory norms—mean that women and men are impacted differently by climate change, environmental issues such as pollution, and the drive toward globalization, and thus have different needs and capacities. Women are present in large numbers in onshore fisheries, processing of marine products, aquaculture, and managing plastic and other waste, and make important contributions to disaster risk reduction initiatives and conservation efforts. Despite their importance in marine ecosystems, their perspectives are not adequately represented in the formulation and implementation of marine ecosystem policy or within research initiatives, and women continue to be underrepresented within marine systems governance. To enable women to equitably contribute to, benefit from, and participate and lead in the development of sustainable marine ecosystem management and governance, the planning, implementation, and monitoring of such initiatives must be made gender responsive, considering both women’s and men’s perspectives and capacities.

The *Ecosystem Based Integrated Oceans Management Under the Vision of Carbon Neutrality* SPS effectively integrates gender considerations at various points within

the text. This begins in the introduction, where the importance of gender equality to “the effective protection of oceans, the sustainable management of ocean and marine resources, and the accomplishment of the SDGs” is recognized, as is the need to improve understanding of a gender-responsive and inclusive approach to ocean management. Gender equality is specifically acknowledged as important to consider in the exploration and implementation of the four ocean-based approaches to carbon neutrality, including the question of how women should be engaged. Gender considerations are then integrated into the priority actions for two of these approaches: Marine Carbon Dioxide Removal and Nature-based Solutions, and Offshore Carbon Capture, Utilization and Storage; considerations include the importance of collecting sex-disaggregated data to better understand gender relations in fisheries and aquaculture and women’s contributions in low-carbon, sustainable seafood production. Importantly, the SPS recognizes that for ecosystem-based ocean management and governance to be successful, gender-responsive planning, implementation, and monitoring and evaluation are required at all levels, which includes engaging women across activities.

Limited data and research have been carried out to date on gender dimensions of ecosystem-based integrated ocean management. This represents an opportunity for future research, which could aim to build understanding of the different facets needed to create gender-responsive and inclusive ocean management to promote greater sustainability. Such research could provide a gender analysis detailing women’s and men’s respective roles and gender dynamics relevant to ocean management in a specific region or value chain, where gender differences could best be illustrated. It could propose specific gender-responsive measures to ensure women’s and men’s different perspectives on sustainable ocean management are represented and incorporated; address any barriers identified to women’s participation and leadership; and progress initiatives in sustainable ocean management toward equitable and gender-responsive outcomes.

F.2.4 River Basins

Climate change impacts women and men differently, because of traditional gender roles of women and men within the household and labour force, which tend to limit women’s access to their rights, input into decision making, and access to and control of resources. Women tend to have a greater reliance on natural resources and bear responsibility for their use and management, including water. However, due to discriminatory gender norms, they also have more constraints, such as limited mobility, and less adaptive capacities and access to resources than men for responding to climate change. Despite their distinctive roles and their increased vulnerability to climate-induced shocks, women are often underrepresented within public and decision-making forums and governance structures. As such, it is important to ensure that a diverse group of women as well as men are included in stakeholder consultation processes and represented within decision making related to the design and

implementation of comprehensive river basin management, to ensure an equitable and sustainable system.

The *Integrated River Basin Management Under Climate Change* SPS very effectively integrated gender through the inclusion of the stand-alone section *Social Equity and Gender Issues in the Yangtze River Basin*. This section included a situational analysis and problem identification; outlined the benefits of empowering women and vulnerable groups; and proposed strategies on social equity and gender in river basin management. The section also included two short case studies on how river basin initiatives had integrated gender considerations. The paper’s final policy recommendations incorporated a focused gender equality recommendation: *Social equality and gender equality should be emphasized in enhancing sustainable response to climate change in the Yangtze Basin, so as to draw more attention to the agenda of social inclusiveness and gender equality*. The sub-sections of this recommendation encompassed many good practices relevant to the integration of gender considerations in integrated river basin management, which were also reflected in the paper. These included the importance of fully understanding the social cost of river basin management, including on women and groups particularly vulnerable to climate change-induced disasters, and promoting gender equality and social equality in any solutions identified. The recommendation also asserted that measures should be in place to ensure security and social equality within river basin management, especially for population groups particularly vulnerable to disasters, such as women, the elderly, and children, as well as those living in rural areas, small towns, flood retention zones, and ecological reserves in the Yangtze Basin. Finally, the paper recommends that gender equality and social inclusion should inform the entire policy-making process for responses to climate change in the Yangtze River Basin, from analysis to planning to implementation. Policy-making should be based on gender and social equality analysis, drawing on consultations with women and other demographic groups, and include gender-sensitive targets and quantitative and qualitative indicators. The recommendation also asserted that women should be represented in river management decision-making bodies, which would ensure their perspectives are included in decision making.

Future research might focus on developing case studies of comprehensive river basin management carried out in the Yangtze River Basin or other river basins, to showcase the results of a gender analysis, the use of gender-responsive measures to understand the needs and perspectives of women and men and the outcomes achieved by considering gender. Other good gender practices that might be showcased to serve as a model for other river basin management initiatives include disaggregating all relevant data by sex; making deliberate efforts to include women in stakeholder consultations; conducting gender impact assessments to understand and address the differential impacts of climate change on women and men in such areas as land use, planting mode, water resource utilization, river transportation, ecosystem services, and any other relevant areas; and enabling the participation and leadership of women in governance and decision-making bodies.

F.2.5 Sustainable Food Supply Chain

Women are central to sustainable food supply chains, as consumers, producers, and household food managers. Despite this, due to gender-discriminatory social norms and rigid gender roles that deprive women of their rights, limit their participation in and input into decision making, and restrict their access to and control of resources, including land, women in many parts of the world are discriminated against economically and socially. This discrimination limits their ability to contribute to and benefit from sustainable food security in their various roles. For example, women make up nearly half of agricultural workers in low-income countries but represent less than 15% of landowners. Women farmers manage smaller plots of land and have less access to agricultural inputs, technical training and assistance, market information, and financial and other services than male farmers, while women living in rural communities suffer greater risk and impacts from climate change. Research demonstrates that rural communities have access to more food, improved nutrition status, higher incomes, and more efficient and sustainable food systems when women have better access to decision making, resources, economic opportunities, and services. To promote sustainability within food supply chains, gender-based barriers facing women in accessing resources and opportunities to participate and lead in programs and initiatives developed to promote food sustainability must be identified. Measures can then be designed and implemented to address these barriers and promote the participation of women as consumers, household food managers, producers, and leaders within sustainable food initiatives.

Gender considerations have been integrated within the *Sustainable Food Supply Chain* SPS, including within recommendations. Drawing on the strong intersection between gender equality and food, the paper has integrated gender perspectives in the following areas of sustainable food supply chain approaches relevant to the Chinese context:

- In a reflection of good global practice, the integral nature of gender to agricultural sustainability, an intersection which is particularly important given the prominence of
- women within agriculture yet their limited access to land, agricultural inputs, innovation, information, and training.
- Related to the topic of food consumption, the importance of using and analyzing sex-disaggregated data to make visible any gender differences and impacts that might need to be addressed, such as differences in nutrition status between women and men and between girls and boys.
- In improving productivity, the importance of designing and implementing gender-responsive measures to ensure that innovations and agricultural technologies reach women farmers, who are often excluded from access to technical training and innovation-related information.

- To ensure women’s perspectives are represented in approaches and strategies to promote sustainable agriculture, institutionalizing the participation and leadership of ministries and other organizations representing women’s agricultural and related interests within committees.

Future research could include developing case studies of gender-responsive food sustainability initiatives that have been carried out, applicable to the Chinese context. Such case studies could include a gender analysis summarizing the socio-economic and gender context and the different considerations for women and men producers and consumers, as well as for institutions, to enable them to contribute to and benefit from the initiative; institutional, policy, and practical measures that were put in place to promote equitable outcomes; and results achieved. Good practices identified could then be incorporated into recommendations at the institutional, policy, and programmatic levels to promote equitable and sustainable food systems.

F.2.6 Green and Low-Carbon BRI

As reflected in the SDGs, there are many linkages between renewable energy, gender equality, and sustainable development. Women’s and men’s roles and positions in society, the economic impact of their differential energy use, their participation within the energy sector, and the gendered impacts of energy-related environmental and climate change issues are equally relevant in the transition to a green and low-carbon BRI. Women are often excluded from participation and leadership within the energy sector—including in renewable energy—and their unique needs and perspectives are often not considered within energy policy and in transitions to green energy. This is despite studies demonstrating women’s greater willingness to change environmental behaviours compared with men’s. By incorporating measures to address identified gender-based barriers, promote women’s participation and leadership within green energy initiatives at all levels, and draw on the perspectives, knowledge, and capacities of women as well as men, policies and approaches in supporting a transition to a green and low-carbon BRI can more effectively contribute to sustainable, inclusive, and equitable development.

The final draft of the *Key Pathways on a Green and Low-Carbon BRI* SPS was not available at the time of writing. However, the draft paper included the text box titled “*The “Whole Lifecycle Approach to Best Practices in Renewable Energy Development”*”, which provided examples of important gender considerations that contribute to the identification of government priorities within renewable energy initiatives, as well as project measures that may be required by governments to identify and address gender-based priorities. Additional identified entry points for integrating gender into research on a green and low-carbon BRI include the following:

- The SDGs acknowledge the importance of gender both as a stand-alone goal and as a cross-cutting theme, acknowledging its intersection with renewable energy and climate change, as does the UNFCCC. This provides an opportunity for a

green and low-carbon BRI to align with international commitments by integrating gender considerations into green energy policy and transitions.

- Labour-market assessments relevant to the transition to a green and low-carbon BRI can be made gender-sensitive by providing sex-disaggregated data where possible and highlighting women’s and men’s concentrations in low- versus high-productivity sectors, enabling the development of gender-responsive measures as needed.
- The intersections between gender equality and clean energy, such as women’s and men’s differential use of energy, their unequal access to clean energy, and the differential impacts of climate change on them, can be unpacked to demonstrate the importance of gender-responsive measures to achieve equitable and sustainable outcomes.

Gender considerations are increasingly considered within environment and social impact assessments for infrastructure projects supported by development financial institutions (DFIs). Future research could look more specifically at how DFIs are integrating gender considerations within environment and social impact assessments for clean energy and other infrastructure projects, to maximize the sustainability of initiatives, and provide case studies demonstrating improved and equitable outcomes resulting from such approaches and recommendations to policy-makers.

F.3 Recommendations to CCICED for the Forthcoming Research Phase

In addition to the current approach, the following recommendations are made to strengthen the integration of gender within the SPS:

- **Consideration should be given to mandating the inclusion of gender from the beginning of the research cycle.** Gender could be required to be integrated beginning at the SPS proposal stage, and its inclusion validated by CCICED staff.
- **Any templates provided within the CCICED Guidance documents should outline to the SPS teams clear steps to further highlight gender issues and considerations.** Requirements for the inclusion of gender could be clearly stipulated within relevant areas of all templates provided by CCICED for use by the SPS teams, such as for proposals or inception plans, in keeping with the approach adopted by other donors and organizations requiring the integration of gender perspectives.
- **Consideration should be given to providing budgetary allocations specifically for gender research within each SPS.** Allocating a specific budget will encourage the integration of gender and allow for appropriate resourcing of time or expertise required for gender research. Gender research might be carried out by SPS team members or by a gender specialist.

- **Commissioning a dedicated gender analysis for each SPS topic should be considered.** A gender analysis could be carried out prior to the development of a detailed research outline, to inform how gender could be approached within the SPS. Introducing a gender analysis at the planning stage would allow it to be integrated into the research plan.
- **Consideration should be given to mandating the inclusion of gender in three areas of the SPS:** as a stand-alone text box or dedicated section near the beginning of the paper to showcase the nexus between gender equality and the specific SPS topic; integrated at relevant points throughout the paper, drawing on the gender intersections acknowledged in the focused section; and within recommendations, with a minimum of one gender-focused recommendation, given that this is the section most likely to be transmitted to the highest levels to influence policy. This approach was highly effective in the few cases where it was carried out.
- **The inclusion of case studies integrating gender considerations should be highly encouraged.** Gender-focused or gender-integrated case studies are remarkably effective in displaying the importance of identifying and integrating gender perspectives in the SPS area, particularly for initiatives that can identify equitable outcomes. Given that gender is an emerging area in some of the SPS research areas, and in keeping with requests for case studies within gender action plans for international environment and climate change conventions, these are particularly helpful in demonstrating the importance of gender equality to sustainable development.

Annex G

CICCED Phase VII Composition (as of March 2023)

CCICED Phase VII Special Advisors

Chinese Special Advisors

1.	Mr. Zhang Yong	Director-General, Bureau of General Affairs, the Office of the Central Financial and Economic Affairs Committee
2.	Ms. Chen Wenling	Chief Economist, China Center for International Economic Exchanges
3.	Mr. Zhang Yansheng	Chief Researcher of China Center for International Economic Exchanges
4.	Mr. Li Haisheng	President of China Research Academy of Environmental Sciences
5.	Mr. Guo Jing	President of BRI Green Development Institute (BRIGDI)
6.	Mr. Zhou Heng	Director General, Department of International Cooperation, China Meteorological Administration
7.	Mr. Ye Yanfei	Senior Inspectorate Advisor, Policy Research Bureau of the China Banking and Insurance Regulatory Commission
8.	Mr. Hu Baolin	Honorary Dean of Research Institute of China Green Development of Tianjin University
9.	Ms. Zhang Chenghui	Member of Committee of Academics, TJD Research Institute
10.	Mr. Zhai Panmao	Intergovernmental Panel on Climate Change (IPCC) Working Group I Co-chair; Chief Scientist and Principle Investigator of Chinese Academy of Meteorological Sciences
11.	Mr. Zhang Yongsheng	Director-General and Research Fellow, Research Institute for Eco-civilization, Chinese Academy of Social Sciences
12.	Mr. Ma Jun	Chairman, Green Finance Committee of China Society for Finance and Banking

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13.	Mr. Li Xiaojiang	Professor and former President, China Academy of Urban Planning and Design
14.	Mr. Yu Ping	Former President of China Council for the Promotion of International Trade
15.	Mr. Zhai Qi	Executive Secretary General, China Business Council for Sustainable Development
16.	Mr. Tang Jie	Professor of Harbin Institute of Technology (Shenzhen), Director of Development Strategy Committee, Director of the Chinese University of Hong Kong (Shenzhen), and former vice mayor of Shenzhen
17.	Mr. Xu Lin	Chairman of China-US Green Fund, Committee Member of Demonstration Area in the Yangtze River Delta on Ecologically Friendly Development, Former Director General of the Department of Fiscal and Financial Affairs and the Department of Development Planning of NDRC
18.	Mr. Li Zhenguó	Founder and President of LONGi
19.	Mr. Wang Yusuo	Founder and Chairman of the Board of ENN Group

International Special Advisors

1.	Mr. Iskandar Abdullaev	Deputy Director, Central Asia Regional Economic Cooperation Institute; Former Executive Director, The Regional Environmental Center for Central Asia
2.	Mr. Knut Halvor Alfsen	Former Head Research Director, Center for International Climate and Environmental Research Oslo
3.	Mr. Howard Bamsey	Chair, Global Water Partnership; Former Executive Director of GCF
4.	Mr. Dimitri de Boer	Regional Director of Programmes for Asia & Chief Representative of China, ClientEarth
5.	Mr. Guillermo Castilleja	Senior Advisor, Global Alliance for the Future of Food
6.	Ms. Galit Cohen	Former Director General, Ministry of Environmental Protection of the State of Israel
7.	Mr. Stephan Contius	Special Advisor on SDGs at the Foundations Platform F20, former Commissioner for the 2030 Agenda for Sustainable Development and Director at the Federal Environment Ministry, Germany
8.	Mr. Mark Halle	Former European Representative and Director for Trade and Investment, International Institute for Sustainable Development
9.	Ms. Jeanne-Marie Huddleston	Director General of Bilateral Affairs and Trade, the International Affairs Branch of Environment and Climate Change Canada
10.	Ms. Bernice Lee	Research Director, Futures, Chatham House-Royal Institute of International Affairs

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11.	Mr. Lei Hongpeng	Regional Director, East and Southeast Asia/Chief Representative, China Children's Investment Fund Foundation
12.	Mr. Liu Jian	Director of the Science Division, United Nations Environment Programme
13.	Mr. Lo Sze Ping	Program Director, China and Southeast Asia, Sequoia Climate Foundation
14.	Mr. Zafar Makhmudov	Executive Director, the Regional Environmental Centre for Central Asia
15.	Mr. Hans Mommaas	Director-General, PBL Netherlands Environmental Assessment Agency
16.	Ms. Neo Gim Huay	Managing Director, Centre for Nature and Climate, the World Economic Forum
17.	Ms. Oyun Sanjaasuren	Director, External Affairs, Green Climate Fund
18.	Mr. Ismo Tiainen	Director-general, Administration and International Affairs, Ministry of the Environment, the Republic of Finland
19.	Mr. Zou Ji	CEO and President of Energy Foundation China

Chinese Members

1.	Mr. Han Zheng	Chairperson of CICCED
2.	Mr. Huang Runqiu	Executive Vice Chairperson of CICCED Minister, Ministry of Ecology and Environment
3.	Mr. Xie Zhenhua	Vice Chairperson of CICCED China's Special Envoy on Climate Change
4.	Mr. Zhou Shengxian	Vice Chairperson of CICCED Former Minister of Environmental Protection
5.	Mr. Zhao Yingmin	Secretary General of CICCED Vice Minister, Ministry of Ecology and Environment
6.	Mr. Liu Shijin	Chinese Chief Advisor of CICCED Former Deputy Director of the Development Research Center of The State Council
7.	Mr. Dou Shuhua	Vice-chairperson, The Environmental Protection and Resources Conservation Committee
8.	Mr. Liao Min	Deputy Director of Central Financial and Economic Affairs Commission General Office; Vice Minister, Ministry of Finance
9.	Mr. Xiao Yanshun	Member of the Leading Party Members Group, State Council Research Office
10.	Mr. Ma Zhaoxu	Vice Minister, Ministry of Foreign Affairs
11.	Mr. Hu Zucui	Vice Chairman, National Development and Reform Commission
12.	Mr. Xin Guobin	Vice Minister, Ministry of Industry and Information Technology

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13.	Mr. Zhu Zhongming	Vice Minister, Ministry of Finance
14.	Mr. Wang Hong	Vice Minister, Ministry of Natural Resources; Director of State Oceanic Administration
15.	Mr. Dai Dongchang	Vice Minister, Ministry of Transport
16.	Mr. Zhang Taolin	Vice Minister, Ministry of Agriculture and Rural Affairs
17.	Mr. Wang Shouwen	China International Trade Representative (minister's level), and Vice Minister of Commerce, Ministry of Commerce
18.	Mr. Qiu Baoxing	Counsellor, the State Council
19.	Mr. Zhang Yaping	Vice President and Academician, the Chinese Academy of Sciences
20.	Mr. Cai Fang	Former Vice President, Chinese Academy of Social Sciences
21.	Mr. Zhang Yuyan	Director, Researcher of the Institute of World Economics and Politics of Chinese Academy of Social Science (IWEPP, CASS)
22.	Mr. Yu Yong	Deputy Administrator, China Meteorological Administration
23.	Mr. Deng Xiuxin	Vice President and Academician, the Chinese Academy of Engineering
24.	Ms. Luo Hui	Director General of Department of International Affairs (Hong Kong, Macao and Taiwan Exchange Office)
25.	Mr. Xue Lan	Dean of Schwarzman College in Tsinghua University; Co-Chair of the Leadership Council of the UN Sustainable Development Solution Network (UNSDSN); Professor at School of Public Policy and Management at Tsinghua University
26.	Mr. He Kebin	Member of Chinese Academy of Engineering; Professor of the School of Environment and Dean of the Institute for Carbon Neutrality at Tsinghua University
27.	Mr. Zhang Yuanhang	Professor, College of Environment Sciences and Engineering, Pecking University; Academician, the Chinese Academy of Engineering
28.	Mr. Dai Minhan	Professor, Xiamen University; Academician of Chinese Academy of Sciences
29.	Mr. Fang Jingyun	Professor, College of Urban and Environmental Sciences, Pecking University; Academician of Chinese Academy of Sciences
30.	Mr. Wang Jinnan	President of Chinese Academy of Environmental Planning; Academician of Chinese Academy of Engineering
31.	Mr. Zhang Xiaoye	Research Fellow of Chinese Academy of Meteorological Sciences; Academician of Chinese Academy of Engineering
32.	Mr. Wang Yi	Vice Chair, National Expert Committee on Climate Change; Professor of School of Public Administration, University of Chinese Academy of Sciences; Member, Standing Committee of the National People's Congress of China
33.	Mr. Shu Yinbiao	Academician of Chinese Academy of Engineering, President of Chinese Society for Electrical Engineering; The 36th President of International Electrotechnical Commission

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34.	Mr. Qian Zhimin	Chairman of the Board, State Power Investment Corporation Limited
35.	Mr. Wang Tianyi	Professor, Hong Kong University of Science and Technology (Guangzhou); International Consultant, Temasek
36.	Ms. Marjorie Yang	Chairman, Esquel Group
37.	Mr. Xin Bao'an	Executive Chairman, State Grid Corporation of China
38.	Mr. Lei Mingshan	Executive Chairman, China Three Gorges Corporation

International Members

1.	Mr. Steven Guilbeault	Executive Vice Chairperson Minister, Environment and Climate Change Canada
2.	Mr. Achim Steiner	Vice Chairperson Administrator, The United Nations Development Programme
3.	Ms. Inger Andersen	Vice Chairperson Executive Director, The United Nations Environment Programme
4.	Ms. Kristin Halvorsen	Vice Chairperson Director, CICERO Center for International Climate Research; Former Minister of Finance of Norway; Former Deputy Prime Minister of Norway
5.	Mr. Scott Vaughan	International Chief Advisor of CCICED Former President and CEO, International Institute for Sustainable Development
6.	Mr. Danny Alexander	Vice President, Policy and Strategy, The Asian Infrastructure Investment Bank
7.	Mr. Peter Bakker	President and CEO, World Business Council for Sustainable Development
8.	Mr. Manish Bapna	President and Chief Executive Officer, the Natural Resources Defense Council
9.	Mr. Børge Brende	President, World Economic Forum
10.	Mr. Francesco La Camera	Director-General, the International Renewable Energy Agency
11.	Mr. Srun Darith	Secretary of State, Ministry of Environment, Cambodia
12.	Mr. Aniruddha (Ani) Dasgupta	President and CEO of World Resources Institute
13.	Mr. John J. DeGioia	President, Georgetown University
14.	Mr. Jan Hendrik Dronkers	Secretary-General, the Ministry of Infrastructure and Water Management, the Netherlands

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15.	Mr. Richard Florizone	President and CEO, the International Institute for Sustainable Development
16.	Ms. Kate Hampton	CEO, Children's Investment Fund Foundation UK
17.	Mr. Arthur Hanson	Senior Advisor and Former President of International Institute for Sustainable Development
18.	Mr. Hal Harvey	President, Climate Imperative Foundation; CEO, Energy Innovation
19.	Mr. Stephen Heintz	President and CEO, the Rockefeller Brothers Fund
20.	Ms. Naoko Ishii	Professor, Executive Vice President and Director of the Center for Global Commons, University of Tokyo; Former CEO and Chair, Global Environment Facility
21.	Mr. Rodolfo Lacy	Director for Climate Action and Environment for Latin America, Special Envoy on Climate Matters to the United Nations, Organization for Economic Co-operation and Development
22.	Mr. Marco Lambertini	International Special Envoy, World Wide Fund for Nature
23.	Mr. Stanley Loh	Permanent Secretary, Ministry of Sustainability and the Environment, Singapore
24.	Mr. Michael McElroy	Gilbert Butler Professor of Environmental Studies, Harvard University
25.	Mr. Dirk Messner	President, German Federal Environment Agency
26.	Mr. Hideki Minamikawa	President, Japan Environmental Sanitation Center
27.	Ms. Jennifer Morris	Chief Executive Officer, The Nature Conservancy
28.	Mr. Gerd Müller	Director General of the United Nations Industrial Development Organization
29.	Mr. Bruno Oberle	Director General, the International Union for Conservation of Nature
30.	Mr. Frank Rijsberman	Director General, Global Green Growth Institute
31.	Mr. Carlos Manuel Rodriguez	CEO and Chairperson of the Global Environment Facility; Former Environment and Energy Minister, Costa Rica
32.	Ms. Gwen Ruta	Executive Vice President, Environmental Defense Fund
33.	Mr. Ahmed M. Saeed	Vice President (Operations 2), Asian Development Bank
34.	Mr. Erik Solheim	Convener of the Advisory Committee, The BRI International Green Development Coalition, International President of the BRI Green Development Institute
35.	Mr. Andrew Steer	President and CEO, Bezos Earth Fund
36.	Ms. Eva Svedling	Former State Secretary, Ministry of Environment, Sweden
37.	Mr. Sukanto Tanoto	Founder and Chairman, Royal Golden Eagle
38.	Mr. James Thornton	Founding CEO, ClientEarth
39.	Ms. Nomfundo Tshabalala	Director-General of the Department of Forestry, Fisheries, and the Environment, Republic of South Africa
40.	Ms. Laurence Tubiana	CEO, European Climate Foundation

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41.	Ms. Christie Ulman	President, Sequoia Climate Foundation
42.	Mr. Juergen Voegele	Vice President for Sustainable Development, the World Bank
43.	Mr. Jan-Gunnar Winther	Specialist Director, Norwegian Polar Institute
44.	Mr. Zhang Hongjun	Board Chair, Energy Foundation China; Partner, Holland and Knight LLP