Chapter 10
Strategic Linchpins and Policy Safeguards

10.1 Policies and Measures for China's Low-Carbon Development

10.1.1 Put in Place and Perpetuate a Complete and Comprehensive Policy Framework

China has created a policy system for low-carbon development that covers a wide range of sectors. Since the end of last century, the central government has deemed climate change policy as part of its sustainable development policy, in particular as part of its energy reform and economic development policy. Despite a milestone in itself, this approach lacks clarity on the importance of climate change, which results in the absence of clear policies for climate change mitigation and adaptation [1]. Since the 12th Five-Year Plan, more independent policies have emerged in the field of climate change, with setting clear and legally binding targets for curbing carbon intensity for the very first time. A variety of low-carbon pilot projects, carbon trading pilot projects, and MRV capacity building have also been launched. During the 11th Five-Year Plan period, the Chinese government established the first energy conservation policy system with binding targets as the centerpiece and performance assessment as the safeguard, contributing to lower greenhouse gas emissions as well as reduced energy intensity. With some revisions, most of the energy saving policies were kept in the 12th and 13th Five-Year Plans. For instance, energy saving mandates were expanded from the industrial sector to transport and buildings; the provincial breakdown of energy saving targets were more science-based; targets were extended from capping energy intensity at the national level to capping total energy consumption and promoting industry-wide energy saving; and more focus was placed on the role of market forces [2, 3]. During the 12th Five-Year Plan period, China set a target for CO_2 intensity for the first time, i.e. a reduction of 17% per 10,000 yuan of GDP, with continued enforcement of the accountability system. The 13th Five-Year Plan

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went a step further to set a national target of reducing CO_2 emission intensity by 18%.

Now, a complete and comprehensive climate policy framework has been created in China, comprising of not only administrative mandatory policies and best practices with Chinese characteristics, but also economic incentives (pricing, trading cap, fiscal subsidy, etc.), regulations (laws, regulations, and standards), and policies for R&D on low-carbon technologies. Meanwhile, there are other policies affecting climate, such as electric power market reform, reform of taxes and fees, etc. At present, the formulation of China's *"Law on Tackling Climate Change"* is underway in a steady manner. The 10th Meeting of the Standing Committee of the 11th National People's Congress adopted *the Resolution on Actively Tackling Climate Change of the Standing Committee of National People's Congress* on August 27, 2009, vowing to make the strengthening of climate change legislation part and parcel of the efforts to build and enhance the socialist legal system with Chinese characteristics, and listing it on the legislative work agenda. Subsequently, legislation on enhancing climate change management was incorporated in the 2010/15 legislative plan in the National Development and Reform Commission. In 2011, the Leading Working Group for Climate Change Laws and Legislation was set up, comprised of 17 government agencies, including the Environmental Protection and Resources Conservation Committee of the National People's Congress, the Legislative Affairs Commission of the National People's Congress, the Legislative Affairs Office of the State Council, etc. The National Development and Reform Commission served as the lead for legislative research, survey and drafting, stakeholder opinions soliciting. The Climate Change Law (Draft) consists of areas including General Provisions, Principles, Supervision and Management, Mitigation, Adaptation, Publicity and Education, etc. [4]. At the moment, no consensus has been reached on the draft law, with ongoing debates over the legislative framework, design of the core system and the coordination with relevant laws.

At the local level, Shanxi, Qinghai, Shijiazhuang and Nanchang have successively carried out individual local legislation to address climate change and low-carbon development. In 2010, Qinghai province promulgated the *Measures of Qinghai Province to Tackle Climate Change,* defining the province's climate change adaptation and mitigation legal system. Shanxi Province released its measures in 2011 for tackling climate change based on its own reality, including identifying key areas of mitigation and adaptation, and lying out specific steps for greenhouse gas concentration monitoring, greenhouse gases list compilation list, verifying regional and corporate greenhouse gas emission output, and minimizing climate change's impact. Shijiazhuang introduced its city-wide regulation on low-carbon development in 2016, which provided stringent provisions on the management of the operation, distribution and use of coal and oil, encouraged the development and utilization of new and renewable energy, and devised incentive policies for building, transportation, lighting, indoor temperature regulation, consumption reduction of daily necessities and other daily residential consumption.

10.1.2 Goal-Oriented Planning, Administrative Mandates, and Market Measures

As oppose to western countries' rule-based governance system centered around legislation, law enforcement, and judicature, China's climate change policy is generally characterized by goal-based governance built upon the planning system, stressing goal-oriented planning, administrative mandates, followed up by market measures [5]. Though the special legislation on climate change is still being drafted, China has incorporated a relatively comprehensive low-carbon planning regime with the "Five-Year Plans" at the core, with detailed steps at the local, and sectoral and territorial level [6]. The Five-Year Plans are one of the fundamental tools of national macro-control. China views climate change management as a long-term strategic task for social and economic sustainable development. Since the 12th Five-Year Plan, China has incorporated carbon intensity as a binding target in the national economic and social development plan, and launched national, regional and sectoral plans, programs and strategies to cope with climate change. Revolving around the national binding target of emission reduction per unit of GDP, efforts have been made to propel the low-carbon transition in energy and economy. The *National Plan for Tackling Climate Change (2014–2020)* was released in 2014. The 12th and 13th Five-Year Plan both had work plans for curbing greenhouse gases, with low-carbon development plans for various industries. These have provided a major boost to China's climate change efforts.

Administrative means are the most distinctive policy tools of China. In spite of China's increasingly full-fledged climate policies, the administrative means centering around "goals" are still predominant [7, 8]. Among the different administrative measures, performance assessment policies of emission reduction, energy conservation and the phase-out of outdated production capacity for local governments and major emitters stand out as typical policy instruments that have adapted to China's current system and institutional mechanism, ensuring the attainment of China's climate change goals. On the other hand, administrative means alone have their deficiencies and adverse consequences. First, administrative means are mostly expensive and economically inefficient. Secondly, this top-down stress escalation may not be properly translated into the spontaneous desire of local governments and enterprises to preserve energy and cut emissions. Thirdly, as the targets of energy conservation and carbon reduction are assigned to multiple levels of government, those at or below the county level bear the responsibilities incommensurate with their administrative authority. Caving in to mighty political pressure from above, grassroot governments may resort to extreme measures such as power cuts to reach their goals, resulting in adverse consequences [9].

Driven by international mechanisms, market-oriented policy system for climate change have flourished from its infancy, marking its milestone with the creation of the carbon market. Holistically speaking, China's market mechanism for climate change has experienced three stages of development [10]. The first stage, spanning from 1992 to 2008, was the exploratory phase featured by mostly project-level,

process-based and single-sided international transactions. As a developing country, China can sell its "Certified Emissions Reductions (CERs)" to developed nations helping them to meet their emission reduction targets through the Clean Development Mechanism (CDM). The second stage, from 2009 to 2015, is marked by efforts to foster the carbon market through innovations by bottom-up, allowance-based local pilots. In 2011, the Chinese government explicitly proposed in the 12th Five-Year Plan to "gradually set up a carbon trading market," recognizing the importance of carbon market in energy conservation and emission reduction for the first time at the national level. Later, to effectively implement the goals set out in the 12th Five-Year Plan, the National Development and Reform Commission issued the *Notice on the Pilot Work of Carbon Trading* at the end of 2011, approving the pilots in Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong and Shenzhen. From 2013 to 2014, the above seven provinces, municipalities, and cities successively promulgated the *Carbon Emission Trading Management Measures*, officially launching the seven pilots. The National Development and Reform Commission has provided each provincial and municipal commission much leeway for building the seven pilots that were distinctively designed in terms of the coverage, allowance allocation and trading rules, gaining rich and diverse practical experience for creating a nationwide carbon market. With the adoption of the Paris Agreement in 2015 and the inclusion of the emission peak target in the policy agenda, China is now embarking on the third stage of market development to combat climate change. In December 2017, the *National Carbon Trading Market Development Plan (Power Generation Sector)* was introduced, specifying that the power generation sector would be the springboard to kick off the national trading system. The first 1,700 power generation companies included in the national carbon market emit over 3 billion tons of CO_2e annually, accounting for about 1/3 of the country's total emissions. By the end of 2018, nearly 800 million tons of carbon emissions had been traded in China. In March 2019, the Ministry of Ecology and Environment released the *Provisional Regulations on the Management of Carbon Trading (Draft for Comments)*—a milestone in the institutional development of the national carbon market, providing the policy basis and legislative guarantee for building a nationwide carbon market.

10.1.3 Strengthen the Coordinated Governance of Environment and Climate Change

In recent years, it has become evident and trendy that coordinated governance between environment and climate change have become increasingly prominent. In the mid and late period of the 12th Five-Year Plan, air quality issues, in particular, PM2.5 and ozone drew tremendous concern both domestically and internationally, prompting swift actions by the Chinese government to introduce a spate of ambitious policies for combating air pollution, including the *Action Plan on Air Pollution Prevention* and *Control*, *Three Year Action Plan for the Blue Sky Campaign and*

Comprehensive Work Plan for Energy Conservation and Emission Reduction of the 13th Five-Year Plan. These policies, through decarbonizing the energy mix, developing clean energy, enhancing energy efficiency, and gradually decrease the use of fossil fuels, have managed to secure the coordinated governance of air pollution and climate change [11]. For example, the central government has enacted policies for curbing and reducing coal consumption, and started with the most polluted areas for stringent restriction on coal use, which were gradually expanded to the entire nation. Thanks to an array of interventions to curtail coal consumption, more than 950 million tons of coals were saved from the closure of small thermal power plants in China between 2005 and 2020. Approximately 15.18 million tons of SO_2 emissions were prevented from the reduced coal use. With over two billion tons of CO_2 emissions forestalled [12]. In a new round of organizational restructuring in March 2018, the climate change and emission reduction responsibilities of the National Development and Reform Commission were integrated into the newly established Ministry of Ecology and Environment, further benefit the coordinated governance of environment and climate change.

10.2 Strategic Linchpins and Policy Safeguards for China's Long-Term Low-Carbon Development

Combating climate change involves every facet of the economy, society and environment. Climate change strategy must also be aligned with the overall national development strategy and integrated into the economic and social development strategies of all industries and sectors, to enable coordinated governance and win–win cooperation among economy, society, environment and climate change. China's 2050 long-term low-carbon development strategy should, first and foremost, support the country's development, and assist in building a modern socialist country that is prosperous, strong, democratic, culturally advanced, harmonious and beautiful. Meanwhile, the strategy should seek to strengthen ecological civilization, green low-carbon circular development, harmonious coexistence between human and nature and sustainable development. It should fulfill the target of deep decarbonization aligned with the global efforts to limit temperature rise well below 2 °C and ideally with 1.5 °C (see Fig. 10.1). From the perspective of national macro strategy, China's climate change strategy and policy support need to highlight the following aspects:

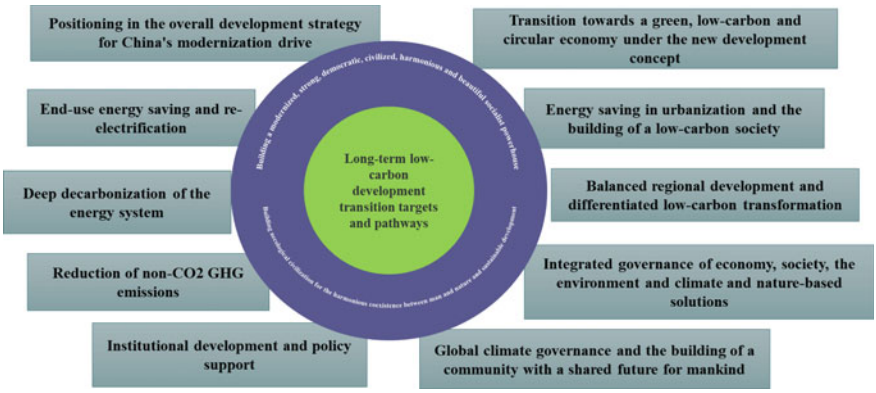

Fig. 10.1 Strategic framework for long-term low-carbon emissions transition

10.2.1 Defining Climate Change Strategy in National Priority and Embed the Pathway of Deep Decarbonization in the Overall Development Goals and Strategies

The 19th CPC National Congress incorporated progress of ecological civilization in the foundation for building socialism in the new era, making a two-stage strategic roadmap. First stage, from 2020 to 2035, aims to basically achieve socialist modernization with fundamental improvement of the ecological environment and the achievement of a beautiful China in general. Second stage, lasting from 2035 to mid-century, seeks to build China into a great modern socialist country that is prosperous, strong, democratic, culturally advanced, harmonious, and beautiful with all-round ecological progress and fulfillment of a beautiful China. Climate change efforts need to be aligned with the two-stage goal, the formulation of long and medium-term and short-term climate plans needs to be integrated into the comprehensive strategies for the economical social environment. During the first stage in 2020–2035, it is important for the national economic and social development strategy to harness the synergy of improving environmental quality and reducing CO_2 emissions, attain China's NDC goals while lowering PM2.5 concentrations in major cities and regions to below 35 $\mu g/m^3$, thus achieving the coordinated governance and a win–win scenario of the economy, energy, environment and climate change. Therefore, it's essential to specify the earlier peak of CO_2 emissions as a major strategic target at this stage, and put forth the peak emission targets and measures to spur the energy revolution and economic transformation. Ideally, 2035 should witness notable reduction in CO_2 emissions from the peak year, with a continuous cut of absolute emissions and the absolute decoupling of sustainable economic and social development from CO_2 emissions, which are to be aligned with a more ambitious emission reduction targets in the second stage [13, 14].

After 2035, as China achieves basic modernization, with ecological environment fundamentally improved, urgency is placed on climate change response and greenhouse gas reduction, which is a more daunting challenge. To fulfill the 2 °C target, the annual decline of global greenhouse gas emissions must exceed 7%, far higher than that of the developed nations before 2030. With this in mind, during the second stage from 2035 to 2050, China's climate change strategy should go beyond the domestic need for resource utilization and environmental protection, it should accommodate the pathway of emission reduction needed for preserving the ecological safety of the earth, honor the historic mission by making contributions to humanity. Using the benchmark of keeping temperature rise below 2 °C with continuous pursuit for 1.5 °C, formulate goals, strategies and pathways for a steep reduction in absolute emissions across all greenhouse gases in the entire economy, and bring to fruition near-zero CO_2 emission and deep emission reduction from other greenhouse gases by the middle of the century. The process of deep decarbonization of the energy system will also effectively roll back the emissions of conventional pollutants, playing an instrumental role in securing a $PM_{2.5}$ concentration below 15 $\mu g/m^3$ in major regions and cities in China by 2050. With the continuous development of China's comprehensive national strength and international influence, China should proactively assume responsibilities and obligations that echo its position in the greater world, placing climate change goals at the center of the strategy of building a socialist modern society, steer the world onto the path of climate-friendly low-carbon economic development, taking on commitment to global ecological civilization, the shared interests of all humanity. Demonstrate world-leading influence and leadership in combating climate change, by historic contribution to the preservation of the earth's ecological safety, and the survival and development of all humankind.

The key to implementing the low-carbon development strategy today lies in changing the mindset of policy-makers at all levels. It is crucial to adhere to the development philosophy of the new era, with innovation at the core of development, shift growth drivers, and transform the way of development. It's imperative to enable harmonious coexistence between human and nature and embark on a path of high-quality green and low-carbon circular development. Policy-makers at all levels must shift their mindset in development concepts, from sole pursuit of the quantity and speed of GDP growth to a more comprehensive effort on the quality and efficiency of economic growth, formulate and enforce binding targets and policy "red lines" for resource conservation, environmental protection and CO_2 emission reduction. Governments at all levels should balance between economic growth, employment, and life quality with resource conservation, environmental protection and carbon emissions, carefully balancing GDP growth with its related losses of resources and environment, to avoid a "dilemma" and enjoy a "win–win". Efforts should be made to take climate change as the centerpiece of building ecological civilization, placing sustainable development strategy featuring green low-carbon transformation high on the agenda of economic development, change the mindset and assessment criteria of policy-maker, and strengthen the accountability of energy conservation, carbon reduction, and ecological protection.

Decision-makers at every position should fully recognize the importance and strategic positioning of global cooperation in addressing climate change. It is an indisputable scientific fact that human activities have caused global climate change, and tackling climate change is a common cause for global cooperation in protecting the ecological safety of the earth and the survival and development of humankind. President Xi Jinping repeatedly stressed that "climate change affects the well-being of everyone and the future of humanity." China's strategy for promoting low-carbon transformation and combating climate change is not only an inherent demand for sustainable development domestically, but also a major step forward to proactively assume international responsibilities, and actively contribute to the progress of humankind. The shared interests of all should be the center in the strategic goals and roadmap for low-carbon transformation of China. It's imperative to proceed from and to take the leadership of the global trend for low-carbon development in combating climate change, (develop competitive advantages for low-carbon technologies and execution capabilities for it to become a milestone in building of a strong modern socialist country.)

10.2.2 Adhere to New Development Concept, Spur Industrial Restructuring and Upgrading, and Facilitate Green, Low-Carbon, Circular Economical Transformation

Since the Chinese economy entered a period of "new normal", the central government has put forth five development notions, namely, "innovative development, coordinated development, green development, open development and shared development," using innovative development as the growth drivers, and green development as the strategic target. The 19th National Congress also enshrined strengthened ecological civilization and the building beautiful China as a fundamental strategy of China's socialist modernization, indicating the need to establish an industrial system that is of green, low-carbon and circular development, build a clean, low-carbon, safe and efficient energy system, and promote comprehensive conservation and utilization of resources. This will help accelerate the strategic restructuring of the economy, catalyze industry transformation and upgrade, enhance development efficiency and quality. It is also a strategic action to reduce CO_2 emissions.

Since the 11th Five-Year Plan period, China has seen remarkable achievements in energy conservation and carbon reduction, with energy intensity and CO_2 intensity per unit of GDP on rapid decline. Given the unique characteristics of economic structure and energy mix at the current stage of industrialization, the energy and CO_2 intensity per unit of GDP are still at a relatively high level. The technical efficiency of energy conversion and utilization and energy consumption per unit of product in China are not far behind that of developed countries, with many areas at world leading level. Yet China's energy consumption per unit of GDP in 2017 was still 1.6 times that of the world's average, and two to four times that of developed countries.

This was mainly due to an excessively high proportion of the secondary industries, especially the heavy chemical sector. Energy consumption from the industrial sector accounts for 2/3 of the total national end-use, as opposed to no more than 1/3 in developed countries in general. Moreover, China's manufacturing products are at the middle and lower end of the value chain with high energy consumption and low added value. The structural factors of the above industries and products are the main contributors to high energy consumption of GDP [15].

At present, the new wave of industrial revolution marked by digitalization and smart technologies is flourishing worldwide with cross influence of two major trends of economic green transformation and digital transformation. The growing construction of data centers during digital transformation will spur up the demand for electricity, and will also lead to tremendous improvement in the efficiency of economic growth and resource utilization, cutting energy consumption intensity per unit increase of GDP as a whole. Therefore, it's vital to grasp and speed up the new economic development marked by digitalization, optimize allocation of resources, and accelerate the spread and application of such digital technologies, including artificial intelligence, 5G, cloud computing, and Internet of Things, during the low-carbon transformation of energy and economy.

From 2005 to 2018, about 1/3 of the decline in GDP energy intensity was attributed to the technological energy saving from the improved efficiency of energy technologies, whereas around 2/3 was from the structural energy saving from the changes and upgrading of industrial structure and product portfolio. In the future, the strategic restructuring shall focus on accelerated high technology industry and modern service industry, reducing the share of the industrial sector, especially the heavy and chemical sector with high energy consumption, while moving up manufactured goods to the higher end of the global value chain. This is an important strategy for low-carbon economic transformation.

It is necessary to establish and perpetuate an energy-saving and low-carbon industrial system by adopting new industrialization trends, vigorously developing circular economy, optimizing the industrial structure, revising the catalogue of industrial restructuring, restoring the expansion of energy intensive and high emission industries, speeding up the phase-out of backward production capacity, vigorously fostering the service and strategically emerging industries, devising targets and action plans for emission control in key industries, and studying and formulating standards for greenhouse gas emissions in key industries. Measures should be made to enhance energy efficiency through energy conservation, restrain emissions from key industries such as electricity, iron and steel, nonferrous metals, building materials, and chemicals, and etc. Strengthen the management of carbon emissions in new projects, actively control greenhouse gas emissions from industrial production, promote the circular transformation of industrial parks and build a green, low-carbon and circular industrial system.

Currently, China's exports mainly comprise of manufacturing goods, and the export of services is relatively low. However, these manufacturing products are mostly medium and low-end with high energy consumption and low added-value, causing persistently high implied energy and CO_2 levels of export in goods, which accounted

for more than 20% of China's total emissions from 2005 to 2014, a percentage only declined until recent years. The implied CO_2 emissions from export in goods made up 15.3% of total domestic emissions in 2018, while implied emissions from imports stood at 542 million tons, and implied emissions from net exports contributed 10.8% to total domestic emissions. Thus, it is imperative to actively place efforts in limiting the extensive expansionary economic growth pattern driven by continuous rise in investment, capacity building of the heavy and chemical industry and expansion in export of manufacturing goods. The export structure should be optimized to curb and reduce the export of energy-intensive products, promote export of higher-end products in the value chain, reduce implied carbon transfer to foreign countries, encourage and boost export of high technology and high-end service industries, and work to strike a balance of imports and exports in terms of implicit carbon, a crucial step to lower domestic CO_2 emissions, and should be deemed a major component of China's low-carbon development strategy. With the ongoing economic globalization, China's efforts in developing export-oriented economy, improving the international competitiveness of manufacturing products and technologies, and moving to the higher end of international industrial value chain also constitute the country's solution to reducing CO_2 emissions and securing low-carbon transformation [16, 17].

It is of great significance to develop a circular economy with improved efficiency of resource utilization to cut energy consumption and CO_2 emissions. Resource utilization efficiency is an important bridge toward green and low-carbon circular development. It emphasizes reduction, reuse and recycling of resources to obtain more higher added-value and sustainable products and services with less resource consumption and emissions. This also marks a key component of green and low-carbon transformation and sustainable development.

By current universal standard, China consumes vast amount of material resources. In 2017, China made up 1/3 of the world's resource extraction. In terms of per capita intensity, China's per capita material resource extraction in 2017 was 23.6 tons, ranking the third in the world, about twice the world's average per capita of 12.2 tons. The resource output of China's economic system is less than 1/10 of that of Germany and Japan. One reason is structural. China is under rapid urbanization and massive infrastructure construction that consume large quantities of material resources, different from post-industrialized developed nations. Second, China is relatively behind in the technology and management of primary resource reduction, efficient processing and conversion, waste recycling, and etc. due to technical impediments. China's overall resource consumption will remain relatively high for a long time in the future. Growing urbanization will keep increasing the stock of material resources in the society, with explosive growth in urban wastes, prompting accelerated efforts in the recycling and reuse of used and scrapped cars, home appliances, photovoltaic components, and electric vehicle batteries. "Urban mines" will partly replace natural minerals to become an important source of metals and non-metallic material resources, with recycling making greater contributions to the guarantee of strategic resources. Under this scenario, it is necessary to make the development of circular economy and the improvement of resource utilization efficiency a crucial component of the long-term low-carbon development strategy, and strive to double

the output of major resources by 2035 and measure up to the world's advanced level of resource utilization efficiency by 2050. Similar to the proposal of the EU Green Deal to decouple economic growth and resource utilization to embark on the path of sustainable development featuring a green and low-carbon cycle [18].

10.2.3 Further Improvement in Energy Conservation and Efficiency for End Use and Facilitate the Substitution of Electricity and Hydrogen for Direct Use of Fossil Energy

The industrial sector is the biggest end user of energy in China, accounting for about 65% of the total end-use of energy nationwide in 2018, of which 70% comes from energy-intensive raw material sectors. China's output of steel, cement, household appliances and other products makes up about half of the world's total. Aside from accelerating industrial restructuring, transformation and upgrading, focus must be placed on the phase-out of backward production capacity, swifter industrial technology upgrade and improve energy efficiency. In particular, for steel, cement, coal and petrochemical industries where emission reduction remains a challenge, revolutionary and deep decarbonization technologies such as hydrogen steel making and hydrogen chemical technologies should be developed. Electric and hydrogen energy should take up greater share in end-use energy composition to bring about the deep decarbonization in the industrial sector. As a manufacturing powerhouse, China will not completely follow the path of developed countries like the Americas and Europe to relocate the manufacturing industry to less-developed regions in its future modernization endeavors. By the middle of this century, China will maintain its strategic positioning of a major and comprehensive manufacturing nation, with the added value of industrial sector to percentage of GDP no less than the current average level of developed countries. Despite the trend of urbanization, the projected rate of growth and proportion of energy consumption and CO_2 emissions in the construction and transportation sectors will overtake that of the industrial sector, but the share of energy end consumption in the industrial sector will remain higher than that in the construction and transportation sectors. Given the great potential of industrial sector for energy conservation and carbon reduction, it should enable an earlier peak of its CO_2 emissions prior to 2030 by ramping up industrial transformation and upgrading, improving energy efficiency and promoting electric energy replacement [19].

In 2017, the end energy consumption of the construction sector accounted for 16% of the total end use in China. To fully unleash the potential of energy conservation in the construction sector, improve related policies on building energy efficiency, and push for the 65% energy efficiency standard for all new buildings by 2020, enhance the mix of energy end-use of buildings, so that renewables could contribute 25% to all energy consumption of buildings by 2020. Accelerated steps should be taken to revamp existing buildings and heating metering for energy conservation, government

should lead the efforts with imposed cap on energy consumption of public buildings. More importantly, the total number of public and civil buildings should be limited. In 2015, the construction industry consumed around 864Mtce of energy, approximately 20% of the national total energy consumption. In the future, the total building area should be kept at about 75 billion square meters with roughly 1100Mtce in energy consumption. Heating in northern China should better leverage the combined use of waste heat and pressure in the power and industrial sector, strengthen distributed renewable energy and electric energy replacement, boost the clean and efficient utilization of biomass energy in rural areas, and strive for emission peak around 2030, support the nationwide peak target, and bring about near-zero emission in the sector by the middle of this century [20].

A comprehensive green and low-carbon transport system should be established to improve the transport structure. Develop railways, urban rail transit, waterways and other modes of transport that are low energy consumption and enhance transport demand management. Fuel consumption limits should be raised across the board for vehicles and vessels with a timetable for phasing out gasoline vehicles. Green mobility should be encouraged with promotions for more trips on public transport. The composition of vehicle fuels should be improved by tapping into biofuels, especially for electric vehicles and hydrogen fuel-cell vehicles. Oil and gas should be replaced with electricity and hydrogen on a large scale. Smart management of transportation must be strengthened to develop combined transport of land and sea with enhanced efficiency. In 2018, 509 Mtce of energy was consumed in the transport sector, equivalent to 10.7% of the country's total energy consumption, with freight taking up over 60%. The future will see increasing proportion of energy consumption in passenger transport with reduced consumption in freight. By adopting proper measures, China is on track to achieve the peak around 2035 in the transport sector, and near-zero emission by the middle of this century [21].

With the end-use sector, promoting the substitution of electricity and hydrogen energy for direct combustion of fossil fuels and utilization of raw materials is a vital step in the low-carbon transition strategy. With the support of near-zero emission energy system dominated by new and renewable energy, replacing fossil energy with zero-carbon electricity and hydrogen generated from electricity is a crucial initiative for the end users to achieve near-zero emission in the future. The share of power in end-use energy consumption in China was about 24% in 2019, projected to rise to over 30% in 2030, and around 55% in 2050 under the 2 °C scenario. Non-fossil energy as a percentage of primary energy will also climb from 15.3% in 2019 to 25% in 2030 and over 70% in 2050. With the increase of non-fossil power in total electricity consumption, more electric power substitution in the end use sectors will be instrumental to lower CO_2 emissions. On the other hand, hydrogen as a clean, zero-carbon secondary energy, can be used as a raw material in the process of industrial production to replace fossil fuels such as coal, oil, coke and gas. It can also be used as a means of energy storage to replace and reduce fossil fuel combustion and direct use of the end users, and should therefore be included in China's long-term low-carbon development strategy as an important strategic resource [22].

10.2.4 Speed up the Decarbonization of Energy Mix and Ensure Clean, Safe, and Economical Energy Supply

Since the 11th Five-Year Plan, China has paced up the development of new and renewable energy and promoted the low-carbonization energy mix. The share of coal in the total energy mix has dropped from 72.4% in 2005 to 57.7% in 2019, non-fossil energy has risen from 7.4% to 15.3%, and CO_2 intensity per unit of energy consumption has fallen by 13.3% in 2019 from the level in 2015. However, the coal-based energy mix is yet to be fundamentally transformed, with the CO_2 intensity per unit of energy consumption more than 20% higher than the world average and 35% higher than that of the European Union. Accelerating the development of new and renewable energy and reducing CO_2 intensity per unit of energy consumption are important measures to cut CO_2 emissions on the premise of ensuring safe and efficient energy supply. By the middle of this century, China is to build a near-zero-emission energy system with new and renewable energy as the mainstay, actively develop technologies like Carbon Capture and Storage (CCS) and Bioenergy with Carbon Capture and Storage (BECCS). These technologies can be applied for massive industrialization after 2030 and enable more than 500 million tonnes of CO_2 capture and storage a year by 2050, paving the pathway for earlier carbon neutrality.

By 2030, non-fossil power should comprise about 50% of the total power generated, with non-fossil fuels taking up about 25% of the primary energy mix before rising up to 90% and over 70% respectively by 2050 under the 2 °C scenario, and over 90% and over 85% respectively under the 1.5 °C scenario. This should be part and parcel of China's long-term low-carbon transformation strategy. China now ranks first in the world in terms of installed capacity and new production capacity of hydro, wind and solar power, which will all exceed 400 million kilowatts by 2030. Taking safety into consideration, nuclear power should be developed on a large scale with an installed capacity exceeding 100 million kilowatts by 2030, and 200 to 300 million kilowatts by 2050. With its high load factor, nuclear power holds the key to the safe and stable operation of grids with a high uptake of renewable energy. With the development of technological innovation and new energy industry, the cost of wind and solar electric power has fallen rapidly to a level on par with that of traditional fossil power in most cases. Energy storage, electric vehicles and other technology costs are also seeing rapid decline, ready to embrace massive industrialization and experience faster growth driven by technological innovation and policy support. Natural gas, as a cleaner, more efficient and lower-carbon source of fossil energy than coal and oil, enjoys its unique advantages and importance in the low-carbon transition of the energy system, providing grounds for the exploitation and utilization of more conventional and unconventional natural gas to replace and reduce the consumption of coal and oil [23, 24].

At present, China is still highly dependent on oil and natural gas imports—a potential hazard for energy security. With the swift energy transformation, additional future energy demand will be met mainly by newly developed energy sources in order to

peak emissions by 2030. The consumption of coal, oil and natural gas will successively experience steady decline, and the oil and gas imports will see a decline. To safeguard the security of national energy supply, focus should be placed on the macro trend of energy transformation to accommodate short and long-term development. The replacement of fossil fuels with renewable energy is the ultimate solution to the security of energy supply. Excessive dependence on coal-to-oil and coal-to-gas is not desirable. Attempts to cut back imports of oil and gas by promoting coal consumption run counter to the world trend of energy transformation, with no prospects for technological competitiveness internationally. The rapid industrialization and lower cost of new and renewable energy is increasingly disrupting the traditional energy market, with growing interest from the finance and investment community for the zero-carbon energy system. Traditional energy infrastructure and capacity expansion might risk early retirement and elimination in the future, incurring huge stranded costs. By the middle of this century, China should put in place a sustainable energy system based on new and renewable energy to ensure the turnaround of environmental quality, achieve the security of energy supply, end the country's dependence on oil and gas imports, thereby creating a clean, safe, economically appropriate modern system of sustainable energy supply to support the goal of building a strong socialist modern country and a "beautiful China" [25].

10.2.5 Push Forward the Reduction of Non-CO_2 GHG Emissions, and Take Measures to Reduce Economy-Wide GHG Emissions

The Paris Agreement calls for absolute emission reduction of all greenhouse gases in the entire economy of developed nations and encourages developing nations to do the same step by step. China's NDC targets and action plans under the Paris Agreement mainly involve CO_2 emissions related to energy activities, which embody the principle of common but differentiated responsibilities. With the rise of China's comprehensive national strength and future progress in global response to climate change, China should steadily press ahead on emission reduction from all greenhouse gases across the economic sectors to rein in and reduce non-CO_2 greenhouse gas emissions, placing it as a crucial component of the long-term low-carbon development strategy, set clear objectives and strategies, and develop holistic plans for coordinated progress.

In 2014, China's emissions of non-CO_2 greenhouse gases such as methane, nitrous oxide and fluorine-containing gases accounted for approximately 16% of the country's total greenhouse gas emissions. These emissions involve a wide range of industries from scattered sources such as methane leakage in oil and gas production, gas emissions from coal mines, replacement of refrigerants for air conditioners and waste disposal. Since the initial cost of emission reduction is fairly low with immediate positive economic benefits, mitigation measures should be vigorously

promoted. But if deep emission reduction or near-zero emission is to be achieved, its marginal cost of emission reduction will mostly be on a nonlinear rise. With the prospect of substantial CO_2 reduction in the energy system, non-CO_2 and other greenhouse gas emissions will make up a larger share and become the biggest challenge for emission reduction, thus taking a more vital role in the future deep decarbonization scenario. To achieve near-zero and net-zero emissions of all greenhouse gases by the middle of this century, China needs to spur innovation and industrial development of non-CO_2 emission reduction technologies. During the 14th Five-Year Plan period, solutions should be crafted and implemented to cut non-CO_2 greenhouse gas emissions to gradually set up a policy framework and management mechanism for reducing all greenhouse gases across economic sectors.

Methane is a short-lived greenhouse gas whose warming potential is 84 times that of CO_2 in 20 years (22 times in 100 years). Methane emission reduction can contribute greatly to controlling immediate temperature rise and is gaining more attention in this regard. Relatively mature emission reduction technologies and measures are available for methane leakage in coal, oil and gas production with low cost and high potential economic benefits. It is necessary to vigorously disseminate these technologies, propose emission reduction targets and plans, formulate industry standards, and incorporate them in national and regional development plans to take the lead in achieving significant results in non-CO_2 emission reduction.

Methane emissions are the most important source of non-CO_2 greenhouse gas emissions in China, comprising 56% of all non-CO_2 greenhouse gas emissions in 2014. It is also the most important area for emission reduction with the biggest potential and effective technology for implementation. Under the macro trend of energy transition, activities in coal and oil and gas production will be reduced, resulting in lower methane emissions. There is also a need for better management and technological progress to facilitate methane recycling and reuse, strengthened management of rice paddies, improved animal feeding and solid waste disposal for the effective control and reduction of methane emissions.

It's vital to step up technological innovation, develop alternative technologies and processes, enhance end-use recycling, reuse, disposal and decomposition, and improve farming methods to effectively curb and reduce greenhouse gas emissions such as nitrous oxide and fluorine-containing gases. By employing a mixture of measures, China can manage to simultaneously peak non-CO_2 greenhouse gases and CO_2 emissions. By 2050, non-CO_2 greenhouse gas emissions, ideally, should fall by more than 50% from the peak year.

The initial cost of reducing non-CO_2 greenhouse gas emissions is fairly low, with some technologies bearing positive economic benefits, but the marginal cost shows a steep rise. Technically and economically feasible tools and measures are not yet available for deep emission reduction of non-CO_2 greenhouse gases, which, nonetheless, are hopeful for a simultaneous peak with CO_2 by 2030 on condition of redoubled efforts. But by 2050, there will still be more than one billion tons of CO_2e in non-CO_2 greenhouse gas emissions that cannot be effectively reduced. To achieve prompt carbon neutrality of all greenhouse gases after the mid-century benchmark, non-CO_2 reduction will be a gigantic obstacle, which calls for the development of negative

emission technologies (such as BECCS) and other CO_2 removal technologies (CDR) in the energy sector to offset the remaining emissions. Therefore, the vigorous development of deep emission reduction technologies and tools for non-CO_2 greenhouse gases is vital to the future goal of carbon neutrality.

10.2.6 Attach Importance to Urban Energy Conservation to Drive the Change of Consumption Patterns and the Construction of a Low-Carbon Society

As China wraps up massive infrastructure construction from industrialization and urbanization, the proportion of energy consumption and CO_2 emissions needed for the production of basic investment goods and raw materials decreases, and the share of energy and CO_2 emissions supporting the production of social and public consumer goods and direct household consumption increases. In this context, promoting policies of energy saving and low-carbon consumption in urbanization will serve an increasingly important role in realizing long-term emission strategy and pathway.

Urbanization is not only a powerful driver for spurring domestic demand, fueling economic growth and improving people's well-being, but also a major contributor to increased energy consumption and CO_2 emissions. China should seek balanced and coordinated development among regions in the process of industrialization and urbanization, devise holistic plans for urban and rural areas, and ensure social fairness and harmony. At the same time, it is necessary to explore the model of social production and consumption centering around ecological civilization and pave the path of a new model of urbanization [26].

President Xi Jinping stressed the need to "give high priority to energy conservation during urbanization, foster diligent and thrifty consumption, and speed up the formation of an energy-conserving society." Energy consumption is bound to rise with the construction of urbanization infrastructure and the migration of rural residents. Given the circumstance, endeavors should be made during urbanization with focus on low-carbon urban planning, infrastructure, lifestyle and consumption, and promote public awareness, and consumption habits. The overall transition strategy should revolve around city size and layout, transportation system and way of travel, building structure and energy-saving standards, energy supply and consumption pattern. Apart from more stringent standards for building energy efficiency, enhanced energy efficiency of home appliances and improved automotive fuel economy, among other energy saving measures, more focus should be placed on the general layout and planning of low-carbon cities, the transition from luxury spending and material pursuits of oversized luxury housing, large-engine vehicles, etc. The change of consumption awareness and habits can effectively curb the final energy demand of the whole society, and spark the transition of economic and social development pattern. Caution must be exercised to avoid copying developed nations'

traditional development model of carbon-intensive infrastructure in urban construction and luxury spending, and avoid the dilemma in which one can only seek low energy consumption and low-carbon emission on specific facilities and individual technologies because high energy intensity and high carbon are commonplace in cities in the first place. Campaigns should advocate ecological civilization and a low-carbon society, explore new models of low-carbon eco-cities and green lifestyle, so as to embark on a new journey of ecological, low-carbon urbanization.

While stressing the shift of development concept and innovation of development model as we build ecological civilization and materialize low-carbon development transformation, priority should also be given to encouraging and reinforcing the transformation and innovation of consumption awareness in order to lead a new trend of consumption. With basic material needs met, clean air, clean drinking water, and a livable environment are deemed more important than personal material comforts. A high quality life is the shared experience and public interest of all, which will boost the accumulation and sharing of public wealth, and fairness and win–win outcomes for all countries and social strata. Therefore, it is crucial to steer the whole society's interest from the path of industrial civilization featuring the one-sided pursuit of economic output and productivity onto the course of ecological civilization characterized by the harmony between human and nature, economy and environment, human and society and sustainable development, and shift from the preoccupation with material wealth maximization to a more healthy, moderate and simple way of consumption with more focus on the ethical and cultural advancement to avoid extravagant consumption and waste, thus prompting the transformation of economic and social development through innovation in people's mindset [27].

The transformation of the way of consumption requires direction from public opinion and media outlets. The dissemination of information should be reinforced to popularize the knowledge and raise public awareness for climate change, and encourage the public to take voluntary actions together through grass-root organizations and associations within various initiatives and joint actions, so that residents can willingly change their consumption behaviors and lifestyles. Moderate and frugal low-carbon consumption pattern and behaviors should be viewed as social morality and the communication and education of low-carbon consumption concepts and behaviors should be strengthened. Public institutions must lead by example by carrying out energy-saving and low-carbon campaigns in institutions, campuses, hospitals, gymnasiums and military barracks to promote moderate consumption and the use of energy-saving and low-carbon products, curb extravagance and waste. The recycling and classification of waste products should also be improved.

Urban development policies and mechanisms should entail incentives for low-carbon consumption to guide, regulate and encourage reflected individual consumption behaviors, and create an enabling environment for low-carbon consumption in accommodation, transportation, food consumption, among others. The shift in the awareness and pattern of public consumption will also trigger the transformation of production pattern. The public preference for low-carbon household appliances and daily consumer goods will incentivize energy saving and carbon reduction in the production process. Through carbon labeling and low-carbon certification of

manufacturing products, consumers and producers can join hands in prompting the low-carbon transformation of the entire society.

Efforts to build smart cities have become the latest urban trend. The application of smart technologies in managing cities and running infrastructure is conducive to efficiency improvement, resource allocation enhancement and energy and material consumption reduction. It promotes the smart distributed energy system, optimizes the match of power source, grid and load, boosts the development of the urban energy network, and energy block chain, and ultimately drives and secures low-carbon urban development. Thus, smart technologies and low carbonization programs should be integrated as two strategic pillars and path for implementation during China's new urbanization.

10.2.7 Promote Coordinated and Balanced Regional Development and a Differentiated Low-Carbon Transition in Line with Local Conditions

Like many developing countries in the world, China faces serious regional disparities. The eastern coastal provinces and municipalities are more economically developed and classified as priority development zones, whereas the central and western regions lag behind, with some being key development zones and some others falling under the category of key ecologically functional zones or restricted development zones. Different regions vary in their energy and resource endowments, hence varied positioning of industries. For instance, Shanxi and northwest China are rich in coal resources, so the bulk of their income comes from high-energy-consuming raw material and coal chemical industry with high energy consumption and high carbon intensity per unit of GDP. With abundant hydropower resources, southwest China is the national hydropower base that is well positioned to foster energy-intensive heavy chemical industry, big data processing and other energy-intensive IT industries. In comparison, the eastern coastal regions lack energy and resources but outperforms in terms of economy and technology. Thus these regions should speed up economic transformation and develop high-tech and modern service industries. On the other hand, China's renewable energy resources are unevenly distributed, with the northwest rich in wind and solar and southwest rich in hydro. Besides meeting the regions' own needs, these renewables can be transmitted to the mid-east regions of China to complement the distributed energy power there, thus achieving an ambitious uptake of renewable electricity in the country. Therefore, during the national low-carbon energy and economic transformation, disparities regarding the positioning, economic structure, energy and resource endowment of each region, province and municipality must be taken into account in order to devise holistic plans to ensure the coordinated, balanced and inclusive development among all regions and advance nationwide low-carbon development.

Pursue innovations in the low-carbon development model by promoting trials of low-carbon provinces, autonomous regions and cities, carrying out pilot low-carbon cities (towns), industrial parks, communities, businesses and transportation, exploring diverse low-carbon development models with distinctive characteristics, and studying effective solutions to carbon emissions in different regions and cities so that such cities will feature rational spatial distribution, intensive utilization of resources, low-carbon production, high efficiency and green and livable environment. Research should focus on trying out and promoting a low-carbon certification and honor roll system in order for products with low-carbon footprint to be certified and labeled.

Implement customized regional strategies and policies to address climate change. Differentiated targets, tasks and approaches for climate change mitigation and adaptation should be determined in light of the resource endowments and industrial structure of the east, central, northwest, southwest and northeast China as well as the federal government determined positioning of the different functional priority zones. Cities under optimized development in eastern China must put strict limit on the consumption of coal and other fossil fuels, with the aim to peak CO_2 emissions first in China. Cities under prioritized development must step up control of carbon intensity, with the old industrial bases and resource-intensive cities in northeast China ensuring faster transition to green and low-carbon development. Southwest China, a region rich in renewable energy resources, could prioritize pursuing 100% renewable energy in the cities, and some provinces and cities can also aim for an earlier peak. Major agricultural products production regions for should build more small to medium-sized cities and towns, encourage proper concentration of population, actively promote a controlled level of agricultural mass production and industrialization. In key ecologically functional zones, ecological red lines should be strictly enforced, and stringent industrial development catalogue formulated to restrict new high-carbon projects. Industries that do not meet their main functions should be withdrawn from the system. Distinctive low-carbon industries should be fostered based on local conditions. Differentiated and inclusive low-carbon transformation should be implemented with a particular focus on the marginal impoverished rural population to improve their work and living conditions and secure the supply of high quality clean energy. Distributed renewable energy programs should be tailored to the local reality and its certified emission reductions (CCER) should be included in the national or provincial/municipal carbon market as an offset mechanism to spur sustainable development in less developed regions.

At present, it is essential to facilitate an orderly peak in CO_2 emissions among regions. Provinces and municipalities in the priority development zones in the east should reach the peak during the 14th Five-Year Plan period. The central, southwest and northeast should hit the peak around 2030, and those in the northwest around 2035, ensuring a roughly nationwide peak prior to 2030.

Regional strategic priorities and measures for near-zero CO_2 emissions by 2050 will vary. Drawing upon the experience of low-carbon pilot cities, a number of zero carbon cities, development zones and communities should be built based on local realities. In the southwest region that possess abundant renewable resources, some

cities can experiment 100% renewables ahead of their peers. The eastern and central regions should gradually build and scale up near-zero-emission cities underpinned by renewable energy.

10.2.8 Harmonize Measures for Economic Development, Environmental Protection, Climate Change, and Biodiversity Improvement

The Paris Agreement stresses the inherent linkage between addressing climate change and the sustainable development. China's climate change strategy also highlights the coordinated management and solutions for overall economic and social development, ecological and environmental protection and greenhouse gas emission reduction to drive the transformation toward green, low-carbon and circular economic development. Advancement in ecological progress is needed for the harmonious coexistence and sustainable development between human and nature. Therefore, increasing focus has been placed on the coordinated and win–win strategies for tackling climate change, boosting economic growth, improving people's livelihood, enhancing environmental quality and protecting biodiversity, of which nature-based solutions (NbS) have drawn increasing attentions worldwide.

Through climate change management and accelerated transition to low-carbon energy and economy, a near-zero-emission energy system primarily based on new and renewable sources of energy should be up and running by the middle of this century, curbing and reducing the emission of conventional pollutants at the source, helping to meet environmental quality standards. For instance, $PM_{2.5}$ concentration in major regions will be limited to below 15 $\mu g/m^3$, and most regions below 10 $\mu g/m^3$by 2050 [28].

NbS refers to the practice of following the rules of natural ecological system through the protection, remediation, improvement and strengthened management of the ecosystem to enhance its functionality, thus effectively and adaptively easing the strain of climate change on society, upgrading climate resilience, preserving biodiversity while producing benefits for human well-being and biodiversity. Through enhancing carbon storage capacity of forests, grasslands, wetlands and agricultural land, emission sources would be reduced and carbon sinks increased, generating new economic growth and jobs, improving water, soil, air quality and food safety, among other synergies. The UN Climate Summit held in September 2019 identified NbS as one of the nine priority areas for coping with climate change, where China and New Zealand jointly hosted the thematic forum on "Nature-based Solutions", arousing strong interests from across the world. It also affirmed that NbS is part and parcel of the implementation of the Paris Agreement, stressing the importance of NbS in boosting harmonious coexistence between human and nature, and ecological progress. It is economically efficient and sustainable, hence an effective approach to a holistic human-centered response to climate change. Since then, NbS

has increasingly become a major strategic and policy option for countries' climate change efforts.

NbS involves agriculture, forestry, grassland, wetland, and etc. It preserves the ecology, improves the environment, prevents and controls desertification, enhances biological diversity, upgrades the quality of life and health, and increases the ecological and economic value of natural systems with greater economic output, among others. It is a strategic move to bring about the harmonious development of human and nature, thus a win–win outcome.

The broader ideology of eco-civilization, envisaged by President Xi Jinping, contains a range of expressions, including "the harmonious coexistence between man and nature", "green is the new gold", "mountains, waters, forests, fields, lakes and grassland are a community of life", "good ecological environment represents the greatest well-being of the people", "preserving ecological environment through the most stringent system and the rigorous rule of law", etc. These ideologies provide guiding principles for the implementation of NbS, a notion that echoes ecological civilization featuring "ecology first" and "harmonious development of human and nature", respects nature and relies on the functional enhancement of natural ecosystems to cope with the global ecological crisis—a new paradigm and major avenue for coordinated and sustainable development of the economy, society and environment. NbS should be guided by and embedded into the framework of ecological civilization in order to showcase its rigor and dynamism, both theoretically and practically speaking. Bearing in mind the harmonious coexistence between human and nature, one should by no means detach the concept from ecological civilization in improving the functionality of natural ecosystem to solve the earth's ecological crisis including climate change and biodiversity, and refrain from stressing or expanding the measures and potential of NbS in an isolated and single-sided manner.

To fulfill the promise of NbS, it is essential to uphold ecological civilization, holistically advance the institutional development of ecological civilization and the coordinated governance of economy, resources, environment and climate change. It is also important to combine adaptation and mitigation of climate change with policy measures in resources-conservation and ecological and environmental protection. For example, formulating balance sheet of natural resources, identifying ecological red line, providing comprehensive governance of mountains, waters, forests, fields, lakes, grassland and other ecological systems, carrying out projects to remediate ecology, reducing and sequestering carbon, preventing and controlling soil erosion and desertification, and preserving biodiversity conservation. NbS should be integrated with efforts on agricultural modernization and "beautiful countryside", as well as improvement of crop cultivation techniques and methods, reduction of fertilizer use, development of ecological agriculture, and cutting of methane emissions from rice fields and livestock. Efforts should be made to utilize and improve marginal land, promote afforestation or planting of energy crops, boost forest management and grassland restoration, convert farmland to forest and grassland, strengthen the modernization of rural areas, enhance the comprehensive and safe use of rural waste, and step up the commercial use of biomass resources, etc. Overall, NbS for climate change should be incorporated in the overall national strategy for economic and

social development as well as the strategy and measures of relevant government authorities so as to maximize the synergy of economic development, social progress, environmental protection, desertification control, biodiversity conservation, greenhouse gas reduction and carbon sink increase, thus catalyzing ecological progress and sustainable development in China.

Major steps should be taken to increase carbon sink, such as afforestation and greening, voluntary tree-planting, continued natural forest protection, grain for green, sandstorm sources control in Beijing and Tianjin, shelterbelts planting, comprehensive treatment of stony deserts, water and soil conservation, strengthening of forest tending and management, etc. Work should also be done to ramp up prevention and control of forest disasters, strengthen protection of forest resources, reduce emissions from deforestation, reinforce protection and restoration of wetland to improve carbon storage, continue to return grazing land to grassland, ensure the balance between pastures and livestock, curb grassland degradation, restore grassland vegetation, step up the prevention of grassland disasters and farmland conservation, and improve soil carbon storage capacity.

The goal of limiting global temperature rises to 2 °C or even 1.5 °C means that carbon neutrality should be achieved by the second half or middle of this century. NbS is of vital importance for achieving carbon neutrality amid deep global emission reductions. During global low-carbon transformation, deep emission reduction can be materialized in energy, industry, transportation, construction and other sectors through the development and application of various emission reduction technologies, but to enable net zero emission, the marginal cost of emission reduction will experience a nonlinear spike. The initial emission reduction of non-CO_2 greenhouse gases such as methane can be achieved at a fairy low or even negative cost, but no feasible technology is available to support near zero emission. Therefore, the implementation of NbS can harness the potential of agriculture, forestry, land use and land use change for reducing carbon sources and increasing carbon sinks, sequestering more carbon to offset the remaining greenhouse gas emissions from sectors where further reduction is a challenge, and secure carbon neutrality as a whole. China's additional annual carbon sink in agriculture and forestry could be kept at approximately 700 million tons by 2050, holding the key to offsetting the remaining emissions from hard-to-crack sectors.

The implementation of NbS hinges on the innovation of science and technology, calling for scientific research to understand and grasp the law of natural ecosystems, protect, restore, and enhance the service of natural ecosystems, and leverage the force of nature to tackle global ecological crisis, especially climate change, as opposed to the sole dependence on technology-based solutions.

Indeed, amid the urgent low-carbon energy and economic transformation under the global actions against climate change, parallel efforts should focus on continued innovation and development of emission reduction technologies to be used in conjunction with NbS. Most of the technical measures for saving energy, improving energy efficiency and strengthening energy substitution also produces the synergy of resources conservation, environmental protection and sustainable development, which represent the main options for low-carbon transformation. The technological solutions

must go hand in hand with NbS to complement and reinforce each other with greater focus on the synergy and joint actions for addressing climate change and sustainable development. On the other hand, implementing NbS also requires technology-based innovation and industrialization. For example, technologies for the comprehensive and safe utilization of agricultural and rural waste, commercial biomass fuel, comprehensive treatment of saline and alkaline land, energy crop planting and management and modern ecological agriculture would require more R&D and realization of advanced technologies for close coordination and joint progress [29].

10.2.9 Improve the Institutional Arrangement for Addressing Climate Change and Form a Policy System, Investment and Financing Mechanism, and Market System

First, push for climate change legislation to provide the legal support for the implementation of climate change strategies, mechanisms and policy systems and the attainment of long-term emission reduction targets. The institutional building for low-carbon development is one of the centerpieces of that for ecological civilization. Given the characteristics of China's current policy framework, it's crucial to sharpen the legal and market tools while maintaining the advantageous administrative measures. it is of fundamental importance to put in legislation efforts as soon as possible in order to lay the basic legal groundwork for nation-wide climate change actions, involving a wide spectrum of fields and issues. Dedicated laws would provide clear legal directions to actions at the national level. What's more important is to specify medium—and long-term quantified emission reduction targets and strategic measures within the climate change law to galvanize low-carbon energy and economic transformation. Internationally, the UK was the first country to pass the Climate Change Act, which has incorporated a carbon neutrality target by 2050 through a recent revision. Japan and Mexico also introduced their climate legislations. The EU has scheduled legislation in 2021 via Green Deal to support carbon neutrality by 2050. China is in dire need of a dedicated law to ensure continued progress of energy conservation and emission reduction. Carbon market, for example, currently operates under only departmental regulations of related ministries and commissions with low legal recognition and limited terms of reference, thus unable to secure the progress and operation of carbon market.

Develop of green finance and establish green investment and financing mechanisms. The transformation of low-carbon development entails financial support, and there are increasing incentives for investing in low-carbon technologies and industries worldwide. The EU Green Deal states that to meet the 2030 climate and energy targets, an average of an additional € 260bn in investment will be needed annually, equivalent to approximately 1.5% of EU's GDP in 2018. In terms of funding channels, 25% of the EU budget and at least 30% of the European Investment Fund will be spent on combating climate change. The European Investment Bank (EIB) will

also ramp up climate-related investment from 25 to 50% by 2025, with a focus on mobilizing private sector for green investment and engaging international investors through the new international sustainable finance platform. In addition, the EU will further push the reform of budget and taxation system to encourage public investment, consumption and taxation in green priority areas through pricing and incentive mechanisms, repeal subsidies that goes against green development (e.g.: subsidies for fossil energy) to make for the shift of tax revenues from labor to pollution.

China also attaches great importance to the development of green finance, creating and implementing a selection of mechanisms and policies for green investment and financing. A guideline on green project investment was formulated to enhance the green credit system, offer green credit asset securitization (ABS) and green bonds, establish mechanisms for green loan incentives and guarantee, improve green review and supervision for investment projects, enhance government green purchase system, and incentivize enterprise and social investment. Along with the development of carbon market, the auctions of emission allocation will be gradually increased, with the future proceeds from the auction or the carbon tax revenue used in an integrated manner to advance the institutional progress of national low-carbon development and key action agenda. At present, the global financial community is devising the guidelines and norms of green investment, rejecting and withdrawing investment in coal, oil and other high-carbon industries and projects. An enabling policy environment for encouraging green investment is being formed in various countries. China's energy and economic low-carbon transformation will entail huge investment—approximately 40 trillion RMB for NDC targets and action plans by 2030 and around 100 trillion RMB for energy and power systems to fulfill the deep decarbonization target by 2050. On the other hand, the gigantic investment in energy and economic transformation also serves as a strong buttress for economic growth, tapping into new sources of low-carbon economic growth and new green jobs to bring about high-quality economic development. Therefore, the government should constantly develop and enhance the green investment and financing mechanism, which should also be embedded in the "Belt & Road" cooperation projects and mechanisms [30].

Presently, it is of pressing importance that the reform of energy system should lay particular emphasis on carbon market development. With the urgency of global actions against climate change, the scarcity of carbon emission and its nature as a production factor are growing increasingly evident. Market levers should be employed to quantify the value of carbon emissions and allowance, prompting emission reduction at the corporate level to enhance the economic output per unit of carbon emissions. The European Union, California of the United States, South Korea and other countries and regions have successively established the carbon markets, with more on the way to advance efforts on this front. During the 12th Five-Year Plan period, China launched a unified national carbon market, apart from the trials of carbon trading in five cities and two provinces, reinforcing market incentives for low-carbon transformation. The uniform national carbon market started with the power sector and would gradually expand to other energy-intensive industries including petrochemicals, steel, building materials, non-ferrous metals, paper making, civil

aviation and chemicals, accounting for about half of the country's total CO_2 emissions. Swifter progress is needed for carbon market in China with enhanced systems of corporate emission accounting, monitoring, reporting and verification and emissions. Carbon pricing signal should be deployed to push mitigation measures in businesses, incentivize private investment and lower the cost of the entire society while safeguarding national emission targets. By quantifying and monetizing the value of carbon allowance, carbon market will spawn a string of financial products in the future. The market itself and carbon finance will also evolve into major instruments in the international competition for low-carbon development [31].

Institutional safeguards for green and low-carbon development should be strengthened. The accountability system of governments at all levels for energy conservation and carbon reduction should be reinforced, and targets for energy saving and carbon reduction included in national and local five-year development plans. Meanwhile, innovations must be explored in the macro-control of energy system to establish and improve the energy legal system, reform and enhance the fiscal, taxation and financial policy systems for low-carbon development, facilitate green finance and reform of the pricing mechanism for energy products and the system of resource and environmental taxes and fees. Advancement for reform of the energy market mechanism to put in place a unified and open market structure and system that are just, fair, and conducive for competition. Market monopolies in certain areas should be eliminated, and disorderly market competition should also be rectified and forestalled. Currently, the pricing mechanism for China's fossil energy fails to fully reflect its social costs. To illustrate, the social costs of air and water pollution and public health damage from coal burning are equivalent to over 50% of the current coal price, but these social costs are yet reflected in the price, and a sound taxation and fee system to transfer the income accordingly is also absent. The internalization of the social cost of resource and environmental losses through the reform of the resource and environmental tax system and the carbon market will help save fossil energy, encourage the development of new and renewable energy, and spur the transformation of energy mix. The reform of energy prices, such as time-of-use and tiered pricing, serves to conserve energy and ensure low-income families equitable access to quality energy services, thereby boosting harmonious social development. On the other hand, technical standards for energy conservation, commodity labeling of energy efficiency, and industry access policies must be tightened. The management of corporate energy use rights and that of carbon allowance should be coordinated with the development of the national carbon market. The medium- and long-term national strategies and goals should be followed to reinforce government binding targets, mandatory standards, fiscal, tax, and financial policies, which should be deployed in parallel with market mechanisms to provide stronger institutional guarantees for the energy revolution and low-carbon development.

It is crucial to promote the institutional building and policy safeguards of technological innovation and industrialization of advanced technologies. Technological innovation is the bedrock for low-carbon transformation. China is working in parallel with developed countries on the R&D of a spate of advanced energy technologies, with its own characteristics and advantages. It is important to ramp up the R&D

and industrialization of advanced energy technologies, leverage the market size of China to sharpen the competitive edge of superior technologies of energy enterprises, harness technological innovation for industrial and technological upgrade and energy system reform, gain an upper hand in technological competition amidst the revolution of world energy system, and enhance the competitiveness of in-house technologies, industries and markets. With the progress of low-carbon energy transformation in the future and the increasing urgency of emission reduction, revolutionary and strategically advanced technological breakthroughs must be made to overcome the nonlinear spike of the marginal cost of emission reduction in most cases under the deep decarbonization scenario of holding temperature rise within 2 °C. More efforts are needed in the R&D and proliferation of deep CO_2 emission reduction technologies, such as large-scale energy storage and smart grid technologies in the context of a large uptake of renewable electricity, BECCS technology for negative CO_2 emission, the technology for producing, storing and utilizing hydrogen as a clean secondary zero carbon energy, technology for producing zero carbon chemical, steel, cement, petrochemical and other raw materials. The R&D and demonstration of technologies for deep emission reduction of such non-CO_2 greenhouse gases as methane should also be strengthened so as to enable deep emission reduction of all greenhouse gases. At the same time, financing services and policy incentives should be provided for small and medium-sized start-ups to encourage all forms of technological innovation. China should proactively develop and demonstrate the pioneering technologies and ensure their prompt breakthroughs and industrialization, making them technically mature and economically viable, in order to gain long-term technological competitiveness in leading the global climate governance and low-carbon transformation under the macro-trend of climate change management and low-carbon economic and social transformation [32].

10.2.10 Promote Global Climate Governance and International Cooperation, and Advance the Construction of Global Ecological Civilization and a Community with a Shared Future for Humankind

China has taken an active part in global climate governance, pioneering international cooperation on climate change, and becoming a major participant, contributor and leader in global ecological progress. As President Xi Jinping pointed out, it is the common cause and interest of all humankind to jointly facilitate global ecological progress and tackle climate change. The Xi Jinping Thought on Ecological Civilization and the vision of building a community with a shared future for humankind embody China's wisdom and proposal for building a fair, reasonable and win–win governance system and cooperation process.

China has been working actively to build ecological civilization, put in place a green, low-carbon and circular economic system, create a clean, low-carbon, safe and efficient energy system, and bring about the coordinated governance and win–win scenario of the economy, energy, environment and climate change. The theories and practices in this regard will provide the world, especially developing countries with successful experiences and useful examples in implementing their strategies of low-carbon development.

China adheres to the goals and principles set forth in the UNFCCC and the Paris Agreement, and has promoted the progress and implementation of the Paris Agreement in a comprehensive, balanced and effective manner. It observes the principle of fairness and common but differentiated responsibilities and respective capabilities, and accommodates the varied national conditions to ensure the balanced progress of the Paris Agreement in mitigation, adaptation, funding, technology, capacity building and transparency, advance win–win cooperation across the world and, in the meantime, build the synergy of climate change management and sustainable development in all countries, especially developing nations. On the other hand, China is also actively engaged in non-UNFCCC cooperation agenda, including initiatives that set standard development of green and low-carbon technologies and products or industry codes of conduct, and joint actions in various international arenas to incentivize low-carbon transformation [33].

China has actively advanced international cooperation on climate change, especially South-South cooperation, promoting "Green Belt & Road" and highlighting climate change policies in "Belt & Road" projects. Use the South-South Climate Cooperation Fund with a Chinese commitment of 20 billion yuan for more green financing options and transfer of green and low-carbon technologies. Stringent environmental protection and energy efficiency standards should be advocated and enforced in "Belt & Road" cooperation projects to avoid high carbon infrastructure and capacity expansion, and joint efforts should be made to explore the strengthening of bilateral or multilateral cooperation on carbon pricing and carbon market mechanisms under the market mechanism framework of Article 6 of the Paris Agreement, so as to jointly promote the implementation of the Paris Agreement and its global cooperation. Meanwhile, China should step up cooperation with developed countries or their local governments or cities, and boost cooperation among businesses, civil society and scientific research institutions, so that climate change governance will set an example for building a community with a shared future for humankind [34].

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