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REVIEW ARTICLE

An outlook on the development of renewable energy, policy measures to reshape the current energy mix, and how to achieve sustainable economic growth in the post COVID-19 era

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Abstract

Currently, COVID-19 due to emergence of various variants shows no signs of slowing down and has affected every aspect of life with significant negative impact on economic and energy structures around the world. As a result, the governments around the world have introduced policy responses to help businesses and industrial units to overcome the consequences of compliance with COVID-19 strategies. Our analysis indicates that global energy sector is one of the most severely affected industries as energy price mechanisms, energy demand, and energy supply have shown great uncertainty under these unprecedented economic and social changes. In this regard, we provide brief overview of demand, supply, and pricing structure of energy products as well as policy mechanisms to provide better outlook about how industrial sector can cope with energy consumption in the post pandemic era. We further propose changes in the existing policy mechanisms so that transition towards renewable energy sources under different environmental agreements can be achieved. Moreover, as a reference, we outline major challenges and policy recommendations to ease energy transition from fossil fuels to environmental friendly energy mix.

Keywords COVID-19 · Energy demand · Energy supply · Clean energy · Sustainable economic growth · Renewable energy

Introduction

In recent years, the world has experienced a number of health pandemics. The World Health Organization (WHO) defines a pandemic as the spread of a new disease which adversely affects a significant portion of the world population (Arslan et al. 2021; Badr et al. 2020). Some pandemics which were lethal in recent centuries are cholera (1817–1823) which originated from the Indian sub-continent and resulted in the deaths of millions of people. In recent decades, AIDS and HIV first appeared in 1976 and still affect a significant portion of the population in developing economies with 36 million confirmed deaths. SARS, another global pandemic, is a severe acute respiratory syndrome and is caused by one of 7 coronaviruses that can infect humans. This pandemic originated from China in 2003 and infected more than 8000 people around the world. Ebola is another example, which was first detected in 1976 but continues to ravage the African continent and has killed approximately 11,325 people (Sun et al. 2020).

However, the most recent pandemic known as the COVID-19 has given grave consequences to the whole

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world. This coronavirus is a single-stranded positive-sense enveloped RNA virus whose genome consists primarily of nearly thirty thousand nucleotides with a genome size from 26 to 36 kb. Its transcription and reproduction be contingent on a combination of two replicate genes encoding pp1a and pp1ab polyproteins (Bilal et al. 2020a). The coronavirus whole-genome level corresponds to a 96% bat coronavirus (Zhou et al. 2020) and is referred to as coronavirus as its club-shaped spikes forming under an electron microscope at the top of a crown-like structure (Fofana et al. 2020). The COVID-19 was declared as a global pandemic on March 11, 2020, by the WHO (Bashir et al. 2020a), and since then, there have been many cases of high fatality rates worldwide and adverse global economic impact (Bashir et al. 2020b). As of March 21, 2022, there were 469,713,452 confirmed cases, including 6,074,560 fatalities (WHO 2021). In addition to massive loss of life, the global economy is estimated to shrink by 6%, and at least 300 million people became unemployed (Qaid et al. 2022; Bashir et al. 2020c).

The COVID-19 is a "communicable" disease, and its dissemination worldwide is entirely associated with community transmission rather than airborne transmission. Although, in recent months, there have been operational vaccines to stop COVID-19 transmission (Aktar et al. 2020; Bashir et al. 2020d), till this day, lockdowns, i.e., prohibiting overseas travel, social distancing, mass quarantine, and region-wise lockdowns, are the widely used preventive measures to reduce the transmission of the COVID19 (Bilal et al. 2020b). The implementation of these preventive measures has sent seismic waves across global energy markets and resulted in an unprecedented 20% reduction in global energy expenditures. This also allows us to confirm that energy markets have been most significantly impacted by the lockdown measures as there is a significant drop in demand for oil and energy products (Bilal et al. 2021a; Gautam 2000b).

Unsurprisingly, the relatively low level of prices propelled both supply shock and policy war between major oil and fossil energy producers, i.e., Russia and Saudi Arabia, as the oil market was hugely affected by demand shocks by the COVID-19 pandemic. Yet, the dramatic effect of COVID-19 on energy is not homogenous, and the consequences are very different for both sustainable and fossil fuel energy use. OPEC Secretary-General Mohammad Barkindo stated, "Covid-19 is an invisible beast that seems to affect everything in its course," and it has up-ended market supply and demand dynamics for the energy market. Currently, the energy sector needs to address two major challenges: first, arrest the health emergency problems from COVID-19 faced by all industries; and second, the low demand and low oil price scenario, because financial liabilities and profits need to be resolved in the near future.

Not only that, from the perspective of the energy sector, many other things have occurred during the spread of COVID-19, which affected the usage of the energy itself (Bashir et al. 2020e; Akrofi & Antwi 2020). For example, the current state of geopolitics has evolved and made a significant impact to spark the oil crisis, as OPEC + countries tended to manufacture and overwhelm extra supplies on the world market, possibly forcing other oil-producing regions to leave the market. Additionally, the full spectrum of the COVID-19 for the energy sector is evolving and is not easy to foresee. The current situation requires changes in policies to help minimize the detrimental effects on the energy sector. Compared with energy use and the COVID-19, the association between the COVID-19 pandemic and the environment has been extensively discussed (Bilal et al. 2021b; Akrofi & Antwi 2020). A significant number of studies have explored the overall environmental effects of COVID-19 (Aktar et al. 2020; Wang & Su 2020), while other studies have explored the association between specific environmental features and the COVID-19 outbreak, i.e., weather, temperature, government policy, pollution, and air quality (Muhammad et al. 2020; Baloch et al. 2020; Bannister-Tyrrell et al. 2020; Wu et al. 2020; Tosepu et al. 2020; Bilal et al. 2021c).

Nevertheless, there is an intrinsic and definite association between environment and energy usage, which has resulted in unprecedented shocks in the energy sector and, therefore, would have environmental consequences, especially towards climate change (Akrofi & Antwi 2020). While the political consensus about climate change remains unresolved, recent decades have highlighted that environmental policies need to be reformed to protect the planet, and the continuous dependence on fossil energy remains as the focal concern (Talbi et al. 2020; D'Adamo et al. 2020). Keeping this in mind, more significant research is required to document and track the changes and impact on the energy sector with a focus on the occurrence of key moments when the global phenomenon in the form of the COVID-19 has induced drastic shifts in the pre-existing patterns so that expected outcomes become obsolete or suddenly change (Fareed et al. 2021; Drezner 2020). Keeping this in mind, our aim is to review various aspects of the COVID-19, how it impacts the energy sector, and provide an overview of the relevant concerns to provide policy suggestions to benefit policymakers, researchers, and the environmental quality.

The current study addresses the following key research questions: (1) What are the ramifications of the COVID-19 pandemic for global energy demand and supply? (2) Analyze the shift in global energy prices from the COVID-19 outbreak. (3) How global energy politics has been impacting by the novel coronavirus? (4) How have policymakers responded to sustain the energy transition? Current research will provide significant implications for environmental stakeholders, policymakers, and scientists to design

and implement a roadmap to curtail the adverse effects of the COVID-19 pandemic by addressing key issues being addressed by the energy sector. This issue is investigated by analyzing the most interrelated and critical elements of the ecosystem. Figure 1 represents the overall picture of the COVID-19 pandemic and what it means for the energy sector, a theme that will be further illustrated in detail in the subsequent sections.

COVID-19 and world energy demand

In recent decades, global economy has been fundamentally transformed due to globalization and emphasis on the rise of technology, higher capital expenditures, and free-market business models (Bashir et al. 2015; Bashir 2018). However, it has also led to environmental degradation from higher volumes of energy consumption (Xia et al. 2022; Bashir et al. 2021e; Shahbaz et al. 2016). Hence, global energy demand, the essential element in eco-social development, shows no sign of slowing down especially in developing economies. Currently, global energy demand has risen to 13.9 Gtoe (Gigatons of oil equivalent) per annum in 2018, with 2.9% growth every year since 2010 (BP 2019). The largest increase in energy consumption has been recorded in Asian economies, especially India and China (Hussain et al. 2021). Figure 2 records the volumes for the ten highest energy consumption countries during the period of 2010–2019. Existing statistics indicate that China consumes 25% of world energy, which almost accounts for half of world energy consumption when the USA and India have been included (Wei et al. 2020).

Energy demand is another indicator to highlight the movement of global resources. Currently, the demand for energy sources is highest in Asian developing economies, with an expected increase of 3.7% per year. It is further estimated that energy consumption in Asia will double in the next 20 years and will be responsible for 65% of total energy demand in developing economies (Bashir et al. 2021a; Vaka et al. 2020). However, it is estimated that demand for energy resources in other developing economies will be slower than in Asian economies, but still, it is projected to surpass the world average (Table 1). As industrial units have a significant role in energy demand and supply, the immense increase in the expected level of energy consumption in Asia is also critical to region's future production of energy resources

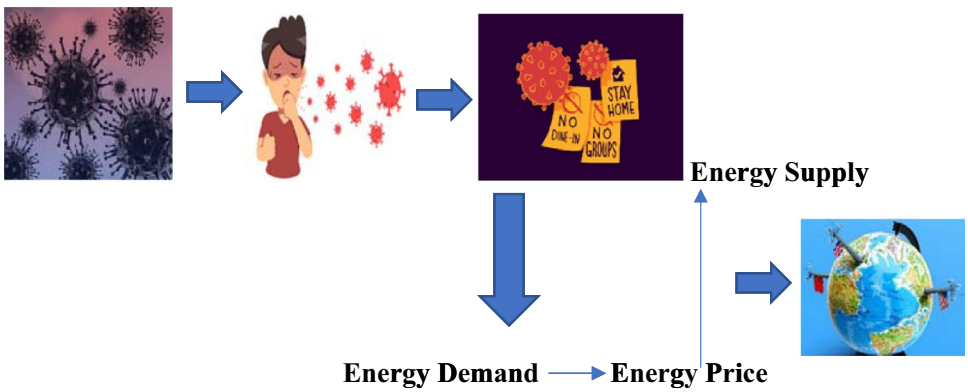

Fig. 1 COVID-19 and the energy industries

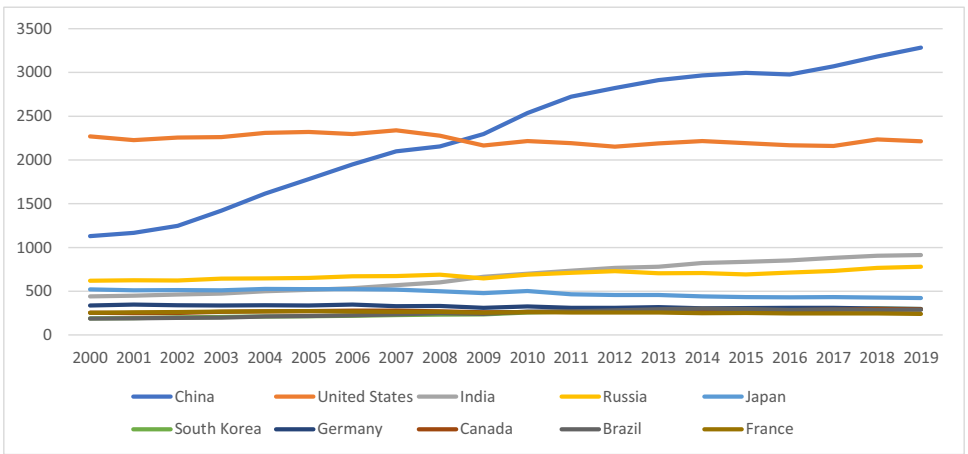

Fig. 2 Energy consumption breakdown by country (Mtoe) for the period of 2000–2019. Source: Global Energy Statistical Yearbook, 2020

Table 1 World total marketed energy consumption by region and fuel, 1990–2030 (quadrillion Btu)

Region	1990	2004	2010	2020	2030
OECD North America	100.8	120.9	130.3	145.1	161.6
OECD Europe	69.9	81.1	84.1	86.1	89.2
OECD Asia	26.6	37.8	39.9	43.9	47.2
Non-OECD Europe and Eurasia	67.2	49.7	54.7	64.4	71.5
Non-OECD Asia	47.5	99.9	131.0	178.8	227.6
Near East	11.3	21.1	26.3	32.6	38.2
Africa	9.5	13.7	16.9	21.2	24.9
Central and South America	14.5	22.5	27.7	34.8	41.4
Total OECD	197.4	239.8	254.4	275.1	298.0
Total Non-OECD	150.0	206.9	256.6	331.9	403.5
Total Sources					
Oil	136.2	168.2	183.9	210.6	238.9
Natural gas	75.2	103.4	120.6	147.0	170.4
Coal	89.4	114.5	136.4	167.2	199.1
Other	26.2	33.2	40.4	46.5	53.5

Source: International Energy Agency

(Bashir et al. 2021b). Fossil fuel consumption, i.e., natural gas, coal, and oil, will also lead to a significant increase in CO_2 emissions worldwide (Vaka et al. 2020). Furthermore, the increase in CO_2 emissions is also expected to contribute to unavoidable environmental damage from climate change and environmental degradation.

The introduction of renewable energy through environmental policies has been preferred by policymakers to limit the damage from economic activities (IEA 2019). The abundance of resources like biomass, sun, and wind allows massive production of renewable energy to have little or no further GHG emissions (Bashir et al. 2021c). Although RE has significant potential to reshape the current energy mix, but the adoption of renewable energy has been relatively slow in developing economies (Malahayati 2020). Currently, the share of renewable energy sources in the global energy supply is 27%, with the rest of 73% coming from fossil fuels (Global Energy Statistical Yearbook 2020). The share of RE in 2019 within the energy mix also significantly varies across different economic regions, 3.8% in the Middle East, 17.6% in commonwealth countries, 20.2% in Africa, 23.7% in Asia, 23.9% in North America, 27.4% in Pacific, 38.7% in Europe, and 58.1% in Latin America (Fig. 3).

The recent surge of COVID-19 has disrupted the energy structure, and as a result, there has been a growing focus on energy self-dependence through renewable energy (Anderson et al. 2020). Additionally, lockdowns and travel restrictions have also created a significant impact on demand for national energy profile such as residential electricity consumption has increased significantly by 40% as the majority of the population comply with movement orders but the lower electricity consumption in the commercial and industrial sector has far more significant socioeconomic impact (Broom 2020). Electricity demand fell by 2.5% globally in 2020. The USA is a key illustration as electricity demand fell by 5.7% during the lockdown measures (Elavarasan et al. 2020). Although there was a significant increase in demand for electricity by the residential sector (World Economic Forum 2020), economic sector reported a negative impact with 15%, 8.6%, and 6.6% lower electricity demand in the transportation, industrial, and commercial sectors. Another example, India, with the second-most reported cases from the COVID-19 pandemic (Worldometers 2020) experienced 20–40% reduction in different states (Aruga et al. 2020). The implementation of lockdown measures in China also reported similar findings where electricity demand by the industrial sector was 8% lower in comparison to the previous year.

The lower demand for energy sources in recent months has led to the contraction of centralized fuel-based power generation (Sadiq et al. 2022; Bashir et al. 2021d), which

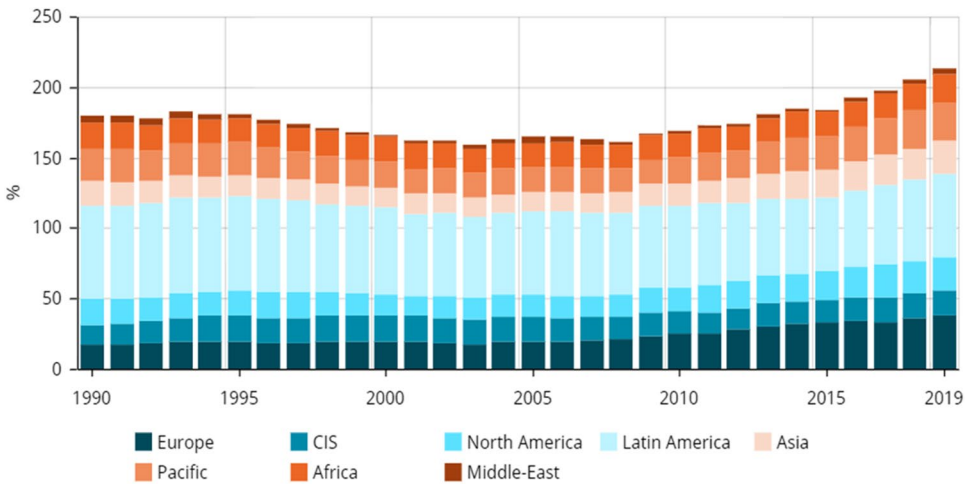

Fig. 3 % Share of Renewables in Electricity Production, 1990–2019. Source: Global Energy Statistical Yearbook, 2020

has emphasized on increasing the share of renewable energy consumption across the globe (see Fig. 4). Countries with stringent environmental policies have introduced and implemented practices to increase the share of clean energy (Sultan et al. 2021). Although natural gas remains the leading source of power generation, renewable energy has surpassed coal-based power plants to generate electricity in recent months. The introduction of lockdown measures in India also resulted in similar outcomes where the share between renewable energy and coal has narrowed as the proportion of coal remains below 70% in the electricity generation, which is in line with the proportion of low-carbon-based electricity. Electricity demand trends recovered in late May 2020, while their seasonal supply was reflected by the increasing share of renewables in the energy mix. The electricity demand recovered after May 2020, where the share of renewable energy sources in the energy mix was higher and remained above 20%, with wind and hydro as the main sources of clean energy. Although coal consumption has increased in recent months in China, the share of clean energy has significantly improved in recent months with significant growth in hydroelectricity (Bashir et al. 2021e). Overall, the renewable energy sector has performed reasonably well and currently accounts for 30% of global energy production (Badr et al. 2020).

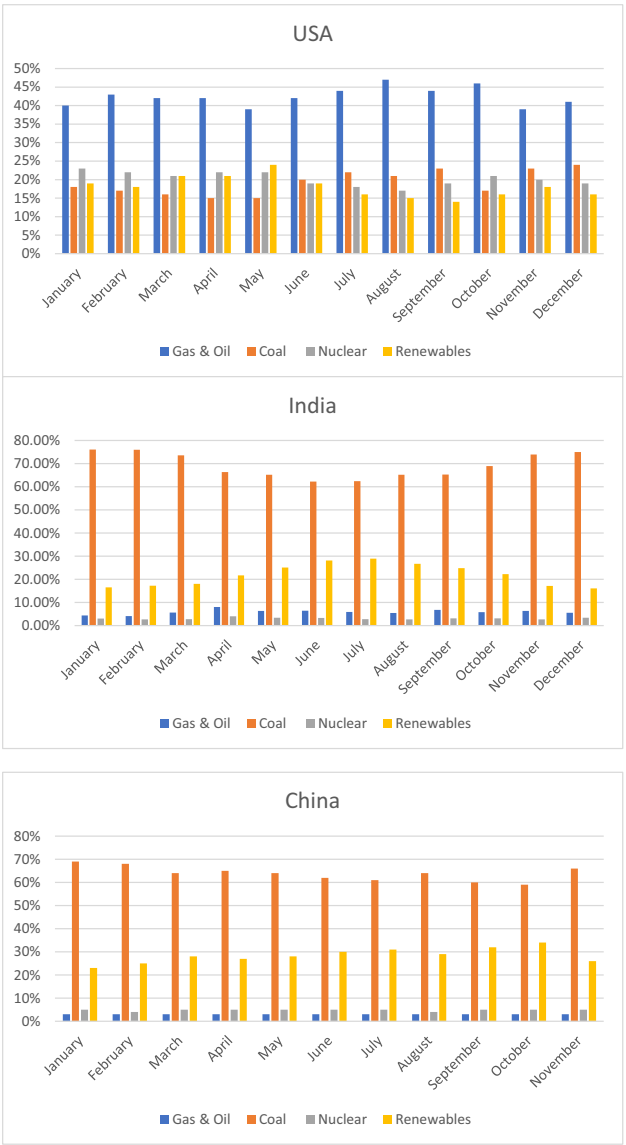

Fig. 4 Electricity generation mix (Source: IEA 2019)

COVID-19 and world energy supply

COVID-19 has not only triggered a financial and public health crisis, it has also had a detrimental effect on the global energy supply. The consequences have been observable in key energy suppliers, i.e., the USA, where "force majeure" notifications have been issued to vendors about delays in the energy production (Bashir et al. 2021f). Similarly, state-owned energy suppliers have announced their inability to fulfill natural gas contracts as they cannot import the required fuel. Similarly, Spain and Italy have suspended production lines in recent months. Similar forecasts have been predicted that the renewable energy sector has possible negative implications that are worrying.

Another key factor is the development of green technology, which had shown encouraging signs before the COVID-19 crisis. The Internal Energy Agency's annual MCED (monitoring clean energy development) reports at least six, i.e., mass transit and electric cars, of possible forty-six indicators were on track to achieve sustainability targets under UN SDGs (IEA 2019). Another twenty-four indicators showed significant improvement, while the remaining sixteen indicators require further reforms. Although the renewable energy sector has not shown a significant decline since the COVID-19 outbreak, IEA estimates that the renewable energy sector will contract by around 13%, with the breakdown of supply chains and limitations on construction activities having a significant impact (Cherp & Jewell 2020). IEA also reports that overall energy expenditures declined by 20% in 2020 alone (Bashir et al. 2022a).

Additionally, construction work to set up renewable energy technology has slowed down significantly. With the slackening production of solar panels in Australia, China, and India up to 17–48%, solar installations declined as expected in 2020 (Singh 2020). The disruptions of solar photovoltaic power have interrupted manufacturing in Italy, Spain, and other leading producers as well (Bashir et al. 2022a), with consumption of material in solar arrays and solar panels negatively impacting Singapore, South Korea, Thailand, Malaysia, and Vietnam (Vaka et al. 2020) with the production of solar panels

which is expected to decrease considerably in the USA, who imports 90% of raw material required. South Africa is also expected to undergo a similar experience where mega-solar projects have been shelved due to disruptions in the supply of the photovoltaic (PV) systems from China (Bashir et al. 2021g; Carrington et al. 2020) which generates around 70% of raw material with Chinese firms working in Southeast Asia which account for another 10–15% of the global share. The implementation of lockdown measures in different parts of China has led to a 16% lower demand for solar panels as China suspended or restricted the production capacity of the solar industry (Vaka et al. 2020).

As the WHO declared the COVID-19 as a global pandemic, it impacted not only the solar industry, but also had an adverse impact over associated renewable sectors, i.e., smart grids, battery technologies, and renewable power. This has led to crisis projections in the wind industry (Bashir 2022). LM Wind power and Siemens Gamesa in Spain announced that the manufacturing units have halted the production of blade wind turbine plants. Likewise, the COVID-19 outbreak has disrupted the construction of 100 wind turbines in Scotland. A report published by the International Renewable Energy Agency (IRENA) indicated that the slower than expected growth in renewable and environmental technology had slowed the progress towards global sustainable goals as material shortages, production shutdown, and higher costs in the renewable energy sector being key attributes (ICIS 2020). Hence, circumstances like these have led to potential conflict from policymakers as more and more countries are exploring to carry on RETs or, despite the ecological indicators, resort back to fossil fuel consumption (Bashir et al. 2022a).

COVID-19 and world energy price

Due to sheer impact, COVID-19 is classified as the biggest threat since World War II (Gautam, 2020a). The dramatic impact on energy consumption is evident as supply and demand will have a significant impact on the energy mix in the industrial sector (Shahbaz et al. 2021). The COVID-19 pandemic in a number of ways has changed the energy price trends as profiles, and historical usage patterns have been dramatically altered. In recent years, the oil and gas industry has deteriorated due to unstable global oil prices; since then, the global fossil prices have evolved at a slightly lower level and hence faced a vicious dual shock in the first few months of the pandemic (Thiéry 2020). The declaration of COVID-19 as a global pandemic coincided with a huge reduction in global demand for fossil fuels; consumption of crude oil was reduced by at least 30% compared to its peak and is expected to be 8% lower than 2020 (Ma et al. 2021a). On the other hand, the disagreement about oil prices between Saudi Arabia and Russia has also led to fluctuations in domestic West Texas Intermediate (WTI) crude oil and international Brent crude oil (Fig. 5). This is due to the combination of these two factors (see Fig. 5).

In recent months, the global crude oil prices for WTI fell by a record 22.30 USD/BBL (WTI), which accounts for 67% reduction; and global crude oil for Brent fell by 22.36 USD/BBL, which is a 65% decline compared to the reference year 2019. The most significant shock came from a drastic drop in transportation, residential, industrial, and commercial usage (Ma et al. 2020a, b). This has contributed to additional pressure on balancing demand and supply to regulate oil prices more efficiently. Also, demand for crude oil dropped by 9.3 mb/d in 2020 and there is a projection that it would further reduce by 29 million barrels/day (mb/d) as the OPEC + agreement came into effect and production fell elsewhere. The total stockpile of oil in OECD countries

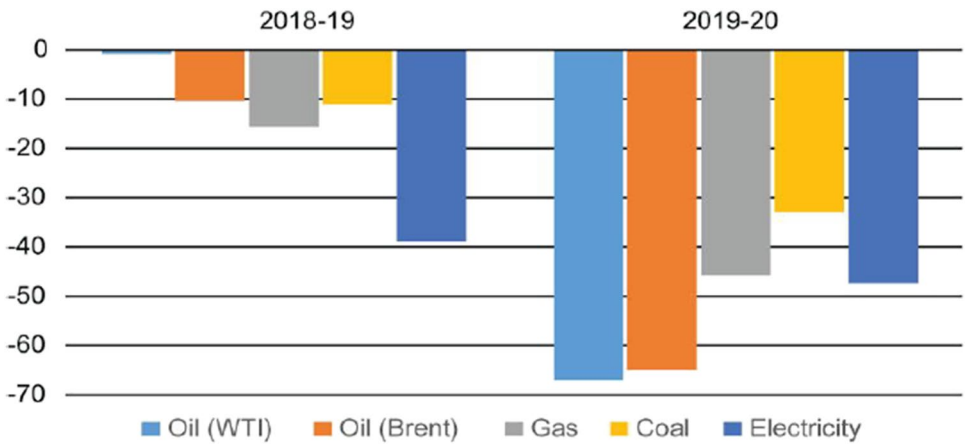

Fig. 5 Changes in energy price (%). Source: Thomson Reuters Datastream, 2020

reached 42.4 Mb in March 2020, where the storage of crude oil rose to 103.1 Mb.

Also, the drop in gas prices further intensified in 2020 as compared to 2019 as the base year, which was powered by lower demand and still relatively high production. The gas prices are particularly poor in Europe due to excessive supply in the pre-pandemic era. The natural gas prices dropped by 16% in 2018–2019 alone, and this pattern continued in the post-COVID-19 era, with gas prices reaching 8.25 EUR/MWhth in 2020 compared to 18.02 EUR/MWhth in 2018 and 15.20 EUR/MWhth in 2019. This indicated that the decline in gas prices was exacerbated by the COVID-19 crisis in comparison to the crisis-free previous year (Farooq et al. 2022a, b).

The trend of declining has also been observed in the electricity and coal sectors as well, although the reduction in coal prices is rather difficult as its prices were already lower than other energy sources. There has been a strong drop in coal prices since 2019, and this trend has persisted since 2019 as the coal prices were reduced to USD 47.40/MT in 2020 from 2019 (70.70 USD/MT). Our analysis also allows us to infer that a lower impact on the coal sector can be attributed to several factors which kept the coal prices under stress (i.e., ETS certificate prices, lower gas prices). Energy prices in European countries continue to decline due to lower electricity demand with 47% less demand than the base year of 2019. The International Energy Agency (IEA) indicates that not only persistent lower oil prices affect fossil fuels but also have a significant impact on the renewable energy sector, with economic shutdowns slowing the transition towards adoption of renewable energy (Bashir et al. 2022b).

COVID-19 and energy geo-politics of the world

Generally, politics is a reference towards the formation of bureaucratic structure and formal and informal working of political institutions. Energy politics is a multi-scalar concept that requires cooperation between regional, international, and sub-national players (Van de Graaf & Sovacool 2020). The emergence of globalization has meant that international politics and energy are profoundly intertwined: international politics is significantly influenced by the essence of energy, i.e., the extent to which it becomes sustainable, but energy also exerts a significant impact on politics (Kuzemko 2019). In the global political and economic system, the degree of energy politics is interconnected with the world energy market (Fig. 6), where stability in the oil exports or changes in the production capacity has the ability to affect the global market. This observation means that the economic threats from the COVID-19 will affect global

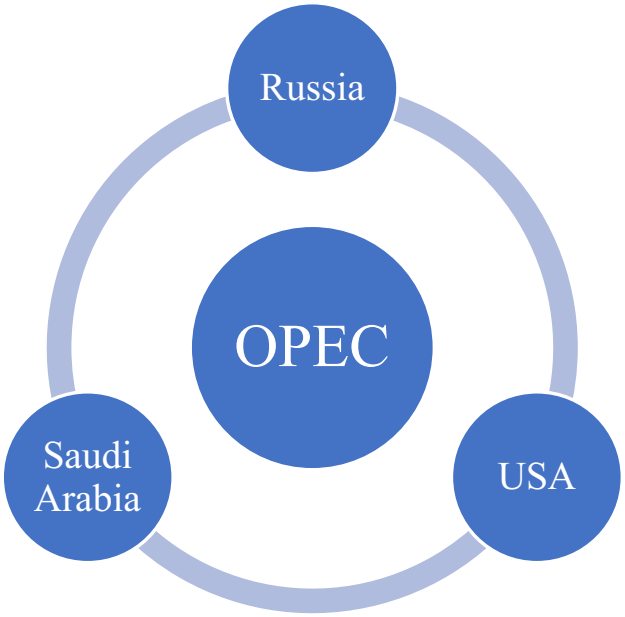

Fig. 6 Interconnected world oil market

economies as a whole, and it is essential to formulate cohesive policy instruments to overcome these challenges as they will also influence global energy politics (Ma et al. 2021b). Historical shocks in price and demand for energy products have established far-reaching indications of changes in the global energy economy, and the current crisis is no exception from this.

On March 9, 2020, the global oil prices, as COVID-19 worsened, witnessed the most significant decline in three decades, which occurred due to OPEC being unable to arrive at an agreement with Russia. OPEC proposed to decrease supply in the global market to sustain price levels by limiting global supply by 1.5 million barrels per day due to lack of demand and suggested that non-OPEC members and Russia also implement similar measures. According to Arezki and Fan (2020), OPEC countries supply 1 Mbd while non-OPEC countries supply for 0.5 Mbd. However, Russia showed reluctance to do so as oil and gas exports account for 40% of national income. However, it showed a reluctant willingness to decrease oil production by 10% from May 2020 (Jefferson 2020), but an immediate reversal from the proposal resulted in oil prices being reduced by a further 10%. Figure 7 below shows world oil consumption, prices, and OPEC oil production and supply adjustment. It is evident from Fig. 7a (changes in oil consumption) that between 2009 and 2017, the demand for crude oil consistently grew but has been declining since then and is expected to decrease further, mainly due to the COVID-19 pandemic and lack of industrial activities. Figure 7 b (crude oil prices in 2020) further illustrates that since January 2020, west Texas intermediate and Brent crude oil prices are under

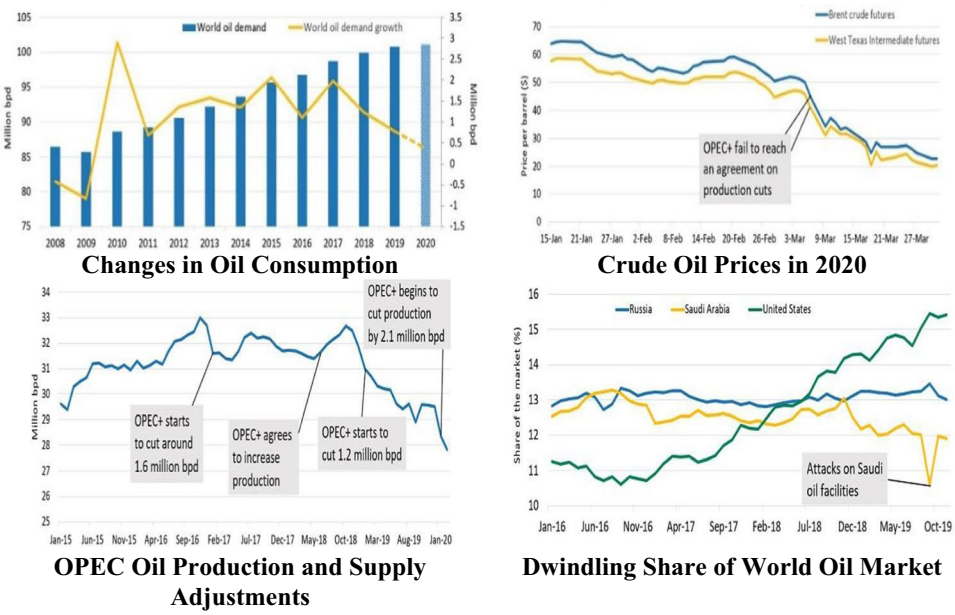

Fig. 7 World oil consumption, crude oil prices, OPEC production and supply adjustments, and share of the world oil market

pressure. Figre 7c (OPEC oil production and supply adjustments) illustrates that in recent years, the focus of OPEC is to balance the oil market by making adjustments in the production capacities. Lastly, Fig. 7d (dwindling share of world oil market) provide details about crude oil market share by Russia, Saudi Arabia and United States, who produce most crude oil globally.

In order to maintain political dominance over the global energy supply, Saudi Arabia increased its daily oil production from 9.7 million barrels a day to more than 10 million barrels a day during February and March 2020 (Jefferson 2020) and further increased the daily production to more than 12 million barrels a day. This caused political controversy as to why the previous decision was to retain production levels by highlighting uncertainty in oil prices from COVID-19. Other reports also asserted that such changes were implemented to harm the other oil exporters such as Russia by low prices as Russia, far more dependent on oil exports for national income, between 2016 and 2019 added sixty oil production fields to generate nearly 1 million barrels per day (Jefferson 2020). Such political moves indicate that a few issues need to be addressed to implement substantial cuts in oil production (Farooq et al. 2022a, b; Johnson & Standish 2020). First, what is the actual size of global oil demand is under consideration, with estimates ranging from 6 million barrels/day to 10 million barrels/day (Johnson & Standish 2020). Second, whether against Saudi Arabia or Russia, another major oil producer, the USA needs to instruct its oil and gas sector to prioritize which areas require investment choices, especially in current times when oil prices have been hit by the global pandemic. This has led to non-compliance with earlier agreements to reduce global energy supply so that oil prices do not fall any further.

Barring political disputes to curb energy supply and overcome price issues, major energy-exporting countries have been implanting significant reforms to overcome economic losses. Meanwhile, energy importers are willing to further import to take advantage of the current low energy prices (Egan 2020), although unstable energy prices are expected to influence infrastructure projects especially in Middle East counties that rely heavily on energy exports to finance public infrastructure initiatives. Keeping this in mind, the political response to overcome the adverse impacts of COVID-19 on the energy process needs to be more innovative, strategic, and sustainable in the near future (Hepburn et al. 2020).

Discussion and post-COVID-19 policy recommendations

The COVID-19 pandemic has adversely impacted many markets, with the energy sector being most significantly impacted as global energy demand plunged in recent months and led to a significant drop in economic and industrial activities. According to Bloomberg statistics, the low oil prices resulted in coal becoming relatively expensive than other energy sources, which further led to less coal consumption in the USA and Europe to take advantage of cheaper renewable energy (Biao et al. 2018; Holder 2020). Although global demand for renewable energy sources has increased by 1% in the last fiscal year, the disruption in

the global supply chain means that the renewable energy sector has downgraded its projects for electric vehicles, battery, solar, and wind sector. This also means that the global fight to combat climate change has been disrupted by the COVID-19 pandemic. Hence, we provide significant changes in policy recommendations as most versatile energy policies are needed to be adopted to navigate energy transition. Figure 8 highlights key policy challenges and policy recommendations from the viewpoint of three distinct policy horizons: immediate response to the COVID-19 crisis is to shield public health (short-term), when economic recovery is stimulated (mid-term), and when trade-off occurs between economic recovery and climate change (long-term).

Given the status of the current pandemic, public health infrastructures must become sustainable to properly function during future pandemics. This change, up to some extent, is guided by the issues faced by policymakers, who need to determine policy shifts to ensure the transition towards clean energy sources (Bashir et al. 2021b; Ma et al. 2021c). In these situations, taking a firm stand against the regulatory structures or negative counterattacks and implementing a safeguard mechanism to ensure transition towards renewable energy must be prioritized. Hence, immediate exemptions instead of systemic reforms must resolve the adverse economic impacts from the COVID-19. Hence, instead of preferring "quick wins" from relief packages, policy changes must be aimed to shape industrial and economic activities in a way that they become compatible with climate agreements, i.e., Kyoto Protocol and Paris Agreement.

Governments around the world have introduced stimulus measures to overcome economic damage by the COVID-19 as the financial outcomes of the COVID-19 will have a significant bearing on the macroeconomic environment, which is why energy transformation towards sustainable energy sources from political and macroeconomic perspectives remains a significant challenge. In this regard, investments from the private sector to encourage energy transition are critical, which must be accompanied by lower borrowing costs from the conventional banking sector. On the other hand, the continuous fluctuations in oil prices can lead to developments in fuel-efficient technologies. Keeping this discussion in mind, further policy changes must be aimed at linking economic stimulus packages with low-carbon pathways through pricing reforms, which can provide incentives to accelerate the transition towards cleaner energy sources, higher investments in energy infrastructure, and lower the financial burden towards energy transition.

Lastly, recent interaction between economic recovery and climate change indicates that energy transition towards cleaner energy is significantly influenced by macroeconomic shocks. As emphasized by the current crisis, instead of investments in new infrastructure, if policy changes only focus on easing current socioeconomic circumstances, the current pandemic will continue to hinder investments in green energy technologies. Such delays will exacerbate the risks of climate change, especially in developing economies. Hence, the key issue faced by policymakers is to integrate policy shifts with long-term energy transition policies. In this regard, the implementation of hybrid instruments, i.e., allocation of funds for infrastructure development, implementation of additional taxation, and elimination of subsidies, can be effective.

Also, the outbreak of COVID-19 has highlighted the deficiencies in political response towards public health crisis, and it is indicated that the post-COVID era will mainly focus on economic recovery rather than politics. The shifts in oil

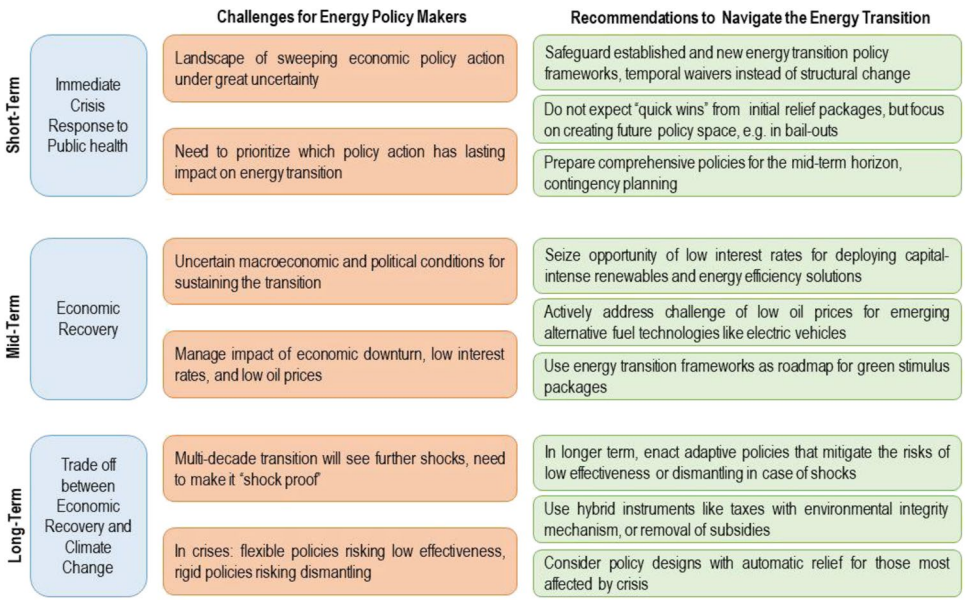

Fig. 8 Key challenges and recommendations for energy policymakers towards renewable energy transition in response to COVID-19

price following the declaration of COVID-19 as a global pandemic has highlighted the significance of "producer economies" to put them on a sustainable path, particularly if "green recovery" leads to an earlier peak in demand for fossil fuels. Failure to accommodate such changes will create tension and uncertainty among global economies both within and between nation-states. Within this context, we suggest that the determination of geopolitical aspects for trade pacts and sustainable energy agreements is critical in the future, while not neglecting the need to retain the democratic nature of global economies' policy formulations.

Conclusion

In recent months, the global energy industry is under constant duress due to the emergence of the COVID-19. The current study has reviewed the impact of the COVID-19 on the energy industry. Although the short-term impact from COVID-19 remains unclear, i.e., demand for energy products fell unexpectedly as well as fluctuating prices, and they correlate with industrial activities. According to the International Energy Agency, the future growth of the renewable sector is under threat in the long run, while medium-term investments in the energy sector are also expected to decrease. Lastly, our analysis indicates that global and geo-political tensions can significantly impact the recovery of the energy sector, which is why the current study recommends three guiding principles to facilitate future energy transition and prevent global climate change: (1) there should be higher restrictions on overspending, especially in the shirt-term; (2) policy goals need to be adjusted to avail economic opportunities during the energy transition; and (3) introduce policy mechanism to ensure consistent energy flow from the renewable energy sector. Furthermore, as COVID-19 is still evolving, especially in developing economies, there is a need for further research to analyze the extensive impact of the current pandemic over energy consumption energy resources and mitigation strategies. Long-term policy rationalizations need to be given further considerations within the energy policy frameworks across the nation/region. Also, further research can analyze the effectiveness of revising energy-related sustainable development goals or how existing energy goals can be affected by the introduction of policy designs proposed by the current study.

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Besma Talbi: Data analysis
Muhammad Adnan Bashir: Review
Muhammad Sadiq: Methodology
Luqman Shahzad: Revision

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Declarations

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