Int. J. of Thermal & Environmental Engineering
Volume 18, No. 1 (2021) 35-44

Prospect of Renewable Energy due to COVID-19 and Opportunity for Transition to Future Fuels

Haider Ali khan[a], Muhammed Zafar Khan[b], Chaouki Ghanai [c], Isam Janajreh[a]*

[a]Department of Mechanical Engineering, Khalifa University, Abu Dhabi, UAE
[b] Department of Mechanical Engineering, Cochin University of Science and Technology, India
[b]Sustainable & Renewable Energy Engineering Department, University of Sharjah, UAE

Abstract

Renewable energy is the energy of the future because it is the best long-term alternative for fossil fuels, which are facing numerous issues, particularly from an environmental standpoint. The world has established a number of targets to address the issues posed by the conventional energy sector. The United Nations has set 17 Sustainable Development Goals (SDGs) to be achieved by 2030; previously, many countries were not on track to meet these goals; however, the Covid-19 pandemic, which not only affected people's health, but also the energy sector, has demonstrated how quickly we are accustomed to change and can respond quickly and collectively with a common goal. As a result, the focus of this article is on the COVID-19's influence on the RE industry and its implications for future greener fuels. We talked about the opportunities that have arisen as a result of the COVID-19 situation that can help with the shift to alternative fuels. Finally, the problems and opportunities facing the creation of more environmentally friendly transportation fuels are identified. This document offers governments practical insights, options, and recommendations to consider.

Keywords: *Renewable energy, COVID-19, Greener fuels*

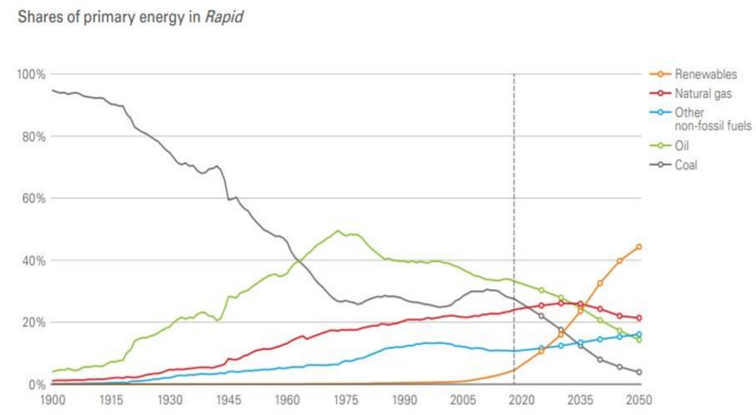
1. Introduction

Hundreds of countries, states, and provinces – mostly in Europe, Asia, and North America – implemented full lockdown measures to contain the pandemic from February to mid-May 2020, while partial lockdowns were implemented in a few other jurisdictions. After the virus mutation was discovered in 2021, countries had no choice but to impose shutdowns to avoid a historical "deja vu." To combat the fresh surge of diseases, numerous European governments have re-imposed restrictions. According to an IEA report [1] detailing the impact of Covid-19 — which it has dubbed a "once-in-a-century disaster" — on worldwide energy demands and CO_2 emissions, transportations including road and air travel have been largely constrained, resulting in a drop in global energy demands. Additionally, because millions of people remain confined to their homes, residential electricity demand has increased while business demand has decreased. According to the analysis, countries on complete lockdown see a weekly drop in energy demand of 25%, while those on partial lockdown see a weekly drop of roughly 18% [1]. However, this may not be cause for "celebration," as it is projected that emissions will rise once economies resume unless governments make a determined effort to shift energy sources. The renewable energy (RE) business has also suffered as a result of issues such as supply chain delays, tax stock

Market issues, and the possibility of not being able to take advantage of government subsidies [2]. Solar photovoltaics penetration in the United States is predicted to drop by 17 percent in the fourth quarter of 2020 [3]. COVID-19 has also had an impact on the supply chain from China, slowing down under-construction renewable energy projects all around the world [4]. Meanwhile, many nations' budgets will almost surely be trimmed in order to deal with COVID-19, and new renewable energy projects will almost certainly be delayed [5]. As a result of this predicament, the current subsidy systems in the RE sector face substantial challenges in recovering in the post-pandemic economy.

* Corresponding author. Tel.: +971 2 312 3286
E-mail: isam.janajreh@ku.ac.ae

DOI: 10.5383/ijtee.18.01.005



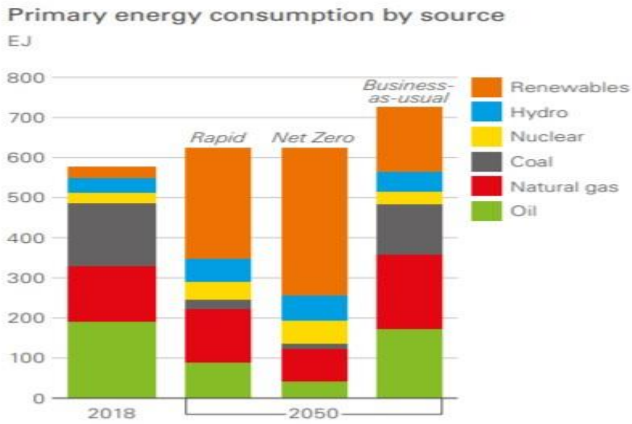


Fig. 1: Describing quantitative and qualitative trends of renewable energy due to COVID-19[5]

Institutional, technical, social-cultural, and behavioral impediments to RE existed prior to the pandemic, as described in [3], and included uncertain governmental policies, environmental damages/pollution, high-risk perceptions of RE technologies, and a lack of infrastructure. Financial and economic constraints, geographical and ecological barriers, and market-related barriers have all been mentioned previously [4]. However, Savacool[6] goes into considerable detail about cultural and societal indifference to RE, as well as psychological resistance.

According to recent IAE report [7], the societal barriers to renewable energy have been undervalued and under-examined.

Maintaining ecosystem services reduces RE potential even more [8]. It should go without saying that in order for governments to be prepared for unforeseen shocks, robust foundations for long-term recovery and resilience must be established. Efficient and successful recovery provides the capacity to rebuild beyond pre-crisis conditions for a more sustainable, safer, and resilient built environment. In the case of a future catastrophe, all actions should be focused toward reducing vulnerability in the face of an unpredictable future, resulting in much lower repercussions in all domains.As a result, the goal of this review is to uncover key information that can help legislators make informed policy decisions in order to accelerate the clean energy transition toward more resilient and sustainable energy systems that can withstand the effects of the current pandemic as well as the risk of future global crises. We shall observe the influence of COVID-19 on several sectors in the following sections.

2. Energy Price, Market and Economy

The pandemic has an impact on consumer spending patterns, business viability, and other factors that directly affect productivity [9]. As illustrated by the current epidemic, there is a major correlation between the global energy market and uncertainty [10]. The globe is going through a dreadful moment as a result of the COVID-19 outbreak, which has a wide-ranging influence on every area of the economy [11,12]. The impact of uncertainty on energy prices is studied using eight different energy prices, including Brent oil, Diesel, Gasoline, Heating

Oil, Kerosene, Natural Gas, Propane, and WTI oil, as well as five different uncertainty measures, including COVID Induced Uncertainty (CIU), Economic Policy Uncertainty (EPU), Global Fear Index (GFI), Volatility Index (VIX), and Misinformation Index of Uncertainty (MIU) [13]. To formulate the hypothesis, they employed all of the uncertainty proxies as inputs and energy prices as outputs. Throughout the study, descriptive statistics on energy costs show that the tendency is bidirectional. Each energy price has its own characteristics of downward (price decline) and upward (price recovery) movement. Essentially, the energy price hypotheses show that uncertainty has a positive and negative impact on energy prices. The pandemic has an impact on consumer spending patterns, corporate viability, and other factors that directly affect productivity [14]. According to Novan et al. [15], the energy sector has reacted quickly to the COVID-19. The strict lockdown has had a significant impact on the airline and transportation industries, as seen by low energy use and low cost. Arugaet al. [16] analyses COVID-19's impact on energy consumption in India. The findings demonstrate that energy consumption lowers significantly during the lockout. When the lockdown is lifted, though, it recovers. Qin et al. [17,18] investigate the link between oil prices and COVID-19, concluding that the pandemic has reduced oil demand, resulting in a drop in oil prices. Nyga-ukaszewska and Aruga[19] investigate the impact of COVID-19 on the oil and gas industry. They discovered that the outbreak has had a major influence on the global energy industry. COVID-19 has a negative impact on oil prices in the US and Japan, but a positive impact on gas prices.

3. COVID-19 Impact on RE and CO_2Emission

Low-carbon energy sources, coupled with nuclear power, surpassed coal for the first time in 2019. In all three scenarios, the fraction of primary energy consumption consumed by renewable is expected to be the greatest until 2050. (Rapid, Net Zero and Business as usual). Figure 1 shows that hydrocarbons' share of primary energy decreases from 85 percent in 2018 to 70-20 percent by 2050 (depending on BP scenario), while renewable energy climbs to 20-60 percent. Because of changing user behavior and preferences, such as a growing demand for integration between energy sectors/services and increased competition among energy kinds, the energy mix becomes more adaptable. Unlike the preceding 150 years, when coal and oil alternated as the dominant fuel sources, there will be no single dominant fuel source in either the fossil or non-fossil category by 2030 [5]. With this year's boost, renewable is poised to extend their lead, with low-carbon sources accounting for 40% of worldwide electricity generation. Due to lower marginal costs of electricity generating, renewable energy generation has been influenced less than the rest of the energy sector, according to Khanna [20]. Renewable are given priority in the grid and are not required to modify their output to meet demand, which protects them from the effects of decreasing electricity demand [21]. New renewable energy capacity increases, on the other hand, have been hit hard by the epidemic; global investment in new renewable capacity is predicted to plummet by 10% in 2020[22]. Germany, in particular, is one of the world's leading producers of renewable energy, with renewable obtaining grid dispatching priority; as a result, coal generation is gradually discouraged and phased out of the energy framework. The decline in overall energy consumption, on the other hand, has had a negative influence on pricing schemes for renewable energy and carbon trading. There was a clear decreasing trend in carbon per-unit price in the US and European carbon cap and trade markets at the onset of the pandemic [23]. The good trend of green and low-carbon energy progress could be harmed by the global fall in economy-driven demand. Although it is too early to predict how severe the pandemic's negative consequences on global renewable and sustainable energy systems would be, a considerable short-term reduction in renewable development is unavoidable [24]. Investors are becoming more wary about investing in new projects as a result of the pandemic, which is causing delays in putting new capacity online. The majority of countries, including the United States, rely heavily on China for a variety of renewable components and raw materials, particularly in the solar energy sector. Supply disruptions from China, as well as other issues such as labor shortages and homeowner cancellations of install orders owing to COVID-19, are expected to significantly slow down solar photovoltaics' in a few years to come [25]. Continuing to invest in renewable energy will necessitate re-establishing global supply networks and bolstering existing renewable energy regulations and investments [26]. In addition to supply chain delays, grid integration of new renewable energy projects has been delayed due to the postponement of non-critical activities by Distribution System Operators [27]. The pandemic, for example, might cause a shortage of electrical components due to disruptions in production and manufacturing. Major planned projects have been put on hold as a result of the pandemic, including 3000 MW of combined solar and wind power in India [28] and up to 25 GW of wind power in the United States [29]. COVID-19's impact on several sectors is depicted in Figure 2. Due to the vast number of incentives implemented by countries in the fight against the Covid-19 epidemic, the first obvious influence on the current situation is in renewable energy investments made in the second plan. The Executive Director of the International Energy Agency [30] has encouraged governments to enhance their warranty and contract processes to avoid financial risks and prevent investors from abandoning renewable energy investments as a result of the Covid-19 epidemic. The Covid-19 epidemic has reduced renewable energy predictions for 2020 by 28% in the solar industry [31]. According to reports, people in the solar energy sector have been fired or have suffered as a result of the Covid-19 epidemic. As a result, job losses in the renewable energy sector are expected to be significant. In the United States, employment in the renewable energy sector has decreased by 13%, including solar and wind technicians, HVAC contractors, and thousands of people working in building and installation. According to conservative estimates, hundreds of thousands of renewable energy workers would have applied for unemployment each year if the government had not intervened. Similarly, jobs in solar plant building and maintenance have decreased in other countries such as India and Bangladesh this year [32].

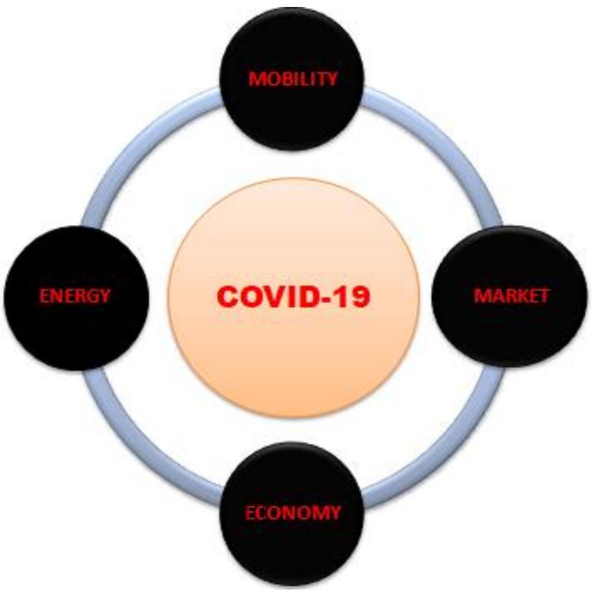


Fig. 2: Impact of COVID -19 on various sectors

Even as overall demand has decreased, renewable is given first priority in many countries when it comes to feeding electricity into the grid, which means solar, wind, and hydropower producers can sell all of the power they generate even as fossil-fuel generators reduce or shut down completely to avoid a system overload. Solar and wind farms have also benefited from more windy and sunny circumstances than usual in some areas. However, the corona virus has affected supply chains for wind and solar farms, as it does for much of the rest of the global economy. According to BloombergNEF, the virus forced the shutdown of about 11% of the world's wind turbines at one point. Work on new wind farms has been hampered by labor constraints and regulatory delays, all of which could result in a halt in new renewable energy projects the following year.

3.1 Impacts on CO_2 Emissions

Because the most carbon-intensive fuels witnessed the greatest drop in demand in the first quarter of 2020, CO_2 emissions fell faster than global energy consumption. Carbon emissions were 5% lower in the first quarter of this year than in the same period last year. The year saw an 8% drop in coal emissions, a 4.5 percent drop in oil emissions, and a 2.3 percent drop in natural gas emissions. Emissions fell the most in areas where the disease had the most impact. For example, emissions in China and Europe decreased by 8%, while emissions in the United States decreased by 9%[33]. Overall, emissions in 2020 could be 8% lower than in 2019[33], the lowest level of emissions since 2010, the biggest level of emission reduction (six times greater than during the 2009 financial crisis), and twice as much as the total of all reductions since World War II. Figure 3 depicts quantitative carbon emission data for the year 2018, which is slightly out of date but still provides a clear picture of CO_2 emissions [34]. Figure 1 shows that renewable will play a big role in the future; it simply displays the pattern of increasing reliance on sustainable energy sources while decreasing reliance on coal by 2050.

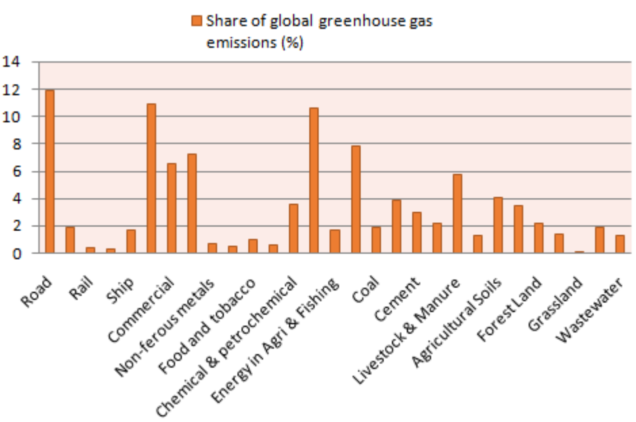


Fig. 3: Quantitative data showing Carbon emissions for the year 2018[34]

During the COVID-19 pandemic, transportation activities were reduced, resulting in a net reduction in GHG emissions [17-21]. Figure 4 displays NASA Earth Observatory photos of nitrogen dioxide NO2 before and during the COVID-19 in Wuhan, China. During the COVID-19 crisis in China, images of clear skies are displayed in Wuhan. It should be mentioned that aviation-related greenhouse gas emissions accounted for 2.5 percent of worldwide CO2 emissions in 2018[7]. Figure 5 depicts the world's energy-related CO_2 emissions, 1985-2020. Around 75 Gt of CO_2 emissions were prevented due to COVID-19[35].

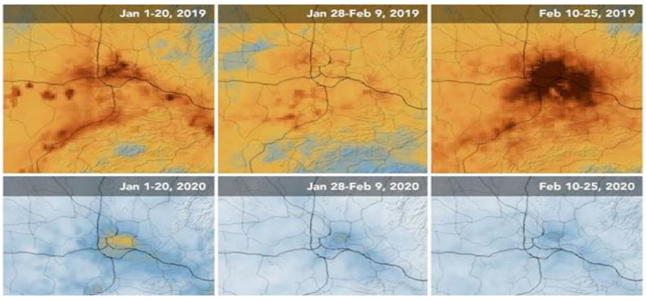


Fig. 4: Nitrogen dioxide NO_2 concentrations in Wuhan before and during COVID-19 [NASA Earth Observatory].

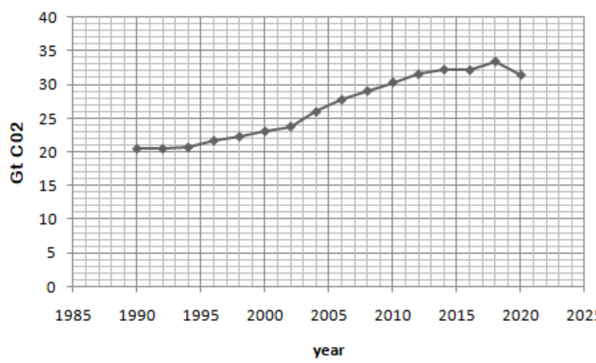


Fig. 5: The impact of COVID-19 on world energy-related CO_2 emissions [35]

It's no surprise that emissions will decrease when fossil-fuel use declines. Although an 8 percent drop is greater than most early predictions and exceeds the most ambitious scenario for limiting global warming, the IEA believes that it will not be adequate to prevent additional increases in the earth's temperature or the stock of greenhouse gases in the atmosphere. The Paris climate agreement set a more aggressive goal of limiting global temperature rise below 1.5 degrees Celsius, which will necessitate halving annual global emissions by 2030 and reaching net-zero emissions by the middle of the century. However, unless significant structural adjustments are made, emissions are anticipated to rise after economies recover. "Governments may learn from that experience by putting clean energy technology (renewable, efficiency, batteries, hydrogen, and carbon capture) at the center of their plans for economic recovery," Birol [24] said. Investing in those areas can also help to create jobs, improve economies, and create a more resilient and greener energy world [36]. In 2020, global CO_2

emissions are predicted to decrease by 8%, reaching their lowest level since 2010. According to the facts and findings of the IAE study [37], worldwide energy, coal, oil, and natural gas consumption decreased in the first quarter of 2020 compared to the first quarter of 2019. The aviation and road industries experienced the greatest reductions in energy usage, with 60 percent and 50 percent reductions, respectively [38]. Energy as the backbone of the global economy has had a significant impact on global energy consumption, fossil fuel demand (coal, oil, and natural gas), and the environment.

3.2 Impacts on Transport and Mobility

The global economy and the energy sector are both affected by the COVID-19 health catastrophe (power generation, transportation, residential and commercial buildings and industrial applications). During the corona virus lockdown period (March 1 – May 29, 2020), Figure 6 depicts the impact of the COVID-19 crisis on the mobility index [39] for some of the world's largest cities. The mobility index is generated by comparing recent usual usage periods to travels taken in a certain place. During the COVID-19 crisis, the economy was shut down and the economy slowed, resulting in a net reduction in the mobility index from 80 to 90%, especially in April and May 2020. The decrease in the mobility index is primarily due to lockdown (restrictions imposed on each country to prevent the sickness from spreading) and reduced utilization of the transportation infrastructure. During the COVID-19, road (passenger movement, mass transportation – buses, trains, and trucks) and air transports were significantly damaged; social mobility, which contributes to numerous carbon emissions, such as student services, has also dropped. China has reported a reduction of roughly 25% in carbon emissions [40]. Air pollution (such as NO_2 and CO_2 emissions) has also been reported to be decreasing in many areas [41]. However, thousands of lives have been lost as a result of this reduction in greenhouse gas (GHG) emissions, as well as negative consequences on people's physical and mental health, economic stagnation, and an overall bleak future. Even the IEA's Sustainable Development Scenario (SDS), which is completely aligned with climate targets of the Paris Agreement [42], the flattening of CO_2 emissions during the solid economic growth of 2019 was far from the yearly 6 percent decrease required in the SDS.

The safety rules and mobility limits, on the other hand, disrupted supply chains and temporarily slowed the development of renewable energy installations in important markets, particularly onshore wind and solar PV. Renewable energy construction projects, equipment supplies, policy implementation (permitting, licensing, auctions), and funding have all been underway since mid-May.

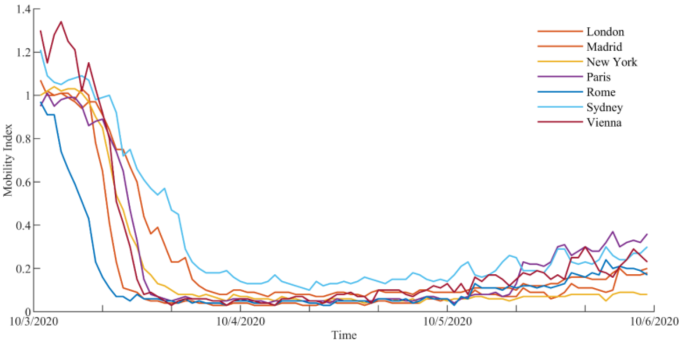


Fig. 6: Impacts of COVID-19 on the mobility index from March to May 2020 [1].

Because project developers and manufacturers adapted their operations to comply to ongoing social distancing rules, several countries' levels have restored to near-normal levels [43]. Renewable energy provides the best prospect of reducing carbon emissions and replacing fossil fuels. Despite their exaggerated size, wind and solar power continue to grow, with renewable energy already accounting for roughly 12% of worldwide commercial energy. The International Maritime Organization (IMO) decided in 2018 to cut GHG emissions by at least half by 2050 compared to a baseline year of 2008[1]. Passenger transportation, for example, accounts for approximately 40% of world oil demand and 15% of global energy-related carbon emissions [1]. The transportation sector's interruption during the COVID-19 crisis (lower oil demand and a net reduction in the transportation sector's carbon footprint) may serve as a spur for more sustainable mobility. It is a chance for both rich and developing countries to show their commitment to greenhouse gas reduction by including more routes into their infrastructure and adopting more sustainable energy methods. This is the optimum time to make the switch to more environmentally friendly and sustainable fuels in order to decarbonize the transportation industry.

4. Renewable energy transition opportunities and challenges:

There have been many contributions of the science in the society covering various technologies, aircraft, automobiles, alternative fuel, renewable energy technology, and nuclear technology. These have impacted and improved the lifestyle of the people. There are however various challenges and opportunities for renewable energy transition amidst the Covid19 pandemic.

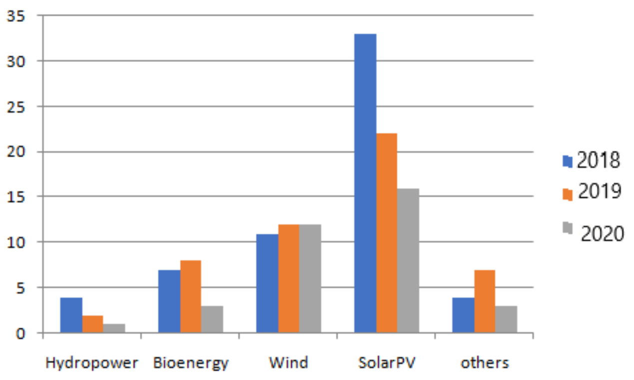


Fig. 7. Growth rates (%) of renewable-based electricity generation of 2020 compared to 2018 and 2019[45].

Despite significant disruptions to global renewable supply chains due to a temporary pause in production and manufacturing operations, Fig. 7 depicts the differing growth rates in electricity generation from various renewable energy resources in 2020, with a significant decrease compared to 2019. In the near future, the lessons learned from the COVID-19 epidemic will very certainly contribute to a growing percentage of renewable energy resources among world generation capacity [45].

4.1Challenges

There are numerous challenges that are being exacerbated due to the outbreak of pandemic that are needed to overcome in order to be able to develop greener fuels and transport de-carbonization:

- ➢ Feedstock diversification and optimization methods and strategies for large production of alternative fuels, using a broader range of feedstock. Increase the availability of high-energy-density crops or plants (biomass) and create new technologies and strategies for optimizing alternative fuel generation. Reduced manufacturing costs, large-scale production facilities, and the development of sustainable fuels are all goals.
- ➢ Security is a critical component in the production, transportation, storage, and use of alternative fuels. These new alternative fuels' potential for hazardous and environmental damage (leakages) as well as fire and explosion threats (fuel combustion and spread) must be thoroughly researched.
- ➢ Technology Development and Innovation: Development of novel and innovative commercially viable technologies for alternative fuel production, storage, and combustion (decrease environmental impact and reduce the fuel costs).
- ➢ Access to funds for the integration and development of future green fuels in the financial and economic systems.
- ➢ Innovative policy – The creation of new policies and regulations that promote green fuel production, infrastructure investment to support the development of future clean fuels, and reductions in gas and particulate emissions from fuel production processes, as well as the transition to clean transportation.
- ➢ Energy deregulations: Increase competition in the existing fuel supply markets to prevent energy monopolies.
- ➢ Educational challenges: new education and research initiatives are needed to support future alternative fuels and the shift to cleaner transportation.
- ➢ Industry and private companies: technology development, innovation, and entrepreneurship as knowledge society drivers
- ➢ Acknowledgement by the public of the transition to clean transportation and the development of cleaner and greener transportation fuels.

4.2 Opportunities

The COVID-19 crisis is giving several opportunities to develop greener fuels as summarized below:

- ✓ Energy Shift: The development of more environmentally friendly and cleaner transportation fuels will hasten the energy transition (de-carbonization).
- ✓ In order to produce greener and alternative fuels, increase the use of renewable resources (renewable power and renewable heat).

- ✓ Transportation de-carbonization and fuel diversification: Reduce the transportation sector's carbon footprint (aviation, maritime, and land transportation) by converting to greener and more sustainable fuels and producing more efficient combustion engines. Renewable alternatives (diversification and introduction of greener and cleaner fuels using resources such as algae, plants, waste cooking oil, and municipal waste). Transportation-related global warming reduction is a critical component of the green energy transition.

- ✓ Transportation sector energy security and sustainable fuels: Develop sustainable transportation fuels using local resources to reduce reliance on fossil fuels (self-reliance). Alternative fuels made from renewable resources will have the same properties and characteristics as conventional fuels and will operate on the same energy infrastructure (fuel storage, fuel delivery, fuel injection, fuel combustion systems, and post combustion emissions reduction technologies).The transportation sector will be susceptible due to a lack of fuel diversification for aviation, marine, and road gasoline supply points, especially during an economic downturn.

- ✓ Fuel Flexibility: Diversifying transportation fuels will aid in the development of reliable combustion systems that can operate on a wide range of gas and liquid fuels for energy security and in the event of a fuel supply disruption.
- ✓ Expand the hydrogen industry (production, storage, transportation, and use): hydrogen is a critical component of future clean and secure energy.
- ✓ Circular Economy: Advanced waste-to-energy technologies are being developed. Treatment of primary solid waste for the development of alternative fuels.
- ✓ Electric Vehicles: promote the use of electric vehicles and the construction of smart charging stations for EVs that use renewable energy sources.
- ✓ The development of new greener transportation fuels has created new commercial prospects and economic growth.
- ✓ Helix triple Model of innovation for enhancing government, industrial, and academic collaboration, as well as worldwide collaboration, in the development of future transportation fuels.

5. Scenarios, Support and policies

Renewable energy adoption can provide significant solutions for the post-COVID-19 problem. Industries can be revitalized by increasing the use of renewable energy technologies and creating new opportunities for the unemployed. In all domains of renewable, employment in the renewable and sustainable energy sectors surpassed 11 million jobs in 2018[10]. By 2050, employment in the renewable and sustainable energy sectors might reach more than 84 million jobs worldwide. Since 2010, over one-third of all US coal power facilities (102 GW) have been shut down, with another 17 GW expected to be shut down by 2025[46], presenting a significant potential for renewable to be substituted in the post-COVID-19 period. Renewable might totally replace coal-fired electricity generation by 2030, according to state legislation and federal tax credits. Some of the steps to consider for a sustainable future after COVID-19 are:

1. Stimulus plans: Due to historically low oil prices, power supplied from renewable energy resources is presently at a considerable cost disadvantage. As a result of low oil prices, governments in emerging economies may be compelled to pay subsidies to fossil fuel companies. Modifications to these subsidy schemes should be evaluated in light of expected increases in oil prices, as well as supporting policies aimed at hastening the transition to a low-carbon economy [47]. As a result, policymakers must address current policy adjustments while also identifying and prioritizing long-term strategic policy initiatives that will lead to a more sustainable and low-carbon energy future [48]. This will provide the much-needed boost to energy efficiency. For example, Japan plans to phase out gasoline-powered vehicles in around 15 years, and the government has set a goal of becoming carbon-free by 2050, with nearly USD 2 trillion in green industry and investment growth [49].In addition, the OECD's "green growth plan" encourages utilities to invest in renewables and hydrogen, while aiming for carbon-free autos by the mid-2030s [50]. In other news, the former US President Barack Obama's statement that the US would "transition" away from oil in favor of renewable energy garnered immediate notice. President Biden administration climate plan aims for the United States to be carbon-free by 2050. He also reiterated his commitment to ending federal oil and gas subsidies. Biden's plan, on the other hand, does not call for a ban on climate-damaging fossil fuels, instead focusing on technologies that absorb pollution from oil and other sources [51].

2. Emerging technologies including as storage and hydrogen may be approaching a tipping point: A large-scale transition to hydrogen energy, according to Dincer [52], might benefit the environment, ecosystem, energy efficiency, resource utilization, economic development, healthier societies, and renewable energy sources, and a disease outbreak in 2020 could herald in the hydrogen age. While assisting existing enterprises, stimulus packages should also continue to promote the development and early deployment of innovations that have the potential to boost national economies' competitiveness in the coming decades. Many of these cutting-edge initiatives can also help to reduce greenhouse gas emissions. Zero-carbon hydrogen production, low-carbon fuels for shipping and aviation, low-carbon materials (such as green cement or green steel), circular business models (particularly used materials collection and recycling activities), and digital solutions for system and energy efficiency, to name a few examples [53].

3. Governments should boost investment in renewable power generation, flexibility provision, and grid infrastructure, notwithstanding the fact that clean energy investments are reasonably resilient. With the deployment of additional renewable generation resources and production facilities, there would be a larger vision of supporting policies and legislative frameworks aimed at a low-carbon economy. Governments must define appropriate pandemic response strategies so that short-term policy goals may be set to help with both recovery and the development of renewable energy sources. They can do so by de-risking private investment in renewable energy generating through competitive

auctions, allowing investment in transmission and distribution systems, and expediting the planning process for shovel-ready projects [53]. The structural consequences in the growing energy system, as well as the possible spillover effects from such policy changes, should be given special consideration [54].Although it may be tempting to promote clean energy and sustainable development as part of the post-pandemic economic recovery plan in the short term, experts advise that the early rounds of stimulus money be spent on minimizing the pandemic's most severe economic consequences and assisting struggling businesses to avoid potential bankruptcy. Rather than focusing on minor immediate gains, policies should be structured to emphasize demonstrable changes as part of a long-term strategy for assisting the transition to a low-carbon economy.

4. Net-zero emissions will necessitate a paradigm shift in innovation: In 2019, public spending on low-carbon energy research, development, and demonstration (RD&D) increased by 6% to USD 25 billion, with Europe, the United States, and China leading the way [55]. Low-carbon technologies are drawing an increasing share of overall public energy R&D, at 80%. In 2019, corporate R&D spending increased 3% to USD 90 billion, with an estimated 60% of that going toward creating low-carbon technologies. In 2019, venture capital investments in early-stage disruptive innovations diversified in terms of sectors and region, reaching USD 4 billion. There was a noticeable increase in storage and hydrogen [56]. The Covid-19 problem may put a strain on publicly sponsored energy research and development, particularly in emerging nations, which are likely to account for much of future energy demand growth. Public initiatives are essential for fostering innovative science and high-risk demonstration projects, as well as determining the course of technological change. But they can't do it all by themselves. Market discipline is imposed on the winnowing of fresh ideas and the refining of technologies for deployment by corporate investments. According to new data, start-ups and innovative small and medium-sized firms (SMEs) will experience financing and liquidity issues in 2020, as well as a reduction in private R&D and capital budgets [57].

6. Conclusion

The Covid-19 pandemic is wreaking havoc on global energy networks, stifling investment and threatening to stifle the spread of crucial renewable energy technology. The good news is that measures to promote sustainable energy are more likely to succeed if they also help to achieve other societal and economic development goals. Governments should look across programs to maximize beneficial synergies where they exist and avoid introducing cost-cutting incentives in order to achieve this. This article presents data on fuel demand and emissions during the COVID-19 crisis, as well as new directions, opportunities, and problems for developing better fuels and making the transition (de-carbonization) to clean transportation. As a result of the pandemic's massive interruptions to travel, trade, and economic activity, global carbon emissions decreased. During the COVID-19 pandemic, the reduction of transportation activity and the need for fuel supply resulted in a net reduction in carbon emissions. Reduced demand for fossil fuels, market volatility, and net reductions in greenhouse gas and particle emissions may serve as catalysts for switches to more sustainable fuels in the transportation sector and transportation de-carbonization. To summaries, the COVID-19 global health and economic crisis provided chances to accelerate the development of future cleaner fuels for all modes of transportation, decarbonization of the transportation sector, development of a robust fuel supply, fuel flexibility, and economic growth. The development of sustainable and innovative technologies for the production of these fuels; safety testing for handling; financial and economic systems to support the development of these fuels; and development of new policies and regulations for a clear path to green fuels are the major challenges for the development of greener transportation fuels. If these challenges can be overcome, the growth of green energy will be a breeze. In reality, two significant risk factors are left out of the calculation. First, if the economy is fueled by sound policies, a decline in economic activity would stifle investment in clean energy technologies. Second, if economic variables and ambitious goals are not included early in the policy-planning process, newly adopted policies are likely to fail to endure the economic shock during the recession and be quickly changed by changing political circumstances. These two primary risk factors are expected to have a significant impact on the transition to renewable energy and a low-carbon economy.

Acknowledgement

The authors would like to thanks many of the anonymous members of the Khalifa University, Abu Dhabi and past colleagues at IRENA that have enlighten our thought to write this manuscripts.

References

[1] *The impacts of the Covid-19 crisis on global energy demand and CO2 emissions,,* International Energy Agency,, April 2020..

[2] F. Birol, *Put clean energy at the heart of stimulus plans to counter the coronavirus crisis.,* vol. pp. 1–4, IEA, Retrieved April 21, 2020,.

[3] J. Painuly, "Barriers to renewable energy penetration; a framework for analysis," *Renewable Energy,* vol. 24, 2001.

[4] D. Kariuki, "Barriers to Renewable Energy Technologies Development," vol. 2302, 2018.

[5] "bp Energy Outlook: 2020 edition," BP, 2020.

[6] B. Savacool, "The cultural barriers to renewable energy and energy efficiency in the United States," *ScholarBank@NUS Repository,* vol. 31 (4), pp. 365-373, 2009.

[7] "Renewable capacity additions by technology and by region, Q1 and Q2 of 2019 and 2020.," IEA,, Paris, 2020.

[8] M. R. Z. K. C. G. M. A. M. S. M. A. Abrar Inayat, "Flowsheet Modeling and Simulation of Biomass Steam Gasification for Hydrogen Production,,," vol. 43, p. 4, 2020.

[9] S. R. S. A. M. T. Ocar Jorda, "Longer-Run economic consequences of pandemics," *COVID economics: vetted and real-time papers,* p. 1 , (2020), .

[10] S. G. K. G. R. H. D. Aloui, " COVID 19's impact on crude oil and natural gas S&P GS Indexes," (2020).

[11] S. B. A. M. K. C. B A. Algamdi, " COVID-19 deaths cases impact on oil prices: probable scenarios on Saudi Arabia economy," *Frontires Pub Health,* vol. 9, pp. 1-6, (2021).

[12] O. E. S. A. C. M. C A.H. Amadi, "Effects of covid-19 on crude oil price and future forecast using a model application and machine learning," *European J Eng Technol Res,* vol. 5, p. 12, 2020.

[13] O. J. A. O. S. Y. A. E. O. A. F. A. Olusanya E. Olubusoye, " Energy pricing during the COVID-19 pandemic: Predictive information-based uncertainty indexes with machine learning algorithm," *Intelligent System with application,* vol. 12, 2021.

[14] S. R. S. A. M. T. Ocar Jorda, "Longer-Run economic consequences of pandemics," *COVID economics: vetted and real-time papers,* vol. 1, p. 3, 2020.

[15] C. P. R. S. M. W. R. Gupta, "Does partisan conflict predict a reduction in US stock market (realized) volatility? Evidence from a quantile-on-quantile regression model," *N Am J Econ Finance,* vol. 43, pp. 87-96, (2018), .

[16] M. M. I. a. A. J. Kentaka Aruga, "Effects of COVID-19 on Indian Energy Consumption," *Sustainability,* vol. 12, p. 5616, 2020.

[17] IEA, "Oil market report," *International Energy Agency, Paris, France,* 2020.

[18] I. IEA, "Gas (2020b)," *International Energy Agency, Paris, France ,* 2020.

[19] S. B. A. M. K. C. A. Algamdi, "COVID-19 deaths cases impact on oil prices: probable scenarios on Saudi Arabia economy," *Frontires Pub Health,* vol. 9 , pp. 1-6, 2021.

[20] M. Khanna, " COVID-19: A Cloud with a Silver Lining for Renewable Energy?," Applied Economic Perspectives and Policy, 2021.

[21] ". "Sustainable Recovery." World Energy Outlook Special Report.," International Energy Agency., 2020.

[22] "The Impact of the COVID-19 Crisis on Clean Energy Progress.," International Energy Agency, 2020.

[23] ICAP, "ICAP," *Allowance Price Explorer,* 2020.

[24] S. Ehsan Hosseini, "An Outlook on the Global Development of Renewable and Sustainable Energy at the Time of Covid-19.," vol. 101633, 2020.

[25] B. a. C. M. Eckhouse, "Coronavirus Crushing Global Forecasts for Wind and Solar Power.," *Bloomberg Green,,* 2020.

[26] Z. Y. H. G. A. S. A. M. S.A.R. Khan, "A state-of-the-art review and meta-analysis on sustainable supply chain management: future research directions," *J. Clean. Prod.,* vol. Article 123357, p. 278 , (2021).

[27] E. Community, " Energy Community DSOs Committed to Keeping Lights on during COVID-19 Crisis," *Energy Community,* 2020.

[28] O. B. Group, "Covid-19 Impact Energy Sector Year in Review 2020," *Oxford Business Group,* 2021.

[29] S. Weko, "Covid-19 and Carbon Lock-In: Impacts on the Energy Transition," 2020.

[30] F. Birol, "Put clean energy at the heart of stimulus plans to counter the coronavirus crisis.," IEA, April 21, 2020,.

[31] A. A. Ghabri Y., "The Impact of COVID-19 Pandemic on Renewable Energy and Commodity Markets," in *Advances in Managing Energy and Climate Risks* , Springer, 2020, pp. 115-142.

[32] R. Whitlock, "America has lost 594,300 clean energy jobs because of COVID-19," *Renewable energy magzine,* 2020.

[33] G. E. R. 2. IEA, "Global energy and CO2 emissions in 2020," IEA, Paris, 2020.

[34] IEA, "The 2018 Global Status Report by the International Energy Agency (IEA) for the Global Alliance for Buildings and Construction (GlobalABC).," IEA, 2018.

[35] " World Energy Outlook 2019," IEA , Paris, 2019.

[36] IEA, *Global energy demand to plunge this year as a result of the biggest shock since the Second World War,* IEA, 2020.

[37] "Global Energy Review 2020," IEA (2020), Paris, 2020.

[38] "Global Energy Review 2020," IEA (2020), Paris, 2020.

[39] "The impacts of the Covid-19 crisis on global energy demand and CO2 emissions, ,," *Global Energy Review 2020,* April 2020..

[40] L. Myllyvirta, "Coronavirus has temporarily reduced China's CO2 emissions by a quarter.," *Carbon Brief,* April 20, 2020.

[41] J. McMahon, "Coronavirus lockdown likely saved 77,000 lives in China just by reducing pollution.," *Forbes,* April 20, 2020,.

[42] "World Energy Model," *IEA,* 2020.

[43] "Renewables 2020," IEA (2020), Paris, 2020.

[44] IEA, "The Covid-19 Crisis Is Causing the Biggest Fall in Global Energy Investment in History Paris," *International Energy Agency (IEA),,* 2020.

[45] Y. V. F. J. K. P. Jiang, " Impacts of COVID-19 on energy demand and consumption: challenges, lessons and emerging opportunities," *Energy,* p. 116441, 2021.

[46] "More U.S. coal-fired power plants are decommissioning as retirements continue - Today in Energy," U.S. Energy Information Administration (EIA), 2020.

[47] T. S. T. Matsuo, "Hybridizing low-carbon technology deployment policy and fossil fuel subsidy reform: a climate finance perspective," *Environ. Res. Lett.,* vol. 1, p. 12 , 2017.

[48] A. P. T. P. S. W. T. Hale, " Variation in government responses to COVID-19," *Blavatnik Sch. Gov. Work. Pap.,,* p. 31, (2020).

[49] *Japan to go carbon-free by 2050, Prime Minister Suga says,* 2020, Retrieved from https://www.marketwatch.com/story/japan-to-go-carbon-free-by-2050-prime-minister-suga-says11603727604. On 26 November, 2020.

[50] OECD, "Towards Green Growth, OECD Green Growth Studies,," OECD Publishing, Paris, 2011.

[51] *https://www.bbc.com/news/world-us-canada-54670269.*

[52] I. Dincer, "Covid-19 coronavirus: Closing carbon age, but opening hydrogen age," *Int J Energy Res,* vol. 44 (8) , pp. 6093-6097, 2020.

[53] G. Luciani, "COVID-19 AND THE ENERGY TRANSITION," Oxford Energy Forum , July 2020.

[54] M. Pahle, "Sequencing to ratchet up climate policy stringency,," *Nat. Clim. Change,* vol. 8 (10), pp. 861-867, 2018.

[55] IEA, "Energy Technology RD&D Budgets: Overview,," *IEA,* 2021.

[56] IEA, " Energy Technology RD&D Budgets: Overview," IEA, Paris, 2021.

[57] IEA, "The impact of the Covid-19 crisis on clean energy progress," IEA, Paris, 2020.