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Covid-19 and energy sector: Unique opportunity for switching to clean energy

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**A B S T R A C T**

The novel coronavirus (2019-nCoV) was extended to 213 countries globally by August 2021. The world has been threatened by rising infection rates and emerged as the catastrophic event in the field of health triggering the international emergency panic button. COVID-19’s sudden arrival wreaked havoc on the world economic picture, particularly in the energy sector. A steep drop in oil prices, as well as an imbalance in energy, was the result of strict travel restrictions, fewer transportation options, and people’s fears of a flu pandemic. However, confined mobility and a drop in energy demand coated the environment with a silver line and drowned the nation’s economic opportunities. Industrial transport, and not to mention every conventional energy-related thing, is completely devastated, but renewables were immunized. Wind, solar, hydrothermal, hydrogen, biomass-based energy systems were on high gear yielding maximum results in counterbalancing the demand–supply chain.

Moreover, the pandemic created an opportunity to showcase the importance of renewable energy and tackle the difficult emergency like now. In addition to this, the mindset of the investors was slowly fading away from conventional fuels and shifting towards renewable energy. However, it is too early to state the booming renewables at the moment, and no idea about its long-time survival. Thus, the present review gives a clear picture of the current status of fossils and renewables, the impact of a pandemic, energy investments, government policy standings, threats, and opportunities, and finally, the key takeaways avoiding energy scarcity in once a lifetime disaster situation.

**1. Introduction**

The world witnessed extraordinary successes in its recent energy development and was challenged by the nemesis Covid-19, which could be named the “Nightmare of 21st century”. The outbreak of the novel Covid-19 diseases swiftly contaminated almost every corner of the globe in less than 30 days infecting approximately 1.25% of the global population at various scales of severity (World Health Organization, 2020). Since the virus began its worldwide spread, governments from the local to national levels have taken drastic and critical action to combat the unprecedented global health crisis. Every nation, organization, NGO’s, health center, epidemic prevention board suggested the only way curtail the spread is through lockdowns or total shutdowns. This impact had a disproportionate effect on 30% of the global population (Bai et al., 2020), with 80% of businesses Hoang et al. (2021), and suggesting that a worldwide economic recession is impending (Gopinath, 2020).

The energy sector has become an integral part, an essential commodity in daily life, posed a tremendous impact on the survival and existence of humankind. Due to extreme reliance on energy in the present scenario, survival and existence without energy have become highly impractical. Thus, the energy sector has become the prime pillar to any nation that defines the country’s shape, power, and status due to the cohesion towards the business, industries, transportation sectors, etc. In other words, the ongoing technological advancements are directly linked to energy, and the majority of the innovations require energy to perform better and lessen the burden on humans. Consequently, the energy demands were touching sky high every year, and in turn, the production rate is also rising the bars. However, contrasting to its powerful nature, it is highly vulnerable and sensitive to natural calamities such as the Covid-19 pandemic we are experiencing. Fig. 1 the sample of energy production and consumption patterns across the globe for the pre and post-Covid era. The ongoing worldwide pandemic has damaged the energy sector in many ways.
1. The stringent lockdown or temporary shutdown procedures during the outbreak restricted public movements both domestically and internationally to hit the transportation sector by directly cutting the energy demands (Yaya et al., 2020).

2. The lockdown policy transformed the work modality and lifestyle, promoting the e-work scenario, e-schooling drastically altered energy consumption patterns. Besides, transportation energy lost its demand, whereas electric power gained prominence (Ghiani et al., 2020) through work from home, online schooling, entertainment watching activities, etc.

3. Covid-19 also disturbed the energy equilibrium market, which is reflected in price fluctuations. In some instances, developed nations trying to dominate and take over the energy-rich countries led to “energy war” strategies.

This pandemic resulted in lowering the economic pace and production activities, thereby dropping the global energy demand affecting the deployment of clean, renewable, and conventional energy sources. As per the numbers of the International Energy Agency (Energy and Iea, 2020), the estimated downfall of energy demand was 3.8% during the first wave of Covid-19 (i.e., during the first quarter of 2020), and to 6% during the initial days of the second-wave (i.e., during the end of 2020). On a global note, this declined energy demand led to a great financial crisis of magnitude greater than 6–8 times than the one experienced during 2008 (Energy and Iea, 2020). Some other agencies predicted that the shock to energy due to Covid-19 is set to be the largest in the past seven decades. Although these energy demand drops look simple, the repercussions are very serious, complicated in dis-functioning the demand and supply balance harmony. With great financial investment and subsidies from governments and regulatory bodies at home and abroad, set out to ensure energy security and alleviate energy poverty during the pandemic (Barbier, 2020).

Conversely, Covid-19 brought dividends to the climate, and the environment by the reduced movement of vehicles closed temporal reduced the NOx, SO2, CO, PM2.5 (Gollakota et al., 2021), and PM10 pollutant emissions in some of the cosmopolitan highly polluted cities across the globe (Chakraborty et al., 2020). Furthermore, the alarming temperature levels due to the GHG emissions were slowly cooling down, bringing timely changes in the atmosphere, i.e., maintaining the balanced ecology (Forster et al., 2020). When it comes to noise pollution through different means of transportation, industries have adverse effects on humans and other living organisms (Zambrano-Monserrate et al., 2020). However, the quarantine and lockdown measures substantially lowered the noise pollution. For instance, 40–50% noise drop was observed in Delhi (Somani et al., 2020). Besides, the unorganized disposal of PPE kits, including face masks, hand gloves, and hospital waste, harms the environment.

Overall, Covid-19 has erupted the social-economic imbalances, taught some serious lessons to the human race for existence. Moreover, this pandemic evaluates the deadly dependence on energy by humans and elevates the importance of the energy sector to national growth, and probes the necessity of alternate energy sources. Many studies were already made available on the glitches of the energy sector during the pandemic. Inspiration from these studies has been made to analyze and identify the research hotspots on the impacts of Covid-19 on energy and summarize the influence. Further, a prognostic trend of energy variations with respect to catastrophes were elucidated, and finally the real damage to the energy sector due to Covid-19 were presented.

2. Global lockdown and economical hiccup

2.1. Lockdown and energy

The pandemic caused by coronavirus has caused a macroeconomic shock in peace. By 28 April, the World Health Organization announced that almost 200 countries and territories reported three million confirmed cases and over 200,000 deaths due to disease.
Only a few countries have seen a peak in the number of cases to date, and to curtail the further spread, most social and economic activities have been restricted by governments worldwide. These include partial or full lock-up, daily restrictions, closing educational and non-essential enterprises, and prohibiting public gatherings. Fig. 2 presents a clear picture of the lockdown strategies implemented by the popular nations drastically hit by the pandemic.

Since December 2019, the crisis has progressively unfolded. Lockout actions with a strong macroeconomic impact were implemented by the Peoples’ Republic of China (hereafter called "China"), China which was first affected by the virus, and represented 16% and 20% of the world’s GDP alone and 24% of energy demand in 2019 (OECD, 2020a). Approximately 3.4 billion people or 54% of the world’s population, or 60% of world GDP, were locked in complete or partial terms by 28 April 2020 and almost everyone in the world is involved in some form of containment (Perkins, 2020). Population accounting for one-third of world energy demand or 53 percent of global primary energy consumption are locked in many parts of Europe, America, and Asia in March 2020. Again, China is the first nation to recover from crisis, began lifting restrictions and restarting factories by this time. Still, social distancing measures continue to be in place that prevents the recovery of the service industry. Although the total number of registered cases in Africa is lower than in the world’s worst-hit regions, the full impact of the crisis has still been felt by the continent. Almost 50 countries in Africa are affected, there is an increase in cases and containment measures (OECD, 2020b). The share of energy consumption at full or partial lock-ups around the world went from 5% to 52% between the middle of March and end of April (Global Energy Review 2020: The impacts of the Covid-19 crisis on global energy demand and CO2 emissions, 2020). These limitations are a difficult combination of supply and demand shock. The supply shock comes from deliberate economic restrictions: restaurants, shopping centers, and factories have been closed in some countries to prevent the virus from the spread. In a small measure, this decline is offset by greater e-business and other economic activity, particularly by an increase in medical equipment sales. However, the overall supply-side capacity is significantly restricted by the restrictions.

### 2.2. Other impacts

For the first time in human history, cross-border travels of all kinds were drastically limited in 2020. This year’s COVID-19 had a devastating effect on tourism, as well as on the mobility of people of all kinds, from international students to family members returning home. International Organization for Migration (IOM) data shows that countries around the world have imposed a staggering number of restrictions on international travel as a result of the pandemic’s spread.

#### 2.2.1. Human mobility

Countries responded to the rapidly changing public health situation by implementing a wide range of travel restrictions and health standards. The first quarter of the 2020 (January to May) saw a large number of countries restricting travel to and from affected regions. As a result of the record number of border closures, even countries in Europe’s border-free Schengen area re-imposed artificial barriers with their neighbors. As of March 31, the governments of all countries, territories, and areas of the world were subject to at least 70 travel bans issued or extended by sub-national authorities. From March through May, public movements of all kinds were severely restricted due to countrywide lockdowns. In April and May of this year 2020, for example, the number of passengers on international flights fell by 92% compared to the same months of 2019 (Meghan et al., 2020). To minimize the worst economic and human costs of emergency measures, many governments introduced or expanded exemptions – including for nationals and residents (and their families), diplomats and staff of international organizations (and health-care workers), and even chartering planes to facilitate the carefully managed movement of people.

#### 2.2.2. Land border closure and phased reopening strategy (June to September)

Airports, land and sea ports were reopened in a staggered fashion in the second phase of the crisis response. Health measures, such as pre-departure COVID-19 certificates, quarantine measures, or health declaration forms, were increasingly being used in place of travel bans during this period. Due to increased health controls...
and/or regional agreements, such as “travel bubbles,” air travel was the first mode of transportation to reopen in many locations. At this point, a variety of approaches began to emerge. New Zealand and Australia, on the other hand, opted for a virus-elimination strategy and closed their borders, while the Caribbean islands opened their doors to tourists. In addition, a country’s health criteria began to exceed its route constraints at a certain point in time. It was mid-July in the Caribbean, whereas other places reached this position in August or September. Many Asian countries, particularly Japan, the Republic of Korea, and Viet Nam, used their visa systems to restrict travel to a greater extent than those in other areas during this phase.

2.2.3. Response to second surge (October to December)

There has been a second (and in some cases third) wave of infections and new strains of the virus since then, and governments have been attempting to establish their competence to apply health measures in the place of travel restrictions. There are countries that have opened their borders to tourists, including Chile, Mexico, and the United Arab Emirates (UAE). As quarantine restrictions and screenings grew less popular, health certificates became the most common health-related travel measure (possibly because quarantine had been demonstrated to be costly and screenings were ineffective). In reaction to the B.1.1.7 and B.1.351 forms of the virus found in the United Kingdom and South Africa in December, governments imposed route restrictions on those nations (Meghan et al., 2020).

2.3. Economical hiccups due to Covid-19

There are numerous ways in which an infectious disease can impact an economy (i.e., direct and indirect). The 2003 SARS outbreak was estimated to have a major impact on economies by reducing consumption of different goods and services, increasing businesses’ operational costs, and resulting in higher risk premiums for regions with increasing risk (Lee and McKibbin, 2004). For instance, the anticipation of highly infectious diseases that lack a vaccine (e.g., pandemic influenza, HIV/AIDS, and SARS) could significantly impact US economies, as shown in the economic impact studies (Chou et al., 2004). In other words, COVID-19 is an infectious and economically destructive pandemic. The emergence in line with the financial harm of World War II (Watts, 2020) as well as a “Black Swan event,” the COVID-19 pandemic has severely devastated the world economy (Renjan, 2020). Some analysts have estimated travel restrictions, border shutdown, and quarantine efforts by the government to “remove the pandemic” (Burkert and Loeb, 2020) have caused reasonable concern over an ongoing economic slow-down and long-term crises (Hall, 2020). The financial losses from COVID-19 are mainly caused by a decrease in energy demand and related services. There are, therefore, not enough customers to buy products and services in the global economy.

Fig. 3 explains the seriousness of energy consumption per capita from 2019 through 2020. The figure shows that the 4.5% drop of the primary consumption as observed, lowest ever since 2009. The major contributor for this declining trend was driven the oil source accounted to (~9.7%) (Looney, 2021). Interestingly, renewables and hydroelectricity consumption patterns show an increasing trend of +9.7% and +1.0%, respectively. Accounting region-wise, Northern America tops followed by Europe, South and Central America, Middle East, and Asia-pacific scores lowest rank in consumption patterns as ~8.0%, ~7.8%, ~3.1% and ~1.6% respectively. Concerning the energy source, oil accounts for the majority of the energy mix, and therefore the long-term oil demand will increase (31.2 percent) (S&P Global Platts, 2021). Coal will remain the second-largest fuel in 2020, with 27.2% of total primary energy consumption. New records for both natural gas and renewable energy at 24.7% and 5.7%, respectively, were set. The share of renewable energy has surpassed nuclear which accounts for 4.3% of the overall energy mix. In 2017, Hydro’s energy share increased by 0.4 percentage points to 6.9% (S&P Global Platts, 2021).

3. Positive outcomes of the pandemic

On the other hand, the positive note of the pandemic substantially reduced the demand for energy due to the shutdowns and prolonged lockdowns of industries and daily life. Because of the total decrease in order during COVID-19, the pandemic caused a slump in various energy prices. In Spain, the current wholesale price for electricity was 60% lower than expected by May 2020. The price was 62 percent lower than expected for natural gas in the same month (Abadie, 2021). In addition, combined with disputes between the main oil exporters, oil sales prices during the pandemic fell sharply. Based on the last crest value, Brent oil prices fell by around 59% by February 17, 2020. In April 2020 (Ou et al., 2020), Western Texas’ mid-March oil price also fell unprecedented negative values. Despite the sharp decline of the oil demand, the supply maintained its pre-paid level, creating for the first time in history a glut of oil and full capacity of oil storage facilities in certain states (Bildirici et al., 2020). As a result, when storage capacity runs out, financial products, like crude oil, must be sold off directly to lead to a huge decline in oil price.

3.1. Carbon emissions

With more than 115 million people deceased and more than 2.5 million infections, the globe has been sick due to Covid-19 (World Health Organization, 2020). However, during 2020, the bad news about this other great infirmity has been buried: the ill state of the earth’s climate. Greenhouse gasses soar when economies boom and people move. Still, then the economic slowdowns and global lockdowns lead to energy consumption and the emissions of greenhouses of gasses falling, and they did. Carbon emissions and their mitigation are currently the buzzing areas of research targeting net-zero emissions by 2050. These fluctuations in fossil energy probed the public’s mindset to transmute towards the non-conventional energy sources such as EVs and renewable-based ideologies (Levin et al., 2021). Unfortunately, the pathway of transformation towards net-zero emissions was not smooth enough. The everyday growing energy needs pulled back the carbon emission targets and pushed forward the fossil energy production, releasing million metric tons of CO2 and multiplying each year.

Consequently, the excess release of carbons and GHGs into the atmosphere created ecological imbalances resulting in severe droughts, flash floods, earthquakes, wildfires, volcano eruptions, and a de-balanced ecosystem cycle (Seneviratne et al., 2012). Thus, the angry nature threw its paw in the pandemic, one way a good sign to nurture nature. Further, before the pandemic, carbon emissions rose 1% each year for the last few decades (Le Quéré et al., 2020). For sample analysis, Fig. 4 projects the million metric tons of CO2 emissions since the start of the pandemic (2019–2020). It is most obvious that heavily crowded continents like Asia-pacific and Northern America were the primary offenders of carbon releases, followed by the middle east, Europe, CIS, etc. However, the emergence of Covid-19 in late December 2019 and stringent movement restrictions in mid-march 2020 across the globe substantially grounded the emission levels.

Nevertheless, the impact was tremendous, dropping the global GHGs, and carbon emission rates by 7 percent and 17% in 2019 (Edo et al., 2019). The downfall of carbon emission was contributed by many different sources, such as a staggering drop of aviation
transport to 70%, causing a decline of 45% emissions from this sector alone, equivalent to 100 million cars on the road. Moreover, the other means of transport such as car, bus, and motor vehicles limitations restrained 50% of the emissions (Le Quéré et al., 2020).

However, the irony is those relaxing regulations and easing restrictions again drifted the emissions compared to 2020, but less than 2019. Further, rising economic activity throughout the world and rebounding energy demands, especially crude oil, led to 650
Mt of CO₂ in 2021 compared to 500 Mt in 2020. Another source of the CO₂ emission was coal-burning, which was bounced back, emitting 640 Mt of CO₂ in 2021, which is 0.4% more than in 2020. Lastly, emissions from the natural gas combusting are expected to throw 215 Mt of CO₂ in 2021, comprising the all-time high of 22% global equivalent emissions (IEA, 2021).

On the other hand, the successful returning to normal life post pandemic is mainly possible through the three important aspects namely regional coordination, travel bubbles, green lanes, public health requirements that includes testing and vaccination.

3.1.1. Coordination

Countries, territories, and areas, by and large, adopted their own plans in 2020. Aside from a few regional trends, most decisions were decided on an individual basis (such as the EEA depending on entry limits and sub-Saharan Africa's transition toward virtually solely using health requirements). Travelers, migrants, and sailors were left stuck as border and airport officials were forced to make decisions with little time for preparation, guidance, or training because of the lack of international consultation. Decision-making based on uncertainty and supply chain disruptions was also difficult to forecast. However, a wave of travel bans announced when the B.1.1.7 form of this virus emerged in late 2020 and early 2021 indicates how rapidly countries might return to a position similar to the one that existed in March 2020 (Meghan et al., 2020). Progress is being made at the global and regional levels, as well as in novel partnerships between the corporate sector and international organizations, which, all together, could provide fertile ground for a new infrastructure for cross-border public health management. Thus, worldwide activity is frantic but scattered, international guidance, minimum standards, and interoperability of existing, newly developed strategies, and technologies are all desperately needed.

3.1.2. Travel bubbles

The Baltic bubble was the first to begin going, opening in May of 2020. Individuals with no signs of a respiratory infection and who haven't been in contact with someone who has tested positive for the coronavirus and have been in Estonia, Latvia, or Lithuania for at least two weeks are allowed to move freely around the region. Though Poland and Finland were not included in the bubble, there was some possible political impact (Meghan et al., 2020). While Latvia (which had one of the lowest rates of infection at the time) announced a 14-day quarantine for newcomers from Estonia in September, the bubble had burst. While the Schengen Agreement was being ratified, Scandinavian countries began to open up to their neighbors. The method chosen by Sweden to handle COVID-19 (less stringent social-distancing measures and more deaths per million residents during the first phase of 2020, from March to May) resulted in numerous countries extending their border closures to the Scandinavian country (Meghan et al., 2020). In Sweden, the response was that this was unjustifiable on public health grounds, and that it would harm relations with Norway.

However, there are a number of lessons to be learned from the history of these numerous travel bubbles. While long-term political and economic linkages tend to lead to the establishment of travel bubbles, it has been unequal public health circumstances that have “blown” them (as in the Baltic case, for instance). Secondly, launching a travel bubble has proven to be far more difficult than planned; also those who want to create travel bubbles and green lanes have had to postpone or abandon their efforts at times because they couldn't find the right partners (Erdbrink, 2020). The third factor is the need for reciprocal trust in the data metrics and technique used to quantify caseloads, as well as trust in a broader public health strategy in general. To summarize, the travel bubble model is still in its infancy and has yet to be tried on a large scale.

3.1.3. Public health requirements

Airport symptoms screening, testing, and temperature checks, as well as health disclosure forms, digital travel passes and other methods aimed at identifying COVID-19 in travelers utilizing sniffer dogs were all implemented in 2020. However, many treatments were experimental and lacked proof, or were based on evidence from prior epidemics that lacked an important element of COVID-19: asymptomatic transmission. For example, temperature readings and symptom screening have been found to be unhelpful (Dollard et al., 2020). Hence, it’s clear that none of these measures will be enough to remedy the current public health problem. Since these policies are so fragmented, there is little effort made to integrate them in the context of an overall strategy. A lack of travelers and widespread community distribution in many countries/territories/areas has made it difficult for governments to develop efficient methods for preventing the spread of viral infections. In response to new technology and scientific findings, these frameworks, which are based on risk reduction methodologies, should be developed and enhanced to combine diverse public health approaches (Meghan et al., 2020). While these precautions have been in place for a year, their implementation and the first few months of vaccine distribution have highlighted the challenges and opportunities that each phase presents.

In summary, there’s a danger of field fragmentation due to rapid innovation, especially since immunization records can serve numerous purposes; for example, they’re just as popular for opening up sporting and music events as they are for travel. The WHO’s Smart Vaccination Certificate consortium, which will be established in January 2021, may be able to assist in coordinating this landscape. Technology solutions must also be accessible, allowing everyone, not just those in a vulnerable position or without access to the necessary technology, to move around freely.

4. Negative impacts of Covid-19

Although Covid-19 taught lessons to the human race and was given a chance to learn from the mistakes and realize the damage done to the environment, the recouping to the normal situation is not within the eyesight and requires a minimum of a decade to stabilize the boat, especially to the underdeveloped and developing nations. The process of recovery from the sudden shock of Covid-19 requires the following threats to be neutralized.

- Increased biomedical waste generation to be curtailed.
- Excessive usage of safety equipment and proper haphazard disposal practices are to be followed.
- Excessive generation of solid waste, reduction in recycling had to be managed efficiently.
- Huge quantities of disinfectants spread on roads and commercial and residential areas to exterminate Covid-19, causing severe ecological imbalance due to harmful chemicals, should only be used when necessary.
- In terms of social status, unemployment increased many folds during the surge of the pandemic.
- Rising CH₄ quantities due to perished agriculture and fish products due to the stringent regulations on transportation.
- Lead to massive quantities of recyclable wastes, where in the advanced nations tends to afford, while the under developed nations can’t meet the expectation and further contaminating the near sources.
- Physiological myths of object contamination i.e., excess usage of plastic bags rather than recyclable bags.
5. Covid-19 and energy: Calming the tumultuous energy nexus

Covid’s main turmoil in the energy sector has been addressed in the prior section. As known, that every corner of the globe is severely hit by the pandemic (Covid-19), and shock the energy security, especially under developed, growing nations, with no exception to the well progressed countries. The pandemic shock forced all the nations to impose stringent regulations described by popular words such as lockdowns, shutdowns, etc. During the lockdown, many daily activities are curtailed, such as mobility, economic activity, construction, and manufacturing, which resulted in the downfall of the energy demand. Realigning energy demands in the lead-up to the COVID-19 pandemic involved energy efficiency, energy-saving, and new energy solutions (Strieklkowski et al., 2021). As the worldwide pandemic rages on, it’s all the more difficult to restore energy demand to absolute stability, which is key economic/urban sustainability indices. In the process of estimating the exact energy demands, the prime thing to account for was avoiding mix-up and concentrated on a single aspect, i.e., extra energy demand fighting Covid-19 is the medical energy sector. Racionalized thinking is instead aimed at balancing additional energy demand from one sector and another is to preserve the regular patterns of energy use.

The energy market and crude oil market are full of uncertainty and fluctuation, which are attracting research interests (Aydın and Ari, 2020) as the pandemic continues to worsen the demand and disrupt energy supplies. Energy and economy are two pillars of any nation, unfortunately, wrecked due to the pandemic. Hence, every country always strives to increase the energy sources each year despite the medical interventions. However, strangely, the consumption patterns fell due to no demand for transportation energy, but substantial improvement can be seen for electric energy. Fig. 5 portrays the variation of consumption of energy trends across the globe for 2019 and 2020. From the figure, it is very understood that the downfall of energy consumption irrespective of the source.

Further, a split of the energy consumption across the various regions indicates that natural gas and crude oil define the energy dependency in North, South, Central America, and Europe. Whereas natural gas is a more prominent source in the middle east, coal holds the primary place in Asia pacific. However, many researchers have examined the links between energy prices, particularly oil prices, and stock returns. Prabheesh et al., (Prabheesh et al., 2020) found that the COVID-19 strengthened the positive association between oil prices and inventory returns in the four main Asian net oil-importing countries. In particular, the stock market has seen the signs of a fall in the pandemic oil price as an adverse demand shock given the high economic turmoil due to the pandemic. The impact on the business performance of COVID-19 is negative, particularly for energy companies. The energy industry was characterized by a higher fixed asset ratio and financial leverage that brought more fixed and operating costs than other industries (Zhang et al., 2021). As a result, the value of energy giants like Royal Dutch Shell and BP from COVID-19 has been adverse (Gerlagh et al., 2020). Based on the decline in energy prices, volatility in energy supply arises from the loss of income of power companies, which are pessimistic investments and increasing volatility in energy supplies (Lee et al., 2002). Unlike some technical firms such as Amazon, Netflix, and Zoom that can use online models to overcome the pandemic shock, energy sectors like mining, electricity, and heating alone cannot complete their tasks using computers (Connolly et al., 2020). As a result, energy companies suffered heavier revenue losses as stock values fell substantially during the lockdown period.

In addition, fluctuations in the energy sector can extend the macro economy's fundamental position to other economic fields (Prabheesh et al., 2020). However, the impact of spillage on the world energy market varies according to countries’ different roles. The fluctuations in the energy market for energy exporters can lead to macroeconomic pressure, with large quantities of oil and gas production and exports reducing the national budget. For example, the fall in world demand for oil due to a pandemic and the pessimism of future energy projections have adversely affected the Russian and Saudi economies (Rostan and Rostan, 2021). On the other hand, the low oil prices have had an impact on energy importers on the macroeconomics. While Turkey's GDP has declined 1.16% due to a decrease in export demand and the loss of truistic, transportation, and tertiary industries’ incomes, the reduction in the prices of import oil may somehow compensate for the decline by lowering energy costs. In 25% and 50% of falling oil prices, the GDP decreases caused by COVID-19 could be offset by 0.72% and 1.56%, respectively (Aydın and Ari, 2020).

As a public emergency incident, Covid-19 has a profound effect on the energy market. The micro perspective shows a decline in
energy prices and in-stock values and considerable fluctuation in the energy market. The spillover effects of energy market volatility have affected both the macro economical condition of energy exporters and importers followed by the energy pricing, and the cost of power demand that leads to fluctuations in energy market. These changes or fluctuations in the major energy markets will have a widespread effect and risk the rest of the economy.

6. Effects of Covid-19 on prime sources of energy sectors

6.1. Fluctuations in transport sector

Covid-19 substantially influenced the public’s behavioral aspects and thinking patterns, particularly the transportation modes. With the constraints on the spread of contagion, the lives of individuals and energy consumption across the economies have been affected. Government obstacles such as enforced lock-ups and concerns over contraction and the spread of mass transit viruses have reduced the demand for passenger transport. Since the outbreak of COVID-19, the global public movement is restricted by almost 30% from external activities (Ghiani et al., 2020). The latest data shows that global economic activity and mobility reduced drastically by 3.8 percent compared to the first quarter of 2019 during the first quarter of 2020 (Abu-Rayash and Dincer, 2020). If the lockdowns last long months and recovery in much of the world is slow, as is becoming more and more likely, the annual energy demand will fall by 6% by 2020, eliminating growth in demand over the last five years. For the last 70 years, such a decrease has not been seen. This loss of energy demand negatively impacts the energy industry; for instance, the COVID-19 pandemic bankrupted at least 19 U.S. top energy companies, but fortunately, the intervention of the government settled the damage extent (Jiang et al., 2021). Perhaps no other sector of energy demand is more visibly affected by the COVID-19 response than transportation. Every facet of our daily routine has been affected by the addition of lockdown and stay-at-home orders. This has changed the energy requirement for raw materials, combustibles, and middle and final consumer goods in national, international, and worldwide supply chains. In contrast, the pandemic has been bad for some industries while being very beneficial for others. For example, the transportation sector sees a significant drop in energy consumption, while the electricity sector sees sky-high consumption rates. A brief overview of the transportation and the electricity patterns were highlighted below.

When it comes to transportation, various means, namely, public transport, rail, aviation, car, EVs, etc., are the modes of mobility. Among the suffered, public transport operations in cities a drop of 70 years low of 50–90% worldwide was seen during the pandemic (Liu et al., 2020). Although freight transportation was also reduced, during the current crisis, the drivers of freight activities are complex, motivated by the factors of supply and demand and the need for essential services to remain operational. As the energy sector has turned over, oil demand has decreased by 5% in the first quarter of 2020 (Energy and Iea, 2020). A majority of global oil demand (around 40%) and 15% of all global carbon emissions are attributed to passenger transport that has been reduced and created a global implication for energy demand.

Further, some populous nations like India, China, Europe, where railways are the main means of transportation and have connections to the neighboring countries also disrupted due to the ongoing pandemic and caused the global reduction of fuel demands. For instance, the world’s largest rail networking nation India next to China, during the lockdown, stopped all passenger train services and lowered freight services to 60% costing approximately 19 billion USD across Asia and 2.5 billion USD in Europe (Bunsen et al., 2019). The remaining portion of operation capacities to maintain social distance reduce maximum rail car occupancy and increase sanitation requirements, rising operational costs and reducing profitability. Alongside public transportation, aviation traffic has been substantially limited to less than half except for emergency flying and cargo transportation. According to the reports of Nižetić (Nižetić, 2020) Europe’s flights decreased by more than 89%, directly reducing aircraft fuel consumption. IATA data shows a significant drop in airline share prices as a result of the pandemic. Between February and April, the most important share price decreases took place. Fig. 6 describes the sufferings the aviation industry faced during the pandemic and the recovery after that. The outbreak in 2019 had a profound effect on the fall of passenger and cargo movements, especially during the initial phase of restricted activities in April, May, and July.

During this phase, there has been a tremendous hit on shareholders and the capital value of the global airline industry. There observed a serious distress among the passenger movement in 2020 due to the announcement of lockdowns that substantially hit the economy and growth of aviation industry. Further Table 1. Presents the clear information of the revenue and expenditure talies to better understand the situation and the hiccups undergone by the aviation sector due to the pandemic emergency. For instance, the shares of North American, European, Asian airlines, and other international airlines were going down to an all-time low. Amidst, in January 2020, the Asian airlines knocked first because the pandemic was already jittering after the announcement by China of an outbreak of the disease at the end of December 2019. China was the first country to undergo a harsh lockdown that led to the early negative performance of the aviation industry from February to March (Maneenop and Kotcharin, 2020). This led down the world airline’s share to an average market of around 49 percent by May. The reason ascribed for this downfall was attributed to a combination of factors, notably the constant lockdown and mobility restrictions, downgrades by global rating agencies, and poor business outlook, etc., subdued the performance of stock prices for Asia, Pacific, and North American airlines.

Later, slightly relaxing the regulations and following stringent sanitation procedures by the aviation industry slowly fueled up to a certain extent in the second, third, and fourth quarters of 2020. Besides, the adoption of Covid-19 aviation safety procedures and arrival tests in many places and news of the disrobement of vaccines Covid-19 have contributed significantly to improving airline shares performance across aeronautically-regions as shown by enhanced price-performance between October and November 2020. As a result, the aviation sector has been more stable but less stable than before in early March 2020. The first to witness recovery in China’s aviation industry was the Asian Pacific market, which was also better than other regions. In addition, from the beginning of May to September 2020, the recovery in Europe was fostered with the opening in June and July of the regional market, which boosted confidence among businesses in Europe. Other measures were also suggested by Nhamo et al., (Nhamo et al., 2021) aviation sector requires additional cash flows cash to ensure that the increasing cash consumption did not lead to the airline’s collapse. Furthermore, airlines must adjust financially to shed unnecessary costs to guarantee the survival of companies. A short-to-medium-term cost reduction is necessary to keep the airline industry afloat amid observed mute growth in the sector. It was fostered that in the second wave of pandemics, domestic demand decreased as compared to the Bangladesh-based non-Covid-base scenario following a significant home outbreak, as of 1000 Covid-19 (7.70%–11.55%) (7.26%–10.89%) and India (6.40%–9.60%) according to the Asian Development Bank (ADB) (International Monetary Fund, 2020). Due to travel constraints or closures by countries to end the spread of the virus around the
world, people cannot buy business or holiday flights. With the decline in customer demand, airlines were forced to lose sales, reducing the overall volumes. Airlines will ultimately reduce employees without government support to reduce the costs further.

6.2. Electricity patterns

The one good thing that happened during the virus outbreak is the distress of electrical energy usage. Every energy sector suffered to the core, while electricity is the one industry that had a significant and unpredictable demand. However, as discussed, the restricted movements and varied work culture patterns, especially work from home by the major IT sectors, enabled the boost up to the electricity industry. Fig. 7 demonstrates the electricity patterns across the globe due to the mobility refinements and the new tendency of working from home. From the figure, it is seen that despite the impact of the energy generation from fossils is significant but showed a declined pattern everywhere. At the same time, renewables showcased an increasing trend, which shows that the transformation is inevitable and not too far.

Moreover, electricity is used extensively in households and industries among the various energy sources and therefore is seen as a fundamental criterion for economic activity (Agdas and Barooah, 2020). Hence, a dip digs down of this feature highly attracts the motive of the modern-day research, especially during the epidemic surge. However, the consumption of electricity had both negative and positive impacts and varied from different nations. The consumption in Rouleau and Gosselin, 2021 indicated that, in the light of a slight increase in total residential power consumption, electricity consumption took place all day rather than at night as before the lockdown. Overall, the impacts of Covid-19 in terms of energy consumption patterns have been split into three aspects. First, the lockdown has resulted in the growing use of resident electricity by students and adults using electronic equipment like smartphones and computers, which has kept them working remotely at home (Krzysztofik et al., 2020). Secondly, electricity consumption increases more slowly in the morning than in pre-pandemic conditions because labor and cooking demand are

![Fig. 6. Aviation industry fluctuations during the period of 2020–2021.](image-url)

| Table 1 | Aviation revenue and expenses statistics during the distress of covid-19. |
|---------|---------------------------------------------------------------|
|         | 2019 | 2020 | 2021 |
| Fuel consumption, billion gallons | 96   | 60   | 78   |
| CO₂ emissions, million tons       | 914  | 574  | 748  |
| Crude price, $/b                  | 65   | 35   | 45   |
| Jet kerosene, $/b                 | 77   | 36.8 | 51.8 |
| Total expenses                    | 795  | 515  | 623  |
| % Change in expenses              | +3.7 | −34.9| +20.5|
| Revenue due to passengers’ movement, $ billion | 612 | 241 | 389 |
| Revenue due to cargo transport    | 102.4| 110.8| 138.1|
| Total revenue, $ billion          | 619  | 353  | 521  |
| % Change in revenues, $ billion   | 3.2  | −50  | +42.6|
lowered (Gu et al., 2020). Third, household entertainment demand remained constant due to low consumption, such as dinner preparation, television, and other electrical equipment, although these peaks are less than previously. Finally, the temporary heterogeneity of the electricity consumption pattern mainly corresponded to changes in residents’ living and working practices during lockdown periods.

In contrast, some studies showed a decline in the electrical consumption of electricity by 28 percent, 17 percent and 5 percent (Aruga et al., 2020; Madurai Elavarasan et al., 2020), respectively during COVID-19, particularly in China, the USA, and India. The pandemic has reduced electricity consumption directly and indirectly. In the first place, the industry’s shutdown led directly to a reduction in total energy consumption. On the other hand, the lockdown policy limited social activities for some nights, weekends, and holidays such as food and entertainment, indirectly leading to lower electricity consumption (Fezzi and Fanghella, 2020). In addition, Covid-19 affected the total use of energy in industrial and service sectors and modified housing consumption patterns (Norouzi et al., 2020). Research shows that the peak electricity consumption rate across five continents was low compared to the same period in 2019. (Energy and Iea, 2020). In another situation, less than 10 percent of the total demand for energy in Korea and Japan has been reduced due to lower restrictions. But 15 percent less electricity is used every week due to lockdowns in China’s hardest-hit provinces. During locks in several countries, regional weekly energy demand decreased 17–25%, and Europe experienced numerous infection and death spikes (Zhang et al., 2021).

Conversely, Australia’s residential electricity demand increased 14% during the March 2020 lockdown compared to the pre-lockdown period. The roughly estimated extra energy required to produce disinfectants and EPIs is calculated at PJ 236.5 per annum based on preliminary estimations (Hsu and Zomer, 2016). In addition, these analyzes are also based on micro and macro scales and approximations of energy demand and consumption patterns. That is macroeconomic; although the worldwide energy market fell by 2020, there was a substantial increase in medical and residential energy demand. From a space–time point of view, but for a shorter time, the space–time changes in energy consumption patterns, in particular electricity consumption, have shifted. If efforts to curb virus expansion and restart savings are more successful, energy demand could only fall by less than 4%. However, there could even be a bumpier restart in the second half of the year, global disruption of the supply chains, and the second wave of infections.

6.3. Contraction to biofuel blends (ethanol, biodiesel)

Though pandemic hit shows positive motives towards renewable energy, it has been a hit to the biofuel sector and been pushed into extreme pressure for survival and reliance. Fig. 8 emphasizes the biofuels production and consumption patterns for 2018–20. It seems that until the pandemic outbreak, i.e., the last phase of December 2019, the balance between production and consumption is more or less the same. In some parts of the globe, consumption overpassed production, for instance, Europe in 2018, 2019 (Silver et al., 2020). However, in the early phase of lockdown, i.e., the first quarter of 2020, the scenario was reversed not only to the conventional fossils but manifolds on biofuels. Forecasts are predicting that global transport biofuel production in 2020 will be 144 billion liters (L), which is 11.6% less than 2019’s record output of 162.8 billion liters (L) during the first quarter of 2021 (Perkins, 2020). This turns down the utilization of the transport fuel demand, thereby lowers production. It is known that the direct consumption of biofuels is very rare, without blending, and the ongoing drop in order will further reduce the prospect of biofuels. Especially in nations where mandate policy requires a fixed percentage of biofuels to be blended with fossil transport fuel, lower transport demand fuel resulting from a Covid-19 crisis reduces biofuel consumption. This downturn phenomenon is not specific to biofuels, whereas it has sunk the fossil stocks. For instance, gasoline demands dropped by 10% and diesel by 6%, respectively (Hill et al., 2006). Among these transport fuels, diesel suffered less due to the exemptions are given in transporting the essential commodities across the globe. Since the beginning of the pandemic, oil prices have dropped, making biofuels less competitive with fossil fuels. The present estimated hand oil price per barrel is approximately $ 40 (2020), which is 38% low, i.e., $ 64 in 2019 (SEAI, 2020). In addition to this, the ASEAN regions were severely affected due to the declined purchasing power of unblended ethanol to approximately 17% (Energy and Iea, 2020). This will delay the progression of the ASEAN biofuel market due to financial implications.
for governments that subsidize biofuels to keep their relative cost advantages versus traditional fuels like gasoline and diesel.

Ethanol is another renewable source of biofuel due to its origin in biomass and is considered a new chapter in renewable fuels. Ethanol blended with the fossils substantially mitigates carbon emissions, and GHG releases improve the octane number and help in proper fuel ejection. Thus, all eyes are on methanol blending and burning fossil fuels into renewable or biofuels. Unfortunately, the maximum blend percentage is limited to 15% with gasoline. Such an inhibiting commodity (ethanol) production and demand are seriously hit during the pandemic. Before Covid-19, the global fuel-grade ethanol global production was 115 billion liters (L) and shrank to 92 billion liters (L) in 2020, which is a drop of 14.5%, a record low since 2015 (Energy and IEA, 2020). The main reason for this is the dip in gasoline demand in several key ethanol markets, and some ethanol-producing countries have surpassed the global average. However, it is anticipated that gasoline demand could rise in 2021, and this would push production up to 109 billion L by 2022 and continue to grow to 119 billion liters (L) by 2023–25 (IEA, 2021), especially through major ethanol-producing nations, namely Brazil, China, India. Similarly, until 2019, the global biodiesel and HVO production was estimated as 48 billion liters (IEA, 2021), and showed great resistance to production and consumption patterns during the pandemic. There was a little drop during the year 2020 with a widespread pandemic, but still managed to pull near to 46 billion L. Majority of the ASEAN regions predicted a strong comeback in 2021, reaching the global output of 53 billion L in 2021 and 56 billion L by 2022, and 63 billion L during 2023–25 which is 35% more than 2019 (Asian Development Bank, 2015).

Looking up to the USA, the staggering 59.5 billion liters of ethanol were produced in 2019. It was expected to be at a similar level in 2020, but the recent pandemic has hugely impacted the U.S. ethanol industry (Independent Statistics and Analysis, 2021). Production is expected to decrease by a whopping 12% in 2020, the lowest since 2014. The pandemic has limited the biofuels industry’s financial impact by allowing producers to claim USD 0.12/L of funding for renewable fuel production between January 1 and May 1, 2020 (IEA, 2021). Anticipation of 2021–22 forecasts that U.S. ethanol production will increase to 55–58 billion L, and the economy will stabilize by 2025. Increasing ethanol exports is one way to help enable higher production. Despite that, to match 2019 production levels in 2025, the record export levels of 2018 would have to be doubled, which will be difficult. In the case of biodiesel, the production rate was set at a record high of 8.9 billion L in 2019, and held steady at 8.2 billion L in 2020, and anticipated to bounce back by 2023–25 with an all-time high of 14 billion L (Energy and IEA, 2020).

In contrast to China, India has a different picture of biofuel status. According to data from the National Development and Reform Commission, 3.9 bln ltr of ethanol production was attained in China in 2019, and the same level is expected to remain stable in 2020. In India, fuel ethanol output in India is almost sound from 1.9 billion L in 2019 to 1.8 billion L in 2020 (Zarvos and Adib, 2020). In the wake of a 13% global drop in gasoline demand, crude prices are no longer sustainable for the industries. Still, these nations managed to pull out the gears and maintain the stability of the biofuel market. Through constant expansion of production capacity and promoting ethanol–gasoline blending, China’s Annual Energy Plan says that the country will pursue various policy changes to improve ethanol deployment. As a result, between 2019 and 2023, average production is predicted to be over eight billion liters, or almost double that of 2019. In India’s case, the gasoline demand recovery will likely lead to record output in 2021 as molasses feedstock becomes more available. Based on anticipated investments to increase production capacity, over 3 billion L per year will be produced in 2023 (Sonnichsen, 2021).

The European nation is one among that heavily deals with biodiesel than ethanol blending, showed a little impact on production and consumption stats of biodiesel, and is directly related to ASEAN regions. In 2019, Europe’s biodiesel and HVO output reached an all-time high of 15.7 billion liters, but a little hiccup of 13.5% drop, 13.6 billion L during 2020. The European Union, France, Germany, Spain, and the Netherlands provide two-thirds of E.U. production, and roughly one-quarter of total E.U. output comes from HVO (IRENA, 2020). This drop was due to the loss of demand and the exceeding the storage capacity production, and dropping prices, financial instabilities. On the other hand, another major nation Brazil with a rich renewable source, produced an all-time high of 5.9 billion L in 2019, through strong demand for blending mandate, and raised to 6 billion L by 2020 despite surging pandemic.

Moreover, current biodiesel plant overcapacity could be reduced if production could scale up to 7 billion L by 2025 (IRENA, 2019). According to the scientific literature, the primary cause of greater output would be implementing the RenovaBio pol-
icy, which would greatly stimulate lower-carbon waste oil and animal fat feedstock output. Another small nation Indonesia holds the key in biodiesel with an annual production capacity of 7.2 billion L in 2019 and increased to 7.9 billion L by 2020. Through the efforts of local governments and continued policy supports towards renewable energy, the national blending mandate increased from 20% to 30% beginning in 2020 despite the conventional diesel consumption rate dropping by 13.5% in 2020 (Sonnichsen, 2021). Production facilities were delayed, however, as a result of the pandemic. Annual biodiesel production in 2025 is expected to be 10.5 billion L per year, which is likely to increase over the 2021–25 period due to a 10% diesel demand growth from the transportation mandate. In addition, a new plant coming online and underutilized capacity both increase production. Finally, Argentina, one of the strongholds of biodiesel, experienced the shock of the pandemic with a 40% drop off, i.e., 1.4 billion L in 2020, and due to a 9% drop in diesel demand. However, the governments’ trade encouragement boosted the production trends soon, anticipating 2.3 billion liters per year, depending on biofuel policies adopted in 2021 (Taylor, 2020).

In conclusion, COVID-19 had sharp fluctuations in the transport sector and was somewhat stable concerning electricity generation and consumption patterns, while the renewables are hard hit. The buildup and expectation of renewable fuels, particularly biofuels, were almost suppressed towards the more sustainable energy medium, i.e., renewable energy, due to a 9% drop in diesel demand. However, the governments’ trade encouragement boosted the production trends soon, anticipating 2.3 billion liters per year, depending on biofuel policies adopted in 2021 (Taylor, 2020).

7. Phasing out the fossil fuels towards renewables: An opportunity created by the pandemic

Reducing the use of fossil fuels helps meet our energy needs and addresses the issues of climate change (Byrne and Taminiau, 2018). In transformation, pollution, and climate change, the chaos created by fossil fuels will be at the forefront of thought. This leads governments, enterprises, investors, and the public to understand that the global economy needs to be decarbonized with renewable resources. Moreover, the threat posed by climate change to humanity and the earthy piles of an ecosystem is existential, provided there are no urgent steps taken to decarbonize energy. According to the famous “Paris agreement,” the 2°C rise in the annual global temperature is to be kept below 1.5°C to prevent long-lasting or irreversible changes and loss of vital ecosystems (IRENA, 2019). But with the current world scenario, instead of decreasing by the end of the century, the global temperature increases to 3°C and leads to an abrupt domino effect which can make the world hole. The decline in the cost of renewables compared to their original emergence is another reason for the transformation.

Therefore, many governments have raised their ambitions to achieve their renewable targets and have taken steps to accelerate renewable energy deployments. Close to 57 countries have developed complete decarbonization strategies, and 179 nations have set targets for renewable energy at the national and state level (Zarvos and Adib, 2020). The lack of oil and gas reserves and an aspiration to become less dependent on energy imports are second reasons for this migration. Fig. 9 presents the status of the total oil reserves by the end of 2020, and a known fact that the very limited continents such as the middle east and northern America hold significant funds (Center for Energy Economics Research and Policy, 2020). In comparison, heavily populated places such as the Asia Pacific and Africa have limited resources of crude reserves. This will create a monopoly and economic dominance of the rich nations over the emerging and underdeveloped economies.

Moreover, from the figure, another important observation is that as time progresses, the oil reserves are depleting with the increasing population and the demand for energy which makes it look for a sustainable alternative, i.e., renewable energy. Further, the advent of technological innovation in the initial stages helped in the accelerated deployment of renewables. For instance, higher energy efficiencies on the solar photovoltaic modules, higher wind turbines, huge charging efficiency on the electric vehicles, upgraded technologies to biomass fuels, renewable transport hydrogen allow renewables to reach a wider range of difficult to electrify sectors, including aviation, shipping and heavy industry (Gielen et al., 2019). Innovations are being made in the energy industry in digitization, updated energy storage, network connectivity, the Internet of things, large-scale data, and artificial intelligence, contributing to the increase in efficiency and the acceleration of energy use in emergent smart generation and distribution systems (IRENA, 2018). Another important aspect of this transformation is the changing mindsets of the corporate giants. Investors are putting pressure on companies to reduce their carbon footprints as per the Paris agreement, and simultaneously the industries recognize the carbon risk to their operations. Finally, the most key variable that has become a hurdle to renewable energy is the cost. With the advent of technologies and changing the thought pattern of industries, the price of renewable energy technologies has fallen and has become the frontrunner of the change. For instance, solar and wind have gained a competitive advantage and some other mature resources such as hydropower, geothermal and biomass, etc. Once rejected as too costly to expand niche markets, solar and wind technologies can now beat cost in many of the best markets worldwide, even without subsidies (Marlene et al., 2018). Fig. 10 clearly shows the rising trends of renewable energy production especially, wind, solar and other renewables which were not limited to one particular region but every corner. Summarizing these facts, it is high on the card that the transformation is not optional anymore and mandated from all corners. Moreover, the current pandemic situation and the

| Advantage | Disadvantage |
|-----------|--------------|
| Biofuels  | Usage of land that could be fertile to produce food |
| Less carbon emissions | Needs a lot of labor |
| Reduce the reliance of fossils | Engine modifications required to use bioethanol |
| Wind energy  | Expensive to build |
| Renewable  | Visual pollution |
| Cheap to run | Noise pollution |
| No polluting gases produced | Unreliable (depends on the strength of wind) |
| Hydroelectric  | Damage to the estuary habitats |
| Renewable  | Damage to valley habitats by flooding |
| No polluting gases released | Trapped and rotting vegetation can produce GHGs |
| Reliable  | Adaptable |
| Solar  | Not every effective |
| Renewable  | Large installations for small results |
| No polluting gases | Unreliable in cold environments |
| Solar cells can generate electricity anywhere with no grid connectivity required |
depleted energy demands help boost the growth of renewables. It is high time, and the most precious time for the investors, governments, financial institutions, corporate giants, industries, and not but not the least people should give their little support to renewables instead of fossil fuels during the bounce backstage of energy demand, i.e., post-Covid.

8. Road map to the renewables

8.1. Pre-Covid era of renewables

Renewable energy during the pre-covid-19 era are not so remarkable and progressing in a lighter vein with no breakthroughs. Despite knowing the potentiality of renewable energy as an alternative to conventional fossil fuels, the production, utilization constraints, feedstock uncertainties, political aspects, and the major oil companies’ reluctance to shift towards renewable energy made this a slow and never-ending transformation till 2018. From Fig. 11, it is seen that the major contributor of energy, i.e., 88% is from non-biomass fuels, wherein a little of 12% is through renewable means. Further, the figure demonstrates the trends of fossil energy production scenarios across the globe for 2015–2020. Each continent preferred fossil energies to renewables, with an exception to Europe and Latin America.

Moreover, Fig. 12 showcases the meager transformation and generation of energy from renewables from 2015 to 2019. Amidst the mild utilization of renewable energy in the transport sector since its origin, renewable electricity has had substantial growth in the past five years. Furthermore, renewable electricity was added to a total of 181 GW, at a steady rate compared to 2017, and the number of countries with a high renewable energy (VRE)
share continues to grow (Zervos and Adib, 2020). As a result, renewables are expected to account for 26 percent of global energy production by the end of 2019. In this steady progress of renewables, private sector, global corporates play a leading role by taking procurement and investment decisions to encourage the deployment of renewability energy. This accounts for worldwide investments of over 200 percent in 2018 from both developed and emerging economies.

In comparison with 2017, roughly 18.1% of the final energy consumption is estimated, representing 4.4% more demand and 10.6% of the total energy capacity from modern renewables (Looney, 2021). By the end of 2018, renewable energy targets are set at the national or state/provincial level in over a hundred and sixty countries. This was thought to be a golden era for renewables, but the flip side has resulted in higher carbon emissions. Despite increased renewables deployment, the world is not on track to meet the Paris Agreement commitments or goals of the SDGs (Sustainable and Goals, 2020). Global energy-related CO2 emissions increased by about 1.7 percent in 2018 due to increased fossil fuel consumption. In 2017, fossil fuel subsidies increased by 11%, and fossil fuel companies spent US$ 480 million lobbying’s to delay, control, or halt climate change policies (IEA and OECD, 2018). With such rapid progress, renewables are expected to replace conventional fossil fuels by the end of 2023 completely. Unfortunately, the pandemic reversed the renewable’s progression and slowed their emergence in global markets, including investments, behavioral patterns, demand and supply counterfeits, and so on.

8.2. Covid-19 a game changer for renewable energy

The global economic slowdown led to a significant drop in demand for energy sources like coal, fuel, gas, etc., but renewables are immune to the pandemic. Though the declining oil prices, and energy demand completely derailed the energy industry due to declining oil prices, energy demand to sustainable energy did not stop completely. There is an uptrend in the consumption patterns for renewables reported. Fig. 13 evidenced the growing trend of

![Fig. 11. Trends of global energy production pre-Covid era (Mtoe).](image1)

![Fig. 12. Global status of renewables and the total share in energy production BC (BC: Before Covid-19).](image2)
renewables targeting 4474 GW, 2434 GW, 1626 GW, 300 GW from solar, wind, hydrothermal, and hydrogen energy, anticipating nearly 400 bln ltr biomass-based fuel blends by 2030 (DNV GL AS, 2020). This was complemented with an increased trend of renewable energy in recent times through the major contribution from the EU, US, China, Japan, Southeast Asia, and Africa. For instance, China alone added more than 92 GW of capacity.

In comparison, the USA contributes 19 GW, and 800 planned clean energy projects worth over $316 billion in eight Asia-Pacific economies: Indonesia, Japan, Malaysia, the Philippines, South Korea, Taiwan, Thailand, and Vietnam soon (EY, 2021) during the pandemic. Countries such as Malaysia and Myanmar, in particular, have obtained large commitments from solar power developers through the COVID-19 relief packages distributed across the other Asian economies. Asia Pacific nations such as Malaysia spent $2.9 billion on energy performance, while South Korea launched its $95 billion Green New Deal (Shin and Cha, 2021). At the same time, other Asian markets have announced their ambitions for sustainability. Another evidence of renewables targeting 4474 GW, 2434 GW, 1626 GW, 300 GW from solar, wind, hydrothermal, and hydrogen energy, anticipating nearly 400 bln ltr biomass-based fuel blends by 2030 (DNV GL AS, 2020). This was complemented with an increased trend of renewable energy in recent times through the major contribution from the EU, US, China, Japan, Southeast Asia, and Africa. For instance, China alone added more than 92 GW of capacity.

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Mainland China stepped in first with a target of 2060, followed by Japan and South Korea in 2050, and many other nations set to reach the goal by 2050 (Suga, 2020). It is high time to focus more on green energy technologies, such as solar PV cells, marine algal reforming, sophisticated wind panels, upgrading biofuel production and blending technologies, using eutectic solvents for a safer environment, etc. The more we invest in green technologies, the safer to humankind and ecology (Intezay and Tabir, 2019). Also, sustainable Renewable Energy (RE) brings many other benefits, including providing additional options, thus diversifying energy resources and helping to secure energy supply. RE is particularly important in supplying access to energy, stimulating economic and social development, and helping to reduce climate change and its effects on the environment and health (Panwar et al., 2011). But for a cleaner future, a transformation from fossil fuels to renewable energy will be necessary (Intezay et al., 2021), with smarter approaches to dealing with the complications of this transition, such as the need to stop fossil fuels by inefficient, traditional methods while meeting energy requirements (Alasser et al., 2020; Pitelis et al., 2020). The transition from fossil-fuel energy sources to renewable resources is called the Renewable Energy Transition (RET) (Li et al., 2020). A huge amount of capital is needed to achieve an effective RET (Hall et al., 2017). Though overall RE costs have been reduced over the years due to technological advances (Taylor, 2020), there have been no further investments. Changes in public policy and the amount of capital involved make investors less prepared to take investment risks. One of the major problems in the 21st century could be the RET financing problem. From the reports of IEA, renewable energy boomed over a 13.4% growth rate amidst the pandemic across the globe. The growth was not easy, but it managed to pull through an all-time high of 45% jump and the largest year-over-year increase since 1999 (Erdogan and Timothy, 2021). Thus, the raging pandemic devastated all forces, but renewable immune energy survived this catastrophe and surfing the boat in the right direction. It is the only means that showed positive signs of recovering the energy sector and created an impact that the end of the fossils is not very far, and the future is renewable energy.

8.3. Renewable energy post Covid scenario

Despite the ax on global energy, renewables contrastingly turned this danger into opportunity through an intelligent reaction and reform measures. The strength gaining process of the renewable companies is augmented to the next levels due to the recent fall of energy prices and realizing the unforeseeable profitability of fossil fuel investments. From the reports of BP, the spot crude price from the global producers of the Middle East, Brent, Nigerian Forcados, and West Texas Intermediates reported a fluctuating pattern shown in Table 3 (S&P Global Platts, 2021).

These fluctuating global oil and gas prices further demoralize the profitability assessment factors that greatly affected the long-term investments in oil and gas contracts, thereby risking the returns. Further reduced costs of natural gas, thereby inducing electricity usage, is a light out of the blue scenario, a great boon to countermand the demand–supply inequalities. Though the arrival of vaccinations and easing the mobility restrictions, gearing up the necessity of energy.

Further, the Post Covid situation varies with regions and the type of renewable energy sources. In this scenario, the only available smooth solution is to look out for renewables. The financial structure of any nation is dependent on the industries and the employment rate. The emergence of renewable energy replacing fossil fuels can ramp up job opportunities for many unemployed people. About 15% of all employment created globally in 2018 was in the renewable and sustainable energy sectors, which could reach 84 million jobs worldwide by 2050 (Ram et al., 2020). Further, decentralized renewable energy technologies will lead to a wide range of communities playing a key role in energy decisions, with broad-ranging social and economic impacts. Deploying sustainable technology to use green energy carriers (e.g., hydrogen, transport vehicle fuel cell), innovative projects (for supply, prompt ambulance for the critical moments, remote urban and agricultural control), and improved storage of electricity and grids can protect society against similar problems. Furthermore, the implementation
of sustainable technologies and reduce costs, research, and innovation are essential here. These foresight plans for the production and use of green energy could lead to low-carbon economic deployment of public policies. Deep insight and the road map of post-Covid investments in the energy sector are showcased in Fig. 14. Still, it’s not feasible to completely phase out the fossils unless knowing the sustainability aspect of renewables. Hence, 42% of the share investments were towards fossils, 29% green technologies, and 29% renewable (Gielen et al., 2019). Shortly, plans are proposed to raise the share of renewables, i.e., 51% alone to renewables that include solar, wind, hydro, biomass, etc. The rest is to be allocated to the conventional means.

Besides, the energy policymakers should determine the short-term renewable energy policies and prioritize strategic action towards a sustainable energy transition to managing Covid-19’s influences on the renewable energy strategies. In contrast, temporary exemptions or delays could help alleviate the burden on sustainable power industries (OECD, 2020c). Renewable energy strategies. In contrast, temporary exemptions or delays could help alleviate the burden on sustainable power industries. The government needs to encourage renewables to cut or increase investment and production tax credits to return to the ordinary situation in the exotica world post-Covid-19 and maintain sustainable energy projects. The private sector could benefit from these opportunities by developing low-carbon technology in the mid-term. The interest rate level significantly impacts the cost of renewable energy, and higher interest rates could improve their competitiveness in fossil-fuel power (Griffiths, 2019). There are three specific benefits of an enhanced economy, complementing the net zero-emission targets and creating new employment opportunities that strengthen the national economy. Lastly, from the previous section, the projected targets mentioned in Fig. 13 should be scaled up to meet the global demands and completely transform to the renewable era. To do so, Fig. 15 enables clear and scaled-up targets by the Paris agreement and the net-zero project emissions. The minimal projected targets for various renewable energies are well within the stipulated achievable levels and planted steps towards that direction. Thus, Covid-19 created a great opportunity for the renewable industry, though it threw every other practice drowned.

9. Energy investment trends and policy landscape

Investment efficacy is a complex phenomenon to evaluate due to its reliance upon its outcomes, i.e., the aftermath of investments. In most cases, the word investment is interested in returns or economic efficiencies. But, the other extremely important variable that holds equal priority when it comes to the energy sector is the environmental efficiency of the investments. Environmental efficiency refers to how well the newly built environment encourages the efficient use of natural resources; in this case, it is energy. It is highly anticipated that global energy demand is set is increase by 5% in 2021 to counterbalance the pandemic distress. Hence, it is projected that nearly 1.9 trillion US$ of energy investments were anticipated across the globe in the coming 2–3 years (Sengupta, 2021). Fig. 16 depicts the trends of energy investments from the past few years and, there observed a shift in the investments towards the power and end-use sectors rather than conventional fuel production. In addition, the overall trends on energy investments took a mucky turn since 2019, especially China, Japan, North America, Europe, Australia pushing towards clean energy and preferring carbon-free transport. This momentum towards the shift, especially after the pandemic, is slightly swinging and hanging between the recovery and structural change towards the cleaner energies.

Moreover, investment in cleaner energies is evaluated, bearing the important factor of net-zero momentum and related CO₂ emissions. The investment in clean energies is moderate and remains far short of the expectations. It is expected that approximately 750 billion US$ will be spent on clean fuels across the globe, which has to be doubled to cater to the global needs and achieve the net-zero targets (IEA, 2021). The contribution of investments from the nations mentioned above is equal to the rest of the world, seen

| Year | Dubai USD/barrel | Brent USD/barrel | Nigerian Forcados USD/barrel | West Texas Intermediates USD/barrel |
|------|------------------|-----------------|-------------------------------|------------------------------------|
| 2015 | 51.22            | 52.39           | 54.41                         | 48.71                              |
| 2016 | 41.01            | 43.73           | 44.54                         | 43.34                              |
| 2017 | 53.02            | 54.19           | 54.31                         | 50.79                              |
| 2018 | 70.15            | 71.31           | 72.47                         | 65.20                              |
| 2019 | 63.71            | 64.21           | 64.95                         | 57.03                              |
| 2020 | 42.41            | 41.84           | 42.31                         | 39.25                              |
from the figure. Besides, the motive of the oil giants towards the conventional fuel investments gradually fading out in 2020 compared to 2019 (Taylor, 2020). A similar trend was followed by emerging investors and new startups looking for clean energy rather than carbonaceous fuels. However, in the near term, investments in liquid and gaseous biofuels are dependent on government policies designed to counteract the uncertainties resulting from the pandemic. As a result, investment in these projects fell to under $8 billion in 2019 and less than the US $7 billion in 2020 (Cunliff and Nguyen, 2021). Within the context of liquid fuels, ethanol production will be superseded by renewable diesel (HVO), also known as renewable diesel, over the next decade.

On the other hand, a 10% increase in upstream oil and gas investment is expected to occur in 2021 as companies recover financially from the shock of 2020. However, the level of expenditure before the crisis is still lower. As demand rose and oil and gas prices higher, investment strategies were polarized. Despite the continuing focus on cost control, several major national oil companies now try counter-cyclically to invest in acquiring market share. In addition, private companies are under enormous pressure to control the portfolios of oil and gas. The overview shows that 84% of future investments in fuel supplies will be made in oil and gas and 14.5% in coal (a much less capital-intensive sector). Low-carbon fuels represent approximately 1.3% of total expenditure (IEA, 2017). In addition, governments, entrepreneurs, and private companies have a crucial role in enhancing renewable energy through changes in current practices and in encouraging clean energy.

Lastly, scaling up the renewables as planned and discussed requires conducive policies, regulatory, and fiscal environments. This means each nation should target, plan to include specific measures to uptake the renewables through special fiscal monitors such as subsidies, quality standards, tariff regulations, etc. Reviewing the decade’s policy frameworks uprooting the renewables is
concentric on electricity access, especially in Europe, followed by the Asia Pacific, America, Africa, and the least bothered nation about the renewables was the Middle east. Also, lower renewable technology cost facilitates the integration into electric grids of higher shares of variable renewable energy. In the field of energy rather than transportation, similar renewable energy targets remain more ambitious. Outside the power sector, policies are considerably at a slower pace, and to be more precise, only 36% of the countries globally have biofuel blend mandates globally (Zervos and Adib, 2020). The need for this special mention was transportation sector was the main driver for the climatic carbon emissions. Fig. 17 shows the global policy status as of 2020 related to the existing, outdated, planned, and announced for the future. Europe is aggressive towards renewable energy from the policy landscape, with the greatest number of policy frameworks existing, designed, and disclosed. Whereas the recent booming economies of Asia Pacific started migrating towards the renewable scape, and growing demands each year with the rising population and unavailability of natural crude to cater the needs boasted the renewable scenario. Thus, Asia Pacific stands next to Europe regarding investments by both existing giants and upcoming investors. Other continents such as America, Africa, and the Middle East were still heavily relied on fossils rather than renewables, and the policy frameworks were not as anticipated.

The American continent is an exception; Africa, with low economic background, is quite miserable shifting to renewables. But the largest crude reserve nations care very little towards renewable. From the figure, an almost negligible number of in force, plans were proposed stepping towards renewables.

Penning down the key takes on the investment strategies of national, international, renowned, and new entrants looking towards renewables but not as ambitious. This takes much more time to invest in renewables completely and fade out fossil fuels. However, upper economy nations should step forward much more aggressively to meet the growing energy demands and cater to them through renewables. This boosts the morale of the under and growing economies to step ahead and invest in renewables in line with the Paris agreement.

10. Factors affecting the transition towards the renewable energy

10.1. Tax breaks for fossil fuels offered by the government

There are two different notions to be addressed when it comes to subsidies: narrow measure pre-tax subsidies and broad range post-tax subsidies. Astoundingly, countries worldwide spend 300 billion dollars a year holding the lid on the price of fossil fuel, stamping out civil unrest and advancing their economies this year by 20% hiking oil prices. Pandemic recovery efforts exacerbates the problem by providing Covid’s fossil fuel-intensive sector relief to 31 major economies at $292 billion. For instance, 77 fossil companies in the USA received $ 8.2 billion in tax breaks from the government to reassure the public’s safety. Also, fuel subsidies are rampant across the globe, from Iran to Argentina to Nigeria; the received subsidies were approximated to $ 320 billion in 2019. To keep fuel prices low or increase the cost of energy produced, governments use subsidies that support fossil fuel production (Skovgaard, 2021). Further, annuities are classified into four main categories, namely: can break down subsidy instruments into four main categories: direct financial transfers, favorable tax treatments, import restrictions, and regulations. The calculation of subsidies is done in 3 different ways: utilizing price gaps, e.g., the price of domestic goods versus the global price of reference, through a bottom-up approach, i.e., through a whole series of aid for a given sector, and by using a comprehensive total aid estimate approach (Taylor, 2020). Forty-two countries around the globe offer tax credits and credit guarantees for production and not consumption, according to the International Energy Agency (IEA). But the dataset excluded the United States and European countries, which provide aid in the form of tax credits and loan guarantees rather than consumption for production. Coady et al., (Coady et al., 2019) referred to subsidies of $649 billion and $289 billion offered by the United States and the European Union in 2015. IEA database was made available to assist and examine the actual facts of energy patterns and their amounts in 2019 by the top 20 sub-mentioning countries. (a). Give governments subsidized fossil fuels to new industrial
zones because the world is dependent on fossil fuels to quickly grow our economies and reduce revenue disparities (Al-Badi and AlMubarak, 2019). Non-sustainable subsidies for energy remain one of the principal obstacles to RE execution despite these problems, both because of their effect on energy generation and the increase of fossil fuel demand. Therefore, these subsidies should be eliminated, although the resources should be re-allocated to RE gradually (Geels et al., 2017).

10.2. Biasing renewable energy

Many energy agencies are very well known and suggested that transition to renewable energy is highly deemed; however, there is a benefit of doubt created by the conventional energy producers (CEP). CEP’s argument suggests that renewable energy is highly unpredictable regarding feedstock availability and the final fuel price. On the other hand, another set of agencies and policymaking bodies strongly argue that global energy demands don’t meet the expected levels with the available feedstock of RE (Gilbert and Sovacool, 2016). Further, the analogy represents that food security will be definite if renewable energy is the primary source. These arguments and differences of opinions impacted the end user’s perceptions of renewable energy and scaffolded the fossils rather than the clean energies.

On the other hand, many scholars and policy firms warn about the security of renewable energy investments and returns. Several other studies revealed that the investor’s strong belief and misconceptions of non-affordability and limited returns investing on renewable energy is the biggest biasing factor of the renewable energy transition to date. This scenario was further exacerbated by several national and international energy agencies’ minimal incentive announcements and minimal policy amendments.

Further, the “Union of Concerned Scientists” report suggested that the unaffordability of renewable energy mainly arises from technologies producing them. The most obvious and widely publicized barrier is capital cost, i.e., installing solar and wind farms, expensive catalysts for the biomass to biofuels, etc. Another factor of refinancement is the “siting and maintenance,” which means conventional energy sources such as coal, nuclear are centralized and offer high output. In contrast, renewables like solar, wind, biofuels were decentralized with limited outcomes. Furthermore, besides the wind, solar requires specific environments such as open barren lands with intense winds and sunlight, whereas the conventional means require no such settings. Moreover, biofuels require a huge feedstock of biomass, again may not be possible in all scenarios as biomass feedstock is purely a seasonal thing. Furthermore, transmission is of the criteria that need a serious address, as the conventional sources of power generation lines were already laid. In contrast, the wind and solar energies can’t be directly transmitted; rather, they have to be stored and then distributed, for which separate facilities are required. Finally, in biofuels, aging is the biggest issue in transportation and highly unstable commodity to travel longer distances.

Summarizing the variables mentioned above, it seems that the majority of the energy producers are participating in fossil fuels rather than renewables, causing serious obstruction to the smoother transition to renewable energy.

10.3. Lack of awareness related to fiscal matters

The lack of national policies, administrative and bureaucratic obstacles, inadequate incentives, non-practical government objectives, standards, and certifications has been the major obstacle to large increases in renewable energy (Stokes, 2013). When countries start to recover from the epidemic, government strategies focus on rebuilding the economy and reviving industries that have been beaten down. Different fiscal policies can create a reduction in project development and deployment, together with increased progress in research into renewable energy technologies. Strong regulatory policies within the energy industry to address inconsistencies between renewable and non-renewable energy are necessary to achieve sustainable development. However, inadequate policy implementation causes department confusion over the provision of subsidies. Issues like an unstable energy policy, a lack of trust in renewable energy technology, and a lack of policy to integrate renewable energy technology with the global market are roadblocks to renewable energy projects (Zhang et al., 2014). It is not enough that governments have put a few measures to end the practice of taxing the imported equipment and parts used in renewable energy plants. To make renewable energy sources more affordable, governments provide subsidies in the form of feed-in tariffs. These tariffs help them compete with traditional energy sources by decreasing renewable energy technologies (Sun et al., 2015). With so many hurdles in renewable energy projects, it is important to get them across the finish line in time, especially since time is money. The authorization will often take long to obtain, which unnecessarily lengthens the project’s development timeline. Permission may be more difficult to obtain because of lobbying. A prolonged project start-up period and a reduced level of investment motivation are all a part of this equation (Ahlborg and Hammar, 2014). The gap between governments’ set policies and their implemented results is quite wide (Groh et al., 2015).

The lack of an achievable target and open loopholes in the implementation process issues to contend with when it comes to overcoming these commitment issues, and governments bear the responsibility. Finally, to promote industrial growth and stability, one must understand the legislation and regulatory issues. To close this gap, governments should become more responsive and reactive.

10.4. Big oils diametric opposition to transition

Another intriguing factor opposing the transition to renewables is the disinclination of reputed (BP, Exxon, Chevron, Shell, Petronas, Eni, Statoil) and emerging firms’ investment into renewable energy (Asmelash and Gorini, 2021). The reluctance to transition is mainly due to the regional base adaptivity coupled with firm-specific experience, regulative and normative socio-economic pressures, and oil firm’s strategies in terms of investments. The majority of the developed nations, such as the one section of the USA and Europe, were very stringent in pausing the fossil stocks and transforming them to renewables. While, on the other side the emerging and underdeveloped nations struggle with this transformation decision to the geographical, political, and food security concerns. In the Middle East, where the global crude supply is happening, they were very much focused on finding new fossil reserves and devoted to spending their investments on fossils rather than renewables. Pickl, (Pickl, 2021) clearly explained in his study that the nations with proven oil reserves are more confined to renewable investments, along with the populous countries of southeast Asia, namely, India, China, Russia, respectively. Another reason opposing the transition is the mixed thoughts of oil giant shareholders, i.e., non-institutional operators are more against renewables than institutional firms. Another key point for this hesitancy is the distinct business models of the fossil fuel companies than the renewable energy; for instance, cost of capital is different for both the firms. It is overridden is unlike fossil fuel wind and solar churn out cash flows akin to annuities for several decades, but involves higher upfront capital (Salzman, 2020). At the same time, conventional energy doubles the returns of an investment but ignores the climatic damages and carbon pricing. Despite the setbacks in volatile markets, oversupply risks, fluctuation in
prices, big giants still look at calls for hydrocarbons due to less appealing profits and minimal margins to renewables. Lastly, the country’s economy has solely relied upon the oil reserves and fuel transactions, which is considered the income source to economies, in a context where societies depend heavily on oil income. As a result, securing finance in comparison with fossil-fuel projects is a difficult issue for renewable energy developers and producers.

10.5. Socio-economic factors

The transition from conventional to renewable energy resources was hindered by resilience and opposition. Further, various public inhibitions regarding the migration to renewable energy might lead to the destruction of scenic coastlines, disruption of migratory patterns, and the acquisition of land used for agriculture, tourism, or other purposes resultant of sheer lack of awareness. Besides, sustainable development with social acceptance is only possible through satisfying human desires via socially recognized technologies, appropriate policies, and regulatory tools. Further understood that social opposition towards migration is mainly due to inadequate information regarding ecological and fiscal aids, lack of knowledge related to the changing expertise, and monetary and market instabilities. Therefore, rather than saying the individual differing to renewable energies, it is more with political concerns, grassroots organizations, national public interest groups, and in some cases environmental groups themselves, etc. In addition, the landscape requirement of the renewable energy plants construction is so huge, and the energy generation is equivalent to that of conventional energy forms with less than 1/4th of the land requirements (Chauhan and Saini, 2015). Therefore, this aspect will always be on the card that creates a sense of laziness to transformation. Also, the skilled working person is a big debate that obstructs the universal conversion of fossils to renewables. This particular thing of qualified and trained professionals suffers a lack of facilities to impart the know-hows especially in commissioning, scaling up, production, storage, and transportation departments.

Looking at economic concerns, the prime obstacle is high capital costs, insufficient financial institutes, the forfeit of financiers, abundant competition from fossil fuels, unpractical subsidies, etc. Moreover, the fuel cost includes exploration, production, distribution, and utilization costs in almost all countries but does not include the environmental or social damage cost. Thus, the invisible costs (externalities) associated with traditional fuels are not covered (Arnold and Yildiz, 2015). Therefore, understanding these effects is essential to assess the actual costs of using fossil fuels for energy generation.

10.6. Technological barriers

Renewable energy has several legitimate technological barriers, including limited access to infrastructure, inefficient knowledge of business and maintenance, insufficient R&D initiatives, technical complexities like storage, and lack of standards. Even in advanced countries, the availability of advanced renewable energy technologies is limited, making it harder than renewable energy is generally available. Although the technology available is exceeded, it is extremely expensive (Dulal et al., 2013). Due to the preference for renewable energy plants, most transmission lines must be connected to the main grid, and most are far from the urban areas. Thus, the current grids must be upgraded or amended to include renewable energy. This demoralizes the transmutation to renewable energy completely by grid integration. There is a lack of knowledge regarding renewable energy operation and maintenance because the technology is new and underdeveloped. It is impossible to operate the plant effectively unless routine maintenance is carried out Sen and Bhattacharyya (Sen and Bhattacharyya, 2014). The cost of production will rise considerably because of the failure to access required equipment, components, and spare parts. These items must be imported from other countries so that the total cost increases (Bhandari et al., 2015). The only way to make renewable energy economically competitive with fossil fuels is to make greater investments in R&D. Unfortunately, renewable energy is premature despite decades of research. Governments and energy firms are hesitant to invest in R&D due to the risk factors involved in renewable energy. There are also no precise standards or rules for maintaining durability, sustainability, and performance, which limits the commercialization of renewable energy growth. To address the challenge of renewable energy storage, technology must be developed through R&D. There should be extra cautious research and development work that has to be focused on this storage aspect, a prime demotivate for renewable energy. Despite their infinite abundance, sunlight and wind don’t provide continuous power to electrical grids, and balancing supply and demand is critical to the operation of electrical grids. Larger batteries are required to deal with these problems since renewable resources are not always available Weitemeyer et al. (Weitemeyer et al., 2015) and there is definite attention to be devoted overcome this refraining possibility.

11. Takeaways from Covid-19 and energy sector

11.1. Dominant fossil fuels overshadowing the renewable sources

Between 2009 and 2019, renewables gained roughly 5% while fossil fuels outperformed (1.7 percent) Another milestone for the installed renewable energy capacity is in 2020, meaning that we now generate about 29% of our renewable energy. At the same time, more fossil fuels are burning than ever. The fossil fuels share in the total energy mix is as high as ten years ago, and the percentage in renewable energy is just slightly higher, as seen in the diagram below.

11.2. Recovery packages pour money into brown economy despite the advantages of renewables

A report published by the organization says that in 2020, there will be a greater wave of commitment to tackling the climate crisis. The targets include China, Japan, Korea of South, and many other regions, nations, cities, and companies for their net-zero carbon emissions. 2020 should have been the year when the world pushed the re-start button for global climate economy and renewables after the public spending announcement for a green economic recovery to a level higher than that for the Marshall Plan in the aftermath of World War II (IRENA, 2020). Instead, the recovery Paquet’s provides six times more investment for fossil fuels than renewable energy instead of driving transformation. Despite all the promises made during the Covid-19 crisis, there was a clear lack of funding for renewables.

11.3. The number of counties with renewable energy support policy did not increase

Setting renewable energy targets steers us in the right direction, but policies are needed to make sure we arrive. The goals are frequently unattainable because of the ineffective policies that prevail. According to some experts, 2020 could very well be the year of new norms, with policymakers lacking concrete measures to decarbonize their economies (OECD/IEA/NEA/ITF, 2015). There was a plateau in 2017 in the number of countries with renewable energy transportation policies following an increase in 2016. At the same time, the number of countries with policies for heating and
cooling rose and has subsequently declined. Renewable energy must be supported by appropriate procedures, such as mandating or incentivizing its use. But governments must do more than phase out the use of fossil fuels; they must eliminate all fossil fuel subsidies as well.

11.4. Shifting to renewable is not only mandate but also makes business sense

The usage of fossil fuels is to blame for climate change, leading to a loss of biodiversity and contamination. Weaning ourselves off of fossil fuels and moving toward renewable energy is an important first step. It does not matter if renewable energy is more or less expensive; our goal is to replace fossil fuels completely. Power sector progress has been impressive. Most new power capacity is now derived from renewable resources. More than 256 GW of new electricity capacity will be added globally in 2020, nearly 30% more than the previous record (Zervos and Adib, 2021). It is now cheaper to build fresh wind or solar power plants than to operate existing coal-fired power plants in many areas, including China, the European Union, India, and the United States. The business world is also starting to realize the importance of employing creative people. Corporate purchasing agreements (PPAs) are a growing source of renewable electricity, with a record 23.7 GW currently sourced in 2020 (Bebon, 2021). Despite the impacts of the COVID-19 pandemic, growth was 18 percent over the last year. For both business and environmental reasons, the renewable energy transition is growing. A wide range of studies indicates that clean, renewable electricity can already support many jobs, save businesses money, and provide energy access to millions. However, businesses and governments need to move faster to keep up with the sustainable economy and modern society in the 21st century.

11.5. Climatic neutrality and lessen carbon emissions

REN21’s 2021 report demonstrates that governments need to make a stronger effort in all sectors to facilitate renewable energy growth. All of the world’s major economies - the European Union, France, Germany, Italy, and the United Kingdom - had defined long-term renewable energy usage targets to attain a certain share of their energy consumption. Further, the report suggests that governments have a responsibility to not only invest in renewables but also rapidly decommission fossil fuel facilities (Zervos and Adib, 2021). Increasing renewable energy usage is a simple way to speed up project development. If ministries also have short- and long-term targets and plans for transitioning to renewable energy with clear termination dates for fossil fuels, then every ministry should have both short- and long-term milestones and a final fossil fuel plan. Also, it suggested that with so much urgency attached to restructuring society from fossil fuels to renewable energy, simply keeping track of renewable energy targets, policies, and investment is no longer sufficient. One way to gauge how much progress we’ve made in fighting climate change and sustainable development is to look at the share of renewable energy in the world’s energy mix. Along with increased renewable energy adoption and decreased fossil fuel use, there have been changes in energy demand, energy conservation, efficiency, and emissions. Thus, it is possible to draw a blueprint for a structural shift in the energy industry from reaching a high renewable energy share. For this indicator to be implemented at every level of decision-making, it should incorporate it. Because energy is present in every nook and cranny, the energy transition must happen in every place. This particular KPIs measures progress and engagement at the global, national, regional, city, and business levels.

12. Opportunity to migration

The global pandemic has widely open the doors for the migration to renewable energy. Somehow, observing the rising fossil energy demands and utilizations, we conclude that the opportunity was not capitalized to the best possible extent. This includes the lack of swift government initiatives, however, we can still turn things around if we begin now as follows:

Step 1: The government funding to the fossil fuel production to cease. As per the sustainable development goals, the government should stop subsidizing the fossil fuel extraction, both during the post pandemic recovery, and on regular basis.

Step 2: Raising fossil energy prices seems counterintuitive. However, the “green tax shift” methodology by the Nordic nations during 1990 to 2008 turned down the global economic crisis. Reducing the growth-stifling burdens on capital and labor can be achieved by raising revenues from taxes on energy, transportation and pollution, as well as on waste. Additionally, taxes increase the cost of air pollution, contribute to climate change, and increase traffic congestion. To ensure that individuals who are most vulnerable to price rises are not adversely affected, these policies should be accompanied with suitable compensation systems.

Step 3: Governments can utilize the money produced by terminating subsidies and accurately pricing fossil fuels to speed up the recovery by creating jobs and expanding the economy in ways that progress the energy transformation as well.

Step 4: It will be imperative that governments stimulate private sector investment in clean electricity in order to keep the economy thriving and the energy transition on track. The private sector is estimated to make about 70% of the investment in renewable energy, but governments must still play a major role in developing policies that encourage investors to put their money into the energy transition.

Step 5: Lastly, people, jobs, and communities are at the heart of the transition—just like the recovery should be. The energy shift will have a profound impact on the whole fossil fuel supply chain, as well as the people who work in it.

13. Conclusions

Over the last two years, the unfolding effects of Covid-19 have significantly altered every aspect of the world, including human life, communities, economic graphs of nations, and so on. Economic twitches completely turned almost every corner of the globe upside down, especially due to the unbelievable drop in energy demands, nearly driving the world to a financial crisis during World War II. Out of the unfortunate and irreversible loss to the world, nature’s thrust to reestablish safe climatic balances was the only positive to be noted. Another positive result of the pandemic is the global expansion of renewable energy. With an unprecedented drop in energy demand and the closure of many fossil fuel production facilities, governments and large investors are turning their attention to renewable energy like never before.

Further, this attraction aims to mitigate the carbon footprint, meet the mandatory objective of fulfilling net-zero emissions, and fulfill the Paris agreement by 2050. Policymakers, industries, and people’s attitudes were gradually shifting toward green energy, with the long-term goal of gradually phase out fossil fuels. In place of this, green energy investments have nearly doubled since the pre-Covid era, which is a positive sign. Through this transformation, the drowned economic situation can be restored to normalcy by establishing and expanding new green energy-based industries, creating opportunities for the unemployed, tak-
ing advantage of government-announced fiscal policies, and so on. While it may be tempting to promote clean energy and sustainable development as part of a post-pandemic recovery plan in the short term, experts advise that early rounds of stimulus money should be spent on mitigating the pandemic’s most severe economic outfalls and assisting struggling businesses to avoid potential bankruptcy. Instead of focusing on short-term gains, long-term planning with proper strategies is highly recommended. As a result of the COVID-19 pandemic recovery effort, governments can take advantage of key renewable energy initiatives to support the clean energy transition while also creating the appropriate conditions for economic recovery and building stronger and more responsive national health care systems capable of withstanding major health crises. Simultaneously, economic responses to the pandemic and climate change risk mitigation are mutually beneficial and part of a multi-pronged sustainability strategy.

CRediT authorship contribution statement

Anjani R.K. Gollakota: Conceptualization, Methodology, Validation, Writing – original draft. Chi-Min Shu: Supervision, Conceptualization, Resources, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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