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The impact of the pandemic on environmental health from the perspective of energy sector

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ABSTRACT

This study reviews the impact of the COVID-19 pandemic on environmental health through the energy sector, based on the close relationship between energy, the economy, and the environment. The lockdown policy to contain the spread of the disease has hampered the global economy. Due to the close relationship between energy and the economy, the decline in global economic growth can be easily indicated by the decrease in world energy consumption. However, this study argues that this situation also opens the opportunity of restoring environmental health. Thus, the objective of the study is to find the opportunity and the lesson that can be learned from the COVID-19 pandemic. This study employs a qualitative method that combines descriptive analysis and literature review. It involves a review, processing, and observation of quantitative data (statistics) and qualitative data. This study finds that the pandemic opens opportunities to relieve the environment damaged by fossil-dominated energy consumption to pursue economic growth. However, this study also finds the challenge to overcome and lesson learned. The challenge is the two-way pressure from demand and prices that renewables must face. The lesson to be learned is mainly to reduce the dependency on fossil energy sources, primarily if it is imported. However, on top of that, the government must be able to seize the opportunities to overcome the challenge. Thus, this study is expected to provide an optimistic view of taking advantage of the blessing in disguise of the pandemic to rehabilitate environmental health through the energy sector.

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1. INTRODUCTION

Energy, the economy, and the environment is intertwined in human life. Energy is the prerequisite for the economy [1], [2]. For example, electricity is a pioneering infrastructure to open and develop economic activities [3]. Thus, it is impossible for the economy to grow without energy. Vice versa, energy needs the economy to be developed. For instance, the more developed the economy of a country, the better its ability to provide energy for all people in the country. Therefore, energy and the economy are inextricable in supporting development and human activities [1]–[4]. However, there is a drawback in the relationship between energy and the economy. The environment will suffer from the development of energy [5], [6] and the economy [5], [7]. The role of the environment in human life is no less important than energy and the economy since the environment provides a place for humans to live and thrive.

However, people tend to ignore the importance of the environment. Governments tend to prioritize economic growth over environmental health as it is believed as a critical element of development. Although later, the role of growth as a sole indicator of development is argued [8], [9]. In more developed countries, the government tries to narrow the gap between economic development and environmental degradation by, for instance, utilizing and prioritizing cleaner energy sources like renewables [10]. However, utilizing clean energy sources in developing countries is challenging as it is costly. The government in these countries, then, tends to provide energy sources suited to their financial capability as it is more affordable for them [4], [11]. They will not sacrifice their economy by providing cleaner energy sources which are unaffordable and requires a longer time to provide. It is because energy must be provided as immediately as possible to support economic activities since delay in providing energy leads to a decline in economic growth [1].

As a result, environmental degradation will increase as the economy grows [3], [7], following the increase in energy consumption. One of the most widely accepted hypotheses to explain this situation is the inverted U-shaped Kuznets Curve. The curve describes the relationship between economic level and environmental damage during economic development. The curve shows that the increase in the economic stage (income) would increase the environmental damage until the peak point of economic development is reached, where the increase in economic growth is no longer followed by the environmental degradation, following the inverted U pattern [12], [13]. It is why environmental health principles are challenging to implement, especially in developing countries.

Therefore, energy consumption is a primary indicator of economic activities. It vitalizes human activities as well as the economy. Under business-as-usual situations, the environmental damages continue to increase as energy consumption to pursue economic growth increases. However, the COVID-19 pandemic has changed the pattern, causing a downturn in economic growth globally. The COVID-19 pandemic has created great pessimistic views among people [14]–[16] and countries [17]–[19]. The health sector is the first and foremost impacted area, affecting many aspects of life today, including the economy [18], [19]. In addition, the containment policies taken by governments to stop the spread of the virus badly impacted the economy. Given the close relationship between energy and the economy [1], [3], [20], the fall of the world's economy can be easily seen from the decline in world energy consumption during the pandemic.

The shock caused by the pandemic has changed the energy pattern and, therefore, the environment's quality globally. Thus, following the nexus of the energy-economy-environment, this study argues that the decline in energy consumption opens opportunities for restoring environmental health. The pandemic poses challenges to global energy, where access to energy is hampered due to the cessation of economic activities. The pandemic has coincidentally promoted the initiative toward the restoration of environmental health due to the decline in fossil-dominated world energy consumption. Thus, this study hypothesizes that the pandemic opens the opportunity to restore environmental health. Previous studies have shown the pandemic's impacts on the energy sector. However, they rarely discuss how the pandemic creates opportunities to restore environmental health, and the lesson learned about the global energy consumption pattern that heavily relies on fossil energy sources. Thus, this study's importance is to encourage an optimistic view about the pandemic, which opens the opportunity to recover environmental damage through the energy sector. It also provides some lessons to be learned and the challenges governments should overcome to maintain environmental health. This study is expected to provide some solutions for repairing the degraded environment caused by the rapid, vast economic activities.

This study uses a qualitative approach to discuss environmental health from an energy perspective (energy-related environmental health). The discussion consists of five major parts. The first part describes what energy-related environmental health is and how it works. The second part observes the nexus of the energy-economy-environment during global shocks. It discusses the pandemic's impact on energy patterns and the environment globally and how the pandemic broke the traditional energy-economy relationship. The following two parts discuss how the COVID-19 pandemic creates opportunities and the lesson learned to restore the environment through the energy sector. The pandemic leads to the emergence of new behavior (the new normal condition) that, by chance, implements the environmental-healthy lifestyle in the energy sector. Last, the discussion covers the challenges that emerge after the pandemic hit. It requires the government to introduce specific policies to minimize the negative impacts. However, the challenges could also open opportunities if the measure to overcome the obstacles could be appropriately conducted. Thus, the objective of the study is to find the opportunity and the lesson that can be learned from the COVID-19 pandemic.

2. METHOD

This study employs a qualitative method that combines descriptive analysis and literature review. It involves a review, processing, and observation of quantitative data (statistics) and qualitative data. The descriptive analysis involves processing and observing quantitative data from related institutions' reports and official publications. The data (numbers) obtained from certain institutions (the International Energy Agency, the World Bank, and British Petroleum) are processed before being displayed in graphs that will be observed

and analyzed further in the discussion. The literature review involves reviewing the qualitative data to obtain the essence from the findings of previous studies as the basis for analysis in this study.

In the discussion referring to the graphs processed by the author, this study applies descriptive analysis by observing the historical pattern of the world's energy use. The aim is to observe global energy consumption, economy, and CO_2 emissions before the pandemic. The data obtained is statistical data that must be processed before being presented. The next step is to observe the energy use pattern during the global shocks and its impact on the world's economy and energy consumption. The data at this stage is obtained from relevant agencies' official publications (in the form of reports or statistics).

The other parts of the discussion apply literature review to review the findings from previous studies. Observations at this stage were carried out on qualitative data. This stage aims to observe and then analyze the findings of previous studies to become the basis for analysis in this study.

The quantitative data (numbers and statistics) are taken from official websites such as the International Energy Agency (IEA), the World Bank, and British Petroleum (BP). On the other hand, the qualitative data primarily come from academic papers and books. The statistics (the quantitative data) are used to make the graphs. The qualitative data are used to build the argument and analysis. The qualitative data mostly are the findings from previous studies to support the analysis in this study.

The consumption of fossil-dominated energy to support economic activities has caused environmental damages such as the pollution of heavy metals, acid rain, climate change due to greenhouse gasses, environmental changes, and other environmental damages. However, due to the limitation in time and resources, this study delimits the observed parameter only to CO_2 emission to represent environmental degradation caused by energy consumption and economic activities. It also aims to simplify and delimit the scope of the study. Moreover, the use of CO_2 emissions to represent environmental damages has been widely used in previous studies [6], [12], [13], [20], [21].

3. RESULTS AND DISCUSSION

3.1. Energy-related environmental health

Energy is closely related to two interacting primary issues: the welfare of people (the economy) and the welfare of the environment (a healthy environment). For the economy, energy is the precondition, while for energy, the economy is the supporting element. Energy is crucial for the economy since energy develops economic activities, and vice versa, the economy increases energy needs. Thus, energy demands would increase as economic activities grow [2], [3]. However, as economic activities are growing, environmental damages are inevitable. The environmental damages, among others, are shown by the amount of emitted CO_2, which increases as the economy or gross domestic product (GDP) grows, followed by the increase in energy needs as shown Figure 1. Energy is required to improve and develop the economy. Thus, Figure 1 shows that primary energy consumption (PEC) increases as the economy GDP rises. However, as a consequence, CO_2 emission -the by-product of energy use- is also growing. Environmental damage, therefore, is inevitable in pursuing economic growth. The situation depicts the close relationship between energy, the economy, and the environment or the nexus of the energy-economy-environment [1], [3], [20]. Therefore, energy is essential to initial and develop the economy. However, energy consumption to support and improve the economy will negatively impact the environment.

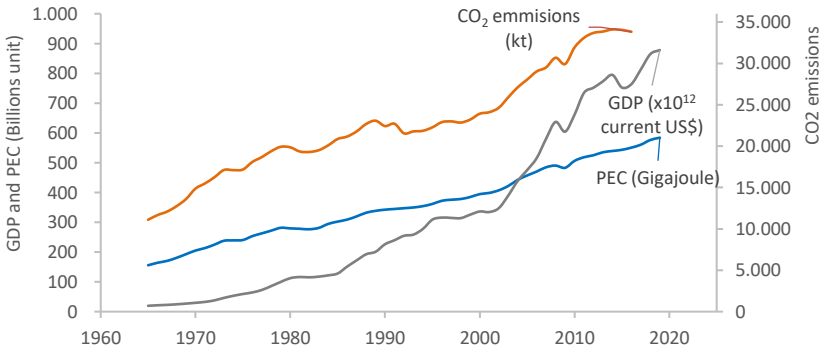

Figure 1. The global CO_2 emission (orange, right-hand scale), which increases as the GDP (gray) rises, for the energy consumption (PEC, blue) is growing [22], [23], processed by the author

The impacts of energy consumption on the environment occur along the energy-processing chain, from exploitation and production to consumption and disposal. In addition, all economic activities require energy that will eventually impact the environment. In other words, consuming a particular energy type will affect the quality of the environment. Thus, selecting an energy source type should be done carefully and wisely and should prioritize the cleaner ones. However, utilizing or prioritizing cleaner energy sources is costly, so implementing them is challenging, especially for developing countries.

Renewable energy (RE) is clean and inexhaustible. Compared to fossil, RE utilization also causes lower environmental damage. Thus, utilizing and prioritizing RE sources over non-RE (fossil energy) will promote the initiatives towards maintaining and improving environmental health. The source of RE is also unlimited, as it comes from nature, such as wind, the sun (solar), the ocean, or hydrogen. Life cycle assessment (LCA) shows that using such energy sources has lower environmental impacts than fossil energy. The utilization of renewable energy also supports the initiative of energy sustainability and the resilience of energy systems. Achieving energy sustainability means securing energy supply, achieving energy equity, and protecting the environment, which all can be achieved by using renewable energy [24], [25].

However, the clean aspect of renewable energy comes with a price. RE is relatively more expensive than fossil. Thus, its development is usually hampered by its relatively low investment. Many RE projects are stopped at the pilot (without implementation) due to low interest in the investment [25]. RE is also utilized to fulfill local demand with few energy needs, making it even harder to reach economies of scale. Fossil, on the contrary, is more affordable, although dirtier. However, its relatively lower price is due to externalizing the environmental impacts it causes. As the environmental impacts are not internalized, fossil energy prices would be relatively lower than RE. RE, on the other hand, is cleaner but requires high initial investment and advanced technology [26]–[28], something that is hard to afford, especially in developing countries [29], [30]. It is why the utilization of RE is not preferable for them. Furthermore, developing countries have constraints in their financial capacity. They have a limited budget to spend on energy utilization [11], [31], [32]. More importantly, a negative relationship exists between delaying energy provision and economic performance. A decline in electricity provision leads to a 1.5% decrease in GDP [1]. Thus, they cannot wait long until their money is sufficient to provide cleaner but more expensive energy sources and sacrifice their economic performance. In maintaining economic performance, energy should be provided as immediately as possible, suited to their financial capability and regardless of its type, although at the expense of environmental health.

In the global energy market, the success of fossil substitution by RE is influenced by oil price as the global energy reference price, since oil is the main energy source for the world. RE could enter the global energy market and substitutes fossil if the oil price is very high and comparable to the RE price. If the oil price is low, it would be challenging for RE to enter the market. However, the oil price fluctuates, and oil has closer substituents (gas and coal), making the substitution with RE even more challenging [33]. The other way to make RE more affordable is through technology to increase the efficiency of RE. When RE efficiency is increased, using the same amount of money will result in higher energy output, creating a lower unit price. The higher price of RE makes it only affordable and preferable for developed countries. Besides, developing countries are now in the industrialization stage, where the economy is at its fastest speed, and energy needs are very intensive. Thus, utilizing RE is regarded as slowing down the pace and negatively affecting economic development.

It is also why the trend of energy consumption and environmental damages (represented by CO_2 emission) in developing and developed countries differ. Today, the growth of CO_2 emissions in developed countries is lower than that of developing countries as shown in Figure 2. Following the hypothetical pattern of inverted U in the Kuznets curve, the developed countries had passed the peak of the economic development stage. Thus, the subsequent increase in economic growth does not mean an increase in environmental damage. In other words, the relationship between the economy and the environmental impact is negative or non-linear. As the economy grows, the environmental damages could be minimized as the unit of energy needs decreases due to the increase in energy efficiency. Energy use is efficient when the same amount of energy consumed results in higher economic output. The pattern differs from developing countries, where energy needs and GDP growth are linear with environmental degradation (in this study, it is represented by CO_2 emissions). Figure 2 shows the CO_2 emission of the Organization for Economic Development (OECD) and non-OECD countries during six decades (1960-2020). Figure 2 shows that the CO_2 emission of developing countries (non-OECD) had passed the CO_2 emission of developed countries (OECD).

For developing countries, economic performance is prioritized, as it is essential for development. During the process, it is likely to neglect environmental health if it is perceived would hinder economic development. As a result, environmental health is perceived as a secondary or even tertiary need and not a priority. Fulfilling the primary needs is more critical than fulfilling the secondary and tertiary needs. It is in contrast to the developed countries, where most people have fulfilled their immediate or basic needs, so secondary needs such as environmental health are currently their priority.

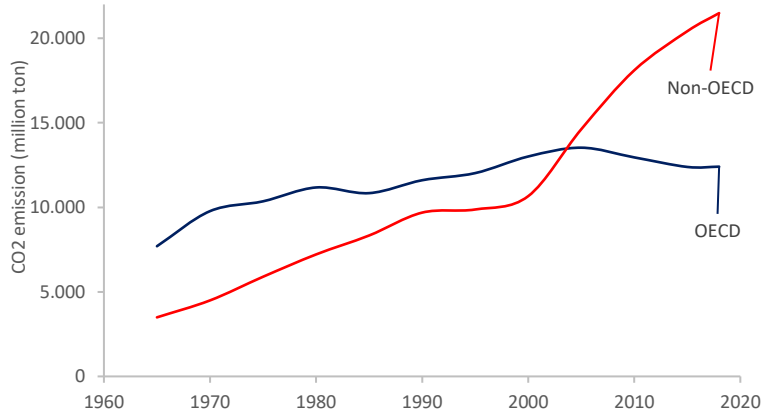

Figure 2. The annual CO_2 emission of developing dan developed countries [34], processed by the author

The economic stage of a country influences its priority. In the first stage of development, a government prioritizes more on fulfilling its people's basic needs. Then, as a country develops and basic needs have been fulfilled, the subsequent needs to be fulfilled would be the secondary needs. Among the secondary needs are life satisfaction and the well-being of the environment. Therefore, developing countries focus more on poverty reduction and equity [35], while developed countries focus on environmental issues [12].

3.2. The energy-economy-environment nexus during the pandemic

The pandemic is an extraordinary, shocking event that influences the pattern of global energy consumption. The lockdown policy to tackle the spread of the virus has stopped the economic activities that lead to the declining global GDP. The shock from the pandemic has broken the traditional relationships between the economy and energy consumption. As a result, the energy demand pattern changed and variably depended on the energy type. For example, fuel aviation demand for planes sharply declined, more profound than the GDP decline, while the demand for residential gas for electricity seemed unaffected [36].

The Covid-19 pandemic has ceased economic activities, resulting in a fall in global GDP. According to the IMF, the global GDP is predicted to decline by 6%. It is the worst scenario with a substantial permanent loss of economic activity. However, if the containment of the virus's spread is effective and macro-economic policies are well-targeted, the decline would not be too deep as shown in Figure 3.

The severe restriction of mobility and economic activities has pulled down the global primary energy consumption (PEC) by 3.8 percent or 150 mtoe (million tonnes of oil equivalent) during the first quarter (Q1) of 2020, compared to the first quarter of 2019 as presented in Figure 4. If the curtailment lasts longer and economic recoveries are slow, the annual PEC in 2020 will decline by 6%. Restrictions on economic activities in Q1 2020 pushed down the global oil, gas, and coal demand by 5, 2, and 8% from Q1 2019. However, the demand for renewable increased by about 2% [36].

The analysis in the region shows that the energy demand is predicted to decline. For example, the energy demand in China and India would decrease by 4%, while the European Union and the US have around 10% as shown in Figure 5. The 10% decline is the highest fall in 2020 energy demand, almost double the decrease caused by the 2009 global financial crisis [36].

However, the pandemic has had a positive effect. As economic activities are curtailed and mobility is reduced, global CO_2 emission is significantly falling. The decline would be about 30.6 Gt or almost 8% lower than 2019 CO_2 emissions. The emission level would be the lowest, six times larger than the reduction due to the 2009 financial crisis as shown in Figure 6. The decline in CO_2 emissions is due to the decrease in oil, gas, and coal consumption by about 1, 0.4, and 1.1 Gt, respectively. According to the region, the most significant decline would be from the US, followed by China and the European Union [36].

The pandemic has broken the traditional relationship between energy and the economy and shaped a new relationship. The new relationship is a moment to promote initiatives toward restoring the environment, as it opens opportunities to ease these efforts. However, the moment may not last forever and only occur briefly. Thus, the government must be able to grasp it quickly and make use of it to relieve the environmental damages due to the increasing economic activities supported by energy consumption.

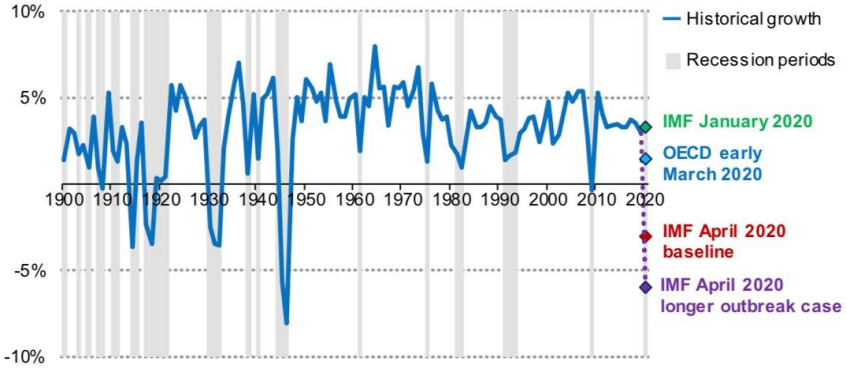

Figure 3. Annual change in the real GDP of the world [36]

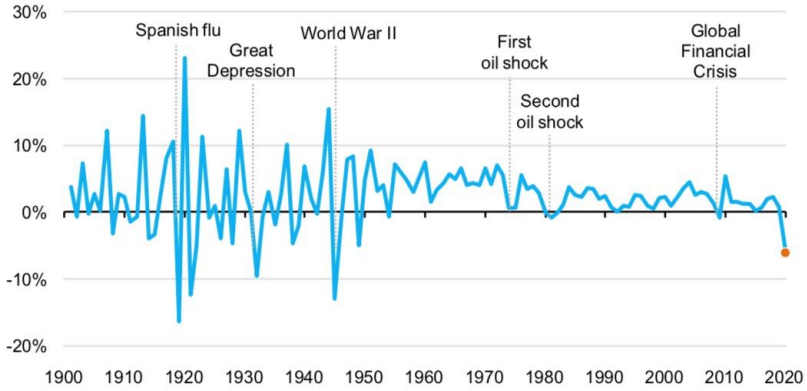

Figure 4. Rate of change of global PEC [36]

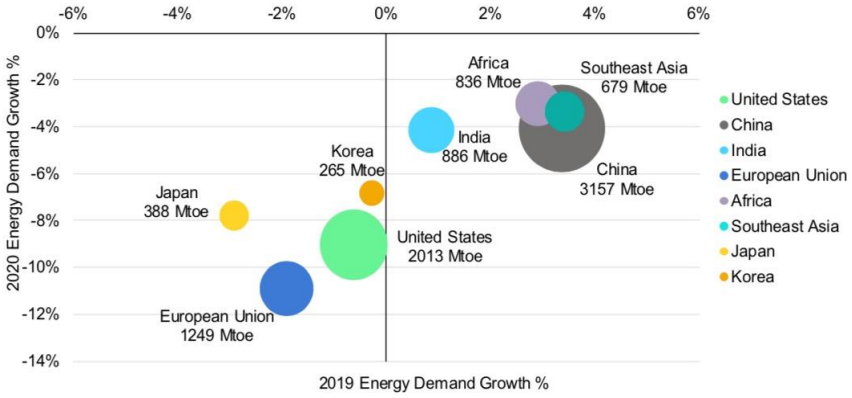

Figure 5. Growth of energy demand at the regional level [36]

3.3. The opportunities for restoring environmental health through the energy sector

The old, broken relationship between energy and the economy caused by the pandemic has created a new relationship pattern that is believed to open opportunities to restore the environment. First, some opportunities are created due to the 'new normal' lifestyle, which is less energy-intensive, such as working from home, online shopping, and distance learning. This situation will open the following opportunity for the governments to implement the supporting policies. These policies are required to maintain and strengthen the new lifestyle and direct it to promote initiatives for restoring the environment. The waste management issues that emerged during the pandemic opened the third opportunity. This waste issue is a blessing in disguise as it opens the opportunity to initiate the waste-to-energy (WTE) program. Last, the difficult economic situation

caused by the pandemic has forced people to save more and use goods for as long as possible. This situation opens the opportunity to implement a circular economy that aligns with the eco-friendly lifestyle.

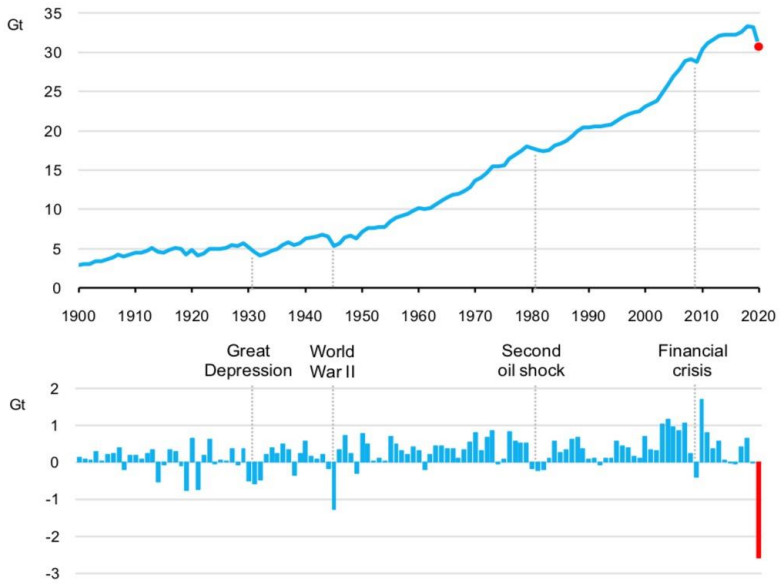

Figure 6. Energy-related CO_2 emissions and their annual change [36]

3.3.1. The new less energy-intensive lifestyle

The pandemic has transformed the old patterns in all aspects of life. The drastic changes have shaped people's lifestyles to adopt 'wireless, less energy-intensive' activities, such as working from home, online shopping, and distance learning [37]. This situation will improve people's awareness of consuming energy more efficiently, eventually improving environmental awareness among people and the community [16]. Environmental awareness is crucial in restoring environmental health, since people and the community are the actors and consumers of energy. They are also very challenging to manage. The awareness that emerges during the pandemic will ease the effort to restore the environment. They will be more prudent in consuming energy and will consume it more efficiently. It is not only due to the change in lifestyle, which requires less energy but also to minimize their spending. It will also promote the initiative on energy conservation. Using energy more efficiently means reducing the environmental degradation caused by energy consumption.

Under this situation, the government may introduce supporting policies to maintain such behavior in consuming energy. The government could introduce, for example, demand side management (DSM) policy. DSM is a policy to regulate people as energy consumers to consume energy more efficiently [38]. DSM can be in the form of discounted electricity rates for households that can save up to a certain percentage of their electricity, the provision of subsidized solar home system equipment, differentiation of electricity tariff systems (for peak and non-peak hours), tax exemption for high energy-efficient technology and equipment, etc. Those policies are directed to shape people's behavior in conserving energy and consuming it wisely. DSM is crucial as it manages the behavior and mindset of many people. Many people are unaware that the energy sources they consume are depleting. DSM would shape people's behavior in consuming energy more efficiently and, at the same time, promote the initiative of energy conservation. It, eventually, will create a healthier environment.

3.3.2. The eco-friendly policies

During the pandemic, one of the salient effects is a healthier environment due to the drastic reduction in human mobility and economic activities. As a result, environmental pollution has decreased drastically, and air quality has improved during the pandemic. There also has been a decrease in the levels of several pollutants such as NO [39], PM2.5 [40], and CO_2, which could reduce global climate change [41]. The reduction in global air pollution and carbon emissions and an increase in less energy-intensive activities (working from home) during the pandemic have provided the opportunity to repair the environmental damages caused by pre-pandemic economic activities. However, the opportunity requires support and government involvement [37].

For instance, the government may subsidize families who use renewables to electrify their houses. It is not only to support the containment policy to stop the spread of the virus (online working and studying) but

also to improve the utilization of renewable energy. Alternatively, the government could revoke the taxes on consuming renewable energy in households. It, for example, is the tax on using renewables for electricity, cooking, or heating purposes. These policies are very likely to implement, as it will relieve the economic hardship caused by the pandemic (massive layoffs and the cessation of economic activities).

Vice versa, to discourage people from using fossil energy, the government, for instance, may impose a tax on energy-intensive goods. These products, among others, are paper and pulp products, metal industry products, cement industry products, and chemical industry products such as ammonia, chlorine, and other petrochemical products. By imposing a tax on these products, people would use these products more efficiently. In addition, it is expected will increase people's awareness of using certain goods wisely.

Those policies are valuable for shaping people's behavior in consuming energy. It will direct people to prefer renewables more than fossil energy sources. Eventually, these policies will promote the initiatives to repair and improve environmental health.

3.3.3. Waste to energy (WTE) and circular economy

WTE is one of the 'most promising' RE sources in a pandemic to support environmental health initiatives through the energy sector. During the pandemic, waste management is one of the issues that has received much attention, where the increase of waste from medical wastes, plastics, and waste from households [39], [42], [43] is not accompanied by better handling. The improper handling of waste can be a new source of spreading disease, especially the medical waste exposed to the virus. However, the situation opens an opportunity to process those wastes into energy sources and start the WTE initiative. A previous study shows that the WTE industry keeps growing by +21 percent during the pandemic. However, other waste management industries drop by -28% and -10%, respectively, for the waste-to-material and disposal industries [44]. The result shows that the pandemic creates the opportunity to restore environmental health by producing clean, renewable energy sources from waste. WTE restores environmental health by providing a solution to manage garbage that piles up and is not appropriately handled during the pandemic and providing a new, clean, inexhaustible, but cheap energy source.

The drastic, entire changes have given a shock, resulting in better people's behavior. The restriction policies and economic hardship have forced people to be more prudent in their consumption and spending. This situation opens another opportunity for recycling and reusing goods through a circular economy system. A circular economy system is an economic system that implements the recycling, reusing, or regenerating of any materials or products. In other words, it is a production-consumption system that involves recycling, refurbishing, or reusing consumer goods for as long as possible. Its implementation, thus, is very likely to reduce the cost and save energy to produce certain products [45]–[47]. Implementing a circular economy during the pandemic is estimated to reduce the final energy use by 1.6 mtoe, CO_2 emissions by 3.8 mt, and PM2.5 emissions by 229 t. Accumulated until 2040 (from 2020), implementing a circular economy would save final energy use and CO_2 emissions by 9.1 mtoe and 17.6 mt [48] and improve the energy security index [49].

3.4. The challenges for restoring environmental health through the energy sector

The pandemic creates opportunities to repair the environment by breaking the old relationship between energy and the economy. However, this new relationship also creates challenges that may hamper the initiative to take advantage of the blessing in disguise of the pandemic to repair the environment. It is mainly for RE, the eco-friendly energy source, which faces a two-way pressure, making it more challenging to substitute fossil. This situation requires the government to introduce specific policies to reduce the pressure on RE. Thus, RE can be optimally used to substitute fossils gradually. In addition, the pressure on RE makes it more unaffordable for the poor. It is another challenge that government must overcome to seize the opportunities the pandemic has created to restore the environment.

3.4.1. A two-way pressure on RE

The pandemic has opened the opportunity to increase the use of locally produced RE to avoid disruption in energy supplies caused by a hampered global economy. The increasing use of RE in some developed countries, such as Europe, is evidence of the opportunity [50]. However, the pandemic also gives challenges to RE utilization. The decline in global demand for fossil energy has caused the decline in world oil prices to the lowest point. West Texas Intermediate (WTI) fell to -37.63 US$ per barrel in April 2020 [51]. The fall in oil prices pulls down other fossil energy prices as global energy prices reference the oil price. As a result, it will widen the price gap between fossil energy and RE, causing RE to be more uncompetitive. Simultaneously, the austerity policies to save the budget also find it difficult to provide incentives or subsidies to narrow or close the price gap, making RE no longer attractive. Under the pandemic situation, where everyone faces economic pressure, the cheapest energy sources would be preferred. Under the pandemic, RE faces two pressures simultaneously: a decrease in demand and a decline in fossil energy prices.

The pandemic could also derail the RE progress due to the decreased production and investment caused by the economic downturn. The lockdown and working-from-home policies have disrupted production activities of RE-supporting equipment, such as lamps and solar panels in the factories. The sluggish economic activities further reduce investment, through the decrease in energy consumption and production activities [39]. Production and investment influence each other and form a vicious cycle. Thus, the development of RE during the pandemic is influenced by the duration of social restrictions in many countries and the time (how long) the government's economic stimulus can overcome the economic downturn [52].

The pressures on RE are the challenges the governments should be cautious of. These challenges hamper the initiative to restore the environment through promoting renewables. To overcome these challenges, the government must introduce policies to reduce the pressure on RE utilization, for example, by encouraging WTE. WTE is likely to relieve the pressures on RE since RE is produced from waste. WTE does not involve many manufacturing processes in its equipment production, like in producing solar energy equipment. Its price is also unrelated to global oil prices since it comes from waste. The conversion of harmful waste into a valuable energy source will solve improper waste management problems during the pandemic and provide an alternative source of renewable energy that the global Covid-19 shock has pressured.

3.4.2. Energy affordability of the poor

Affordability is one of the critical indicators of energy security. It is a level of how affordable an energy source is, an index of the ability of people to afford an energy source. Thus, it is closely related to the price of energy. It measures whether an energy source can be provided at an affordable price or how much people can afford a certain price level and access the energy [53]–[55].

Under normal, non-pandemic situations, the poor are the least able to access energy. The economic hardship created by the pandemic has made energy more unaffordable for the poor. During the pandemic, access to energy is detached, and the poor, especially those living in rural and remote areas, have the least access to clean energy. This situation needs the government to give special attention to the poor in accessing energy, especially RE or clean energy [56], [57]. Giving such energy access to the poor could increase their ability to prepare for and recover from threats such as pandemic-like events [58]. Access, for example, is solar energy through the solar energy safety net program. The programs are conducted by distributing lamps and solar home systems to poor households in rural and remote areas. In addition, government assistance could be conducted through financial support for the general energy consumer. It, for example, is a risk-based sharing system that reduces electricity rates and delays consumer payments [59]. It could also be conducted for the poor who already access energy but are affected by the pandemic.

The increasing concern for the poor increases their energy affordability and opens the opportunity to increase renewable energy consumption during the pandemic. It, eventually, will gradually increase the share of renewable energy consumption in the national energy mix. Therefore, the pandemic has opened the opportunity to start initiatives that promote the utilization of renewable energy sources for restoring the environment that has been degrading by the increased fossil energy consumption.

3.5. The Lesson-learned: reducing the dependence on imported, fossil energy sources

Fossil energy-producing activities have a long business chain and involve many workers. The upstream activities (exploitation), midstream (refineries), and downstream activities (the distribution to the consumers) require many workers and a site to conduct. As such energy-producing activities are impossible to conduct from home, the lockdown and containment policies have inhibited the activities that disrupt the energy supply. Furthermore, the austerity policy during the pandemic disrupted the energy provision [37]. Under a normal (non-pandemic) situation, a country's dependency on fossil energy reduces energy security [49], [53], [54]. Thus, it is crucial to minimize or reduce the dependency on fossil energy. The pandemic creates the opportunity and lesson learned to be not dependent and to start the initiative to reduce the dependency on fossil energy, mainly if it is imported.

The pandemic situation induces the awareness of not using energy involving a long production chain, which is very vulnerable to pandemic-like events. Thus, it triggers the initiative and strategy to reduce the reliance on energy sources that involve a long production chain and the dependence on oil (fossil energy) producing countries. As a result, many governments would think to substitute the global, long chain-involving energy with locally able-produced energy sources. The new strategy in the energy sector, then, opens the opportunity to increase RE development. The utilization of RE is suited to the local energy source or the energy source available in an area. It is very likely to produce RE locally, as RE only requires a one-time installation, and the energy would be produced continually. The process differs from fossils, where the energy should be produced through the continuing process. When an extraordinary, unexpected situation hampers the process, there would be no energy to produce. In RE, the disruptions only occur partially. For example, lamps and solar

panel production may be hampered by the pandemic-like event. However, the disruptions only occur partially, not in the entire chain production process, like fossil in energy production.

Generally, the production process in RE differs from the production process in fossils. Several types of RE, such as solar energy, wind energy, waste energy, and hydro energy, do not require long, continuous production activities in the factories, which involve many laborers, as is the case with the fossil energy production process. Such RE only requires tools and storage batteries manufactured in the factories. After the installation, the subsequent process is the energy production process that the pandemic-like event would not disrupt. In RE, the fuel to produce the energy comes from nature, while in fossil, the fuel comes from the manufacturing process. It is the fuel origin that distinguishes RE from fossil energy. The pandemic may hamper the production of solar panels, lamps, turbines, or batteries. However, for those already installed, energy production will continue. In fossils, the pandemic disrupts the fuel distribution (oil fuels, gas, or coal) from the processing site (refineries), then the energy production will be stopped as the fuel supply stop. The utilization of RE makes the energy provision continue without being hampered by the pandemic. Thus, in some countries, the consumption of RE is increasing [50]. The situation shows that the pandemic opens the energy policy transformation opportunity to optimize clean energy [60]. The initiatives to reduce the reliance on fossil and optimize RE means strengthening the efforts to restore the damaged environment through the energy sector.

4. CONCLUSION

Energy, the economy, and the environment is intertwined in human life. Environmental degradation will increase as the economy grows, following the increase in energy consumption. The pandemic is an extraordinary event that influences the pattern of global energy consumption. The lockdown policy to tackle the spread of the virus has stopped the economic activities and broken the traditional relationships between the economy and energy consumption. As economic activities are curtailed and mobility is reduced, global CO_2 emission is significantly falling, opening the opportunities to promote and encourage initiatives to restore the environment's health.

The old, broken relationship between energy and the economy caused by the pandemic has created a new relationship pattern that open the opportunities to restore the environment. The opportunities are created due to the 'new normal' lifestyle, which is less energy-intensive, such as working from home, online shopping, distance learning, etc. Waste issue during the pandemic also opens the opportunity to convert wastes into renewable energy through WTE. Unfortunately, this new relationship also creates challenges, i.e., RE must face two-way pressure from demand and prices sides. However, the pandemic also gives some lessons to be learned, i.e., reducing the dependency on fossil energy sources, mainly if it is imported. Thus, the government must be able to seize the opportunities to overcome the challenges.

REFERENCES

[1] A. Afful-Dadzie, E. Afful-Dadzie, I. Awudu, and J. K. Banuro, "Power generation capacity planning under budget constraint in developing countries," *Applied Energy*, vol. 188, pp. 71–82, 2017, doi: 10.1016/j.apenergy.2016.11.090.

[2] F. Riva, H. Ahlborg, E. Hartvigsson, S. Pachauri, and E. Colombo, "Electricity access and rural development: Review of complex socio-economic dynamics and causal diagrams for more appropriate energy modelling," *Energy for Sustainable Development*, vol. 43, pp. 203–223, 2018, doi: 10.1016/j.esd.2018.02.003.

[3] R. Best and P. J. Burke, "Electricity availability: A precondition for faster economic growth?," *Energy Economics*, vol. 74, pp. 321–329, 2018, doi: 10.1016/j.eneco.2018.06.018.

[4] N. M. Ha and B. H. Ngoc, "Revisiting the relationship between energy consumption and economic growth nexus in Vietnam: New evidence by asymmetric ARDL cointegration," *Applied Economic Letters*, vol. 28, no. 12, pp. 978–984, 2020, doi: 10.1080/13504851.2020.1789543.

[5] M. Murshed, "The impacts of fuel exports on sustainable economic growth: The importance of controlling environmental pollution in Saudi Arabia," *Energy Reports*, vol. 8, pp. 13708–13722, 2022, doi: 10.1016/j.egyr.2022.09.186.

[6] Z. Wang and X. Jia, "Analysis of energy consumption structure on CO_2 emission and economic sustainable growth," *Energy Reports*, vol. 8, pp. 1667–1679, 2022, doi: 10.1016/j.egyr.2022.02.296.

[7] M. Mulyadi and D. J. Safrudin, "Pollutant levels comparison in tofu industrial and domestic wastewater in Ternate City," *Jurnal Kesehatan Masyarakat*, vol. 15, no. 3, pp. 366–371, 2020, doi: 10.15294/kemas.v15i3.20748.

[8] World Bank, "World Development Indicators (WDI)," 2021. [Online]. Available: https://datacatalog.worldbank.org/dataset/world-development-indicators (accessed: Dec 14, 2022).

[9] I. Nuraini and H. F. Hariyani, "Quality economic growth as an Indicator of economic development," *Jurnal Ekonomi Pembangunan: Kajian Masalah Ekonomi dan Pembangunan*, vol. 20, no. 1, pp. 80–86, 2019, doi: 10.23917/jep.v20i1.7104.

[10] B. Li and N. Haneklaus, "Reducing CO_2 emissions in G7 countries: The role of clean energy consumption, trade openness and urbanization," *Energy Reports*, vol. 8, pp. 704–713, 2022, doi: 10.1016/j.egyr.2022.01.238.

[11] N. D. Asri and P. Yusgiantoro, "The energy provision dilemma of coal versus wind from the economic, environmental, and social perspective within the energy security framework," *Defense Journal*, vol. 6, no. 3, pp. 310–327, 2020, doi: 10.33172/jp.v6i3.1049.

[12] R. Ulucak, Danish, and B. Ozcan, "Relationship between energy consumption and environmental sustainability in OECD countries: The role of natural resources rents," *Resources Policy*, vol. 69, no. May, p. 101803, 2020, doi: 10.1016/j.resourpol.2020.101803.

[13] S. Farhani, S. Mrizak, A. Chaibi, and C. Rault, "The environmental Kuznets curve and sustainability: A panel data analysis," *Energy Policy*, vol. 71, pp. 189–198, 2014, doi: 10.1016/j.enpol.2014.04.030.

[14] D. Nasrullah *et al.*, "Psychological impact among health workers in effort to facing the COVID-19 in indonesia," *International Journal of Public Health Science (IJPHS)*, vol. 10, no. 1, pp. 181–188, 2021, doi: 10.11591/ijphs.v10i1.20524.
[15] A. J. M. Shindaini, A. Irin, M. M. Rahman, and S. Afrin, "Assessment of mental health conditions among working class people during COVID-19: Insights from Dhaka South City, Bangladesh," *International Journal of Public Health Science (IJPHS)*, vol. 11, no. 2, pp. 518–526, 2022, doi: 10.11591/ijphs.v11i2.21264.
[16] E. A. Severo, J. C. De Guimarães, and M. L. Dellarmelin, "Impact of the COVID-19 pandemic on environmental awareness, sustainable consumption and social responsibility: Evidence from generations in Brazil and Portugal," *Journal of Cleaner Production journal*, vol. 286, p. 124947, 2021, doi: 10.1016/j.jclepro.2020.124947.
[17] M. Hyman *et al.*, "Data analytics to evaluate the impact of infectious disease on economy: Case study of COVID-19 pandemic," *Patterns*, vol. 2, no. 8, p. 100315, 2021, doi: 10.1016/j.patter.2021.100315.
[18] M. R. Keogh-Brown, H. T. Jensen, W. J. Edmunds, and R. D. Smith, "The impact of COVID-19, associated behaviours and policies on the UK economy: A computable general equilibrium model," *SSM - Population Health*, vol. 12, p. 100651, 2020, doi: 10.1016/j.ssmph.2020.100651.
[19] M. Shehabi, "Modeling long-term impacts of the COVID-19 pandemic and oil price declines on Gulf oil economies," *Economic Modelling*, vol. 112, no. March, p. 105849, 2022, doi: 10.1016/j.econmod.2022.105849.
[20] N. D. Asri and P. Yusgiantoro, "A revisit of the energy-economy-environment nexus with multi-regression," *International Journal on Advanced Science, Engineering and Information Technology*, vol. 12, no. 5, pp. 1866–1874, 2022, doi: 10.18517/ijaseit.12.5.15907.
[21] E. Rehman and S. Rehman, "Modeling the nexus between carbon emissions, urbanization, population growth, energy consumption, and economic development in Asia: Evidence from grey relational analysis," *Energy Reports*, vol. 8, pp. 5430–5442, 2022, doi: 10.1016/j.egyr.2022.03.179.
[22] British Petroleum, "BP statistical review of world energy 2020," London, 2020. [Online]. Available: http://www.bp.com/statisticalreview (accessed: Dec 2, 2022).
[23] World Bank, "CO_2 emission," Tennessee, 2021. [Online]. Available: https://data.worldbank.org/indicator/EN.ATM.CO2E.PC (accessed: Dec 4, 2022).
[24] M. Aziz, "Advanced green technologies toward future sustainable energy systems," *Indonesian Journal of Science and Technology*, vol. 4, no. 1, pp. 89–96, 2019, doi: 10.17509/ijost.v4i1.15805.
[25] M. Satriawan, Liliasari, W. Setiawan, and A. G. Abdullah, "Unlimited energy source: a review of ocean wave energy utilization and its impact on the environment," *Indonesian Journal of Science and Technology*, vol. 6, no. 1, pp. 1–16, 2021, doi: 10.17509/ijost.v6i1.31473.
[26] T. Gómez-navarro and D. Ribó-pérez, "Assessing the obstacles to the participation of renewable energy sources in the electricity market of Colombia," *Renewable and Sustainable Energy Reviews*, vol. 90, no. March, pp. 131–141, 2018, doi: 10.1016/j.rser.2018.03.015.
[27] L. P. Ghimire and Y. Kim, "An analysis on barriers to renewable energy development in the context of Nepal using AHP," *Renewable Energy*, vol. 129, pp. 446–456, 2018, doi: 10.1016/j.renene.2018.06.011.
[28] S. F. Kennedy, "Indonesia's energy transition and its contradictions: Emerging geographies of energy and finance," *Energy Research & Social Science*, vol. 41, no. June 2017, pp. 230–237, 2018, doi: 10.1016/j.erss.2018.04.023.
[29] R. Dutu, "Challenges and policies in Indonesia's energy sector," *Energy Policy*, vol. 98, pp. 513–519, 2016, doi: 10.1016/j.enpol.2016.09.009.
[30] S. Martosaputro and N. Murti, "Blowing the wind energy in Indonesia," *Energy Procedia*, vol. 47, pp. 273–282, 2014, doi: 10.1016/j.egypro.2014.01.225.
[31] N. D. Asri and P. Yusgiantoro, "Investigating a hampered NRE utilization in Kaltim's energy system: Is there an energy policy with a syndrome of the energy-abundant area?," *International Journal of Renewable Energy Development*, vol. 10, no. 4, pp. 653–666, 2021, doi: 10.14710/ijred.2021.37135.
[32] N. D. Asri and P. Yusgiantoro, "Is sustainability challenging in Indonesia's energy provision? - Fuel type vs externalities in electricity cost analysis," *Sustinere Journal of Environment & Sustainability*, vol. 5, no. 2, pp. 103–132, 2021, doi: 10.22515/sustinere.jes.v5i2.154.
[33] P. Yusgiantoro, *Energy Economics: Theory and Practice* , 1st ed. Jakarta: Pustaka LP3ES, 2000.
[34] British Petroleum, "BP statistical review of world energy 2019," London, 2019. Accessed: 20 Dec 23, 2022). [Online]: Available: http://www.bp.com/statisticalreview.
[35] I. Ozturk, "The dynamic relationship between agricultural sustainability and food-energy-water poverty in a panel of selected Sub-Saharan African Countries," *Energy Policy*, vol. 107, no. May, pp. 289–299, 2017, doi: 10.1016/j.enpol.2017.04.048.
[36] IEA, "Global energy review 2020," 2020. [Online]. Available: https://www.iea.org/reports/global-energy-review-2020 (accessed: Dec 5, 2022).
[37] B. K. Sovacool, D. F. Del Rio, and S. Griffiths, "Contextualizing the COVID-19 pandemic for a carbon-constrained world: Insights for sustainability transitions, energy justice, and research methodology," *Energy Research & Social Science*, vol. 68, no. July, p. 101701, 2020, doi: 10.1016/j.erss.2020.101701.
[38] E. S. Sahin, I. S. Bayram, and M. Koc, "Demand side management opportunities, framework, and implications for sustainable development in resource-rich countries: Case study Qatar," *Journal of Cleaner Production*, vol. 241, p. 118332, 2019, doi: 10.1016/j.jclepro.2019.118332.
[39] M. Mofijur *et al.*, "Impact of COVID-19 on the social, economic, environmental and energy domains: Lessons learnt from a global pandemic," *Sustainable Production and Consumption*, vol. 26, no. September 2020, pp. 343–359, 2021, doi: 10.1016/j.spc.2020.10.016.
[40] T. Zhang, H. Che, Z. Gong, Y. Wang, J. Wang, and Y. Yang, "The dominant mechanism of the explosive rise of PM2.5 after significant pollution emissions reduction in Beijing from 2017 to the COVID-19 pandemic in 2020," *Atmospheric Pollution Research*, vol. 12, no. 2, pp. 272–281, 2021, doi: 10.1016/j.apr.2020.11.008.
[41] K. M. Perkins, N. Munguia, M. Ellenbecker, R. Moure-Eraso, and L. Velazquez, "COVID-19 pandemic lessons to facilitate future engagement in the global climate crisis," *Journal of Cleaner Production*, vol. 290, p. 125178, 2021, doi: 10.1016/j.jclepro.2020.125178.
[42] B. N. Kulkarni and V. Anantharama, "Repercussions of COVID-19 pandemic on municipal solid waste management: Challenges and opportunities," *Science of the Total Environment*, vol. 743, p. 140693, 2020, doi: 10.1016/j.scitotenv.2020.140693.
[43] D. Hantoko, X. Li, A. Pariatamby, and K. Yoshikawa, "Challenges and practices on waste management and disposal during COVID-19 pandemic," *Journal of Environmental Management*, vol. 286, no. November 2020, p. 112140, 2021, doi: 10.1016/j.jenvman.2021.112140.
[44] C. Zhou, G. Yang, S. Ma, Y. Liu, and Z. Zhao, "The impact of the COVID-19 pandemic on waste-to-energy and waste-to-material industry in China," *Renewable and Sustainable Energy Reviews*, vol. 139, no. October 2020, p. 110693, 2021, doi: 10.1016/j.rser.2020.110693.

[45] J. Pollard *et al.*, "Implementing a circular economy business model canvas in the electrical and electronic manufacturing sector: A case study approach," *Sustainable Production and Consumption*, vol. 36, pp. 17–31, 2023, doi: 10.1016/j.spc.2022.12.009.
[46] T. Seljak, J. Baleta, and H. Mikulčić, "Integration of energy systems, circular economy and efficiency measures," *Cleaner Chemical Engineering*, vol. 5, no. December 2022, p. 100088, 2023, doi: 10.1016/j.clce.2022.100088.
[47] N. L. Trivyza, A. Rentizelas, S. Oswald, and S. Siegl, "Designing reverse supply networks for carbon fibres: Enabling cross-sectoral circular economy pathways," *Journal of Cleaner Production*, vol. 372, no. May, p. 133599, 2022, doi: 10.1016/j.jclepro.2022.133599.
[48] C. Su and F. Urban, "Circular economy for clean energy transitions: A new opportunity under the COVID-19 pandemic," *Applied Energy*, vol. 289, no. February, p. 116666, 2021, doi: 10.1016/j.apenergy.2021.116666.
[49] M. Taifouris and M. Martín, "Towards energy security by promoting circular economy: A holistic approach," *Applied Energy*, vol. 333, no. November 2022, p. 120544, 2023, doi: 10.1016/j.apenergy.2022.120544.
[50] S. Halbrügge, P. Schott, M. Weibelzahl, H. U. Buhl, G. Fridgen, and M. Schöpf, "How did the German and other European electricity systems react to the COVID-19 pandemic?," *Applied Energy*, vol. 285, no. November 2020, p. 116370, 2021, doi: 10.1016/j.apenergy.2020.116370.
[51] J. Amborse, "Oil prices dip below zero as producers forced to pay to dispose of excess," *The Guardian*, Apr. 2020.
[52] H. Bahar, "The coronavirus pandemic could derail renewable energy's progress." The International Energy Agency, 2020.
[53] F. Bin Abdullah *et al.*, "Energy security index of Pakistan (ESIOP)," *Energy Strategy Reviews*, vol. 38, no. August, p. 100710, 2021, doi: 10.1016/j.esr.2021.100710.
[54] S. F. Sanchez, M. A. F. Segovia, and L. C. R. López, "Estimating a national energy security index in Mexico: A quantitative approach and public policy implications," *Energy Strategy Reviews*, vol. 45, no. November 2022, p. 101019, 2023, doi: 10.1016/j.esr.2022.101019.
[55] A. Cherp and J. Jewell, "The concept of energy security: Beyond the four As," *Energy Policy*, vol. 75, pp. 415–421, 2014, doi: 10.1016/j.enpol.2014.09.005.
[56] K. Ravindra, M. Kaur-sidhu, S. Mor, J. Chakma, and A. Pillarisetti, "Impact of the COVID-19 pandemic on clean fuel programmes in India and ensuring sustainability for household energy needs," *Environment International*, vol. 147, no. November 2020, p. 106335, 2021, doi: 10.1016/j.envint.2020.106335.
[57] M. Thakur, E. A. Boudewijns, G. R. Babu, and O. C. P. van Schayck, "Biomass use and COVID-19: A novel concern," *Environmental Research*, no. April, p. 109586, 2020.
[58] R. Zaman, O. van Vliet, and A. Posch, "Energy access and pandemic-resilient livelihoods: The role of solar energy safety nets," *Energy Research & Social Science*, vol. 71, no. October 2020, p. 101805, 2021, doi: 10.1016/j.erss.2020.101805.
[59] Y. Tsao, V. Thanh, J. Lu, and H. Wei, "A risk-sharing-based resilient renewable energy supply network model under the COVID-19 pandemic," *Sustainable Production and Consumption*, vol. 25, pp. 484–498, 2021, doi: 10.1016/j.spc.2020.12.003.
[60] M. M. Mohideen, S. Ramakrishna, S. Prabu, and Y. Liu, "Advancing green energy solution with the impetus of COVID-19 pandemic," *Journal of Energy Chemistry*, vol. 59, pp. 688–705, 2021, doi: 10.1016/j.jechem.2020.12.005.

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