International Journal of Green Energy

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ljge20

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To cite this article: Folakemi Ope Olabiwonnu, Tor Haakon Bakken & Bokolo Anthony Jnr (2021): The role of hydropower in renewable energy sector toward co_2 emission reduction during the COVID-19 pandemic, International Journal of Green Energy, DOI: 10.1080/15435075.2021.1930005

To link to this article: https://doi.org/10.1080/15435075.2021.1930005

Published online: 29 May 2021.

INTERNATIONAL JOURNAL OF GREEN ENERGY
https://doi.org/10.1080/15435075.2021.1930005

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The role of hydropower in renewable energy sector toward co_2 emission reduction during the COVID-19 pandemic

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ABSTRACT

Due to the Coronavirus 2019 (COVID-19) pandemic social distance became a necessary strategy adopted in order to curb the fast-rise of infection. However, this strategy adopted by the government has impacted the socio-economic activities and lives of citizens as such new adaptive measures had to be put in place to cope with the pandemic. Accordingly, this study explores the relationship between the current COVID-19 pandemic on hydropower and energy sector in relation to Carbon dioxide (CO_2) emission reduction. This paper employs a systematic review of secondary data grounded from document reports and existing literature to explore the trend of COVID-19 pandemic on hydropower and energy sector in relation to CO_2 emission reduction. Findings from this article offer empirical evidence toward the impact of COVID-19 on hydropower and energy sector in relation to CO_2 emission decrease during the pandemic. More importantly, findings from this study discuss the relationship of COVID-19 on energy sector, impact of COVID-19 on the hydropower sector in comparison to other renewables, impact of COVID-19 and oil demand, and connection of COVID-19 on CO_2 emission reduction during the lockdown. Finally, implications are provided to guide policy makers in making decision toward sustainable energy production and CO_2 emission reduction.

ARTICLE HISTORY
Received 6 January 2021
Accepted 20 April 2021

KEYWORDS
Renewable energy; hydropower; energy sector; CO_2 emission; OPEC; lockdown; COVID-19 pandemic

1. Introduction

A pandemic is an outbreak that is prevalent globally and the current Coronavirus 2019 (COVID-19) pandemic has impacted most economies in 2020 with its first case traced back to November 2019 according to South China post (Ma 2020). As at then, nobody knew that the world was in for a shock to come in 2020 (Venter et al. 2020). By December 2020, about 80 million people were confirmed infected in 191 countries with over 1.7 million global death recorded by the Center for System Sciences and Engineering (CSSE) Johns Hopkins University (Jnr 2020; John Hopkins center 2020). In spite of this, a lot of European countries have gotten past the peak of the first wave of Coronavirus 2019 and are presently going through the second wave of the virus and new cases arise daily. However, COVID-19 has affected the economy of several countries in 2020 and hydropower sector may not be left out. Hence, several sectors have been affected by the pandemic as reported in the literature (Anthony Jnr, 2020a; Bokolo 2020).

As highlighted by IEA (2020a) the global consumption of renewable energy has increased by 1.5%, while renewable energy generation increased to almost 3% in the first four months of 2020 as compared to the same period in 2019. This was because of hydropower, solar, wind, and so on projects implemented over the past year and since renewables have lower operational cost. Besides, findings from IEA (2020b) stated that the impact of the COVID-19 pandemic is seven times more renowned than 2008 financial crisis on global energy. In addition, results from the International Hydropower Association (IHA) in 2019 suggested that hydropower generated about 4,305 Terawatt-hour (TWh) all over the world which is a definite increase from that of 2018 generation of 4,200TWh (IEA 2020c).

Furthermore, global Carbon dioxide (CO_2) emission has been a cause for concern (Anthony Jnr et al. 2020), as recorded by Olivier, Schure, and Peters (2017) due to CO_2 resulting in 72% increase in Greenhouse gas (GHG) emissions which are as a result of fossil fuel combustion. Thus, an annual increase is constantly being observed (Olivier, Schure, and Peters 2017). Besides, findings from prior studies (Olivier, Schure, and Peters 2017) reveal that the trends of CO_2 emission have increased from 0.3% in 2016 to 1% in 2017 and 2% in 2018. Moreover, in the year 2018, 76% of the energy supply consumed across the world is from fossil fuel combustion (Olivier, Schure, and Peters 2017) which affects the environment and biodiversity as well as inherently results in climate change (Bazzaz 1990).

In addition, government regulation and policies amidst the COVID-19 pandemic have considerably impacted energy demand across the world (Luo et al. 2020; Wang et al. 2020). As international borders were closed, and residents were confined to their homes, mobility decreased and energy consumption patterns changed (Le Quéré et al. 2020). As at May 2020 the global demand for electricity reduced due to lockdown but not as low as compared to the demand for oil. In countries such

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as the United States (US) and Europe, electricity consumption in 2020 is projected to be about 2.2% lower as compared to 2019, with high demand in residential electricity consumption partly offsetting the decrease in industrial and commercial electricity demand. In the United States as at June 2020 more electricity was generated from renewable sources more than from coal for the first time and renewable energy is projected to increase from 17% in 2019 to 20% in 2020 (Roidt et al. 2020). This is because since the start of the COVID-19 pandemic, energy produced from renewable sources has been resilient to the COVID-19 quarantine measures imposed (Khanna 2020).

In Europe there has been a significant decrease in energy demand as observed since March 2020, after several countries employed quarantine and lockdown to contain the spread of COVID-19 infection (Roidt et al. 2020). Likewise, a reduced electricity consumption of about 2% to 7% was observed across Europe due to shutting down of industries, which has resulted in lessening CO_2 emission due to a fewer combustion of fuels for electricity generation (Manan et al. 2020). Also, energy generation during working days decreased due to slower economic activities. This reduction in consumption of electricity during the COVID-19 pandemic also decreased the utilization of hydropower water resources used for energy generation. As compared to baseline values in 2016 to 2019, hydropower operations in Europe decreased by 21% on average amidst the lockdowns (Boretti 2021; Roidt et al. 2020).

Thus, hydropower is significant for CO_2 reduction as energy generation from hydropower lessens CO_2 emission and supports energy transition toward a greener and cleaner energy (Vaka et al. 2020; Yusup et al. 2020). Therefore, there is need to explore the connection between hydropower, energy sector, and CO_2 emission during the COVID-19 pandemic. Accordingly, this study presents the following research questions to be explored.

- **RQ1**: What is the impact of COVID-19 pandemic on the energy sector?
- **RQ2**: What is the impact of COVID-19 pandemic in hydropower sector as compared to other renewable?
- **RQ3**: What is the impact of COVID-19 pandemic and global oil demand?
- **RQ4**: What is the impact of COVID-19 pandemic on CO_2 emission during the lockdown?

In order to address the research questions, this article discusses the relationship between COVID-19 and energy sector, relationship between COVID-19 and hydropower sector in comparison to other renewables. In addition, this study explores COVID-19 and oil demand, and correlation of COVID-19 on CO_2 emission during the lockdown. Secondary data from documents report and existing literature were employed to examine the impact of COVID-19 pandemic on hydropower and energy sectors in relation to CO_2 emission. Findings from this study also present insights as regards to the connection between hydropower, energy sector, and CO_2 emission reduction during the COVID-19 pandemic.

2. Method and material

This study employs a review of prior studies by using secondary data from existing literature, document report, and web sources. Data from secondary sources helped to provide empirical evidence of the connection between hydropower, energy sector, and CO_2 emission reduction during the COVID-19 pandemic. As recommended by (Jnr 2020), the research method adopted in this study is shown in Figure 1.

Figure 1 depicts the research method which involves search strategy and data sources, inclusion and exclusion criteria, quality assessment criteria, data extraction and synthesis, and findings. Each of these phases is described below.

2.1. Search strategy and data sources

The search strategy involves using keywords to search from online databases. The keywords comprise COVID-19 and hydropower, COVID-19 and CO_2 emission, COVID-19 and oil demand, COVID-19 and hydropower sector, hydropower, and pandemic.

The search of the keywords was carried out on the following online database: Google Scholar, ScienceDirect, ProQuest, Taylor & Francis, Springer, ACM, and Wiley. The review was conducted in May 2020. Figure 2 depicts the study selection process employed in selecting suitable papers to be utilized in providing answers to the research questions. As seen in Figure 2 in the first phase a total of 131 papers were identified. In the second phase all paper titles were checked in order to manually assess their relevance to this study. In this stage, 57 papers that did not fully relate to the connection between hydropower, energy sector and CO_2 emission reduction during the COVID-19 pandemic were excluded which led to 74 papers. Also, in the second stage, all remaining papers were also checked in terms of their abstracts and scope as related to this study. Next, in phase 3 the selected 74 papers were screened based on the inclusion and exclusion criteria, then 29 papers were excluded. The remaining 45 papers were further evaluated for quality assessment. The data sources include 45 secondary sources which comprises scientific articles and available documents as seen in the reference section.

Figure 1. Research method adopted.

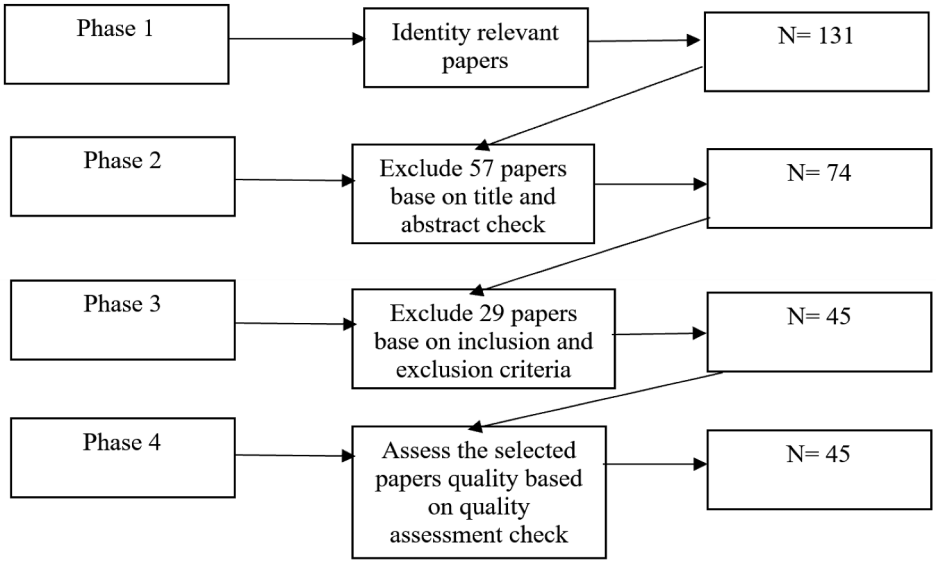

Figure 2. Secondary data sources selection flow.

2.2. Inclusion and exclusion criteria

Due to the importance of the secondary data selection stage in determining the validity of selected sources, inclusion and exclusion criteria were specified. Sources were eligible for inclusion if they focused on hydropower, energy sector and CO_2 emission reduction during the COVID-19 pandemic. Besides, as previously stated this study includes published sources from journals, documents report, web sources, and blogs. Papers that were not written in English were not included.

2.3. Quality assessment

The selected secondary sources were assessed in terms of the scientific rigor, research methods adopted, credibility of findings, and relevance of the study in relation to hydropower, energy sector and CO_2 emission reduction during the COVID-19 pandemic. Also, the selected journal articles were assessed to check if the articles were indexed in ISI Web of Science and/or Scopus database. The check suggests that more than 50% of the journals are indexed in ISI Web of Science and/or Scopus database.

2.4. Data extraction and synthesis

This stage of the review aims to extract and synthesize findings from the selected sources based on the explored research questions. Therefore, secondary data related to hydropower, energy sector and CO_2 emission reduction during the COVID-19 pandemic were individually extracted from each source. As shown in Figure 4 the selected studies explored area are categorized to depict the areas that have been explored by prior studies as related to hydropower, energy sector and CO_2 emission reduction during the COVID-19 pandemic.

3. Findings

This section presents findings from the review based on prior studies investigating the relationship of COVID-19 on hydropower and energy sector toward CO_2 emission during the pandemic.

3.1. Distribution of selected secondary sources

Considering the methodology applied in the 45 studies, findings from Figure 3 show that literature review is the most used method for data collection for studies related to the connection between hydropower, energy sector, and CO_2 emission reduction during the COVID-19 pandemic with N = 22 (49%), followed by online blog studies with N = 12 (27%). Next, are studies that used experiments and simulations with N = 8 (18%), and case study with N = 2 (4%). Lastly, the remaining study N = 1, (2%) deployed modeling as a method.

Considering the selected studies based on explored research area. Findings from Figure 4 indicate that (N = 6) studies are based on general COVID-19 study. Furthermore, the findings suggest that (N = 4) studies are based on trends in global CO_2, and COVID-19 and oil production respectively. Next, (N = 2) studies are based on hydropower and COVID-19, oil market report, COVID-19 and thermal electricity generation water footprint, COVID-19 and solar energy generation, and air travel and COVID-19 respectively. Lastly (N = 1) mostly explored other areas as seen in Figure 4.

Figure 5 illustrates the types of sources included for this study. The results suggest that (N = 12) studies were published as web-based document. Next, (N = 11) of the studies were review articles, (N = 6) are articles, and (N = 4) are document reports. Next, (N = 3) studies are based on editorials. Also, (N = 2) studies are perspective, commentary/comment, and preprint respectively. Next, (N = 1) papers are letter and featured articles, and short communication perspective.

3.2. Prior COVID-19, hydropower, and CO2 studies

Few studies have contributed toward exploring COVID-19, CO_2 emission, energy sector, and the renewable energies

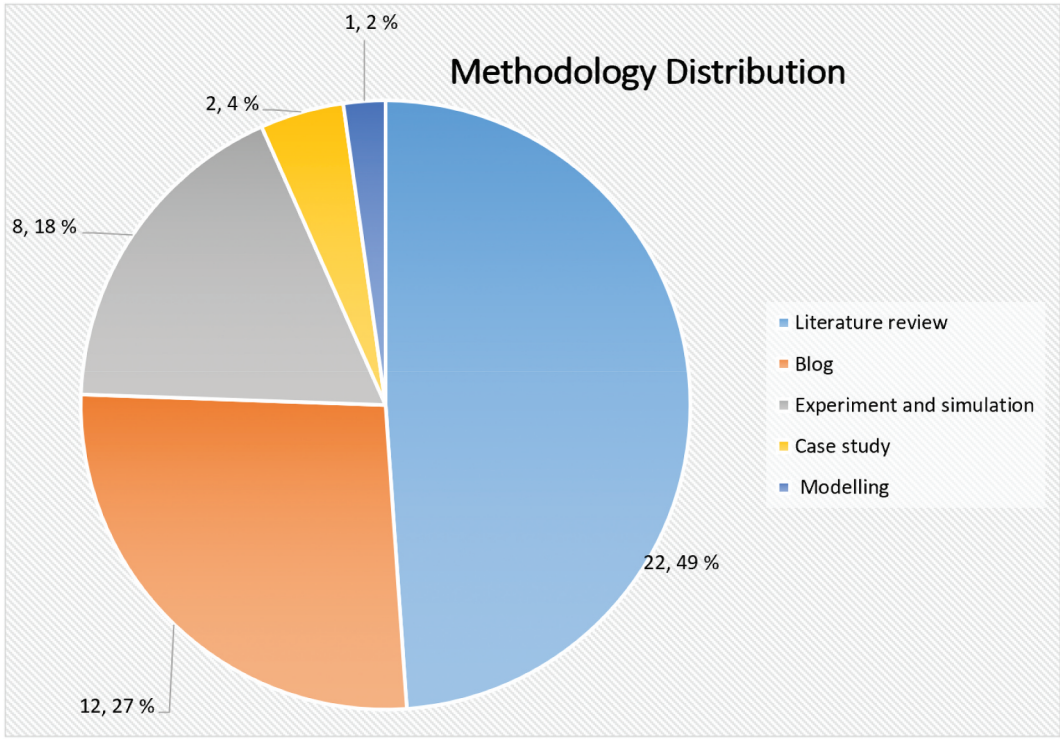

Figure 3. Distribution of selected studies in terms of methodology.

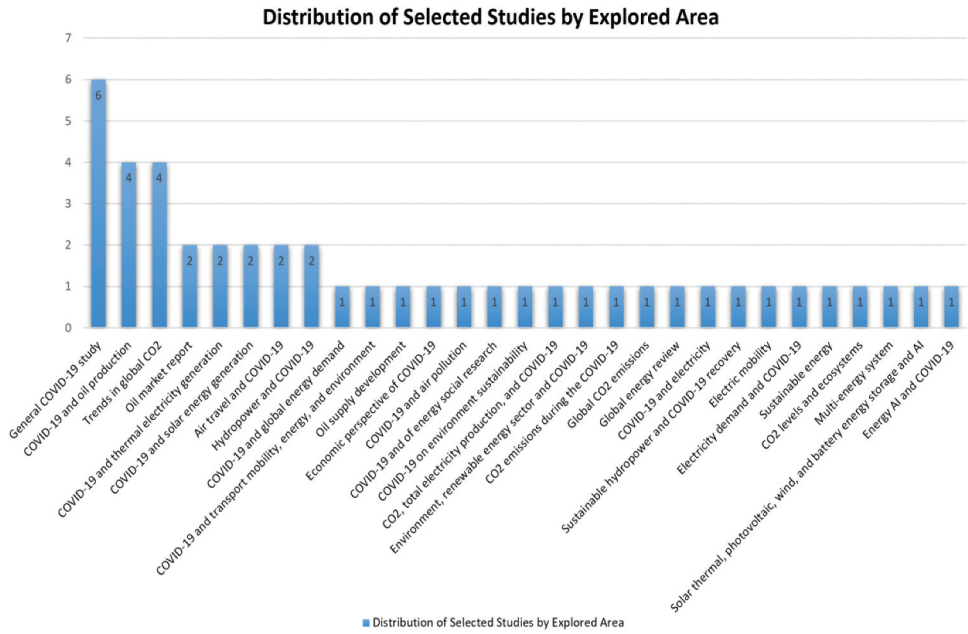

Figure 4. Distribution of selected studies by explored area.

especially hydropower sector. A few of these studies are reviewed as seen in Table 1.

Findings from the reviewed studies as seen in Table 1 reveal that the authors explored the impact of the COVID-19 pandemic in several areas. However, none of the reviewed studies explored the connection between hydropower, energy sector and CO_2 emission reduction during the COVID-19 pandemic. Hence, there is a need for a study that provides insight on hydropower, energy sector, and CO_2 emission amidst the COVID-19 pandemic.

3.3. Impact of COVID-19 on renewable energy sector

According to International Energy Agency IEA (2020a), the temporal shut down of industrial sectors in countries due to the tight lockdown has resulted in low demand for electricity

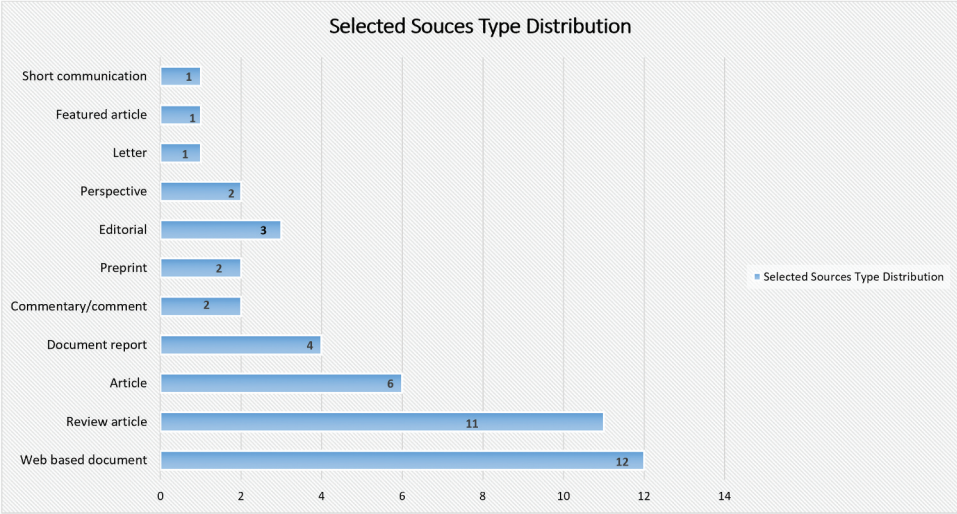

Figure 5. Distribution of selected sources type.

which has fallen by 5% to 10%, especially in European countries such as Spain, Italy, and so on. This raised the need for electricity operators needed to balance the demand and supply of energy (Chen et al., 2020; Jnr et al., 2020b; Jnr et al., 2020a). Since the renewable energies are largely unaffected, their demand has increased (IEA 2020b). Hence, energy consumption from renewable sources has immensely increased due to their flexibility and environmental benefits (IEA 2020c). However, IEA (2020a) has had to review their forecast due to the global crises. Hence, IEA forecasts that there would be 13% decline in renewable electricity capacity in 2020 in comparison to 2019 (IEA 2020b).

Furthermore, investment in renewable energy has been increasing as investors, predominantly in Europe, are putting pressure on oil corporations to decrease CO_2 emissions (Anthony Jnr 2020b; Wolde-Rufael and Weldemeskel 2020). Accordingly, financial institutions are redirecting finance toward renewable inventions. Thus, amidst the pandemic renewable energy production has been less impacted as compared to other energy sectors due to less marginal costs of energy generation (Khanna 2020). The UN Environment Program projected that global CO_2 emissions must decline by 7.6% annually from 2020 to 2030 to keep increasing temperature to lower than 1.5 Celsius. This transition to renewable energy sources such as hydropower will be assisted by acknowledging the environmental benefits to be derived such as cleaner air, better water quality and mitigating CO_2 emissions (Khanna 2020).

3.4. Effect of COVID-19 in hydropower sector as compared to other renewables

As at 2019, an increase in global hydropower installed capacity was recorded by International Hydropower Association (IHA) in their 2020 Hydropower status report as shown in Figure 6. The results suggest that there are uncertainties on what to expect for at least 3 years after 2020 due to the global COVID-19 pandemic.

Figure 6 shows the five years hydropower installed capacity difference between 2015 and 2019. The results suggest that the average year-on-year growth of each installed capacity was 2.1% (IHA 2020a). As seen in 2019, 1.2% growth rate was achieved for the annual growth in installed capacity (IHA 2020a). Moreover, findings from a survey conducted by the IHA between March and April 2020 indicated that due to the impact of the pandemic across the world, it was observed that respondents have digitalized their operations in all hydropower stations. But there are few primary workers who make sure the maintenance and provision and supply of power demands are met. Hence, findings from IHA reported that current COVID-19 has had less impact on the hydropower sector as a result of their dependence on technology and existing policy and regulations in the energy domain which has been ongoing for a long while (IHA 2020b).

Nonetheless, IHA commented that as a result of COVID-19, there is insecurity in financing many hydropower projects. Thus, they explained that this is due to currency fluctuation and cash shortage (IHA 2020a). Furthermore, IHA mentioned that reduction in the energy demand and fall in energy prices have been experienced in some markets due to COVID-19 to the extent of having negative pricing at some points (IHA 2020b). Similarly, a few grid operators still sometimes have a hard time maintaining grid stability. However, it is important to note that projects are financed by long-term power purchases are mostly unaffected (IHA, 2020a).

In addition, IEA (2020c) confirmed that renewable energies were not significantly affected like other sources of energy like coal and oil. Since the renewable energies are largely unaffected, their demand has increased. Hence, countries dependent on hydropower have had steady electricity for essential workers to use in their job during the pandemic and hydropower is a reliable energy source during the pandemic (IHA 2020a). Respectively, findings from the literature indicate that

Table 1. Prior COVID-19, Hydropower, and CO_2 Studies.

Author	Contribution	Findings	Country
Maijama'a et al. (2020)	Explored corona virus outbreak and the global energy demand based on a case study of people's republic of china.	Using the data gotten from China, the authors discovered that an increase in corona virus resulted to drastic decreases in crude oil price.	China
Abu-Rayash and Dincer (2020)	Analyzed electricity demand trends amidst the COVID-19 coronavirus pandemic.	Result signifies that notable drop in electrical energy demand occurred as a result of the COVID-19 pandemic and decrease in GHG benefitted the environment during this period.	Canada
Rajput et al. (2020)	Investigated how coronavirus rattles commodity markets.	Findings reveal that there was a collapse in oil process and decline in oil demand and supply occurred as a result of the travel limitation necessitated by COVID-19.	Global
perspective			
Nižetić (2020)	Examined the impact of coronavirus (COVID-19) pandemic on air transport mobility, energy, and environment grounded on a case study.	Using two airports as case studies, findings from their study indicate that due to reduction in transport mobility CO_2 emission has reduced.	Croatia
Eroğlu (2020)	Explored the effects of COVID-19 outbreak on environment and renewable energy sector.	Findings indicate that operators of renewable energies such as solar and wind power were also affected by the COVID-19 pandemic.	Global
perspective			
Usman et al. (2020)	Investigated the economic perspective of coronavirus (COVID-19).	Results show that the COVID-19 pandemic affected developments related to hydropower project in some countries.	Global
perspective			

hydropower is less affected by the pandemic as compared to other sources of renewable energy (IEA 2020a).

3.5. Relationship between COVID-19, oil demand and CO_2 emission

Findings from The Organization of the Petroleum Exporting Countries (OPEC), which is an international organization that comprises 13 petroleum exporting countries suggest that the pandemic has affected economic operation as related to energy generation in their operation (Peters, 2020). According to OPEC (2020a), COVID-19 has had an adverse effect on the global oil demand in the first and second quarter of year 2020 and this also have effect on CO_2 emission. As at May 2020, transportation fuels and industrial fuels were most affected in Europe and America and this resulted in reduced CO_2 due to reduced mobility within cities and as a result of the measures imposed by the government during the COVID-19 pandemic (OPEC 2020b). As of June 2020, with even more decline in air travels (blog.iiasa.ac, Davies-Jones 2020), continents such as America, Europe and Middle East have reported a significantly low demand for jet fuel and gasoline unlike in the past years (OPEC 2020c).

Furthermore, countries such as Norway which is one of the largest crude oil producers in Europe have had to reduce oil production as a response to year 2020 oil crisis, so as to stabilize their market (Peters 2020). Thus, between March 2020 and May 2020, the demand for crude oil rate declined, and a high production was observed which affected oil storage capacity (Sönnichsen, 2020aa). Hence, there was an oil surplus as of April 2020 which raised serious concerns about excess oil storage, even as crude oil products were stored onshore and on floating vessels (Sönnichsen, 2020b). Additionally, findings from world oil demand in three continents during COVID-19 pandemic represented in Figure 7 shows a decline in oil demand in the months from March 2020 to December 2020 due to lockdown and reduced mobility which is caused by the COVID-19 pandemic. This of course will help to reduce CO_2 emission.

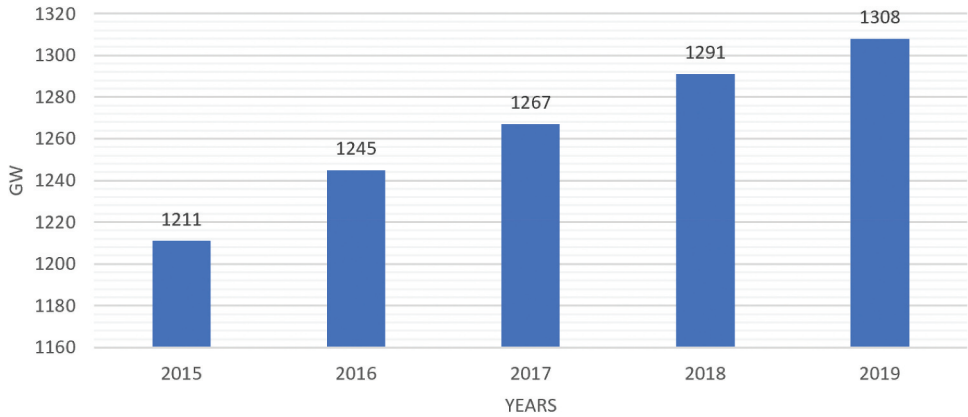

Figure 6. Installed capacity from 2015–2019 (IHA 2020a).

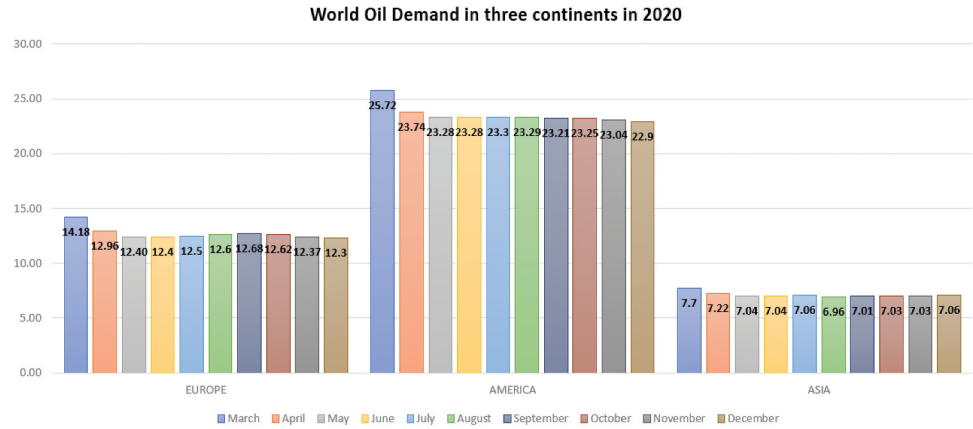

Figure 7. World oil demand in three continents during pandemic (OPEC 2020a).

Figure 7 illustrates the world oil demand in three continents during the highest peak of COVID-19 pandemic across three continents (Europe, America, Asia) (OPEC 2020a).

3.6. COVID-19 and CO_2 emission during the lockdown

In 2018, the Intergovernmental Panel on Climate Change (IPCC) published a report which stated that the climate is increasing by 0.2°C per decade (Le Quéré et al. 2020). Even though there is increasing awareness and use of renewable energies. It was discovered that instead of renewable energies replacing hydrocarbon-based fuels, renewable energies are consumed alongside. According to IEA (2020b), CO_2 emission has been steadily increasing all over the world from 1990 to 2019.

Hence, IEA (2020b) measured the CO_2 emission within advanced economies or countries (such as Japan, South korea) and other countries. The results revealed that there was a reduced CO_2 emission within advanced economies from 1990 to 2019. Although, the result indicated that CO_2 emission doubled in the 20th century in other countries. However, in 2020 COVID-19 has affected the world so much that partial and total lockdown had to be enforced differently in countries around the world which has surprisingly resulted in reduced pollution. In Wuhan, China, where the Virus was first discovered and where the earliest quarantine began, a reduction in the CO_2 and Nitrogen dioxide (NO_2) emission was recorded. Now, across the world, as of May 2020, over 84 countries have enforced partial or total lockdown. Hence, the lockdown resulted in decrease in transportation and reduction in industrial activities which in turn led to minimal CO_2 and NO_2 emission (Davies-Jones 2020; Tamás 2020).

In addition, the temporary ban of international travels and activities (such as international trade) has benefitted the environment due to reduced CO_2 and NO_2 emission. Special awareness is being given to climate change and emission of greenhouse gases through the reduction of hydrocarbon-based fuel and the use of renewable energy. However, findings from IEA (2020c) reported that CO_2 emission during the months of March 2020 to May 2020 were considerably reduced due to the lockdown in major countries which aimed to contain the spread of the virus. Evidently, COVID-19 seems to have had more impact on CO_2 emission than any disaster or previous pandemic (IEA 2020a). Likewise, further findings from the international energy agency indicated that the global emissions of CO_2 would lessen to 8% which was at the same level as 10 years ago decline in demand for oil, coal, and gas (IEA 2020b). Also, the reduced use of automobiles during the pandemic has helped to lessen the global emission of CO_2 and NO_2 emission. This was supported by researchers such as Venter et al. (2020) who mentioned that air pollution has decreased by 20% in over 27 countries during the pandemic.

4. Discussion and implications

4.1. Discussion

There is widespread consumption of renewable energy, particularly hydropower, solar, and wind energy, which provides energy without increasing carbon dioxide emissions. The COVID-19 pandemic has resulted in an unprecedented decrease in global economic activity (Venter et al. 2020). The extensive amount of CO_2 produced by various manufacturing industries and automobile to the air contributes to air pollution. However,the pandemic has contributed to improving the air quality, particularly in countries which observed lockdown and quarantine (Yusup et al. 2020). According to a report by NASA, the CO_2 emissions have been lessened to 30% and 25% respectively in 2020 (Manan et al. 2020). Le Quéré et al. (2020) mentioned that 69 countries have now had imposed some type of quarantine measures between the beginning of January 2020 to May 2020.

These measures have resulted in an unprecedented decrease in demand for energy for mobility and electricity. By mid-April energy consumption in countries under full lockdown reduced by 25% as compared to the average energy demand in 2019. This resulted in lower oil prices declined to about 85% amidst January 22nd, 2020, and April 21st, 2020 (Khanna 2020). Thus, researchers such as Le Quéré et al. (2020); Khanna (2020) predicts that CO_2 emissions decreased by 17% as at April 2020 as compared with the mean 2019 levels. Le Quéré et al. (2020) further mentioned that before the COVID-19 pandemic, CO_2 emissions were increasing for about 1%

per year over the decade. As about half of the CO_2 emissions reductions came from transportation sector (Peters et al. 2020).

A report published by CarbonBrief (www.carbonbrief.org), on 19th May 2020, suggests about 17% global decrease in daily CO_2 emissions across 69 countries (Le Quéré et al. 2020; Peters et al. 2020). According to Yusup et al. (2020) as of March 2020 the United States recorded +0.002% electricity production at 14% of CO_2 emissions. Similarly, Europe (United Kingdom, Poland, Germany, France, and Italy) recorded −13% electricity production at 6% CO_2 emissions. India recorded +16% electricity production at 7% of CO_2 emissions. Also, there was a decreased in electricity production and CO_2 emissions in other countries due to national restriction imposed by respective governments (Yusup et al. 2020).

Accordingly, this study highlights recommendations for renewable energy such as hydropower during the COVID-19 pandemic. Findings from this study argue that policymakers must act now and ensure that renewable energy sources should be adopted to enable the ongoing energy transition. This study contributes to existing literature to illustrate that during the pandemic there has been an increase in share of renewable energy sources consumption. The findings highlighted that the pandemic has resulted in reduced CO_2 emissions, air pollution, and carbon footprint. Hydropower is suggested in this study as a renewable energy source as it is environmentally friendly as it does not emit carbon emissions thus aids in mitigating climate change.

5. Implications and limitation

5.1. Implications for practice

The energy sector plays an important role in modern life that is now been unprecedentedly affected by the pandemic. The current COVID-19 pandemic has made an impact on the society to change the path toward decarbonization and implementing clean energy technologies toward attaining sustainable energy. Renewable energy sources such as hydropower is significantly providing the energy needs and addressing climate change thus reducing CO_2 emission (Das 2020). At present it is uncertain how long the current pandemic will last and how the recovery will look, and consequently how CO_2 emissions will be impacted.

Therefore, in connection to green energy this study explores the connection between hydropower, energy sector and CO_2 emission reduction during the COVID-19 pandemic. Findings from the literature (Yusup et al. 2020) suggest that a decrease of 3.7% was observed for the global energy demand in the first quarter of 2020 as compared to the same first quarter of 2019 due to the decline in global activities. Moreover, this study advocates for keeping track of the evolving CO_2 emissions as this can help provide information to policy makers to make decisions in response to future emissions trajectories after the pandemic.

Evidently, findings from this study suggest that the total energy consumption and CO_2 emission decreased significantly due to COVID-19. Hence, the oil and coal price also reduced greatly. So, people will choose to consume more renewable energy to help contribute in reducing carbon emission. On the contrary energy sourced from fossil energy can also be used by consumers if the price of energy produced from fossil energy is low. Additionally, one of the problems of distributed renewable energy is maintenance, and the possibility of maintaining the renewable energy systems may be a problem due to the lockdown or social distance due to COVID-19. But this issue can be mitigated as presently most countries are now partially locked down so maintenance can be easily carried out by technical teams involved across the country.

5.2. Implications for policy

The oil and gas industrial sector plays an important role in determining a country's energy and Gross Domestic Product (GDP). However, the oil and gas industrial sector also contributes to environmental issues such as CO_2 emission. Thus, there is need for new policies and approaches to support and encourage the implementation of renewable energy resources (Vaka et al. 2020). Therefore, findings from this study in relation to green energy shed light to improve the understanding on the connection between hydropower, energy sector and CO_2 emission reduction during the COVID-19 pandemic. In summary, the findings can be used to inform future actions during and after the pandemic for planning of renewable energy infrastructures to reduce CO_2 emission.

As recommended by Fell et al. (2020) findings from this study provide a road map for government toward achieving a low-carbon energy transition. Finally, the findings from this article offer empirical evidence toward the impact of COVID-19 on CO_2 reduction in energy sector during and after the pandemic. Thus, in order to recover smoothly after the COVID-19 pandemic IHA (2020b) recommends the extension of deadlines for concession agreement related to hydropower projects to ensure investments are not wasted.

Furthermore, findings from the literature suggest that the pandemic has caused lower CO_2 emissions, its occurrence has also led to the decrease in renewable energy costs, insistently lower oil prices, higher debt in fossil fuel sector and raised investor concerns about the effect of fossil fuels on CO_2 emissions. This has resulted in environmental regulations set to lower capital investment in fossil fuels while making renewable energy such as hydropower one of the fastest growing sector. The pandemic has resulted in low-carbon infrastructure to lower CO_2 emissions that may stimulate the economy, and possibly increase employment.

5.3. Limitations

Every study has limitations and this study is not an exception. This study only used secondary data from document reports and existing literature. Hydrological data, power market data and atmospheric data were not used to assess the impact of hydropower, energy sector, and CO_2 emission reduction during the COVID-19 pandemic.

6. Conclusion and future direction

The COVID-19 pandemic has created a public health and economic crisis for the world and societal and government response to managing this crisis has significantly reduced

energy use which had a negative impact on the oil and gas sectors. COVID-19 has greatly affected the society in several ways. Hence, this study explores the impact of the pandemic on the energy sector. Findings from IHA (2020b) suggest that electricity supply and demand in most countries where lockdown and restrictions were implemented experienced decreases in the total electricity consumption, although there was an increase in residential loads. The total energy generations reduced, and the coal-based energy generation is affected the most. Conversely, the share of renewable energy generations increased during the pandemic. But while the world is still faced with the pandemic the long-term impact of COVID-19 on the energy sector is still not certain.

This current article contributes to green energy domain by investigating the connection between hydropower, energy sector and CO_2 emission reduction during the COVID-19 pandemic. Secondary data from document reports and literature was employed to examine the impact of the COVID-19 pandemic on hydropower and energy sectors in relation to CO_2 emission. Accordingly, this study presents findings on the impact of COVID-19 on renewable energy sector, effect of COVID-19 in hydropower sector as compared to other renewables and relationship between COVID-19, oil demand and CO_2 emission. Findings from this article discuss the impact of COVID-19 on energy sector, effect of COVID-19 on the hydropower sector in comparison to other renewables, COVID-19 and oil demand, and the impact of COVID-19 on CO_2 emission during the lockdown.

In addition, IHA intends to assist by supporting research into technological advancement in the hydropower sector in ways to aid full recovery after the pandemic. Future work will involve using analysis of power market data, hydrological data and atmospheric data to monitor how energy production and supply were affected during the COVID-19 pandemic as it covers the cost of energy production.

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