Managerial Economics
2025, Vol. 26, No. 2, pp. 233–264
https://doi.org/10.7494/manage.2025.26.2.233

Jaya Singh Parihar*, Mansi Gupta**,
Gagan Deep Sharma***

The impact of COVID-19 on the global renewable energy sector. An integrative review exploring the challenges and emerging opportunities

1. Introduction

COVID-19 has had detrimental effects on multiple dimensions of human life, society, and the global economy. Although it is recognized that the virus had no direct influence on the environment or the energy sector, it certainly indirectly affected these sectors. The outbreak is predicted to reduce capacity growth for global wind and solar energy by 4.9 GW and 28 percent, respectively (International Energy Agency 2020) and there have been several layoffs and changes in the energy industry. The governments worldwide needs to move promptly to establish necessary steps to limit the outbreak's negative impact on the renewable energy sector (Eroğlu 2021)

The outbreak of COVID-19 has had a huge influence on the renewable energy sector. Sharp economic downturns have slowed renewable energy supply chains, while a drop in market-based funding and government incentives for renewable energy investment has generated major concern among entrepreneurs (Karmaker et al. 2021). Global energy consumption has been reduced due to pandemic-related outages, which has had a huge influence on renewable energy programs.

* Guru Gobind Singh Indraprastha University, Centre of Excellence in Disaster Management Studies, New Delhi, India, e-mail: jayaparihar.90@gmail.com, https://orcid.org/0000-0002-0092-3978
** Guru Gobind Singh Indraprastha University, University School of Management Studies, New Delhi, India, e-mail: guptamansi007@gmail.com, https://orcid.org/0000-0002-4066-1386
*** Guru Gobind Singh Indraprastha University, University School of Management Studies, New Delhi, India, e-mail: angrishgagan@gmail.com, https://orcid.org/0000-0001-5379-0761

Meanwhile, government incentives have been shifted to epidemic relief efforts. The abrupt halt in production has caused substantial disruptions in the worldwide renewable energy supply chain (Ivanov, Dolgui 2021).

The impact of the pandemic on the renewable energy sector is demonstrated by the closure of numerous significant wind turbine manufacturing plants (Eroğlu 2021). Similar negative consequences can be seen in the solar business where there was a 28 percent drop in demand in 2020 (Hoang et al. 2021). As a worldwide health calamity, the COVID-19 epidemic has been a severe blow to the world economy, notably the oil industry (Chakraborty, Maity 2020). Personal automobiles and other main forms of transit were severely restricted due to containment measures (Elavarasan et al. 2021). As a result, energy production fell substantially in response to falling global demand, as indicated by lower output from nuclear reactors in Europe and the United States in the first quarter of 2020. China's tightly managed lockdowns in several of the country's hardest-hit provinces have resulted in a 15% decrease in the country's weekly energy demand (Bertram et al. 2021). Even though the regulations were initially limited to Hubei and nearby provinces, they swiftly expanded to cover most of China (Sharma et al. 2023). Looking back on 2019, many EU countries were on the edge of failing to meet their obligations owing to a lack of effective measures to assist the needed number of renewable energy projects (Stern et al. 2020). Diverse patterns of conventional and renewable energy supply across regions resulted in varying levels of energy poverty in specific geographies, resulting in divergent energy saving and consumption behaviours (Deller 2018; Castaño-Rosa et al. 2019; Zhang et al. 2019, 2021; Ampofo, Mabefem 2021). Additionally, there is a disparity in terms of energy poverty, energy consumption, and energy conservation between persons of different races and ethnicities, leading the scientific community to the subject of racial disparities in energy usage (Oppel Jr. et al. 2020).

Certain fiscal policies may obstruct project development and deployment, as well as research advancements in renewable energy technology (Gebreslassie 2020) Due to its considerable position in the existing electrical generation mix, dropping natural gas costs would naturally increase power demand, according to basic economic considerations. Energy demand and consumption are on the rise, which could provide a boost to economic growth (Fu, Shen 2020). Experts examining the impact of the COVID-19 pandemic on the global energy industry expressed conflicting opinions on the demonstrable influence on the speed and integrity of system rearrangement in response to the outbreak (Pareek et al. 2020). The transition to a low-carbon economy, as well as increased public interest in alternative energy sources, have all had an impact on these changes (Bertrand et al. 2020). As a result, power firms changed their operations in reaction to the pandemic's

effects by postponing new investment projects, tightening budgets, and eliminating wasteful spending, resulting in major short-term implications on worldwide renewable energy (Klein et al. 2018).

This study provides a fresh perspective on the problems associated with creating fundamental changes in our economy and society needed to make them more environmentally sustainable, especially in response to challenging times. The concept of managing the transition to renewable energy has taken centre stage in the policy debate on sustainable development. This paper offers an innovative approach to the role of public policies in managing this transition and covers a variety of perspectives from political science, sociology, economics, innovation studies, complex systems theory, and evolutionary thinking. Neo-classical thought regards innovation as involving market failures due to positive externalities of research and development and highlights the behavior of innovators and the users of innovators (Bergh, Bruinsma 2008). This study extends the existing theories that emphasize the need for a system-wide approach that takes into account sector interactions as well as the complex relations between the technologies, institutions, and behavior of the firms and consumers (IRENA 2020; Tung et al. 2022).

The extant literature has assessed the impact of COVID-19 on the energy sector from many perspectives (Gebreslassie 2020; Jiang et al. 2021; Tung et al. 2022) However, there is a need for a comprehensive assessment of the overall pandemic influence on the renewable energy sector. To fill this gap, we conducted an integrative review in a systematic and structured manner to meet multiple objectives. One objective was to identify research hotspots detailing the impact of COVID-19 on renewable energy while outlining the influencing mechanisms. The second objective was to propose fresh research directions based on existing findings. For the third objective, taking our cues from Fan et al. and Thomas and Tee (Fan et al. 2022; Thomas, Tee 2021), we centered our study around a theoretical framework (Fig. 1) to provide a conceptual framework for future research attempting theory development in the area needed to provide practical and theoretical implications for researchers and policymakers.

The purpose of this research is to provide an in-depth analysis of the worldwide implications and difficulties of the COVID-19 pandemic on the renewable energy industry, as well as to highlight energy-related lessons and upcoming prospects by documenting key trends and hotspots in the area. The major contributions of the study are threefold. First, the integrative review identifies five themes and explores the influence mechanism within each theme. Second, the study identifies the aspects of renewable energy that are influenced by the COVID-19 pandemic. Third, the study proposes a conceptual framework highlighting the effects and challenges of the COVID-19 pandemic on renewable energy demand

and consumption patterns, with aggregate dimensions discovered through inductive analysis to back up these findings. The three main energy challenges are: the healthcare sector primarily dealing with disease control; associated environmental impacts with challenges relating to fluctuating and uncertain energy demand and consumption, structural and pattern changes, greenhouse gas emissions, local air quality, energy transmission infrastructure, and oil production and transmission network; associated economic impact associated with activities including households, agriculture, public and commercial sector, energy import/export, sales revenue, and expenditure, social sector including human resources, labor force, population, employment, partnerships, funding schemes, and subsidies, technology R&D, and overall economic welfare and GDP. This study also makes practical propositions for researchers and policymakers.

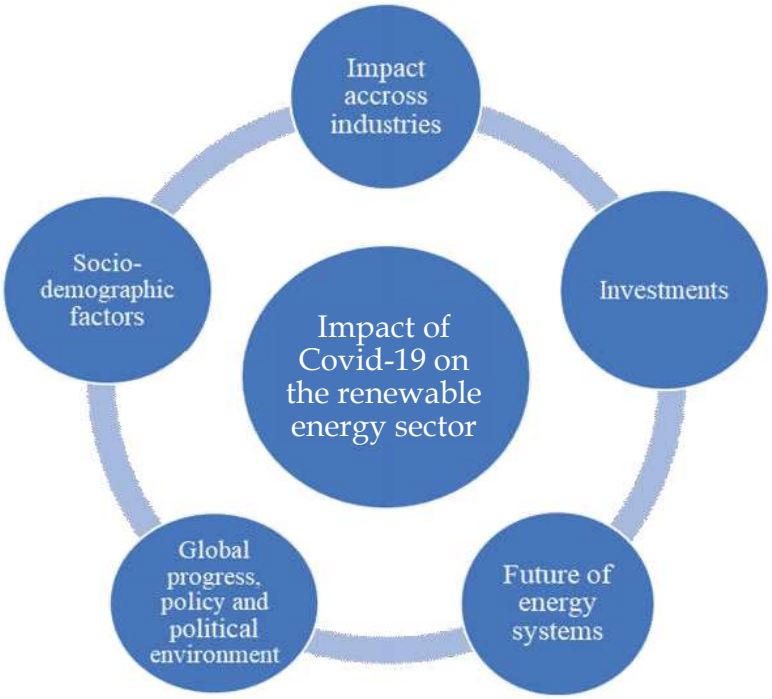


Figure 1. Theoretical framework

The paper progresses as follows: The following part describes the techniques used for this review; and the third section presents the findings; the fourth section offers the discussion along with the integrative review, fifth sections provides

future research agendas and the last section presents some conclusions and policy implications.

2. Methodology and materials

This study employed an integrated strategy combining a bibliometric review with a manual insightful review (Fig. 2). Integrative reviews aim to provide new theoretical frameworks and viewpoints by reviewing, critiquing, and synthesizing "representative" literature (Cronin, George 2020). A bibliometric review is a type of theme-based review that emphasizes facts and trends in a review subject (Paul et al. 2021). In addition, we conducted a manual in-depth review that consolidated the relevant research and synthesized the objectives, techniques, predictors, and policy suggestions. The Bibliometrix R package software was used in the study to retrieve and analyse information from documents (Aria, Cuccurullo 2017). Bibliometrics R-Tool is a piece of free software that can provide a full set of literature information analysis and scientific mapping (Rodríguez-Soler et al. 2020).

Figure 2. Methodological flowchart

The search was run in February 2022 via a Boolean operator using the keyword strings (Fig. 3). Given its consistency with social science, Web of Science (WoS) is the most extensively utilized citation database (Li et al. 2010). Following some important reviews that employed systematic research methodologies (Talan, Sharma 2019; Thomas, Tee 2021), we used the Web of Science (WoS) database to collect relevant literature. The WoS is the most extensively used database for scientometric analyses with full literature data from 1985 up to the present (Cañas-Guerrero et al. 2013; Liu et al. 2021; Lv et al. 2021). This search results in 80 research studies between 2019–2022..

The original search query results were sorted by inclusion-exclusion criteria, resulting in the inclusion of 80 publications (Fig. 3). This refinement results in

80 research articles, which are then exported as a '.txt' file with comprehensive title, author, citations, country, and so on.

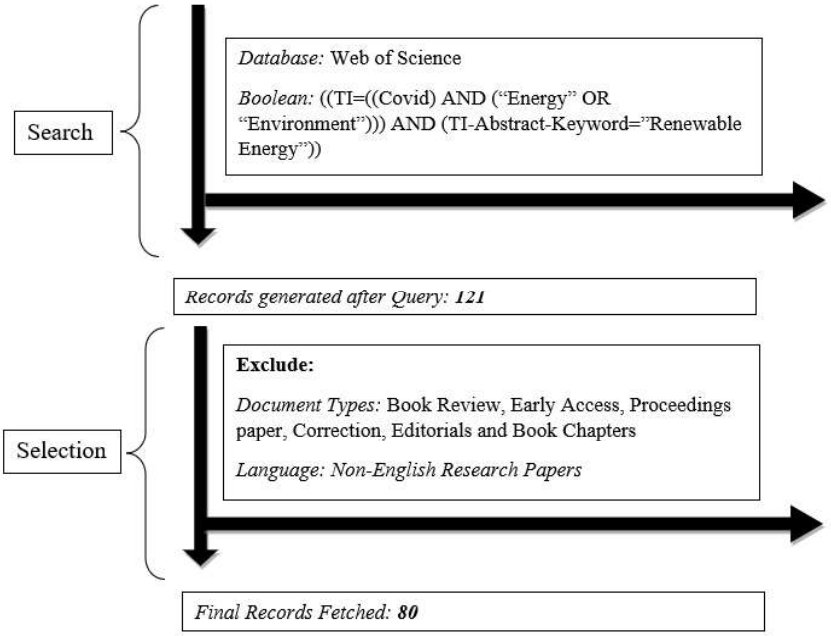


Figure 3. Search and selection process

3. Results

This section presents the social, intellectual, and conceptual structures that define the research landscape on COVID-19 and renewable energy.

3.1. Social structure

Social structure encompasses the patterns of co-authorship and country collaboration that reveal key authors, research clusters, and the geographic distribution of networks shaping the development in the field. Co-authorship visualization analysis

Co-authorship analysis is an important feature of research collaboration not only at the individual level but also at the country level (Jalal 2019). Figure 4

depicts a graphical analysis of co-authorship among the top 50 authors who have co-authored at least one publication together. The authors' links reflect their collaboration patterns, with five distinct hues signifying the authors' clusters of collaborations. The following clusters represent the most prominent and important author collaboration networks and reached the following conclusions: blue (with five authors) – that reduced energy consumption had a major impact on the operations of small electric grids, while further highlighting the challenges posed by the pandemic including the impact on the electricity generation and demand patterns, frequency deviations and load forecasting (Carmon et al. 2020; Navon et al. 2021); Orange (with three authors) opine that a resilient energy supply network with a risk-sharing model tended to stabilize the company's total profit with varying degrees of impact from the pandemic, and that renewable credit and supplier subsidy models should be considered to recover the renewable energy market (Tsao et al. 2021). The remaining three clusters show moderate collaboration with only two authors. Iqbal et al. highlight that the COVID-19 pandemic had a significantly negative effect on energy consumption and carbon dioxide emissions patterns (Iqbal et al. 2021). While Iqbal and Bilal argue that governmental offices, energy ministries, and other linked departments should provide utmost assistance for energy efficiency optimization (Iqbal, Bilal 2021). Most papers were dual-authored, thereby emphasizing the need to improve collaborations.

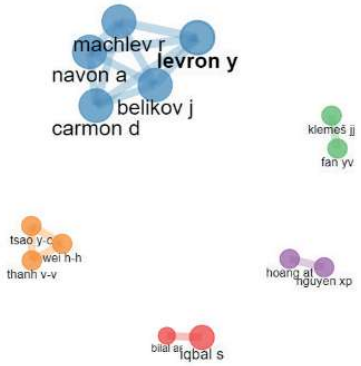


Figure 4. Co-authorship visualization analysis

3.1.1. Country collaboration map

Figure 5 illustrates another bibliographic network considering collaboration links between scholars worldwide. The deeper the blue tint, the more publications a country's researchers have. Collaborations are shown as lines, with the thickness of the lines denoting the number of publications provided by the nations

combined. A list of the countries where the scholars produced the majority of research in "COVID-19 and Renewable Energy" was compiled between 2019 and 2022. The highest rate of collaboration between scholars occurred between India and China, followed by China with Japan. It's worth noting that the country's most severely hit by COVID-19 have the highest collaboration rates, implying that they shared knowledge and assisted one another in obtaining scientifically significant findings. There were some notable collaborations between the USA with China and Thailand and Australia with the UK and Vietnam. The highest rates of networking often occur with nations that were far apart geographically and seemed to be influenced by policies and practices linked to healthcare mobility policies.

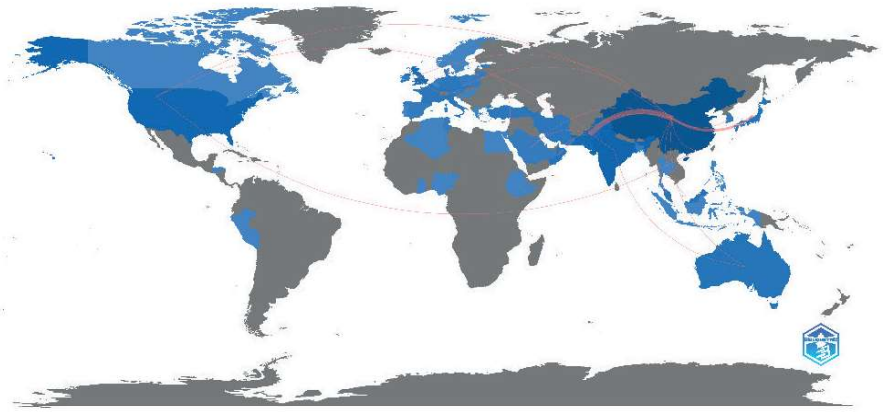


Figure 5. Co-authorship visualization analysis

3.2. Intellectual structure

The intellectual structure reflects frequently cited works and thematic linkages that collectively shape the research field.

3.2.1. Co-citation analysis of authors

As examples, Figure 6 presents two clusters showing co-citation analysis. The blue cluster shows authors like Wang, Zhang, Liu, Jiang, Li, Wu, and Huang. These authors have worked together closely. Wang has collaborated with Zhang, Chen, Liu, Xu, and Jiang. Wang has collaborated with different authors from varied fields of interest, and this has ultimately let him capture broader research areas. For instance, in one research paper Wang et al. confirmed and highlighted the versatile role of three-dimensional printing in tackling COVID-19 challenges,

leading future researchers to focus on the hurdles encountered by the additive manufacturing industry, indicating the need for further investigations to enhance three-dimensional printing technology (Wang et al. 2021). Alternatively, as part of the COVID-19 implications for BRICS Countries (Wang et al., 2021) opine on green finance as an appropriate financial strategy to reduce carbon dioxide emissions. The shape of the sphere represents how many co-citations are done by the author, the bigger the sphere is, the larger the number of co-citations of the authors. The red cluster represents the authors Hosseini, Steffen, Klemes, Elavarsan, and Birol. The combination of the pandemic epidemic and turbulent market circumstances has diverted policymakers', corporate leaders', and investors' focus away from renewable energy transitions. Hosseini and Birol explain the need to re-structure energy and climate policies over the next few years to better achieve the desired long-term trajectory towards green power generation and utilization (Birol 2020; Hosseini 2020). Additionally, the inter-cluster association is also clearly visible from the figure. For instance, Wang has collaborated with Hosseini, and Hosseini has collaborated with Zhang, and Chen as well.

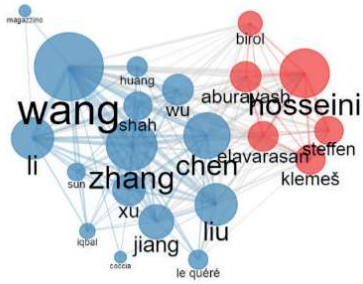


Figure 6. Co-citation authors network

3.3. Conceptual structure

This section, using the conceptual framework of the relevant scholarship, discusses the many facets of COVID-19's influence on the energy industry, including keyword co-occurrence (Fig. 7) and the strategic diagram of the thematic map. (Fig. 8), further cushioned by the inductive analysis that highlights the aggregate dimensions from the study.

Keyword co-occurrence examines the authors' main keywords by developing strategic diagrams utilizing co-occurrence network analysis and co-word analysis (Fig. 7 and 8), highlighting the major themes studied in the 80 publications covered in this study (Aria, Cuccurullo 2017). Co-word analysis provides insight into

various themes or concepts within a knowledge domain (Eck van, Waltman 2010). Keywords co-occurrence reveals the patterns and linkages between the themes of the document (Župič, Čater 2015).

Every article has at least four and up to six author keywords which play an important role in characterizing the content of papers. Figure 7 displays the co-occurrence network analysis of 50 terms that appeared at least twice in the 80 articles. The higher the frequency, the larger the nodes; the lines connecting these nodes show co-occurrence. The most commonly included keywords 'renewable energy, 'COVID-19', 'CO_2 emissions', 'SDG 7', 'sustainability', 'air pollution, and 'energy sector' have the highest total link strength for the research studying et al. the impact of COVID-19 on the renewable energy sector.

The most relevant keywords are organized into four groupings in Figure 7. First, with the corpus of knowledge concerned with COVID-19, the focus of research has been on the future of renewable energy. Second, renewable energy has borne great losses during the energy transition, and this is considered in terms of its efficiency and consumption. The third cluster includes terms like energy policy, coronavirus, sars-cov-2, power system stability, and health crisis. The fourth section is devoted to information on COVID-19, its initial outbreak in China, and the control mechanisms of lockdown.

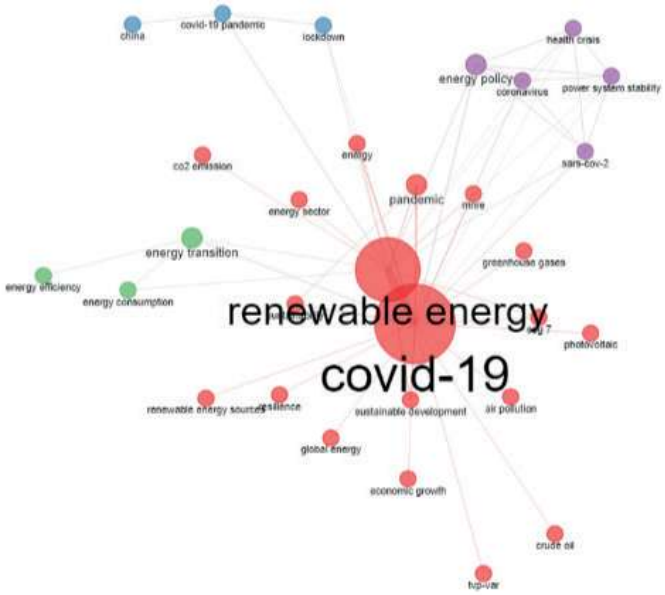


Figure 7. Keywords co-occurrence

To further investigate the influence of COVID-19 on the renewable energy industry, we develop the strategic structure (thematic map) of the relevant scholarship. We examined 50 keywords and utilized the bibliometric package with R software to create the strategic diagram. The strategic diagram categorizes the topics based on two measures: centrality and density (Cobo et al. 2015). The thematic map (Fig. 8) presents seven themes spread across the four quadrants namely motor, Niche, Emerging or Declining and Basic themes.

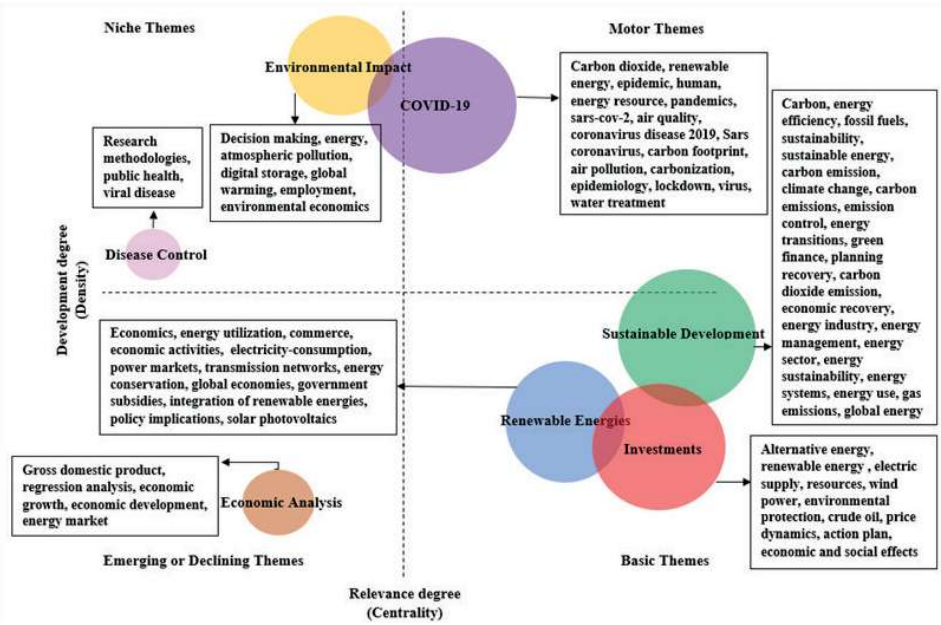


Figure 8. Thematic map

Motor themes include COVID-19 with subthemes such as carbon dioxide, renewable energy, epidemic, human energy resources, pandemics, carbon footprints, and air pollution. This industry has seen a considerable drop in emissions (58 percent of the overall reduction by sector for January–April 2020), with coal power generation's carbon dioxide emissions decreasing by 508 Mt CO2 compared to the same period in 2019. The entire reduction was projected to be 1749 Mt CO2, or 14.3%, with the COVID-19-induced lockdown from January to April 2020 accounting for the majority of the decline (Sikarwar et al. 2021). In contrast to this lockout, measures have a large short-term impact on carbon emissions. Although the reduction in carbon emissions was only transitory, it demonstrated that we

can cut carbon emissions in the long run if suitable restrictions are implemented at the city, national, continental, and global levels. Several major cities and nations with substantial carbon-emission-related operations and long-term lockdown efforts lowered carbon emissions dramatically in 2020. Numerous large cities and nations, on the other hand, that were either unaffected by COVID-19 or did not implement rigorous lockdown measures in 2019 had a limited or no influence on carbon emissions in 2020. This implies that considerable reductions in carbon emissions may be unachievable in the long run without major and long-term changes in human activities that cause a rise in carbon emissions (Ray et al. 2022). Recent studies have shown genetic material of the SARS-CoV-2 virus can be found in sludges and wastewater. When it comes to COVID-19, a significant portion of the human faeces waste generated in impoverished nations is not appropriately processed. Additionally, there is a critical shortage of skilled staff to operate and maintain the treatment works. In order to effectively manage the COVID-19 risk, the challenge is to place a greater emphasis on process control and to incorporate extra treatment stages, such as chlorination, and the use of renewable energy in the treatment process (Chen et al. 2021).

Niche themes include environmental impact and disease control, and these further incorporate energy, atmospheric pollution, and public health respectively. The quantity of medical waste created in Ahmedabad, India, surged from 550–600 kg/day to roughly 1000 kg/day during the first phase of the lockdown. COVID-19 created around 206 million tons of medical waste each day in Dhaka. As a result, medical waste (such as needles, syringes, bandages, masks, gloves, used tissue, and discarded medications) must be properly managed in order to avoid further infection and environmental pollution, which is now a global problem (Doremalen van et al. 2020; Rume, Islam 2020). Although experts and responsible authorities advise that home organic waste and plastic-based protective equipment (hazardous medical waste) be disposed of and separated appropriately, combining these wastes increases the risk of disease transmission and trash workers' exposure to the virus (Ma et al. 2020; Somani et al. 2020).

Emerging or declining themes include economic analysis which further includes subthemes such as economic development and economic growth. Apergis and Apergis suggest that COVID-19 has caused supply shocks by destroying production capacity and disrupting supply systems (Apergis E., Apergis N. 2021). Even if human capital is disrupted (due to a recession), growth can be the result of technological progress, provided manufacturing supply embodies product innovation and the latest methodologies to accommodate change. Inegbedion implemented a standard global computable general equilibrium model to describe the underutilization of labor and capital, an increase in international trade costs, and a redirection of demand away from activities that require proximity between

people (Inegbedion 2021). COVID-19 has brutalized communities by spreading infection and death indiscriminately across countries (Lucas 2020).

Basic themes include sustainable development, renewable energies, and investment, these further include subthemes such as climate change, power markets, and alternative energy respectively. Setting up a sustainable system is an effective, yet urgently needed, answer. Priority areas are identified in seven early lessons: reducing environmental harm and vulnerability to dangerous feedback; promoting urban sustainability; and improving risk analysis and management. These lessons will be useful in coping with the impending global disasters that humanity faces, such as starvation, water shortages, further pandemics, and, eventually, climate change — which will worsen all other crises (Munasinghe 2020). The deployment of sustainable systems necessitates strong and effective policies in the region, as well as the most appropriate methodologies and practices (Amir and Khan 2022). The COVID-19 epidemic is the first of its kind, and it brought global economic activity to a halt. It is projected to have a significant negative impact on businesses' cash flow. Unlike the global financial crisis, which began because of financial suffering, the COVID-19 pandemic is a health disaster with worldwide economic ramifications, accompanied by disruptions created by lockdowns and travel-related restrictions. There is a great deal of ambiguity about how it will affect various economic, social, and political structures. The availability of vaccines, as well as how rapidly consumer and business sentiments may return to pre-pandemic levels, will determine future success. During a downturn, investors pay more attention to corporate fundamentals. As a result, the ESG approach's relative outperformance stems from the fact that the likelihood of its returns being influenced by the other two safer investment methods rises during times of crisis. It denotes a shift of capital from defensive and EAFE (stocks from Europe, Australasia, and the Far East) portfolios to ESG (environmental, social, and governance) portfolios. Investors seek sanctuary in an ESG strategy which focuses on a company's long-term viability (Singh 2020).

This strategic map develops an understanding of a theme which requires immediate attention: economic analysis. COVID-19 in the context of renewable energy lacks a focus on the economic losses endured by countries which can be attributed to the reduction in renewable energy production during the pandemic. As a result of this, many countries experienced setbacks in terms of economic growth and development, with some nations in Africa, for example, suffering more losses based on the structure of their economies, the export of certain goods, the scope of trade and investment, the present state of public finances, the level of rigor, and the duration of public health measures implemented. According to the United Nations Conference on Trade and Development, the Solar PV business employs 3.9% of Africans. These employment opportunities in East, West, and

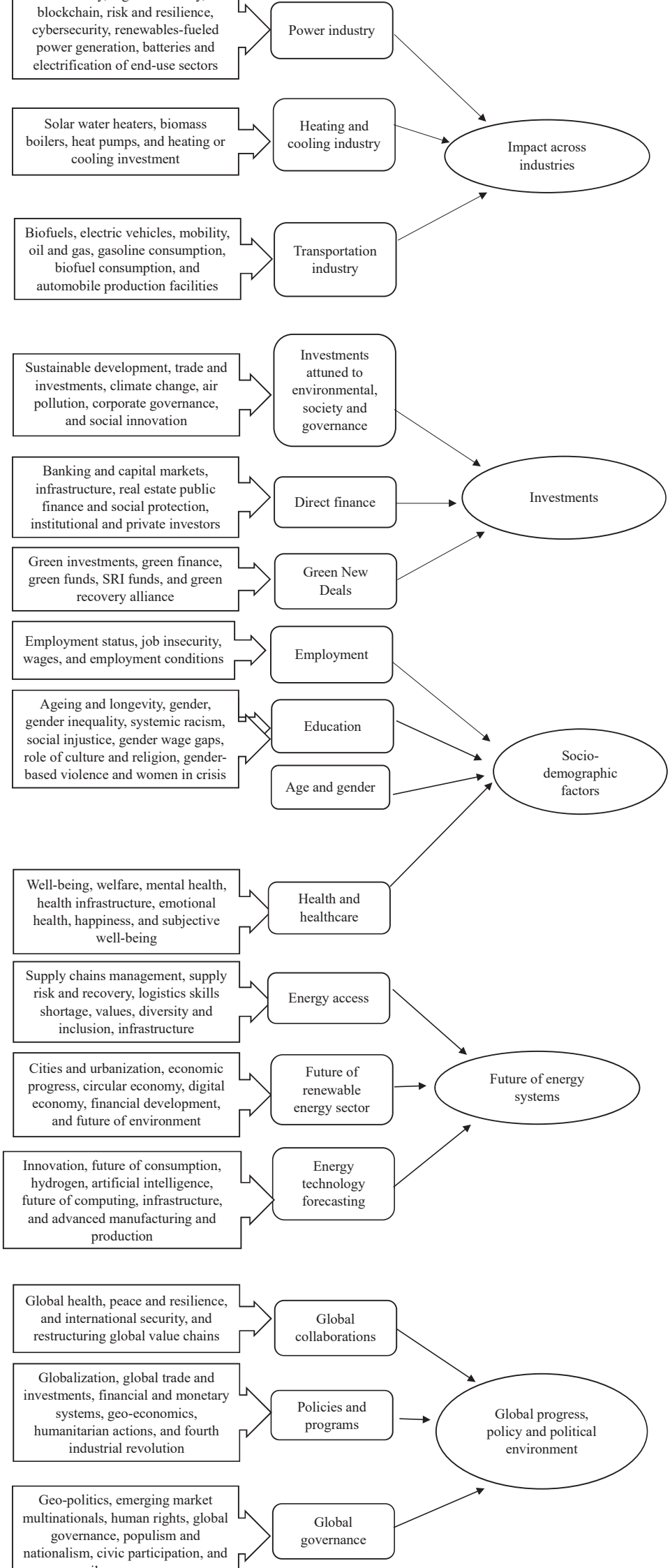
Central Africa can be filled by at least seven million people using a sustainable value chain (Amir, Khan 2022).

The sector is also facing challenges such as supply chain delays, stock market concerns, a lack of incentives, and the possibility of losing access to government subsidies. If incentives are not matched with clean energy targets, there will most likely be a large drop in clean energy expenditures, which will have a domino effect. Forecasts of a wind energy catastrophe, for example, have already begun. LM Wind Power and Siemens Gamesa in Spain have announced their decision to cease production of wind turbine blade plants. It was reported that the installation of 100 wind turbines in the Outer Moray Firth was halted due to the COVID-19 outbreak, and that other aspects of the delivery phase were also halted (Amir and Khan 2022). The identical scenario applies to the solar business. Because of the COVID-19 pandemic, renewable energy predictions for 2020 are down by 28%. According to reports, persons working in the solar energy industry have been laid off or have suffered as a result of the COVID-19 pandemic (Eroğlu 2021)

4. Discussion

The thematic map of the data structure and keyword co-occurrence form the foundation for conceptualizing the framework and are derived from commonalities revealed in the examination of the conceptual structure of the existing literature, which are reinforced by inductive analysis (Fig. 9 on the interleaf).

Figure 9 represents inductive analysis, indicating aggregate dimensions, themes, and concepts. COVID-19 has affected various industries but majorly affects power industries, transportation industries, and heating-cooling plants. Large electrical consumers, such as industries and commercial buildings, were obliged to shut down or reduce their operations due to the restrictions. This considerably alters working and living styles due to which changes in the volume, profile, and composition of power demand distribution are observed. The shift in load pattern has an additional impact on the electricity system's operation and control. Total electricity generation has decreased in tandem with demand, with coal-fired generation bearing the brunt of the loss. Although the share of renewable power has increased, curtailment rates have also increased. Furthermore, electricity prices in major areas have plummeted, with European electricity markets experiencing the world's largest price drop. The majority of investment projects have been halted, although long-term investments in the electrical sector, as well as the eventual transition to renewables, are projected to be relatively unaffected (Zhong et al. 2020).


blockchain, risk and resilience, cybersecurity, renewables-fueled power generation, batteries and electrification of end-use sectors
Power industry
Solar water heaters, biomass boilers, heat pumps, and heating or cooling investment
Heating and cooling industry
Impact across industries
Biofuels, electric vehicles, mobility, oil and gas, gasoline consumption, biofuel consumption, and automobile production facilities
Transportation industry
Sustainable development, trade and investments, climate change, air pollution, corporate governance, and social innovation
Investments attuned to environmental, society and governance
Banking and capital markets, infrastructure, real estate public finance and social protection, institutional and private investors
Direct finance
Investments
Green investments, green finance, green funds, SRI funds, and green recovery alliance
Green New Deals
Employment status, job insecurity, wages, and employment conditions
Employment
Ageing and longevity, gender, gender inequality, systemic racism, social injustice, gender wage gaps, role of culture and religion, gender-based violence and women in crisis
Education
Age and gender
Socio-demographic factors
Well-being, welfare, mental health, health infrastructure, emotional health, happiness, and subjective well-being
Health and healthcare
Supply chains management, supply risk and recovery, logistics skills shortage, values, diversity and inclusion, infrastructure
Energy access
Cities and urbanization, economic progress, circular economy, digital economy, financial development, and future of environment
Future of renewable energy sector
Future of energy systems
Innovation, future of consumption, hydrogen, artificial intelligence, future of computing, infrastructure, and advanced manufacturing and production
Energy technology forecasting
Global health, peace and resilience, and international security, and restructuring global value chains
Global collaborations
Globalization, global trade and investments, financial and monetary systems, geo-economics, humanitarian actions, and fourth industrial revolution
Policies and programs
Global progress, policy and political environment
Geo-politics, emerging market multinationals, human rights, global governance, populism and nationalism, civic participation, and
Global governance

COVID-19 outbreak has had a significant impact on the solar energy business, which is one of the most important renewable and sustainable energy sources. The sector's key concerns are severe employment losses, short-term difficulties for businesses, and job disruption or delay. It has been noticed that relatively large businesses can overcome challenges quickly. The effects of the pandemic disrupt the dynamics of the sector, which is heavily reliant on people's transportation. In addition, based on prior crises' recoveries, the solar energy sector is projected to rebound quickly following the pandemic. In general, governments in the industry are expected to provide significant incentives and take action to alleviate the backlog (Eroğlu, Cüce 2021). The outbreak has had a significant impact on interstate travel as well as movement within and between cities. Sobieralski examined the airline industry, discovering that major airlines' capacity had dropped by 60–80% Employees with lesser skill levels will be affected more severely (Sobieralski 2020). Airlines reacted differently to travel restrictions imposed by the government. The pandemic had a tremendous influence on the cruise liner business as well.

Investments attuned to the environment, society, and governance, direct finance, and Green New deals form an aggregate dimension of investment. Some investors have yet to come across socially responsible investing (SRI) funds on the market and are concerned about the absence of national support and endorsement for SRI funds. Investors are more interested in SRI funds as a result of the salience of the pandemic, adding to the idea that the general public is risk-averse in situations of disease yet cares about the environment (social benefits and sustainable development) (Xu et al. 2022). The prospect of a pandemic isn't the only issue deterring investors. Business environment, inadequate infrastructure, natural disasters, diverse and difficult geography, and climate change are some of the other factors to consider (Chaudhary et al. 2020). Many green initiatives have larger short-run multipliers (they require a large initial investment), but low operational costs, minimal climatic imprint, and hence increased long-term sustainability. The Green New Deals being proposed in many nations should prioritize such investments. Some of these are self-evident, such as solar power or building retrofits. Carbon intensity provides some insight into corporate performance during the epidemic, although ESG data appears to be less informative. We suggest that financial data be used to build new indicators that can be used to guide investors (Mukanjari, Sterner 2020).

Socio-demographics contribute towards constructing one aggregate dimension including themes such as employment, education, age, gender, health, and healthcare. This aggregate dimension is used as a backdrop to understand the influence of COVID 19 on another aggregate dimension.

The future of the energy system includes themes such as energy access, the renewable energy sector and energy technology forecasting. Meanwhile,

the future of renewable energy depends upon the seamless implementation of technologies to produce renewable energy. There is a direct connection between the level of technological maturity and the presence of economic barriers. An economic barrier is present when the cost of a particular technology is higher than the cost of competing alternative technologies, even under perfect market conditions. Although they are not directly economic in nature, the remaining sorts of obstacles are still considered to play a significant part in determining the prices of renewable energy sources which in turn hinders the implementation process. The significance of the obstacles varies according to both the technology and the market, and the order of priority shifts as a product develops along the path to commercialization. On other hand, there is a wide range of renewable energy technologies that are currently accessible, each of which is in a different stage of the development cycle. Both hydropower and biofuels are rapidly becoming significant contributors to the global energy supply. Even if their technological viability has been demonstrated and they are commercially available, other options still only cover a small portion of the markets that may be served by them. Because of this, there are a multitude of options to enhance performance while also lowering expenses (Ellabban et al. 2014).

Global progress, policy and political environment include themes such as global collaboration, policy, programmes and global governance. Renewable energy policies differ widely in terms of the technologies and energy sources they contain, as well as the policy tools used to promote them. There are required and optional targets, various incentive programs, varied suggested renewable energy sources, and other differences in policies such as renewable portfolio standards (RPSs) at the state level in the United States, as well as several regional and municipal governmental policies. These policies are samples of the numerous policy kinds that exist (Levenda et al. 2021).

In addition, the conflict between Ukraine and Russia has had significant effects on the global energy landscape (Trunina et al. 2022; Liao 2023). The constrained state of the global energy market, which has been exacerbated by a variety of supply-and-demand fluctuations, is a crucial factor exacerbating the energy crisis. Among these are the COVID-19 pandemic and geopolitical tensions in other regions (Chen et al. 2023). This combination of factors has caused a global increase in energy costs, with some regions experiencing natural gas price peaks never seen before (Osička, Černoch 2022). Russia's incursion into Ukraine in February 2022 sent shockwaves throughout Europe and exposed starkly the continent's geopolitical dependence (Kuzemko et al. 2022). The Russia-Ukraine conflict has exacerbated Europe's energy crisis by interfering with gas deliveries and heightening preexisting concerns about energy security. Given Russia's significant role as a supplier of natural gas to Europe, any disruptions to this supply chain

have significant effects on energy costs and availability (Bricout et al. 2022). The termination of long-term agreements for additional volumes of Russian gas has had a substantial impact on immediate solutions to the energy crisis (Estrada, Koutronas 2022). In the long-term, this geopolitical dynamic has eroded Europe's resistance to Russian energy pressures, culminating in a European energy crisis characterized by decreased production, limited gas reserves, elevated prices, and constrained global supplies (Kravchenko et al. 2023). However, the conflict has served as a wake-up call, highlighting the significance of renewable energy, particularly in Europe. The insufficiency of energy resources prompted European businesses to reduce their reliance on Russian oil and gas, highlighting the need to investigate alternative avenues, such as the development or acquisition of renewable energy (Liao 2023). Alternately, the development of energy ties between Europe and Ukraine is motivated by distinct political interests, and the economic dimensions of these ties are materialized by the assurance of securing additional electricity in the event of unforeseen events (Koval et al. 2023). These geopolitical upheavals have shed additional light on Europe's reliance on natural gas and emphasized the need to fasten the transition to renewable energy sources (Carfora et al. 2022). Europe has already implemented a variety of measures to reduce its reliance on gas, including the promotion of renewable energy sources such as wind and solar power and the improvement of energy efficiency. However, the crisis has highlighted the need to expedite these initiatives and promote more robust and resilient energy systems (Kravchenko et al. 2023).

Figure 10 represents a conceptual framework. This hierarchical framework positions the healthcare sector with an emphasis on disease control as the first tier, environmental impact as the second tier, economic impact, sustainable development, and investments as the third tier, and finally, the top tier is occupied by clean and affordable energy. Disease control is positioned at the lowest tier, as the first step to achieving clean energy is controlling the pandemic at the healthcare level. Many countries imposed extraordinary curfews and proclaimed states of emergency. It generated fear, worry, and a climate of stress in both developed and developing cultures. However, social anxiety and panic owing to uncertainty, economic recessions, and excessive mental stress are a result of its extreme isolation and lockdown tactics (Studdert et al. 2020). Within two weeks of full vaccination, the vaccine was proven to be 94–95 percent effective against the original strand of the COVID-19 virus. Vaccines also have a high effectiveness rate in protecting patients against the COVID-19 virus's devastating diseases. SDG-3 (good health and well-being) has aims, which emphasize the importance of understanding and resolving "communicable, non-communicable, and environmentally induced diseases," and are particularly significant for efforts to battle COVID-19 and other infectious diseases. With the paucity of screening

tests, hospital beds, medical supplies, and essentials like water and toilet paper, COVID-19 has forced many to reassess its impact on society. COVID-19 has stressed the necessity of potential preventative actions like as facemask use, social distance, frequent handwashing, school and university closures, and further travel limitations (Seshaiyer, McNeely 2020).

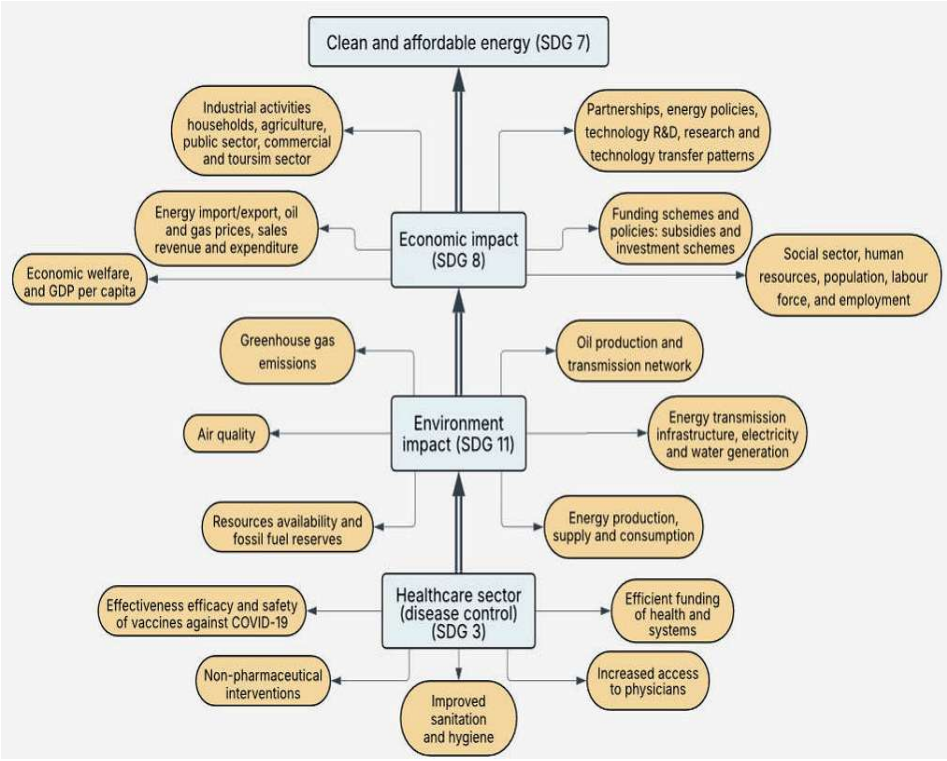


Figure 10. Conceptual framework

COVID-19 has severe effects on the environment and, in particular, the renewable energy industry. Soil and water quality are negatively impacted when individuals cleanse their hands more frequently, governments and local governments mass disinfect, and single-use plastics containing bisphenol A (BPA) are mass-produced. Products containing alcohol that are poured in water are hazardous to aquatic life, and products containing alcohol that are smeared on soil can contaminate groundwater. Detergents discharged into water create froth in bodies of water. Soap use over an extended period of time may lead to soil

contamination, degrading the soil's quality (Ankit et al. 2021). The COVID-19 outbreak is also causing havoc in the worldwide renewable energy supply chain. If incentives are not aligned with renewable energy goals, clean energy investment will almost certainly fall precipitously, causing a domino effect. The spread of COVID-19 and the suspension of a wind power station in North Dakota are two prime examples of the epidemic's effects on the renewable energy industry. Due to the COVID-19 outbreak, the installation of 100 wind turbines in the Outer Moray Firth was halted, as were some aspects of the delivery phase. The solar industry is in a comparable situation. As a result of the COVID-19 epidemic, solar energy workers have reportedly been dismissed or have suffered other negative consequences (Eroğlu, 2021) . The pandemic has also exhibited a significant lack of comprehensive disaster risk management policy at all levels of government (Pradhan et al. 2021). Recognizing changes in energy consumption patterns, establishing online portals, and developing post-pandemic methods for launching new projects are just a few of the numerous issues that have surfaced in the aftermath of COVID (Elavarasan et al. 2021).

The third tier of the framework includes economic analysis, partnership, and investment. Economies have to go through large contractions. Multiple fundamental factors have contributed to this economic downturn. These include direct reductions in the available personnel resulting from fatalities and infections, as well as the associated medical expenses. In addition, there are declines in household expenditure and corporate investment, primarily due to security measures and heightened uncertainty. The disruption of global trade and value chains as a result of lockdowns has also played a role, as have potential persistent effects that impede a return to the economy's pre-crisis state (Caracciolo et al. 2020). According to Chudik et al., the COVID-19 pandemic could result in enduring declines in global real GDP, with varying consequences across regions and countries (Chudik et al. 2021). While the impact on the United Kingdom and other developed economies could be severe, it is anticipated that China and other emerging Asian economies will be relatively unaffected. In addition, it is anticipated that the pandemic will temporarily drive long-term interest rates in advanced core countries below their levels prior to COVID-19. Emerging regions, on the other hand, are likely to encounter the opposite scenario, posing challenges for managing debt service costs.

COVID-19 has ushered in the world's biggest economic downturn since the Great Depression, resulting in 400 million job losses in the second quarter of 2020, and a 4.2 percent drop in GDP per capita in 2020. Contributing to the formulation of an economic recovery plan is extremely important in this regard, especially with a focus on the research avenues, such as performing evidence-based economic

assessments for long- and short-term recovery planning and policy initiatives to promote small and medium firms after COVID-19 (Ranjbari et al. 2021). By identifying and testing the linkages between essential aspects of behavioral and social change partnerships, global efforts are taken in terms of investment. When it comes to managing behavioral difficulties, this research has demonstrated the importance of trust, commitment, shared values, and teamwork (Duane et al. 2022).

All three tiers lead to the fulfilment of the common objective of clean and affordable energy. The energy sector was directly confronted with several technical issues, including decreased energy demand and a shift in demand patterns. It eventually had an impact on the utilities' revenue collection and caused them to postpone development initiatives. Due to COVID-19 restrictions, a significant portion of the workforce utilized digital technology to work from home, increasing the risk of cyberattacks on networks and control systems. As energy demand has decreased, the oil-exporting economies have become especially susceptible to COVID-19, suffering from price declines and labour disruptions due to closures. It is generally accepted that harvesting renewable energy is the safer and more eco-friendly option that will benefit both humanity and the environment. According to the technological evaluation, the transportation and construction industries have substantial opportunities to reduce emissions. The construction of energy storage systems and the improvement of passive cooling systems are two additional methods to reduce energy consumption. Additionally, for a community, thermal storage containers combined with renewable-based heating could make it economically feasible to spend as a group rather than individually, which would be environmentally beneficial. If the market for electric vehicles in the transportation industry expands in the post-COVID era, it will accelerate the digital revolution in a variety of disciplines, from smart infrastructure to autonomous vehicles. Massive expenditures and technological advancements are necessary for large-scale hydrogen generation and storage in order to see a change in pollution mitigation. Meanwhile, the emphasis should transition from hydrogen production based on fossil fuels to ecological hydrogen production based on renewable energy. Nonetheless, this would encourage renewable energy system growth (Elavarasan et al. 2021).

5. Future research agendas

Figure 7 is a network diagram illustrating the co-occurrence of terms in paper titles and abstracts, with the intent of identifying emerging themes related to COVID-19 in the global renewable energy literature. Each node on the map

represents a unique term and is sized based on its frequency across the eighty documents analysed. The distance of the connections between nodes represents the degree of association between the words. The nodes are color-coded and divided into clusters based on their similarity, which facilitates the identification of distinct subfields and prospective research gaps for future study.

The six major sectors highlighted are human resource management (HRM), finance/economics, education and research, marketing, micro-level (operations), and macro-level (destination). These thematic areas highlight topics that present research opportunities. Understanding how the pandemic has affected renewable energy and post-COVID practices, particularly in terms of development, is a focus of HRM. In the realms of finance and economics, the phase of recovery following the pandemic elicits questions regarding the adoption of renewable energy, investor confidence, financial mechanisms, and government interventions. Education and research provide opportunities for shaping research agendas in the post-pandemic environment by integrating educational technologies, investigating experiential learning approaches, and broadening the scope of the discipline via a curriculum adapted to the post-COVID era.

6. Policy implications and concluding remarks

The global COVID-19 epidemic has had a significant impact on individuals, communities, and nations. It is evident from the preceding discussion that economic activities in each country have had a significant impact on the transition to renewable energy. Policy actions taken in the energy sector during the COVID-19 epidemic have had an impact on renewable energy production and use. The impacts of the COVID-19 pandemic on the energy industry have been thoroughly studied in the literature, however the implications on renewable energy generation remain unexplored (Dong et al. 2022). Policies that can withstand severe disruptions and protect investments in renewable energy from potential dangers are highly desirable. The government may accelerate the renewable energy by abandoning conventional forms of energy production. Government officials must define authorized pandemic responses in order to establish short-term policy goals that promote both the recovery effort and the growth of renewable energy sources (Hoang et al. 2021). The structural ramifications of the changing energy system, as well as the potential collateral impacts of such policy changes, should be given special consideration (Pahle et al. 2018).

The ongoing conflict between Ukraine and Russia and the uncertainty around natural gas supplies have significant implications for the future development of

the European energy transition. Ukraine has historically served as a key transit route for Russian gas supplies to Europe, and any disruption to this supply chain can have far-reaching consequences. One of the main consequences of the Ukraine-Russia conflict is that it has highlighted the need for Europe to diversify its energy sources and reduce its dependence on Russian gas (Bricout et al. 2022; Carfora et al. 2022). The Ukraine-Russia conflict serves as a reminder that Europe must reduce its reliance on fossil fuels and accelerate the transition to greener, more sustainable energy sources. It highlights the importance of developing a more diverse and resilient energy system that is less vulnerable to geopolitical risks and supply chain disruptions. The policy responses to the crisis thus far have had varying effects on these objectives. On the one hand, there is significant potential for the acceleration of Europe's renewable energy supply. This could contribute to the reduction of greenhouse gas emissions and the improvement of air quality, which would have positive environmental and health effects. On the other hand, there are complications for fossil fuel phase-out. The crisis has had a significant impact on oil and gas prices, which has made it more difficult for some countries to transition away from fossil fuels. In addition, some governments have provided financial support to fossil fuel companies, which may slow down the transition toward clean energy. In terms of energy equity and social justice, the crisis has had significant implications both within and beyond Europe. The economic impacts of the crisis have hit vulnerable populations the hardest, and there is a risk that the transition toward clean energy could exacerbate existing inequalities. For example, if energy prices rise because of investments in renewable energy, low-income households may be disproportionately affected.

Considering the pandemic scenario, research should be conducted to create the most efficient solar cells at the lowest cost, mass produce them, and deploy them. Potentially, solar energy production and energy storage could be combined by using novel electrocatalysts and renewable energy, synthesizing chemicals and fuels more efficiently, or generating electricity from a variety of fuels more efficiently using improved fuel cells. Since electrifying vehicles can cut fossil fuel usage (despite crude oil's historically low price), more powerful, less expensive, and safer Li-ion batteries are needed (Jin 2020).

The well-being and prosperity of current and future generations can be assured through successful regulation of the use of natural resources. To address every aspect of the problem, effective environmental policies, including carbon-neutral policies, would necessitate the use of one (or a combination) of the available instruments, such as direct regulation (of water quality or vehicle emissions), public spending, and technology programs, as well as information provision and policies to address barriers to behavior change. Furthermore, public-private collaborations in renewable energy producing projects are critical for job

development and economic recovery. State funding agencies and government programs should be expedited to provide financial relief measures to enhance the supporting factors behind renewable energy generation and restoring the energy distribution network.

As all the studies, our study also has a few limitations. The availability and quality of data is affected as the database used in the study is WoS and this led us to omit papers that may be found in other sources such as Scopus. This limited data extraction may have compromised the comprehensiveness of the study and introduced potential biases or uncertainties into the findings. The study also suffers from limitations in terms of publications, resulting in the exclusion of pertinent information from unpublished or non-English sources. This could affect the overall representativeness and generalizability.

This study uses predetermined timeframes (includes studies until March 2022), therefore the swiftly evolving nature of the subject matter may result in the omission of recent developments or studies that were not yet published during the review period. Moreover, the methodology of the review may have certain limitations, namely the exclusion of certain keywords during data extraction.

Declaration of competing interest

None

Role of funding source

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

We are grateful to our employers for providing us with the infrastructure and resources to conduct this research.

References

[1] Amir, M. and Zubair, S. (2022) 'Assessment of renewable energy: Status, challenges, COVID-19 impacts, opportunities, and sustainable energy solutions in Africa', *Energy and Built Environment*, vol. 3, No. 3, pp. 348–362, https://doi.org/10.1016/j.enbenv.2021.03.002.

[2] Ampofo, A. and Mabefem, M.G. (2021) 'Religiosity and Energy Poverty: Empirical evidence across countries', *Energy Economics*, vol. 102, No. July, 105463, https://doi.org/10.1016/j.eneco.2021.105463.

[3] Ankit, Kumar, A., Jain, V., Deovanshi, A., Lepcha, A., Das, C., Bauddh, K. et al. (2021) 'Environmental impact of COVID-19 pandemic: more negatives than positives', *Environmental Sustainability*, vol. 4, No. 3, pp. 447–454.
[4] Apergis, E. and Apergis, N. (2021a) 'The impact of COVID-19 on economic growth: evidence from a Bayesian Panel Vector Autoregressive (BPVAR) model', *Applied Economics*, vol. 53, No. 58, pp. 6739–6751, https://doi.org/10.1080/00036846.2021.1946479.
[5] Aria, M. and Cuccurullo, C. (2017) '*bibliometrix*: An R-tool for comprehensive science mapping analysis', *Journal of Informetrics*, vol. 11, No. 4, pp. 959–975, https://doi.org/10.1016/j.joi.2017.08.007.
[6] Bergh, J.C.J.M. van den and Bruinsma, F.R. (eds.) (2008) Managing the Transition to Renewable Energy: Theory and Practice from Local, Regional and Macro Perspectives, Cheltenham, UK; Northampton, MA, USA: Edward Elgar.
[7] Bertram, C., Luderer, G., Creutzig, F., Bauer, N., Ueckerdt, F., Malik, A. and Edenhofer, O. (2021) 'COVID-19-induced low power demand and market forces starkly reduce CO2 emissions', *Nature Climate Change*, vol. 11, No. 3, pp. 193–196, https://doi.org/10.1038/s41558-021-00987-x.
[8] Bertrand, M., Briscese, G., Grignani, M. and Nassar, S. (2020) 'How are Americans coping with the COVID-19 crisis? 7 key findings from household survey', Chicago Booth. The University of Chicago Booth School of Business, Rustandy Center for Social Innovation, [Online], Available: https://www.chicagobooth.edu/research/rustandy/stories/american-households-coping-with-covid19-crisis-7-findings [8 Oct 2025].
[9] Birol, F. (2020) Put Clean Energy at the Heart of Stimulus Plans to Counter the Coronavirus Crisis, IEA, [Online], Available: https://www.iea.org/commentaries/put-clean-energy-at-the-heart-of-stimulus-plans-to-counter-the-coronavirus-crisis [8 Oct 2025].
[10] Bricout, A., Slade, R., Staffell, I. and Halttunen, K. (2022) 'From the geopolitics of oil and gas to the geopolitics of the energy transition: Is there a role for European supermajors?', *Energy Research & Social Science*, vol. 88, No. 102634, https://doi.org/https://doi.org/10.1016/j.erss.2022.102634.
[11] Cañas-Guerrero, I., Mazarrón, F.R., Pou-Merina, A., Calleja-Perucho, C. and Díaz-Rubio, G. (2013) 'Bibliometric analysis of research activity in the 'agronomy' category from the web of science, 1997–2011', *European Journal Agronomy*, vol. 50, pp. 19–28, https://doi.org/10.1016/j.eja.2013.05.002.
[12] Caracciolo, G., Cingano, F., Ercolani, V., Ferrero, G., Hassan, F., Papetti, A. and Tommasino, P. (2020) 'Covid-19 and economic analysis: A review of the debate', *Banca d'Italia*, vol. 2, No. 1, pp. 1–11.
[13] Carfora, A., Pansini, R.V. and Scandurra, G. (2022) 'Energy dependence, renewable energy generation and import demand: Are EU countries resilient?', *Renewable Energy*, vol. 195, pp. 1262–1274, https://doi.org/10.1016/j.renene.2022.06.098.

[14] Carmon, D., Navon, A., Machlev, R., Belikov, J. and Levron, Y. (2020) 'Readiness of Small Energy Markets and Electric Power Grids to Global Health Crises: Lessons from the COVID-19 Pandemic', *IEEE Access*, vol. 8, pp. 127234–127243, https://doi.org/10.1109/ACCESS.2020.3008929.
[15] Castaño-Rosa, R., Solís-Guzmán, J., Rubio-Bellido, C. and Marrero, M. (2019) 'Towards a multiple-indicator approach to energy poverty in the European Union: A review', *Energy and Buildings*, vol. 193, pp. 36–48, https://doi.org/10.1016/j.enbuild.2019.03.039.
[16] Chakraborty, I. and Maity, P. (2020) 'COVID-19 outbreak: Migration, effects on society, global environment and prevention', *Science of the Total Environment*, vol. 728, https://doi.org/10.1016/j.scitotenv.2020.138882.
[17] Chaudhary, M.K., Ghimire, R.P. and Ghimire, D.M. (2020) 'Impact of Covid-19 pandemic on foreign direct investment in Nepal with South Asian perspective', *Journal of Developing Economies*, vol. 5, No. 2, pp. 137–146, http://dx.doi.org/10.20473/jde.v5i2.21409.
[18] Chen, C., Hayward, K., Khan, S.J., Örmeci, B., Pillay, S., Rose, J.B., Thanikal, J.V. et al. (2021) 'Role of wastewater treatment in covid-19 control', *Water Quality Research Journal*, vol. 56, No. 2, pp. 68–82, https://doi.org/10.2166/wqrj.2020.025.
[19] Chen, Y., Jiang, J., Wang, L. and Wang, R. (2023) 'Impact assessment of energy sanctions in geo-conflict: Russian–Ukrainian war', *Energy Reports*, vol. 9, pp. 3082–3095, https://doi.org/10.1016/j.egyr.2023.01.124.
[20] Chudik, A., Mohaddes, K., Pesaran, M.H., Raissi, M. and Rebucci, A. (2021) 'A counterfactual economic analysis of Covid-19 using a threshold augmented multi-country model Q', *Journal of International Money and Finance*, vol. 119, 102477, https://doi.org/10.1016/j.jimonfin.2021.102477.
[21] Cobo, M.J., Martínez, M.A., Gutiérrez-Salcedo, M., Fujita, H. and Herrera-Viedma, E. (2015) '25 years at Knowledge-Based Systems: A bibliometric analysis', *Knowledge-Based Systems*, vol. 80, pp. 3–13, https://doi.org/10.1016/j.knosys.2014.12.035.
[22] Cronin, M.A. and George, E. (2020) 'The why and how of the integrative review', *Organizational Research Methods*, vol. 26, No. 1, https://doi.org/10.1177/1094428120935507.
[23] Deller, D. (2018) 'Energy affordability in the EU: The risks of metric driven policies', *Energy Policy*, vol. 119, pp. 168–182, https://doi.org/10.1016/j.enpol.2018.03.033.
[24] Dong, C., Ji, D., Mustafa, F. and Khursheed, A. (2022) 'Impacts of COVID-19 pandemic on renewable energy production in China: transmission mechanism and policy implications', *Economic Research.– Ekonomska Istraživanja*, vol. 35, No. 1, pp. 3857–3870, https://doi.org/10.1080/1331677X.2021.2005651.

[25] Doremalen van, N., Bushmaker, T., Morris, D.H., Holbrook, M.G., Gamble, A., Williamson, B.N., Tamin, A. et al. (2020) 'Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1', *New England Journal of Medicine*, vol. 382, No. 16, pp. 1564–1567, https://doi.org/10.1056/NEJMc2004973.
[26] Duane, S., Domegan, C. and Bunting, B. (2022) 'Partnering for UN SDG #17: a social marketing partnership model to scale up and accelerate change', *Journal of Social Marketing*, vol. 12, No. 1, pp. 49–75, https://doi.org/10.1108/JSOCM-10-2020-0200.
[27] Eck van, N.J. and Waltman, L. (2010) 'Software survey: VOSviewer, a computer program for bibliometric mapping', *Scientometrics*, vol. 84, No. 2, pp. 523–538, https://doi.org/10.1007/s11192-009-0146-3.
[28] Elavarasan, R.M., Pugazhendhi, R., Jamal, T., Dyduch, J., Arif, M.T., Manoj Kumar, N., Shafiullah, G.M. et al. (2021) 'Envisioning the UN Sustainable Development Goals (SDGs) through the lens of energy sustainability (SDG 7) in the post-COVID-19 world', *Applied Energy*, vol. 292, No. April, 116665, https://doi.org/10.1016/j.apenergy.2021.116665.
[29] Ellabban, O., Abu-Rub, H. and Blaabjerg, F. (2014) 'Renewable energy resources : Current status, future prospects and their enabling technology', *Renewable and Sustainable Energy Reviews*, vol. 39, pp. 748–764, https://doi.org/10.1016/j.rser.2014.07.113.
[30] Eroğlu, H. (2021) 'Effects of Covid-19 outbreak on environment and renewable energy sector', *Environment, Development and Sustainability*, vol. 23, No. 4, pp. 4782–4790, https://doi.org/10.1007/s10668-020-00837-4.
[31] Eroğlu, H. and Cüce, E. (2021) 'Solar energy sector under the influence of Covid-19 pandemic: A critical review', *Journal of Energy Systems*, vol. 5, No. 3, pp. 244–251, https://doi.org/10.30521/jes.942691.
[32] Estrada, M.A.R. and Koutronas, E. (2022) 'The impact of the Russian Aggression against Ukraine on the Russia-EU Trade', *Journal of Policy Modeling*, vol. 44, No. 3, pp. 599–616, https://doi.org/10.1016/j.jpolmod.2022.06.004.
[33] Fan, D., Breslin, D., Callahan, J.L. and Iszatt-White, M. (2022) 'Advancing literature review methodology through rigour, generativity, scope and transparency', *International Journal of Management Reviews*, vol. 24, No. 2, pp. 1–10, https://doi.org/10.1111/ijmr.12291.
[34] Fu, M. and Shen, H. (2020) 'COVID-19 and Corporate Performance in the Energy Industry', *Energy RESEARCH LETTERS*, vol. 1, No. 1, pp. 1–5, https://doi.org/10.46557/001c.12967.
[35] Gebreslassie, M.G. (2020) 'COVID-19 and energy access: An opportunity or a challenge for the African continent?', *Energy Research and Social Science*, vol. 68, 101677, https://doi.org/10.1016/j.erss.2020.101677.

[36] Hoang, A.T., Nižetić, S., Olcer, A.I., Ong, H.C., Chen, W.-H., Chong, C.T., Thomas, S. et al. (2021) 'Impacts of COVID-19 pandemic on the global energy system and the shift progress to renewable energy: Opportunities, challenges, and policy implications', *Energy Policy*, vol. 154, 112322, https://doi.org/10.1016/j.enpol.2021.112322.

[37] Hosseini, S.E. (2020) 'An outlook on the global development of renewable and sustainable energy at the time of COVID-19', *Energy Research and Social Science*, vol. 68, 101633, https://doi.org/10.1016/j.erss.2020.101633.

[38] Inegbedion, H. (2021) 'Impact of COVID-19 on economic growth in Nigeria: opinions and attitudes', *Heliyon*, vol. 7, No. 5, e06943, https://doi.org/10.1016/j.heliyon.2021.e06943.

[39] International Energy Agency (2020), 'Global Energy Review 2020 The Impacts of the Covid-19 Crisis on Global Energy Demand and CO2 Emissions', Global Energy Review 2020, https://doi.org/10.1787/a60abbf2-en.

[40] Iqbal, S. and Bilal, A.R. (2021) 'Energy financing in COVID-19: how public supports can benefit?', *China Finance Review International*, vol. 12, No. 2, pp. 219–240, https://doi.org/10.1108/CFRI-02-2021-0046.

[41] Iqbal, S., Bilal, A.R., Nurunnabi, M., Iqbal, W., Alfakhri, Y. and Iqbal, N. (2021) 'It is time to control the worst: testing COVID-19 outbreak, energy consumption and CO_2 emission', *Environmental Science and Pollution Research*, vol. 28, No. 15, pp. 19008–19020, https://doi.org/10.1007/s11356-020-11462-z.

[42] IRENA (2020) Post-COVID Recovery: An Agenda for Resilience, Development and Equality, International Renewable Energy Agency, Abu Dhabi, [Online], Available: https://www.irena.org/publications/2020/Jun/Post-COVID-Recovery [8 Oct 2025].

[43] Ivanov, D. and Dolgui, A. (2021) 'OR-methods for coping with the ripple effect in supply chains during COVID-19 pandemic: Managerial insights and research implications', *International Journal of Production Economics*, vol. 232, 107921, https://doi.org/10.1016/j.ijpe.2020.107921.

[44] Jalal, S.K. (2019) 'Co-authorship and co-occurrences analysis using BibliometrixR package: a case study of india and bangladesh', *Annals of Library and Information Studies*, vol. 66, pp. 57–64, http://op.niscair.res.in/index.php/ALIS/article/view/22404.

[45] Jiang, P., Van Fan, Y. and Klemeš, J.J. (2021) 'Impacts of COVID-19 on energy demand and consumption: Challenges, lessons and emerging opportunities', *Applied Energy*, https://doi.org/10.1016/j.apenergy.2021.116441.

[46] Jin, S. (2020) 'COVID-19, Climate Change, and Renewable Energy Research: We Are All in This Together, and the Time to Act Is Now', *ACS Energy Letters*, vol. 5, No. 5, pp. 1709–1711, https://doi.org/10.1021/acsenergylett.0c00910.

[47] Karmaker, C.L., Ahmed, T., Ahmed, S., Ali, S.M., Moktadir, M.A. and Kabir, G. (2021) 'Improving supply chain sustainability in the context of COVID-19 pandemic in an emerging economy: Exploring drivers using an integrated model', *Sustainable Production and Consumption*, vol. 26, pp. 411–427, https://doi.org/10.1016/j.spc.2020.09.019.
[48] Klein, R.A., Vianello, M., Hasselman, F., Adams, B.G., Adams, R.B., Alper, S., Aveyard, M. et al. (2018) 'Many labs 2: Investigating variation in replicability across samples and settings', *Advances in Methods and Practices in Psychological Science*, vol. 1, No. 4, pp. 443–490, https://doi.org/10.1177/2515245918810225.
[49] Koval, V., Savina, N., Sribna, Y., Filipishyna, L., Zherlitsyn, D. and Saiapina, T. (2023) 'European energy partnership on sustainable energy potential', *IOP Conference Series: Earth and Environmental Science*, vol. 1126, No. 1, 012026, https://doi.org/10.1088/1755-1315/1126/1/012026.
[50] Kravchenko, M., Ilyash, O., Smoliar, L., Boiarynova, K. and Trofymenko, O. (2023) 'Changes in the energy supply strategy of the EU countries amid the full-scale Russian invasion', *IOP Conference Series: Earth and Environmental Science*, vol. 1126, No. 1, 012035, https://doi.org/10.1088/1755-1315/1126/1/012035.
[51] Kuzemko, C., Blondeel, M., Dupont, C. and Brisbois, M.C. (2022) 'Russia's war on Ukraine, European energy policy responses and implications for sustainable transformations', *Energy Research and Social Science*, vol. 93, No. September, 102842, https://doi.org/10.1016/j.erss.2022.102842.
[52] Levenda, A.M., Behrsin, I. and Disano, F. (2021) 'Renewable energy for whom? A global systematic review of the environmental justice implications of renewable energy technologies', *Energy Research and Social Science*, vol. 71, 101837, https://doi.org/10.1016/j.erss.2020.101837.
[53] Li, J., Burnham, J.F., Lemley, T. and Britton, R.M. (2010) 'Citation analysis: Comparison of Web of Science®, Scopus™, SciFinder®, and Google Scholar', *Journal of Electronic Resources in Medical Libraries*, vol. 7, No. 3, pp. 196–217, https://doi.org/10.1080/15424065.2010.505518.
[54] Liao, S. (2023) 'The Russia–Ukraine outbreak and the value of renewable energy', *Economics Letters*, vol. 225, 111045, https://doi.org/10.1016/j.econlet.2023.111045.
[55] Liu, Z., Ye, C., Chen, R. and Zhao, S.X. (2021) 'Where are the frontiers of sustainability research? An overview based on Web of Science Database in 2013–2019', *Habitat International*, vol. 116, 102419, https://doi.org/10.1016/j.habitatint.2021.102419.
[56] Lucas, B. (2020) Impacts of Covid-19 on inclusive economic growth in middle-income countries, [Online], Available: file:///C:/Users/biuro/Downloads/811Covid-19andinclusivegrowth.pdf [8 Oct 2025].
[57] Lv, W., Zhao, X., Wu, P., Lv, J. and He, H. (2021) 'A scientometric analysis of worldwide intercropping research based on Web of Science Database between 1992 and 2020', *Sustainability*, vol. 13, No. 5, 2430, https://doi.org/10.3390/su13052430.

[58] Ma, Y., Lin, X., Wu, A., Huang, Q., Li, X. and Yan, J. (2020) 'Suggested guidelines for emergency treatment of medical waste during COVID-19: Chinese experience', *Waste Disposal and Sustainable Energy*, vol. 2, No. 2, pp. 81–84, https://doi.org/10.1007/s42768-020-00039-8.
[59] Mukanjari, S. and Sterner, T. (2020) 'Charting a "Green Path" for Recovery from COVID-19', *Environmental and Resource Economics*, vol. 76, No. 4, pp. 825–853, https://doi.org/10.1007/s10640-020-00479-0.
[60] Munasinghe, M. (2020) 'COVID-19 and sustainable development COVID-19', vol. 23, Nos. 1/2, https://doi.org/10.1504/IJSD.2020.10034408.
[61] Navon, A., Machlev, R., Carmon, D., Onile, A.E., Belikov, J. and Levron, Y. (2021) 'Effects of the COVID-19 pandemic on energy systems and electric power grids – A review of the challenges ahead', *Energies*, vol. 14, No. 4, https://doi.org/10.3390/en14041056.
[62] Oppel Jr., R.A., Gebeloff, R., Lai, K.K.R., Wright, W. and Smith, M. (2020) 'The Fullest Look Yet at the Racial Inequity of Coronavirus', *The New York Times*, July 5.
[63] Osička, J. and Černoch, F. (2022) 'European energy politics after Ukraine: The road ahead', *Energy Research and Social Science*, vol. 91, 102757, https://doi.org/https://doi.org/10.1016/j.erss.2022.102757 et al.
[64] Pahle, M., Burtraw, D., Flachsland, C., Kelsey, N., Biber, E., Meckling, J., Edenhofer, O. et al. (2018) 'Sequencing to ratchet up climate policy stringency', *Nature Climate Change*, vol. 8, No. 10, pp. 861–867, https://doi.org/10.1038/s41558-018-0287-6.
[65] Pareek, M., Bangash, M.N., Pareek, N., Pan, D., Sze, S., Minhas, J.S., Hanif, W. et al. (2020) 'Ethnicity and COVID-19: an urgent public health research priority', *The Lancet*, vol. 395, No. 10234, pp. 1421–1422, https://doi.org/10.1016/S0140-6736(20)30922-3.
[66] Paul, J., Lim, W.M., O'Cass, A., Hao, A.W. and Bresciani, S. (2021) 'Scientific procedures and rationales for systematic literature reviews (SPAR-4-SLR)', *International Journal of Consumer Studies*, vol. 45, pp. 1–16, https://doi.org/10.1111/ijcs.12695.
[67] Pradhan, P., Subedi, D.R., Khatiwada, D., Joshi, K.K., Kafle, S., Chhetri, R.P., Dhakal, S. et al. (2021) 'The COVID-19 Pandemic Not Only Poses Challenges, but Also Opens Opportunities for Sustainable Transformation', *Earth's Future*, vol. 9, No. 7, pp. 1–14, https://doi.org/10.1029/2021EF001996.
[68] Ranjbari, M., Shams Esfandabadi, Z., Zanetti, M.C., Scagnelli, S.D., Siebers, P.O., Aghbashlo, M., Peng, W. et al. (2021) 'Three pillars of sustainability in the wake of COVID-19: A systematic review and future research agenda for sustainable development', *Journal of Cleaner Production*, vol. 297, 126660, https://doi.org/10.1016/j.jclepro.2021.126660.

[69] Ray, R.L., Singh, V.P., Singh, S.K., Acharya, B.S. and He, Y. (2022) 'What is the impact of COVID-19 pandemic on global carbon emissions?', *Science of the Total Environment*, vol. 816, 151503, https://doi.org/10.1016/j.scitotenv.2021.151503 .
[70] Rodríguez-Soler, R., Uribe-Toril, J. and De Pablo Valenciano, J. (2020) 'Worldwide trends in the scientific production on rural depopulation, a bibliometric analysis using bibliometrix R-tool', *Land Use Policy*, vol. 97, https://doi.org/10.1016/j.landusepol.2020.104787.
[71] Rume, T. and Didar-Ul Islam, S.M. (2020) 'Environmental effects of COVID-19 pandemic and potential strategies of sustainability', *Heliyon*, vol. 6, e04965, https://doi.org/10.1016/j.heliyon.2020.e04965.
[72] Seshaiyer, P. and McNeely, C.L. (2020) 'Challenges and Opportunities From COVID-19 for Global Sustainable Development', *World Medical and Health Policy*, vol. 12, No. 4, pp. 443–453, https://doi.org/10.1002/wmh3.380.
[73] Sharma, G.D., Verma, M., Taheri, B., Chopra, R. and Parihar, J.S. (2023) 'Socio-economic aspects of hydrogen energy: An integrative review', *Technological Forecasting and Social Change*, vol. 192, 122574, https://doi.org/10.1016/j.techfore.2023.122574.
[74] Sikarwar, V.S., Reichert, A., Jeremias, M. and Manovic, V. (2021), 'COVID-19 pandemic and global carbon dioxide emissions: A first assessment', *Science of the Total Environment*, vol. 794, https://doi.org/10.1016/j.scitotenv.2021.148770.
[75] Singh, A. (2020) 'COVID-19 and safer investment bets', *Finance Research Letters*, vol. 36, 101729, https://doi.org/10.1016/j.frl.2020.101729 .
[76] Sobieralski, J.B. (2020) 'COVID-19 and airline employment: Insights from historical uncertainty shocks to the industry', *Transportation Research Interdisciplinary Perspectives*, vol. 5, 100123, https://doi.org/10.1016/j.frl.2020.101729.
[77] Somani, M., Srivastava, A.N., Gummadivalli, S.K. and Sharma, A. (2020) 'Indirect implications of COVID-19 towards sustainable environment: An investigation in Indian context', *Bioresource Technology Reports*, vol. 11, 100491, https://doi.org/10.1016/j.biteb.2020.100491.
[78] Stern, N., Unsworth, S., Valero, A., Zenghelis, D., Rydge, J. and Robins, N. (2020) 'Strategy, investment and policy for a strong and sustainable recovery: An action plan. A CEP Covid-19 analysis', Paper No. 005, LSE, [Online], Available: https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2020/07/Strategy-investment-and-policy-for-a-strong-and-sustainable-recovery.pdf [8 Oct 2025].
[79] Studdert, D.M. and Hall, M.A. (2020) 'Disease Control, Civil Liberties, and Mass Testing – Calibrating Restrictions during the Covid-19 Pandemic', *The New England Journal of* Medicine, vol. 383, No. 2, pp. 102–104, https://doi.org/10.1056/nejmp2007637.

[80] Talan, G. and Sharma, G.D. (2019) 'Doing well by doing good: A systematic review and research agenda for sustainable investment', *Sustainability*, vol. 11, No. 2, 353, https://doi.org/10.3390/su11020353.
[81] Thomas, L.D.W. and Tee, R. (2021) 'Generativity: A systematic review and conceptual framework', *International Journal of Management Reviews*, vol. 24, No. 2, pp. 255–278, https://doi.org/10.1111/ijmr.12277.
[82] Trunina, I., Pryakhina, K. and Yakymets, S. (2022) 'Research on the Development of Renewable Energy Sources in the World Due to the War in Ukraine', *IEEE 4th International Conference on Modern Electrical and Energy System (MEES)*, IEEE, Kremenchuk, Ukraine, https://doi.org/10.1109/MEES58014.2022.10005696.
[83] Tsao, Y.-C., Thanh, V.-V., Lu, J.-C. and Wei, H.-H. (2021), 'A risk-sharing-based resilient renewable energy supply network model under the COVID-19 pandemic', *Sustainable Production and Consumption*, vol. 25, pp. 484–498, https://doi.org/10.1016/j.spc.2020.12.003.
[84] Tung, C.T., Van Fan, Y., Lee, C.T. and Klemeš, J.J. (2022) 'Post COVID-19 ENERGY sustainability and carbon emissions neutrality', *Energy*, vol. 241, 122801, https://doi.org/10.1016/j.energy.2021.122801.
[85] Wang, Y., Ahmed, A., Azam, A., Bing, D., Shan, Z., Zhang, Z., Tariq, M.K. et al. (2021) 'Applications of additive manufacturing (AM) in sustainable energy generation and battle against COVID-19 pandemic: The knowledge evolution of 3D printing', *Journal of Manufacturing Systems*, vol. 60, pp. 709–733, https://doi.org/10.1016/j.jmsy.2021.07.023.
[86] Xu, X., Xie, Y., Xiong, F. and Li, Y. (2022) 'The Impact of COVID-19 on Investors' Investment Intention of Sustainability-Related Investment: Evidence from China', *Sustainability*, vol. 14, No. 9, 5325, https://doi.org/10.3390/su14095325.
[87] Zhang, T., Shi, X., Zhang, D. and Xiao, J. (2019) 'Socio-economic development and electricity access in developing economies: A long-run model averaging approach', *Energy Policy,* vol. 132, pp. 223–231, https://doi.org/10.1016/j.enpol.2019.05.031 .
[88] Zhang, L., Li, H., Lee, W.-J. and Liao, H. (2021) 'COVID-19 and energy: Influence mechanisms and research methodologies', *Sustainable Production and Consumption*, vol. 27, pp. 2134–2152, https://doi.org/10.1016/j.spc.2021.05.010.
[89] Zhong, H., Tan, Z., He, Y., Xie, L. and Kang, C. (2020) 'Implications of COVID-19 for the electricity industry: A comprehensive review', *CSEE Journal of Power and Energy Systems,* vol. 6, No. 3, pp. 489–495, [Online], Available: https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9160443 [8 Oct 2025].
[90] Župič, I. and Čater, T. (2015) 'Bibliometric Methods in Management and Organization', *Organizational Research Methods*, vol. 18, No. 3, pp. 429–472, https://doi.org/10.1177/1094428114562629.

Summary

The shift from traditional fossil fuel energy to cleaner, renewable energy has the potential to help achieve long-term sustainability goals. The COVID-19 pandemic has had a significant impact on the renewable energy sector. This study aims to provide an integrative review of the global impacts and challenges of the COVID-19 pandemic on the renewable energy sector and highlight the energy-related lessons and emerging opportunities by capturing the main trends in the field. First, the integrative review identifies five themes. Second, the study identifies the aspects of renewable energy that are influenced by the COVID-19 pandemic. Third, the study proposes a conceptual framework highlighting the impacts and challenges of the COVID-19 pandemic on renewable energy demand and consumption patterns, and these results are further supported by the aggregate dimensions identified through inductive analysis. The three main energy challenges are: the healthcare sector primarily dealing with disease control; associated environmental impacts with challenges relating to fluctuating and uncertain energy demand and consumption, structural and pattern changes, greenhouse gas emissions, local air quality, energy transmission infrastructure, and oil production and transmission network; associated economic impact dealing with industrial activities including households, agriculture, public and commercial sector, energy import/ export, sales revenue and expenditure, social sector factors, funding schemes, and subsidies, technology R&D, and overall economic welfare. The study also makes theoretical and practical propositions for researchers and policymakers.

JEL codes: I18, Q42, Q5

Keywords: *renewable energy, COVID-19, integrative review, energy impacts, energy transition, energy recovery*

Received: March 24, 2025.
Accepted: September 25, 2025.