



The impact of the COVID-19 pandemic on global energy consumption: a systematic review

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Abstract

Objectives: The COVID-19 pandemic has had a profound impact on human social and economic structures, making it one of the most significant crises of the 21st century. The production and consumption of energy sources, such as electricity, oil, and gas, have also been affected by the pandemic. Therefore, this study aims to systematically review the effects of the COVID-19 pandemic on energy consumption.

Methods: This study presents a systematic review of the impact of the coronavirus on energy consumption. Initially, relevant keywords were selected, and a systematic search of studies was conducted in databases including Web of Science, PubMed, Scopus, and ScienceDirect from 2020 to May 2022. Following screening, articles meeting the eligibility criteria were included in the study.

Results: Through this systematic review, a total of 19,551 studies were identified, of which 18 met the eligibility criteria. All included studies investigated electricity consumption, while two studies focused on gas and fuel consumption, and only one study examined heating oil consumption. The most significant decreases in electricity, natural gas, and transportation fuel consumption were 55.4%, 32.4%, and 75.9%, respectively. On the other hand, heating oil consumption saw an increase of 12%.

Conclusion: The results of this systematic review indicate that the COVID-19 pandemic has resulted in reduced energy consumption across various sectors, including electricity, transportation fuel, and natural gas, leading to a decrease in greenhouse gas emissions. However, some studies reported an increase in electricity consumption in the residential sector due to prolonged periods of staying at home and remote work during quarantine.

Keywords: COVID-19 Pandemic, Energy Consumption, Electricity, Fossil Fuels.

Introduction

Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), the virus responsible for Coronavirus disease 2019, was initially identified in Wuhan, China, in December 2019.^[1,2] SARS-CoV-2 is a positive single-stranded RNA virus classified in the Coronaviridae family.^[3] The rapid global spread of the coronavirus disease led to infections and fatalities affecting millions of individuals worldwide.^[4,5] The World Health Organization declared the COVID-19 outbreak a public health emergency,^[2,6] marking it as one of the most significant crises of the 21st century,^[7,8] profoundly impacting human societies, healthcare systems, economic frameworks, and

social interactions.^[9,10] Various countries implemented measures like travel restrictions, nationwide lockdowns, and remote work policies to curb the spread of the disease.^[11,12]

Energy sources are broadly categorized into primary, secondary, and tertiary forms. Energy plays a crucial role in sustaining human life and supporting the advancement of diverse sectors including industry, agriculture, communications, and transportation.^[13,14] Studies suggest that adequate energy provision during colder seasons can help prevent respiratory illnesses and ensure access to hot water, essential for maintaining hygiene standards and reducing foodborne diseases.^[15-17]

Energy is defined as the power and capacity required for various activities, and its production and consumption are influenced by economic, political, technological, environmental, and social factors.^[14,18] Global warming and greenhouse gas emissions from energy use pose significant threats to the environment, with CO₂ emissions being a major contributor.^[19] The strict lockdown measures imposed during the pandemic led to a substantial decrease in energy consumption related to aviation, transportation, commercial operations, and industrial activities, while residential energy usage notably surged.^[20]

In 2020, global electricity consumption witnessed an 8.6% decline compared to 2019 as reported by the International Energy Agency.^[21] Furthermore, restrictions resulted in reduced oil and by-product demand across industries and transportation sectors,^[22,23] with global oil and gas demands decreasing by 5% and 2%, respectively.^[24] The collective decrease in electricity consumption and oil demand contributed to an international 8% reduction in carbon emissions.^[25,26] Research by Rouleau et al. in Canada revealed a 17.5% increase in residential electricity consumption during the initial month of lockdown and a subsequent 5.8% decrease in the third month compared to the previous year.^[27] Additionally, a study by Samuels et al. in South Africa noted a 30-40% decline in electricity usage in schools during the lockdown period.^[28]

One of the challenges in energy studies lies in the varying conditions of the areas under study, different study periods, and the types of energy being consumed. These factors make it challenging to synthesize data and report comprehensive changes in energy consumption. Particularly in the context of sustainable development, the environmental and economic impacts of high energy consumption are crucial considerations in environmental planning. Furthermore, studies underscore the importance of addressing energy issues during the COVID-19 pandemic to efficiently manage similar crises in the future.

Objectives

Given the absence of a systematic review on the effects of the COVID-19 pandemic on energy consumption, this systematic review aims to investigate the influence of the pandemic on energy consumption. This research seeks to shed light on how the pandemic has impacted energy usage and provide valuable insights for future energy management strategies.

Methods

Search Strategy

The primary research question posed was: "Has the COVID-19 crisis impacted energy consumption?" To conduct a systematic review on the effects of the coronavirus on energy consumption, a comprehensive search was carried out in databases such as Web of Science, PubMed, Science Direct, and Scopus from 2020 to May 2022. The search terms for the two key components were as follows: SARS-CoV-2 OR 2019-ncov OR covid-19 OR "coronavirus 2019" OR "2019 novel coronavirus" OR "novel SARS-CoV-2" OR "COVID-19 pandemic" OR "covid19 lockdown" OR "environmental COVID-19 impact" AND (energy OR "energy consumption" OR "renewable energy" OR fuel OR electricity OR "natural gas" OR "clean energy" OR "crude oil"). All stages of article selection, screening based on title and abstract, selection for full-text review, full-text examination, and data extraction were independently carried out by two reviewers. In case of discrepancies between the two reviewers in the initial stage, a discussion was held, and if consensus was not reached, the opinion of a third reviewer was sought as the final decision.

Screening

To enhance sensitivity and encompass most available research, additional records were identified through manual searching and reviewing the reference lists of retrieved papers. Following the search, articles were imported into Endnote X9 software for screening. Initially, duplicate articles were eliminated, followed by screening based on titles and abstracts. Subsequently, full-text articles meeting eligibility criteria were included.

Inclusion Criteria

The following inclusion criteria were applied:

- 1) Original articles (excluding short communications, conference papers, letters, and review articles).
- 2) Articles published in English.
- 3) Articles assessing at least one type of energy consumption (gas, fuel, electricity).

Articles based on modelling or forecasting data, those lacking comprehensive presentation, or being incomprehensible were excluded. The PRISMA flowchart was utilized to document the workflow process.^[29]

Data Extraction

A data extraction form was developed to extract necessary information from each article for analysis. The extracted results were then organized into tables and

charts according to specific objectives. Data visualization was done using Datawrapper. Study details included the author's name, title, publication year, country, continent, study duration, and the impact of the coronavirus on energy consumption.

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki. Institutional Review Board approval was obtained.

Results

Search Process

A total of 19,551 articles were identified through searches in databases such as Web of Science, PubMed, Science Direct, and Scopus. Among these articles, 7,792 were duplicates, resulting in 11,759 unique articles that underwent screening based on their titles and abstracts. Subsequently, 153 articles were selected for full-text review based on eligibility criteria. Excluded were papers outside the study's scope, preprints, short communications, letters, conference papers, reviews, or those with unclear or modeled data presentation. Ultimately, 18 studies met the

inclusion criteria. The search results and article screening details are outlined in the PRISMA flowchart provided in [Figure 1].

Descriptive Results

The findings from the 18 studies are summarized in [Table 1], categorized by energy consumption type, continent, country, and study duration. The distribution of publication years shows a majority of studies published in 2021, followed by four studies in 2022. Analysis by continent reveals that Europe and Asia had the highest number of studies, each with six, while Africa and North America had four studies each. South America and Oceania had one study each. Notably, China in Asia and Spain in Europe had the most studies on energy consumption. Details on studies based on other countries are illustrated in [Figure 4].

In terms of energy consumption types, electricity consumption was the most studied (18 studies), followed by two studies on natural gas and transportation fuels. One study each was conducted on heating oil consumption and total energy consumption, as depicted in Figure 5.

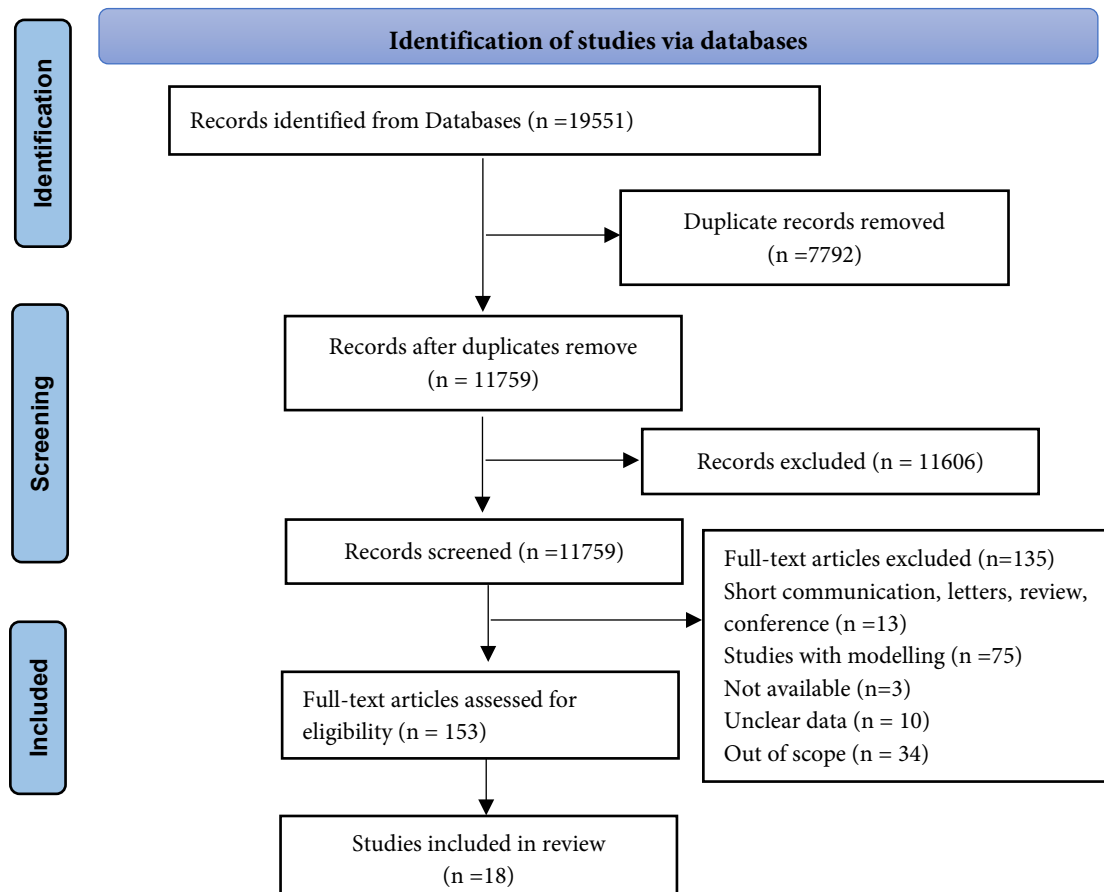


Figure 1. PRISMA flow diagram

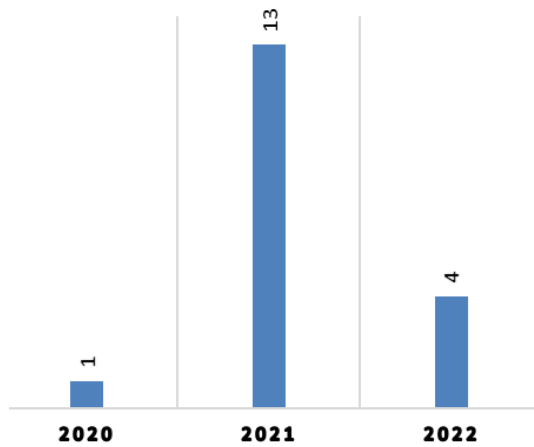


Figure 2. Number of studies based on year of publication

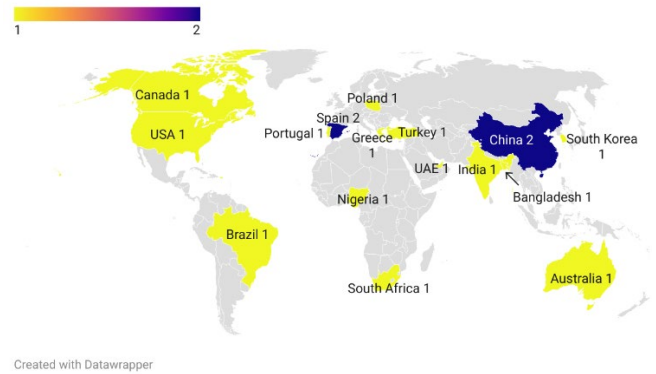


Figure 4. Number of studies based on countries from 2020 to May 2022

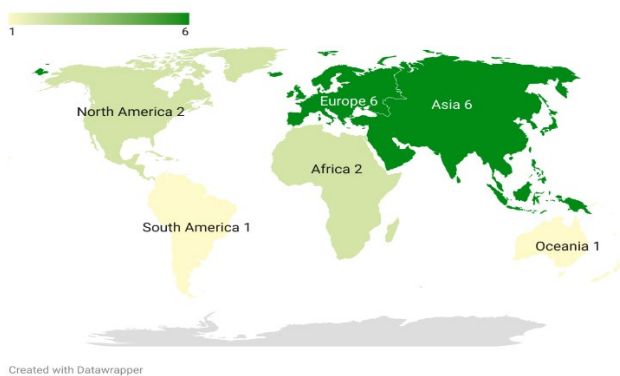


Figure 3. Number of studies based on continents from 2020 to May 2022

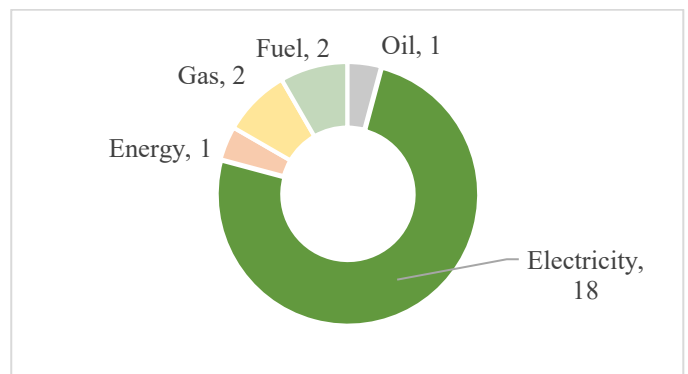


Figure 5. Number of studies based on energy type from 2020 to May 2022

Table 1. Data extracted from a review of the effects of the COVID-19 pandemic on energy consumption

I D	Author, year	Country	Continent	Period Study	Result (Decreasing / Increasing)				
					Electricity	Oil	Gas	Fuel	Energy
1	Geraldi et al. (2021) ^[30]	Brazil	South America	Mar to Jul of 2020, same period 2018-2019	-50%				
2	Liu et al. (2021) ^[31]	Australia	Oceania	2020, same period 2016-2019	-2.3% to -10%				
3	Bhattacharya et al. (2022) ^[32]	India	Asia	Mar 25 to Aug 31 same period 2019	-11%				
4	Samara et al. (2022) ^[33]	UAE	Asia	1 Jan to 31 Dec 2020, same period 2016-2019	-1.04%				
5	Kang et al. (2021) ^[34]	South Korea	Asia	Jan to May 2020, same period 2019	-4.46%		-10.35%		
6	Russo et al. (2021) ^[35]	Portugal	Europe	Mar to Dec, same period 2019	-31.6% to +23.2%		-32.4% to +26.7%	-75.9% to -4.8%	-15.7%
7	Lalas et al. (2021) ^[36]	Greece	Europe	2020, same period 2019	-5%	+12%		-13%	
8	Yüksel et al. (2022) ^[37]	Turkey	Europe	Mar 2019 to Mar 2020- 2021	Pre: 16719 kWh to 10970 kWh during				

9	Edomah et al. (2020) ^[38]	Nigeria	Africa	1st Mar to Apr 5, 2020	+49%
10	Bielecki et al. (2021) ^[39]	Poland	Europe	16 Mar to 18 Apr 2020, same period 2018	+16%
11	Chihib et al. (2021) ^[40]	Spain	Europe	2020, same period 2019	-2% to -44%
12	Kawka et al. (2021) ^[41]	USA	North America	Apr to Dec 2020, same period 2018	+21.2%
13	Samuels et al. (2021) ^[28]	South Africa	Africa	Nov 2018 to Oct 2020	- 30% to - 40%
14	Rouleau et al. (2021) ^[27]	Canada	North America	Apr 2020 to Jul 2020, same period 2019	-5.8% to +17.5%
15	Su et al. (2022) ^[42]	China	Asia	Jan 2019 to Dec 2020	-55.4%
16	Santiago et al. (2021) ^[43]	Spain	Europe	Mar 14 to Apr 30 2020, same period (2015–2019)	-13.49%
17	Khan et al. (2021) ^[44]	Bangladesh	Asia	Mar to May 2020, same period 2019	-14%
18	Zhao et al. (2021) ^[45]	China	Asia	Jan to Apr 2020, same period 2019	-10.1%

Discussion

This study delves into the impact of the COVID-19 pandemic on energy consumption. As depicted in [Figure 5 and Table 1], the majority of studies focused on electricity consumption. Most studies indicated a decrease in electricity consumption during the lockdown period. Electricity production is a significant contributor to global greenhouse gas emissions. Therefore, the decline in electricity consumption during the COVID-19 pandemic resulted in reduced emissions.^[46,47] Notably, the most substantial percentage decrease in electricity consumption was observed in a study by Su et al. in China, showing a 55.4% reduction in commercial buildings.^[42] Similarly, Geraldi et al.'s study in Brazil reported a 50% decrease in electricity consumption.^[30] Another study by Chihib et al. in Spain highlighted a decrease in university electricity consumption ranging from 2% to 44%.^[40] On the contrary, the smallest percentage decrease in electricity consumption was noted in a study by Samara et al. in the UAE, accounting for 1.04%.^[33] However, some studies reported an increase in electricity consumption. For instance, Edomah et al.'s study in Nigeria revealed a 49% increase in household electricity consumption.^[38] Similarly, Bielecki et al.'s study in Poland demonstrated a 16% increase in household electricity use.^[39] The rise in residential electricity consumption can be attributed to people staying at home and working remotely during the

lockdown, leading to increased use of electrical appliances for cooking and air conditioning.^[38]

Additionally, two studies examined the effects of the COVID-19 pandemic on natural gas consumption. Results from Kang et al.'s study in South Korea indicated a 10.35% reduction in gas consumption.^[34] Furthermore, Russo et al.'s study in Portugal revealed a decrease of 32.4% in gas consumption in the service sector, while household gas consumption increased by 26.7% due to the lockdown and the increased time spent at home by individuals. The surge in household gas usage can be attributed to heightened activities such as cooking and hot water usage.^[35]

Another energy source to consider is oil and fuel, with two studies focusing on fuel consumption and one study on heating oil [Figure 5]. In a study by Lalas et al. in Greece, findings revealed a 12% increase in heating oil consumption attributed to the decline in oil prices. Conversely, road transport fuel consumption decreased by 13%.^[36] Additionally, a study by Russo et al. in Portugal demonstrated a significant drop of 75.9% in transportation fuel consumption.^[35] The reduction in demand for oil and its derivatives was a direct result of the cessation of road transportation and airline operations during the pandemic, leading to reduced carbon dioxide emissions. Moreover, the decline in fossil fuel consumption during the COVID-19 crisis contributed to lower levels of air pollutants such as nitrogen dioxide, thereby positively

impacting environmental quality.^[48-50]

In the study by Russo et al. in Portugal, it was noted that total energy consumption decreased by 15.7%.^[35] Globally, environmental, social, and economic conditions are heavily reliant on and influenced by fossil fuel energy. The combustion of fossil fuels to satisfy energy requirements results in substantial greenhouse gas emissions, accounting for 72% of such emissions and contributing significantly to climate change impacts.^[19,51] The COVID-19 pandemic has altered energy consumption patterns, ultimately leading to reduced greenhouse gas emissions, particularly carbon dioxide.^[52,53]

The variations in study periods, energy types consumed, geographical conditions, seasons, among other factors, pose challenges in synthesizing data and reporting comprehensive changes in energy consumption.

Conclusions

This systematic review examined the impact of the COVID-19 pandemic on energy consumption. The findings from the studies revealed a decrease in electricity, transportation fuel, and natural gas consumption, highlighting one of the positive effects of the pandemic on energy sources. This reduction in energy usage during the COVID-19 crisis has resulted in lower levels of pollutants and greenhouse gas emissions. However, some studies reported an increase in electricity consumption in the residential sector, attributed to individuals staying at home and engaging in remote work during quarantine. The insights gained from this systematic review can offer valuable information for energy policy development. It is worth noting that our review did not encompass studies on the impact of the COVID-19 pandemic on renewable resources, which could be a focus for future research.

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Competing interests

The authors declare that they have no competing interests.

Abbreviations

Coronavirus disease 2019: COVID-19;
Severe acute respiratory syndrome coronavirus 2: SARS-CoV-2.

Authors' contributions

All authors read and approved the final manuscript. All authors take responsibility for the integrity of the data and the accuracy of the data analysis.

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Availability of data and materials

The data used in this study are available from the corresponding author on request.

Ethics approval and consent to participate

This work was approved by the Ethics Committee of Tehran University of Medical Science, Iran (58086). The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

By submitting this document, the authors declare their consent for the final accepted version of the manuscript to be considered for publication.

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