A Systematic Literature Review on Optimization Modeling to Electricity Strategy Business during Covid-19 Pandemic

Diah Chaerani, *Member, IAENG,* Herlina Napitupulu, Athaya Zahrani Irmansyah, Nur Widi Priambodo, Muhamad Iqbal Felani, Handrea Bernando Tambunan, and Joko Hartono

***Abstract*—The electricity strategy business during the Covid-19 pandemic is essential in various fields of study, especially in mathematics in formulating optimization models. The optimization model in this field can analyze how the Covid-19 pandemic impacts are based on total consumption and consumption profiles representing critical economic sectors, including a comparative analysis of energy consumption from 2019 to 2021. Therefore, a Systematic Literature Review (SLR) in Optimization Modeling to Electricity Strategy Business during the Covid-19 pandemic is needed. The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) steps adopted in this case. PRISMA was chosen because it provides clear guidance on conducting an SLR and improving reporting quality and methodology. The following topics are examined in this paper: (a) the effect of the electricity business because of the global economic downturn, (b) what will happen if the world economy gradually recovers, (c) a business strategy that is appropriate during the pandemic, and (d) parameters need to be monitored to ensure that company policies such as energy transition, customer service improvement, green booster, and others continue to run according to the plan. This paper uses the R-bibliometrics command in RStudio software and the Python programming language to support SLR, so a final database of 12 selected articles was used. Furthermore, an analysis of bibliometric maps' evolutionary and determination of research gaps is presented. Finally, study and analysis of the role and contribution of Operations Research and Optimization Modeling (OROM) in the electricity strategy business' optimal decision-making strategy during the pandemic are taken. In addition, a recommendation on considering the importance of data uncertainty is given since, in many situations, the uncertainties must be considered. Thus, Robust Optimization is proposed for handling the uncertainties.**

***Index Terms*—Electricity strategy business, Covid-19 pandemic, operations research, optimization modeling, systematic literature review**

Manuscript received May 25, 2022; revised May 12, 2023. This research is carried under research collaboration project between Universitas Padjadjaran and PT PLN (Persero) Indonesia and fully funded by PLN Research Institute, PT PLN (Persero) Indonesia: 0870.BA/HKM.02.01/C30000000/2021.

Diah Chaerani is an Associate Professor at Department of Mathematics, Faculty of Mathematics and Natural Science, Universitas Padjadjaran, Sumedang, 45363, Indonesia (corresponding author to provide phone: +62-813-949-815-91, email: d.chaerani@unpad.ac.id).

Herlina Napitupulu is Assistant Professor at Department of Mathematics, Faculty of Mathematics and Natural Science, Universitas Padjadjaran, Sumedang, 45363, Indonesia (email: herlina@unpad.ac.id).

Athaya Zahrani Irmanyah is Assistant Researcher at Department of Mathematics, Faculty of Mathematics and Natural Science, Universitas Padjadjaran, Sumedang, 45363, Indonesia (email: athaya17002@mail.unpad.ac.id).

Nur Widi Priambodo is researcher at PLN Research Institute, PT PLN (Persero), Jakarta, Indonesia (email: nur.priambodo@pln.co.id).

Muhamad Iqbal Felani is researcher at PLN Research Institute, PT PLN (Persero), Jakarta, Indonesia (email: muhammad.felani@pln.co.id).

Handrea Bernardo Tambunan is researcher at PLN Research Institute, PT PLN (Persero), Jakarta, Indonesia (email: handrea.tambunan@pln.co.id).

Joko Hartono is researcher at PLN Research Institute, PT PLN (Persero), Jakarta, Indonesia (email: joko.hartono@pln.co.id).

I. INTRODUCTION

As its name implies, operations research (OR) involves "research on operations." Thus, OR is applied to problems that concern on how an organization is managed especially in decision making [1]. Some results as mentioned in [1] show that OR has an important impact on improving the efficiency of numerous companies worldwide [1]. In the process, OR has contributed significantly to increasing productivity in various aspects, especially in the Electricity Strategy Business during the 2019 Coronavirus Disease (Covid-19) pandemic. The utilization of optimization modeling in emergency situations has become an impactful technique since its initial implementation in the maritime disasters in the 1970s [2]. The emergency of the electricity strategy business caused by the Covid-19 Pandemic supports the implementation of Operations Research and Optimization Modeling (OROM). Study and analysis of the role and contribution of OROM in the electricity strategy business's optimal decision-making strategy during the pandemic are needed. Furthermore, research of optimization models is required to ensure company policies such as energy transition, customer service improvement, green booster, and many others.

This paper presents a study on how Covid-19 pandemic impacts electricity businesses in various countries. Referring to Tingting *et al*. [3], the spread of Covid-19 significantly affects economic activity worldwide and kills many people. As of May 31st, 2020, based on the Covid-19 monitoring platform created by Johns Hopkins University (JHU), more than 6.530.241 cases of Covid-19 were recorded worldwide. As a result, various country have enforced limitations to decelerate the transmission of the virus, such as shutting

down educational establishments, implementing partial or complete lockdowns, and mandating employees to work remotely when feasible. Consequently, the energy industry, which is a crucial component of the worldwide economy, has been severely impacted. Many countries have enforced limitations to decelerate the transmission of the virus, such as shutting down educational establishments, implementing partial or complete lockdowns, and mandating employees to work remotely when feasible. Consequently, the energy industry, which is a crucial component of the worldwide economy, has been severely impacted.

According to Malec *et al.* [4], the Covid-19 pandemic has also changed the power consumption profile by adjusting the electricity demand. This is significant from the viewpoint of energy companies and provides an estimate of the amount of energy utilized, given the quick changes in energy costs. Many of the corporate clients examined in this research are limited-scope economic entities. Therefore, studying how the pandemic affects these entities' shifting energy consumption quantities and profiles is crucial. Analysis of consumer behavior during a pandemic, particularly during a lockdown, is forced by the requirement for precise energy volume planning to prepare for another probable wave of the pandemic.

The impact on the electricity business of midwives was felt in various countries; for example, on April 7th, 2020. According to Tingting *et al.* [3], the Japanese government proclaimed a state of emergency in response to the rapid spread of the Covid-19 outbreak. Empirical estimates have been made of how the crisis has affected Japan's demand for power. A cross-domain methodology is offered to analyze the short-term effects of Covid-19 on the U.S. electrical industry because the country is among the worst affected. The findings indicate a considerable decrease in electricity use, which is closely associated with the incidence of Covid-19, social isolation, and economic activity. Analyzing Covid-19's effects on power is crucial due to the significant shift in energy load consumption caused by alterations in human behavior during the pandemic.

Research on a related subject is discussed in D'alessandro *et al.* [5] and considers fluctuations in monthly power generation and consumption in Japan during the Covid-19 pandemic. The triple exponential smoothing approach compares observed grid power demand and generation types for January to June 2020 with anticipated values based on patterns from 2016 to 2019. For home energy consumers, regional power demand data show only minor deviations from projected trends. Still, demand for business and industrial networks was lower than anticipated, particularly in the 50-2000 kW cohort. In May 2020, electricity demand was probably going to vary from the current trend, which coincides with voluntary lockdown activities. These outcomes align with trends in other international studies on Covid-19's effect on power usage. Due to Japan's location within the more significant energy transition, generation was cut in May and June 2020 with no discernible impact on generation makeup. These results support earlier research and contribute to a more comprehensive understanding of the factors that influence different types of users' power demand behavior. Previous research looked at the impact of full and partial lockdowns on electricity use. This analysis furthers the conversation by describing the effects of the lockdown.

Malec *et al.* [4] examined how pandemics and restrictions impacted variations in the total volume of energy consumption and the demand profile. Data gathered from Polish energy trading, and sales organizations formed the basis of the analysis. It concentrates on the energy usage of its business clients. The aggregate energy consumption volume for all of the company's clients and the primary types of economically limited companies are among the studied data. The analysis demonstrates how pandemic limitations affect corporate clients' energy consumption. There are noticeable variances between the various economic sectors. According to research, offices and shopping malls have seen the most significant decreases in energy use. Compared to the projected values, the limits caused energy consumption to drop by 15 to 23% during the first lockout; and a maximum of 11% during the second lockdown.

It might be discovered through a literature search as well. The impacts of Covid-19 and the ensuing lockdown measures are documented in Ceylan [6]; consequently, energy demand in business and industry has drastically decreased. The management of energy generation, in particular the creation and supply of electricity, is made more difficult by these variations in demand. A trustworthy model must maintain secure, assured, and dependable electricity. Forecasts of the power demand must accurately judge future investments and strategic planning that can be relied upon. The objective of this study is to precisely forecast the demand for electricity during Turkey's shutdown by presenting the entire Covid-19 implications on the electricity sector. This study can assist decision-makers in creating the best policies to manage the risks associated with the ongoing pandemic crisis and unforeseen emergencies. For this, well-known machine learning methods, such as linear regression, reduced error pruning tree, correlated Nyström view, sequential minimum optimization regression, and M5P tree model were utilized. With the lowest mean absolute percentage error (3.6851%), mean fundamental error (21.9590), mean square root error (29.7358), and root-relative square error (36.5556%) in the test dataset, the SMOreg algorithm fared best.

Additionally, to contain the Covid-19 pandemic, The government of Romania had to take harsh measures (see Iancu *et al.* [7]). Additionally, they placed the most challenging limitations on the E.U. Everything stopped during the lockdown period, which lasted more than a month. Schools and institutions only offered online courses, domestic and international travel was severely restricted, and meetings and flights were all outlawed. This study examines how Romania's pandemic-related economic growth affected variations in power use. To gain a better comprehension of the association between gross domestic product (GDP) and electricity consumption (E.C.) in diverse economic scenarios, the time span ranging from 2008 to 2020 has been categorized into three series. These series consist of the financial crisis period from 2008 to 2012, the subsequent recovery phase, and the years of economic growth from 2013 to 2019 and the pandemic period from Q1 to Q3 of 2020. The authors discover that GDP and E.C. are separated in the first period measured using correlation coefficients and regression analysis. In the second phase, the rise in GDP resulted in rising power demand and RES-generated electricity

production. However, the real GDP did not match the calculated GDP in Q3 2020 due to the pandemic. Climate will impact the amount of electricity produced by RESs if it is possible to adapt it to financial requirements. Due to the country's economic downturn, Romania's pandemic's power use decreased during the first nine months. The greatest notable declines were hydroelectric and coal-fired power facilities' electricity output.

The effect of Covid-19 on the electricity selling price in Spain has been detailed more thoroughly in Norouzi *et al*. [8]'s discussion of the country. With repercussions of the current pandemic appear to be unprecedented. Research gaps must be filled to provide new decision support mechanisms that can lower risks and guarantee more accurate forecasts for energy investment and management that will be encountered, given the high level of uncertainty in the global energy market. This paper develops and tests an econometric model to ascertain Covid-19's effect on the Spanish electricity market. This article's main contribution is a paradigm that forecasts the electrical market's dynamic behaviour during a change, specifically the Covid-19 pandemic.

In this paper, our review complements the existing reviews on this topic (see Table I). Table I summarizes the differences between our article and the existing relevant literature review articles. The categorization is based on content analysis, article timescale, OROM analysis, and the absence of strategy analysis during the Covid-19 pandemic in the electricity business. Based on Table I, all seven articles have content analysis in the form of explanations of research objectives, research gaps, future research, and state-of-the-art related to the topic with different periods.

TABLE I
DIFFERENCE BETWEEN RELEVANT LITERATURE REVIEW ARTICLES AND OUR ARTICLE

No	Author	Content analysis? Yes (Y) or No (N)?	Time span	OROM? Yes (Y) or No (N)?
1	Naegler *et al*. [9]	Y	2012-2020	Y
2	Naval and Yusta [10]	Y	2011-2020	Y
3	Navon *et al*. [11]	Y	2016-2021	N
4	Abdulrahman *et al*. [12]	Y	-	N
5	Ahmad and Zhang [13]	Y	1990-2040	N
6	Naz *et al*. [14]	Y	-	N
7	de Doile *et al.* [15]	Y	-	N
8	Chaerani *et al.* (this paper)	Y	2019-2021	Y

Furthermore, only two review articles by Naegler *et al.* [9] and Naval and Yusta [10] contain OROM. In addition, only one review article discusses the Electricity business strategy during the Covid-19 pandemic, namely Navon *et al.* [11], so our review article is the primary reference for comparing the writing of the review articles that we made. Navon *et al*. [11] point out the main difficulties that the pandemic has brought about by demonstrating the patterns of electricity production and demand, deviations in frequency, and predictions for load requirements. They also analyze how the pandemic will affect the integration of renewable energy sources and whether the existing expansion plans for the power system will be altered due to the Covid-19 pandemic.

Based on the mentioned background above, questions arise regarding the impact of the Covid-19 Pandemic on the world's electricity business strategy profile, specifically Indonesia. Therefore, an initial search was carried out using the Publish or Perish software and around 58 articles discussing the impact of the Covid-19 pandemic on the electricity business in Indonesia, among others.

An interesting article by Al-Hakim *et al.* [16] discusses the Analysis of the Increase in Electricity Bills during the Covid-19 pandemic based on the Consumptive Behavior of Electrical Energy in Indonesia. Hasiholan and Tampi [17] discussed the protection of postpaid electricity users against the sudden increase in bills during the Covid-19 Pandemic (April-May and June 2020 electricity increase studies).

There are several questions to be answered, such as how will the global economic downturn affect the electricity business? Moreover, what will happen if the world economy gradually recovers? What business strategy is appropriate during the pandemic, and what parameters need to be monitored to ensure that company policies such as energy transition, customer service improvement, green booster, and others continue to run according to the plan? This study aims to answer the following questions (see Hasiholan and Tampi [17]): Knowing the sustainability of the world electricity utility business strategy during the Covid-19 pandemic. Provide information on the impact of Covid-19 on the electricity business. Provide recommendations to national electricity companies regarding strategies taken during and after the Covid-19 pandemic.

To this end, this paper discusses a Systematic Literature Review Study with a discussion of Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA). Furthermore, the Bibliometric Analysis, analysis of daily statistical data for consumption, and the role of Operations Research and Management Science in strategies for handling the impact of the Covid-19 pandemic in the world electricity business) is taken.

II. MATERIALS AND METHODS

A. Materials

This paper discusses the Systematic Literature Review (SLR) on optimization problems related to the electricity strategy during the Covid-19 pandemic. Before starting the SLR method using PRISMA, it is necessary to arrange keywords based on the desired research topic and determine the article database source. The authors use five databases in this study: Scopus, Google Scholar, SAGE, Dimensions, and Science Direct. The database from mining on these five sources serves as the material used in the PRISMA steps.

In the application of database mining, data type filtering is also required. The searched database is filtered under several conditions in this paper: (1) The database is open access, that is, unlimited access via the internet, (2) Databases are publications published in the last three years, from 2019 to 2021, plus articles published in the following year (e.g., 2022) (3) The database is research in mathematics or mathematical

science (4) In addition, the database includes research articles and conference papers (5) Source type database is journals and proceedings that have been published, and lastly (6) The database uses English.

B. Methods

Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA)

A literature review is a survey of scientific articles, books, and other sources relevant to specific problems in research, theory, or method. The literature review aims to obtain an objective and comprehensive summary and the results of a critical analysis of previous research relevant to the topic being studied. The literature review in this paper was conducted using the PRISMA steps referring to Matthew and Moher [18]. PRISMA consists of four stages, as shown in the next paragraphs.

The first stage in the PRISMA steps is Identification. At this stage, there are two activities. The first is the total database records of the keyword input results at the specified source. The second is the addition of other articles if there are articles from other sources not included. At this stage, the number of n articles was identified and symbolized.

In the second phase, known as Screening, from n articles, duplication screening checks are carried out. It aims to delete articles identified as more than one because they are sourced from various sources so that at the end of stage two, the number of new articles has been reduced due to duplication screening. The duplication screening is done using Python software by checking the identical article title. After duplication screening, lists of titles, abstracts, and keywords were checked to see whether any combination of Keywords in A, B and C subsets existed.

The third stage is Eligibility. An assessment through an entire article is carried out at this stage based on the determination of the criteria, which will be explained further in the next section. Reading articles thoroughly reduces the number of articles and leaves selected more specific articles, and the topic is closer to the desired research. Qualitative synthesis is carried out at this stage.

The fourth stage is Included. Quantitative synthesis (meta-analysis) is carried out at this stage. The selected final article will be used as material for determining the state-of-the-art and analyzing the research gap using a bibliometric map with the help of R Software.

Furthermore, research questions are determined through the PICOT (Problem, Intervention, Comparison, Outcome, Time) stages [19]. Bibliometric Analysis is needed to map state of the art in knowledge within the scientific field and identify important information that can serve various objectives, including seeking prospects for research and supporting scientific research.

C. Bibliometric Analysis using R-Bibliometric in R Software

Once the final article database has been acquired through the utilization of the PRISMA Method, one other method is used to assist the process of determining state-of-the-art and research gap analysis, namely the R-bibliometric method used by the R Software. This method is used to issue related outputs. Research activities include bibliometric maps, evolution analysis maps, maps of the most relevant things in research articles, and so forth. The usage of open-source software in bibliometric analysis [20] is explored. Package “library(bibliometrics)” is a comprehensive science mapping analysis. To run the program, R Software instructs the user to access the Shiny web interface directly by entering a new command, "biblioshiny()", in the R-console [20].

III. RESULTS

A. Systematic Literature Review with PRISMA on Case Study

The PRISMA steps in this study, with four stages of the process: identification, screening, eligibility, and included, refer to Matthew and Moher [18]. Based on Matthew and Moher [18], the detailed process is given in the following section. The step starts from searching the database through keywords to finding the appropriate final article.

Identification

This study discusses optimization modeling for electricity strategy business during the Covid-19 pandemic, and the authors set keywords as seen in Table II. Based on Table II, keywords are divided into six focus sections. Descriptor A focuses on types of research related to electricity; descriptor B focuses on research that discusses the impacts brought about by the Covid-19 pandemic; descriptor C focuses on studies on operations research. Descriptor AB and AC concentrate on A and B, A and C descriptors, respectively. At the same time, keyword D combines keywords A, B, and C. In brief, this research collects the metadata using descriptors A, AB, AC, and D to specify the data mining to our research focus.

TABLE II
KEYWORDS USED IN THE IDENTIFICATION STEP OF PRISMA

Descriptor	Keywords
A	"Load forecasting" OR "power system planning" OR "Electricity Subsidy" OR "Electricity Demand" OR "Energy Demand" OR "Electricity Consumption" OR "Electricity Load" OR "Electricity Supply" OR "Electricity Generation" OR "Electricity Production" OR "Electricity Market" OR "Electricity Sales" OR "Electricity Revenue" OR "Electricity Customer" OR "Electricity Operation" OR "Electricity Strategy" OR "Electricity Business" OR "Electricity Policy" OR "Electricity Industry" OR "Electricity Sector" OR "Electric Power System" OR "Distribution Network" OR "Transmission Network"
B	"Effect of Corona" OR "Effect of Pandemic" OR "Effect of Covid-19" OR Corona OR Pandemic OR "Covid-19" OR "new normal"
C	Optimization OR "Operation Research" OR Programming
AB	(Keywords A) AND (Keywords B)
AC	(Keywords A) AND (Keywords C)
D	(Keywords A) AND (Keywords B) AND (Keywords C)

Next, the database sources are determined: Scopus, Google Scholar, SAGE, Dimensions, and Science Direct. Data with Scopus and Google Scholar sources is obtained with the Publish or Perish application, while the other three sources access each database's website. Data is obtained from these five sources as materials used in the PRISMA flowchart. The results of the database mining from the five database sources is shown in Table III.

Table III shows that the entire database is n = 22.909, where the Google Scholar database donates the total number of articles as much as 11.871 with SAGE in opposite 7.696. The most critical data is in descriptor AC as much as 6.861, which means that research concerning electricity and optimization is quite considerable among other descriptors. Meanwhile, the smallest total data obtained is from descriptor AB, research about electricity during the Covid-19 pandemic, as much as 4.897; this might be because the pandemic began only in 2019. Take note that this stage is done before any screening process is taken.

TABLE III
DATABASE MINING RESULTS ON THE FIVE DATABASE SOURCES

Des-crip-tor	Scopus	Google Scholar	SAGE	Dimens-ions	S. Direct	Total
A	600	2966	406	500	1500	5972
AB	403	2974	38	500	982	4897
AC	600	2965	296	500	2500	6861
D	44	2966	29	500	1640	5179
Total	1647	11871	769	2000	6622	22909

Screening and Eligibility

In this study, part of the metadata screening process was carried out with Python 3.7.4 scripts running Jupyter Notebook. Several essential functions of the Pandas package are used in this study's screening and eligibility process; the procedure's explanation is brief as follows.

1. *pandas.read_csv()*: function to read files with comma-separated values (.csv) format, while the import data from pandas is data frame type data
2. *dataframe.drop()*: function to delete the desired row or column in the data frame
3. *dataframe.drop_duplicates()*: function to help remove duplicates from data frames
4. *dataframe.reset_index()*: the function to rearrange the *dataframe* index ranges from 0 to the length of the data minus 1.

At this screening stage, two cleaning processes with Python are carried out.

1. Cleaning 1. Delete data with the article of the same title; at this stage, the remaining data is n = 9.152.
2. Cleaning 2. Delete data with the title or name of a Journal containing the words "review" or "book." At the remaining data stage, n = 8.779.

Thus, the cleaning process is done using the Python program at the eligibility stage, and the remaining process is done manually, as follows.

1. Cleaning 3: Check whether the title, abstract, and keywords in the data contain at least one combination of keywords with Code A, B, and C in Table II; otherwise, the data is deleted. At this stage, the remaining data is only n = 29.
2. Cleaning 4: Check if there is a complete paper version; we checked whether the whole paper is in English.

Included

At the included stage, an assessment was conducted on a full paper based on its association with the study theme, namely "Contribution of Optimization, Mathematical Modeling and Operations Research in Measuring the Impact of Covid-19 on the World Electricity Business Strategy". Read the article thoroughly, then leave the selected topics related to the research theme. Next is the Included stage, where qualitative and quantitative synthesis (meta-analysis) are carried out. The final article selected in this study was 12. It was used as material to define state-of-the-art and analyze the research gap with bibliometric analysis with the help of R Software. The complete PRISMA process of our systematic literature review can be seen in Figure 1. Furthermore, the specific process performed in Figure 1 is stated in the flowchart of Figure 2 and is described in detail in the following section. We develop Figure 2 specifically in this paper.

As shown in Figure 2, the final selection yields 12 papers we use to set up the state-of-the-art. These 12 final articles selected in this study using PRISMA steps are presented in Table IV.

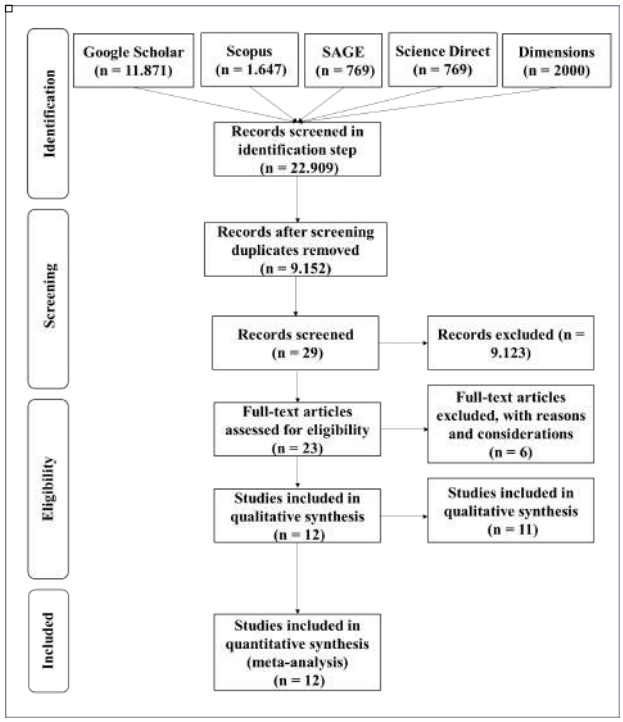

Fig. 1. PRISMA Flowchart of our case study.

This summary gives details of solutions for handling electricity business strategy during the Covid-19 pandemic using OROM studied from the reviewed literature. The most common research objective, which accounts for more than half of the articles, is to assess OROM contributions in handling electricity business strategy during the Covid-19 pandemic, as shown in Table V and Table VI. These two tables present varieties of research methodologies and methods from the 12 literature studies. Most of the research objectives studied are related to electricity demand prediction. This is due to the sudden change in electricity demand resulting from various social restriction policies from the respective governments, such as lockdowns and other similar procedures.

Bibliometric Analysis

We design a structure of bibliometric analysis of the optimization modeling to electricity bussiness during the Covid-19 pandemic topic which can be seen in detail in Figure 3.

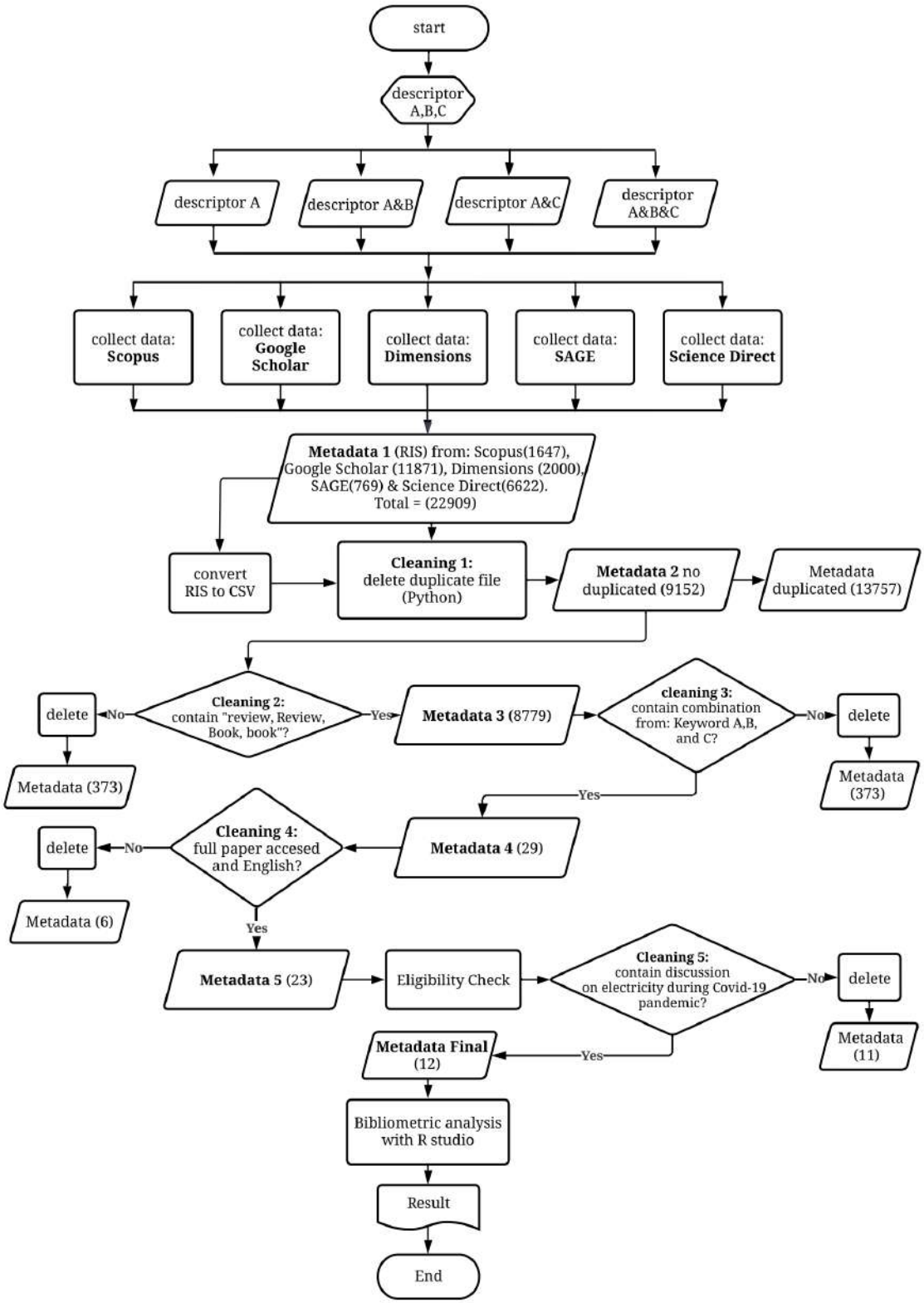

Fig. 2. Detail of the PRISMA steps for our case study.

Bibliometric analysis is used to see the results of identifying the data that has been collected and inputted into the R Software using the "library(bibliometrics)" syntax and the "biblioshiny()" command [20].

1. Data Identification

The first stage of bibliometric analysis is to see the results of identifying the data that has been collected and inputted into the R Software. As in the state-of-the-art analysis stage in the previous subchapter, we input raw data containing metadata from 12 selected articles. The inputted raw data includes authors, DOI, keywords, titles, sources, pages of articles, the volume of articles, URLs, number of citations, and so on for each article. This data identification stage shows that all articles have a period from 2020 to 2021. The twelve articles, on average, were published 0,167 times per year, and each article received an average of 3.167 citations per document, and average citations per document per year.

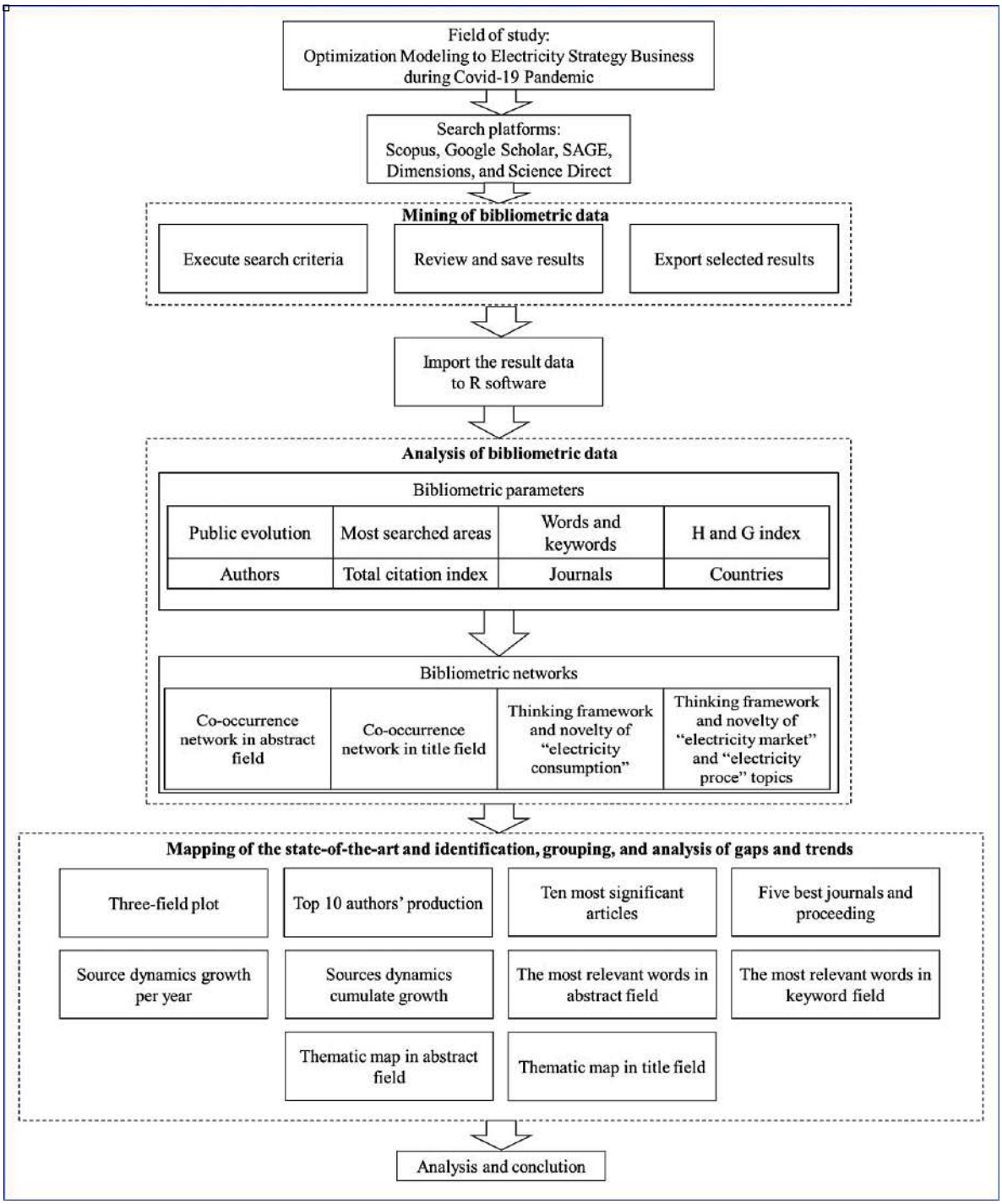

Fig. 3. Structure of bibliometric analysis for the topic optimization modeling to electricity business during the Covid-19 pandemic in our paper.

The twelve articles combine nine, two conference papers and one review. Furthermore, these twelve articles have 463 references, 139 plus keywords, and 43 authors' keywords. Thirty-four authors were involved in the twelve articles, with two authors in single-authored documents and 32 authors in multi-authored documents. This data identification serves as the initial step in preparing for a more in-depth analysis of the complete article, as discussed in the subsequent subchapter.

2. Articles' Evolution Between 2019-2021++

A study on optimization models for problems electricity strategy business in the Covid-19 pandemic period is identified by the inputted metadata contains two articles published in 2020 (with an average of two citations per publication) and ten articles published in 2021 (with an average of 3.4 citations per publication). Therefore, 2021 is the year with the highest annual scientific production. In the 2020-2021 period, a three-field plot map between countries, authors and keywords can be visualized, as shown in Figure 4. The left column shows the countries involved in the article, the middle column shows the article author's name, and the right column shows the keywords used in the article written. This three-field plot can represent the relationship between the three characterizations in the entire database input.

TABLE IV
STATE-OF-THE-ART OF 12 FINAL ARTICLES

Ref.	Electricity Business Strategy Aspects	Problem to be Solved During the Covid-19 Pandemic Period	Expected Conditions
Ceylan [6]	Electricity Demand in Turkey during the lockdown period.	The demand for energy in business and industry has dropped significantly because of the lockdown, difficulty in managing energy generation, especially electricity production and delivery.	Needed a reliable model to continue safe, secure, and reliable power, A reliable decision in strategic planning, and electric investments in the future.
Gulati *et al.* [21]	The electricity load forecasting in Haryana, India.	A major electric shock has introduced considerable unpredictability within the global electricity industry.	Assist in ensuring a secure electricity supply and efficient scheduling for the power system, while minimizing waste due to the challenging nature of electricity storage
Lu *et al.* [22]	Electricity load forecasting.	Develop an electricity consumption prediction model that can be effectively utilized during the pandemic through data processing modeling, and optimization.	The precise forecasting of electricity demand would have a heightened significance in safeguarding energy security across nations.
Casaravilla *et al.* [23]	Analyze the consequences of abrupt variations in Electricity Demand and the prices of usable fuels in thermal power plants for the electricity sector.	Social isolation on a global scale caused a drop in the demand for electrical energy and a more significant reduction in the global consumption of fuels derived from petroleum, which implied a drop-in fuel prices due to the impossibility of instantaneously reducing the offer.	The model can assess the effect on the electric system in terms of investment planning and calculate the risk level of demand and generating agents. The decision regarding what and when to install infrastructure to ensure the supply of Electric Power demand in the best economic conditions can be made by tool PIG (Planning of Electric Power Generation).
He *et al.* [24]	Selects factors influencing electricity demand under the new regular economy and concludes that socio-economic indicators significantly impact electricity demand.	To find an electricity demand's accurate estimation.	A more accurate estimate of electricity demand is advantageous to ensure that the electric power system runs securely, steadily, and reliably as well as to hasten the growth of the electricity market economy.
Ramadan and Helmi [25]	Power systems capabilities improvement.	Operation at risk due to varying load, demand, generation, and line failures in emergency conditions.	To create a dependable, customizable Distribution Network for intelligent grids that is fault-tolerant and quick to recover.
Alvarez [26]	Enhance the operations of power systems under pandemic situations and ensure the electricity supply.	The impact of the pandemic on different power plants (affected the personnel of power plants) and considering the number of cases in other regions.	To determine the optimum operation of an electric power system.
Peñaranda *et al.* [27]	Obtain the maximum economic benefits.	Changes in the demand due to Covid-19 that is affecting the behaviour of energy prices (market pattern).	Precision in the prediction of market behaviour.
Marwan and Marwan [28]	Optimizing Air Conditioning operations to reduce cost.	-	Reducing the cost of electricity.
Khan *et al.* [29]	Adaption strategy for operation of electricity supply source.	Optimum operation because of low storage levels in the reservoir (hydropower plants), intense dispatch of the thermal plants, and demand reduction due to pandemic.	To determine the trade off and adaptation strategy.
Elkamel *et al.* [30]	Stable electricity demand.	The pandemic has substantially impacted electricity consumption and the profile of electrical load demand.	It is assessed how Covid-19 will affect the scheduling of power plants.
Lima *et al.* [31]	Power generation planning.	The most efficient cost system for generating electricity.	Attaining the government's desired national targets of reducing emissions, increasing renewable energy sources capacity, enforcing the utilization of hydroelectric and nuclear power, and meeting technical and financial prerequisites.

TABLE V
RESEARCH METHODOLOGY AND METHOD/OROM CONTRIBUTION

Ref.	Methodology	Method/OROM Contribution
Ceylan [6]	• Input: Dataset Collection • Data were pre-processed with Input variables: daily load 2019, Curfew, temperature, a national holiday, weekend, day in a week, actual time, and lagged variables. Output: daily load 2020 • Training Set • The process of Machine Learning • Performance evaluation • A ranking model with TOPSIS • Selected best model • Electricity Demand Forecast	Machine learning (ML) algorithms: • Gaussian process regression (GPR) • Sequential minimal optimization regression (SMOReg) • correlated Nyström views (XNV) • Linear Regression (L.R.) • reduced error pruning tree (REPTree) • M5P model tree Performance Test: • Mean Absolute Percentage Error (MAPE) • Mean Absolute Error (MAE) • Root Mean Square Error (RMSE)
Gulati *et al.* [21]	• Electricity demand data analysis • Prediction of electricity load for the next week: ✓ Input: 4-month dataset short (day to day) and long (week data) term data ✓ Process with ML	Conventional machine learning (ML) approaches: • Linear Regression (LR) • Support Vector Regression (SVR) • Decision Tree Regression (DTR) • Random Forest Regression (RFR) • Artificial Neural Networks (ANN) Performance Test: MSE.
Lu *et al.* [22]	• Prediction system: 1)Collecting data. 2)Data pre-processing: Data decomposition and normalization. 3)Optimize and predict: the SVM training process and the optimization of SVM performance evaluation.	• A hybrid model with the structure of a "data cleaning method optimizer-basic prediction model." (ICEEMDAN-MOGWO-SVM). • Performance test: MAE, RMSE, and MAPE.
Casaravilla *et al.* [23]	• The PIG serves as a decision-making tool for infrastructure installation, utilizing OddFace: a distributed optimization platform designed for high-cost evaluation functions. • Identifies how much of each technology, lowest investment and operating expenditures is acquired based on a predefined set of potential technological infrastructures decided by the planner. • Assessing the optimized cost function involves the interaction between OddFace and the SimSEE platform.	• Tools SimSEE and OddFace. There are two proposed OddFace optimization scenarios given. • Parameterizable genetic optimization.
He *et al.* [24]	• Examination of the factors impacting electricity demand. -Utilization of multidimensional variable selection through Granger causality analysis. -The mechanism analysis of influencing factors on electricity demand is conducted using path analysis. • The prediction of electricity demand relies on the SA-CSO algorithm. -Develop three electricity demand estimation model. -Construct a Hybrid SA-CSO algorithm for the electricity demand forecasting model. • Performance test.	• The proposed SA-CSO (Simulated Annealing Chicken Swarm Optimization) algorithm as a solution outperforms other algorithms to optimize the electricity demand estimation model. • Performance test: MAPE.

TABLE VI
RESEARCH METHODOLOGY AND METHOD/OROM CONTRIBUTION

Ref.	Methodology	Method/OROM Contribution
Ramadan and Helmi [25]	• Studied systems and problem formulation. Achieving an effective, robust, and applicable optimization solution for the DN reconfiguration problem, including addressing challenges related to the search space and the initial feasible population. • Metaheuristic optimization (MRFO algorithm).	• The MRFO (Manta Ray Foraging Optimization) algorithm is compared to two conventional optimizers, namely PSO (Particle Swarm Optimization) and GWO (Grey Wolf Optimization). The primary aim is to minimize the overall active power losses.
Alvarez [26]	• Propose two single-objective models and compose to multi-objective model. ✓Model 1: Widely spread problem of minimizing the generation cost. ✓Model 2: A model for minimizing risk. • Lexicographic optimization implemented in the field of epsilon-constrained methods. Test the efficiency by studying two systems: 6 bus and three generator test system.	Multi-objective model and lexicographic optimization are implemented.
Peñaranda *et al.* [27]	• Propose an appropriate battery degradation model that utilizes an upper piecewise linear estimation, integrated into the arbitrage strategies, to enhance the reliability and resilience of the outcomes.	Create a Mixed Integer Linear Programming (MILP) optimization problem incorporating a battery degradation model based on an upper piecewise linear approximation and a Recurrent Neural Network (RNN) utilizing Short-Term Long Memory (LSTM) architecture.
Marwan and Marwan [28]	• Create a ground-breaking plan to decrease the energy consumption of air conditioning, introducing a cooling model for buildings and a pre-cooling model designed for two different building characteristics, to optimize the thermal properties of the building, minimize overall energy consumption, and reduce costs.	Optimizing the thermal feature of the building and implementing other technologies aimed at reducing overall consumption and cost utilizing the numerical optimization technique.
Khan *et al.* [29]	• Proposed Multi-objective Optimization Model, calculating the energy Levelized cost • Developing models for the production of electrical energy (constructing three models with the objectives of minimizing the levelized cost of electricity, minimizing the total present value of energy costs, and maximizing the present value of total energy generated).	• Employing a Flexible Fuzzy Goal Programming Approach to determine the optimal mix of power generation. • The constraint equations are associated with factors such as unit electricity production, CO2 emissions limits, and the proportion of non-fossil fuel sources.
Elkamel *et al.* [30]	• Process: Input (load, units, and network data), forecast load data with LSTM networks, Units and Network data, and Formulation of UC problem to minimize objective function with constraint. • Performance test: mean absolute error (MAE), mean absolute percentage error (MAPE), and root mean square error (RMSE).	UC Problem formulation, where the objective function can be expressed as a Bounded-variable mixed-integer linear programming (BVMILP) with the following constraints: Load balance limit, power generation limit, power reserve limit, minimum uptime and downtime limits, and machine learning such as Deep LSTM systems, comparison with MLP and SVM, and Performance Test (MAE, MAPE, RMSE).
Lima *et al.* [31]	• Analysis of the demand evolution and run the HIDROTERM model with different hydrological scenarios and current system physical data.	Nonlinear programming (NLP) by the General Algebraic Modelling System package (GAMS 2020) and individual hydropower plants with aims tp to minimize the expected value.

3. Authors' Analysis

Two fields must be analysed to evaluate the author's relevance in the twelve articles: productivity and impact. Figure 5 fulfils these two types of particular fields in the form of the ten top internationally authors' production over 2020-2021.The authors' productivity can be evaluated based on the number of articles they have successfully published between 2020 and 2021. According to Figure 5, the size of the circle increases proportionally with the number of articles published. One can observe from Figure 5 that all circles have the same size, indicating that each author published only one article during that time and were evaluated accordingly. Therefore, all ten articles exhibit an equal level of productivity. Furthermore, the impact can be assessed by examining the total yearly citations. Referring to Figure 5, the more citations were obtained. Ahmadian A in Khan *et al.* [29] have the most cited with nine citations per year, followed by articles written Ali in Khan *et al*. [29] with five citations per year.

TABLE VII
TEN MOST SIGNIFICANT ARTICLES

Rank	Local Author	Journal	H and G Index	Total Citations
1	Lu H in Lu H [22]			15
2	Ma M in Lu H [22]	Energy	1	15
3	Ma X in Lu H [22]			15
4	Ali I in Khan *et al.* [29]			9
5	Chauhan J in Khan *et al* [29]			9
6	Khan MF in Khan *et al* [29]	Sustainability (Switzerland)		9
7	Modibbo UM in Khan *et al*. [29]			9
8	Pervez A in Khan *et al.* [29]			9
9	Ceylan in Ceylan [6]	International Journal of Energy Research		5
10	Guang F in He *et al* [24]	Electric Power Systems Research		4

In addition, global authors are authors of articles successfully indexed in bibliographic databases (WoS, Scopus, Dimensions, and many others). In other words, the article is indexed and incorporated with articles worldwide. On the other hand, local authors are the authors of articles indexed only on the collection of articles entered (in this study, only 12 articles were indexed).

One must be checked to identify local articles (only considering the comparison of the twelve articles entered) that significantly influenced the articles. Therefore, the ten most significant articles are presented in Table VII.

Furthermore, Table VII shows the total citations, H index values, and G index values in the ten most influential articles (overall in 2021).

4. Sources Analysis

Twelve articles on optimization models for problems of electricity strategy business during the Covid-19 pandemic have been published in various best journals and proceedings in the 2020-2021 timeframe. In Table VIII, the five best journals and proceedings based on the number of articles published and the total number of most relevant citations are presented to describe the impact of these journals and proceedings. *R* means rank in every journal name.

TABLE VIII
FIVE BEST JOURNALS AND PROCEEDING

# Journal Name Locally	R	Number of Article(s)	# Journal Name Locally	R	H and G Index	Total Citation Index
Energy	1	2	CEE	1	1	7
IJER	2	2	EPSR	2	1	5
2020 IEEE	3	1	Energy	3	1	4
Batteries	4	1	IJER	4	1	2
CEE	5	1	Sustainability	5	1	2

The left side of the table is the results for ranking the most productive journals based on the total number of articles that have been published. The energy was ranked first by successfully publishing two articles, namely the article written by Lu *et al.* [22] and Alvarez [26]. Then the International Journal of Energy Research was ranked next with the same number of articles published.

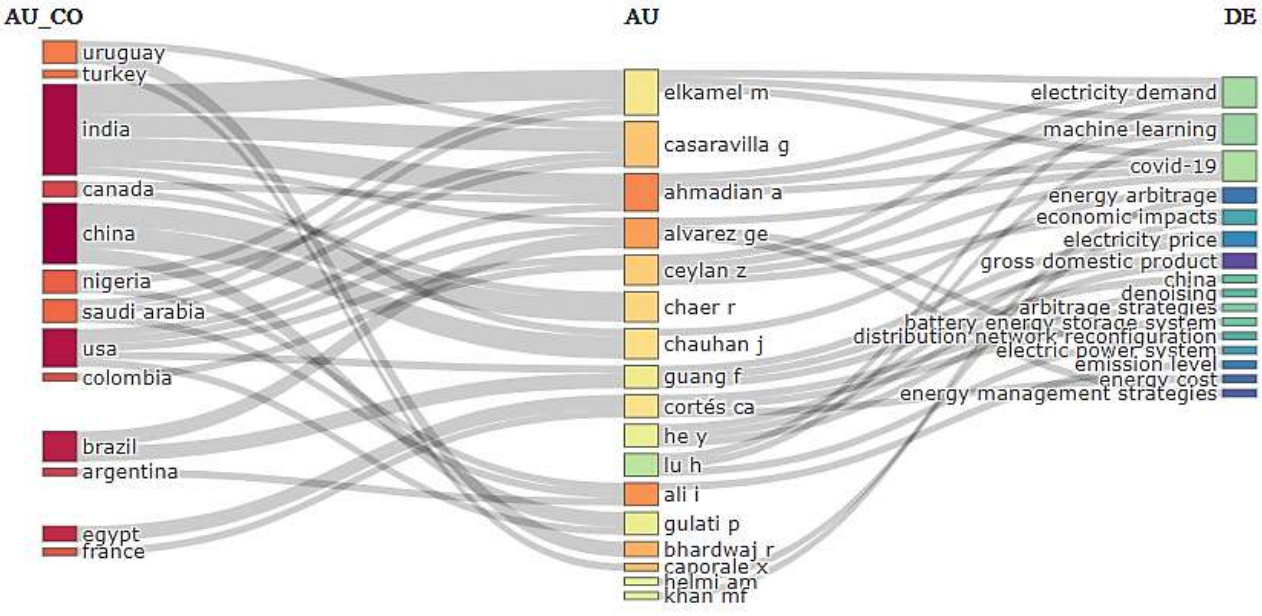

Fig. 4. Three-field Plot between countries, authors, and keywords.

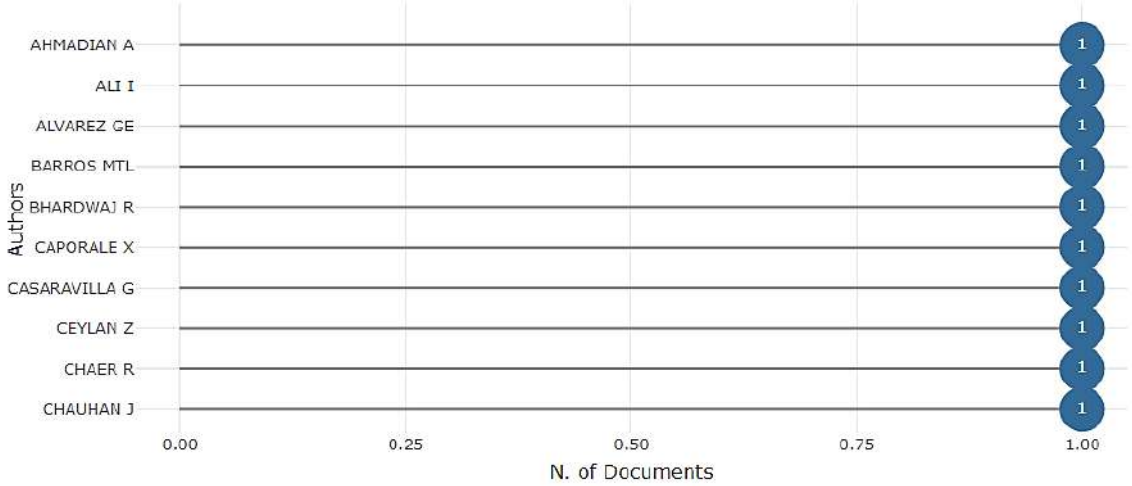

Fig. 5. Top 10 authors' production.

Furthermore, Table VII on the right presents the rank publishers based on the H and G indexes. The five articles have the same H and G index values. In other words, all five articles have the same number of citations and the average of citations.

At the source analysis stage, the overall development of the article can be seen in Figures 6 and 7. For the publishers of the 12 selected articles, it can be seen that there are some line slices (which indicate the type of publisher) that have decreased the number of publications in 2021 and several other line slices that have increased the number of publications in 2021, for example. Furthermore, the source dynamics cumulative growth can be seen in Figure 6. Figure 7 represents the source dynamics growth per year.

5. Word Analysis

A crucial analysis that follows is focused on identifying the most relevant words. R Software generates the output of the most pertinent words, which can be classified into three types: unigram (maximum of one word appears), bigram (maximum of two words appear), and trigram (maximum of three words appear).

In this study, the focus is on identifying the most relevant groups of three words (trigrams) from the abstracts and keywords of the 12 articles included. This analysis of word relevance aims to identify frequently and infrequently appearing keywords, explore potential research opportunities related to certain keywords, and assess which keywords have been widely studied.

Figure 8 presents the most relevant words in keyword field. The word Covid-19 topped the list with four appearances in the keyword section in Figure 8, followed by electricity demand with three occurrences. Based on the explanation, it can be concluded that the ten relevant words produced already represent the topic of this research, namely the optimization of electricity problems. In Figure 9, the most relevant words in the abstract field is presented. Furthermore, in Figure 9, chicken swarm optimization and annealing chicken swarm in He *et al.* [24] were ranked first and second with 5 and 3 occurrences.

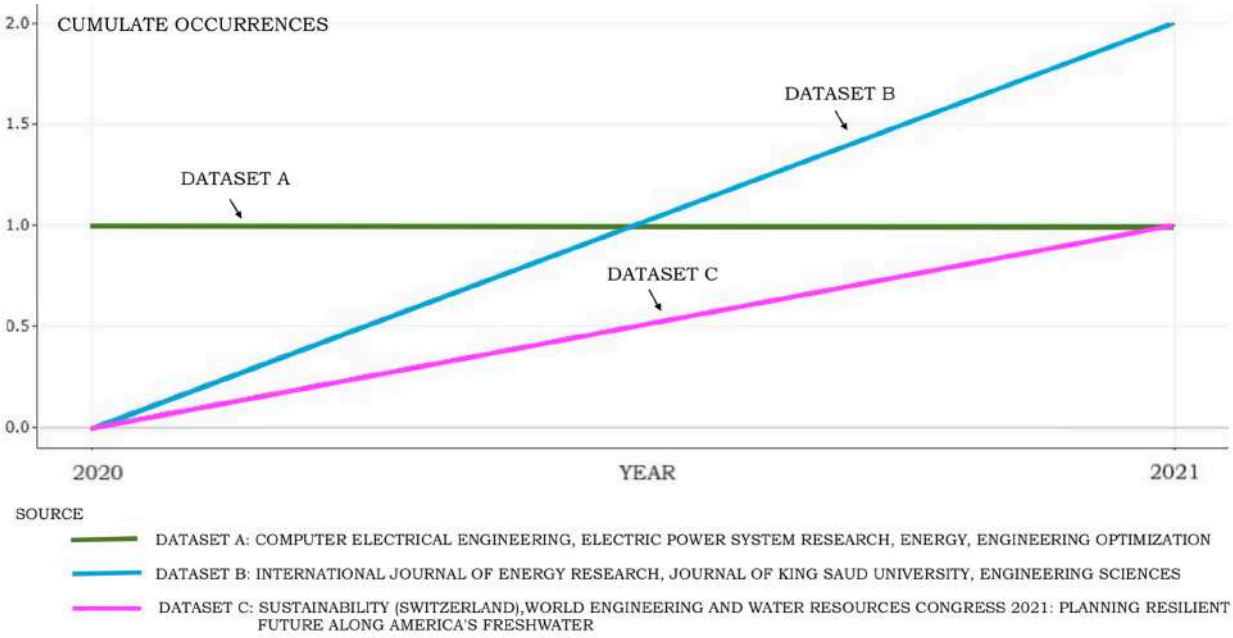

Fig 6. Sources dynamics cumulate growth.

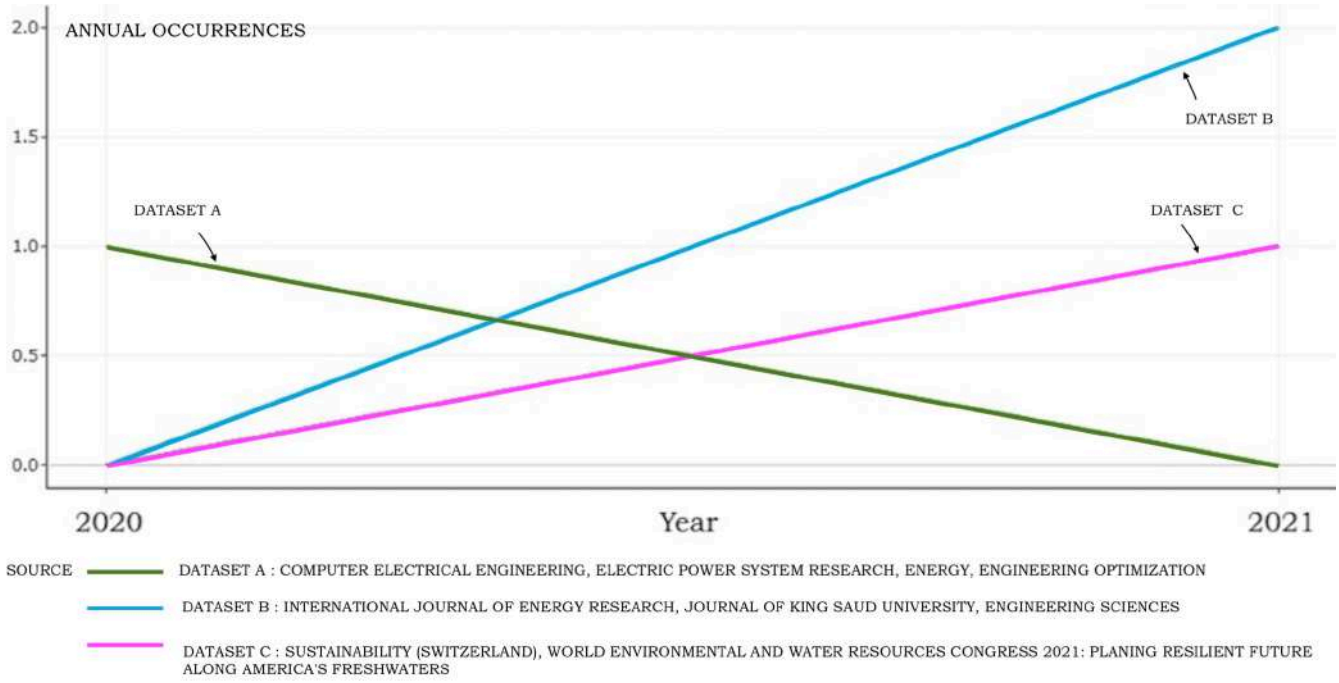

Fig 7. The source dynamics growth per year.

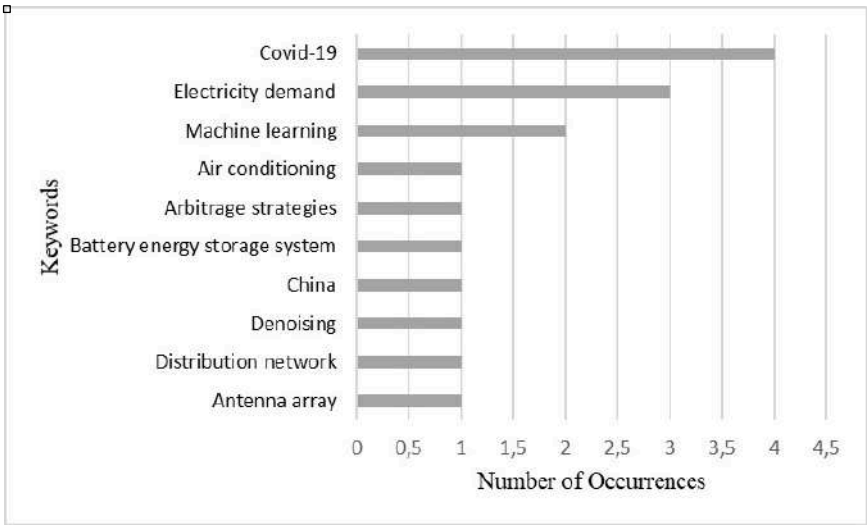

Fig 8. The most relevant words in the keyword field.

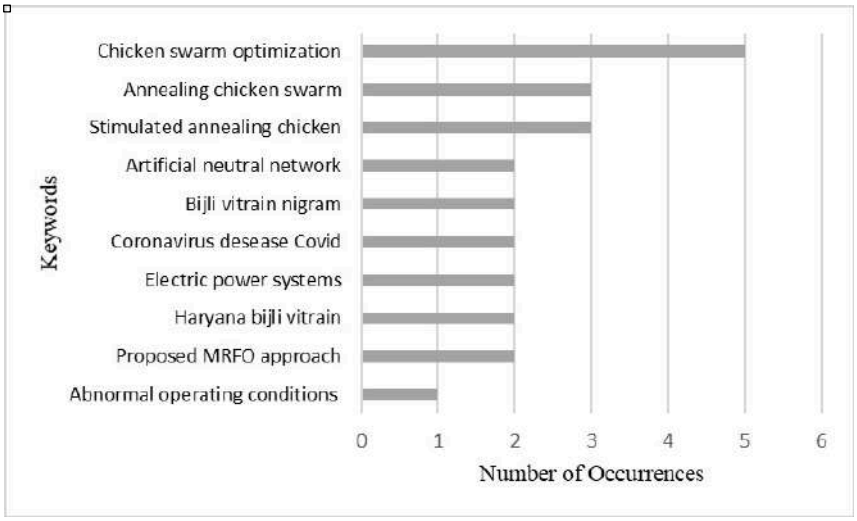

Fig 9. The most relevant words in the abstract field.

6. Conceptual Structure Mapping

Analyzing conceptual structure mapping helps researchers emphasize the relationship between collections of words and terms that appear, commonly called co-occurrence.

This study identified co-occurrence based on the keywords in the abstract and the title of the twelve database articles entered. The fifty most developed and related keywords followed the algorithm Louvain cluster. The mapping generated in this subsection's conceptual structure is bibliometric, presented in Figures 10 and Figure 11. The Co-occurrences network in the abstract field is presented in Figure 10, and the Co-occurrences network in the title field is presented in Figure 11.

The discussion shows that the more keywords identified, the larger the rectangle size for keywords that appear. Figures 10 and Figure 11 show five color clusters (green, red, blue, purple, and orange). Color differences mean cluster differences. In the case of these two bibliometric maps, the type of grouping in each cluster can be seen in Table IX and the complete list of topics based on color clusters can be seen in Table X.

A thematic evolution of the topics can be identified to provide significant details concerning the distinctions in subtopics by article authors based on clusters acquired in the 2020-2021 timeframe.

TABLE IX
TYPE OF GROUPING IN FIVE CLUSTERS

Co-occurrences Network in the Abstract Field		Co-occurrences Network in the Title Field	
Cluster Color	Grouping Type	Cluster Color	Grouping Type
Green	Electricity demand	Green	Unclear
Red	Power system	Red	Electricity demand
Blue	Unclear	Blue	Unclear
Purple	Swarm optimization	Purple	Unclear
Orange	Unclear	Orange	Unclear

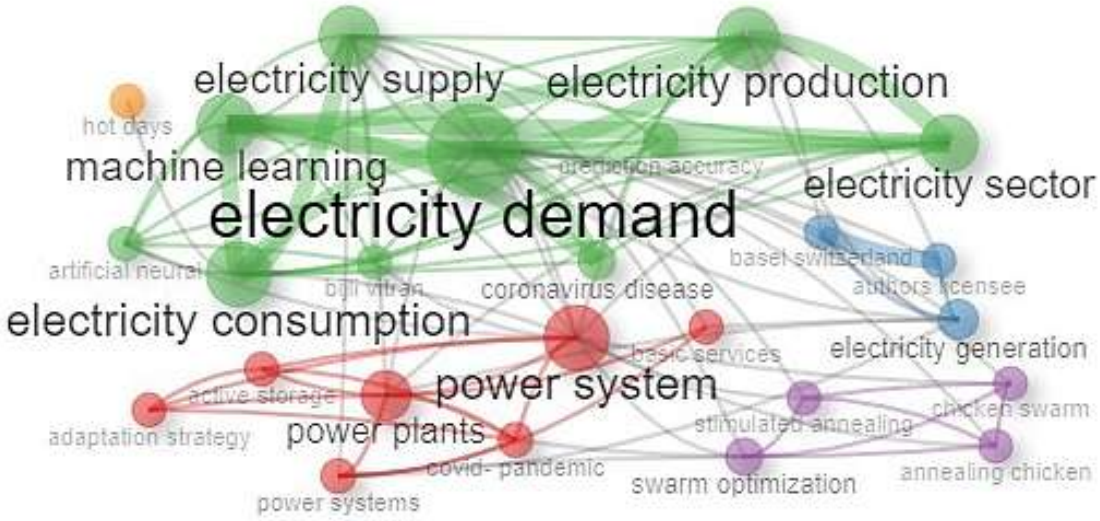

Fig 10. Co-occurrences network in the abstract field

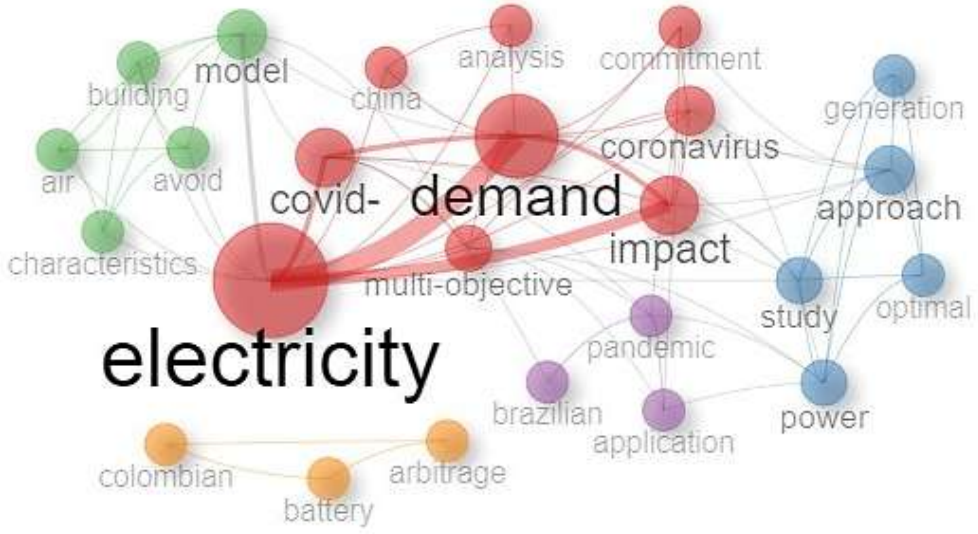

Fig 11. Co-occurrences network in the title field.

TABLE X
COMPLETE LIST OF TOPICS BASED ON COLOR CLUSTERS

	Co-occurrences Network in the Abstract Field	Co-occurrences Network in the Title Field
Color	Topics	Topics
Green	Electricity supply, electricity production, machine learning, prediction accuracy, coronavirus disease, artificial neural, electricity sector	Model, air, avoid, building, characteristics
Red	Adaptation strategy, active storage, power plants, power systems, covid-pandemic, basic services	Electricity, covid, demand, impact, coronavirus, commitment, analysis, china
Blue	Basel Switzerland, authors licensee, electricity generation	Generation, approach, study, optimal, power
Purple	Stimulated annealing, chicken swarm, annealing chicken, swarm optimization	Brazilian, application, pandemic
Orange	Hot days	Arbitrage, battery, colombian

Thematic evolution is shown in Figure 12 and Figure 13. Where the thematic map in the abstract field can be seen in Figure 12 and the thematic map in the title field is presented in Figure 13. The thematic evolution map can be used to examine topic progression across four distinct quadrants, which are determined by their centrality (level of relevance) plotted along the X-axis and their density (level of development) plotted along the Y-axis. In addition, the degree of centrality indicates the level of inter-cluster interaction, which measures the extent to which a topic is linked to other issues. Similarly, density refers to the timeframe during which keywords within a specific cluster are connected, thus developing a theme.

After examining the X and Y axes in the thematic map, it becomes evident that the topics with high centrality and density is plotted in upper right quadrant, indicating that these topics have a significant impact on research and are well-established. The topics with strong centrality but weak density can be seen in the lower right quadrant, suggesting that they hold considerable control over other issues but are not adequately developed. The lower left quadrant encompasses topics with weak centrality and density, implying that they have little influence on research and are not well-established. Lastly, the upper left quadrant represents topics that are the opposite of the lower right quadrant.

Based on Figure 12, the emerging topics such as electricity power optimization and optimal operation plants reside in the upper right quadrant, signifying that they hold the potential to impact research significantly and have been thoroughly developed. The same thing happened to the approach generation optimal in Figure 13.

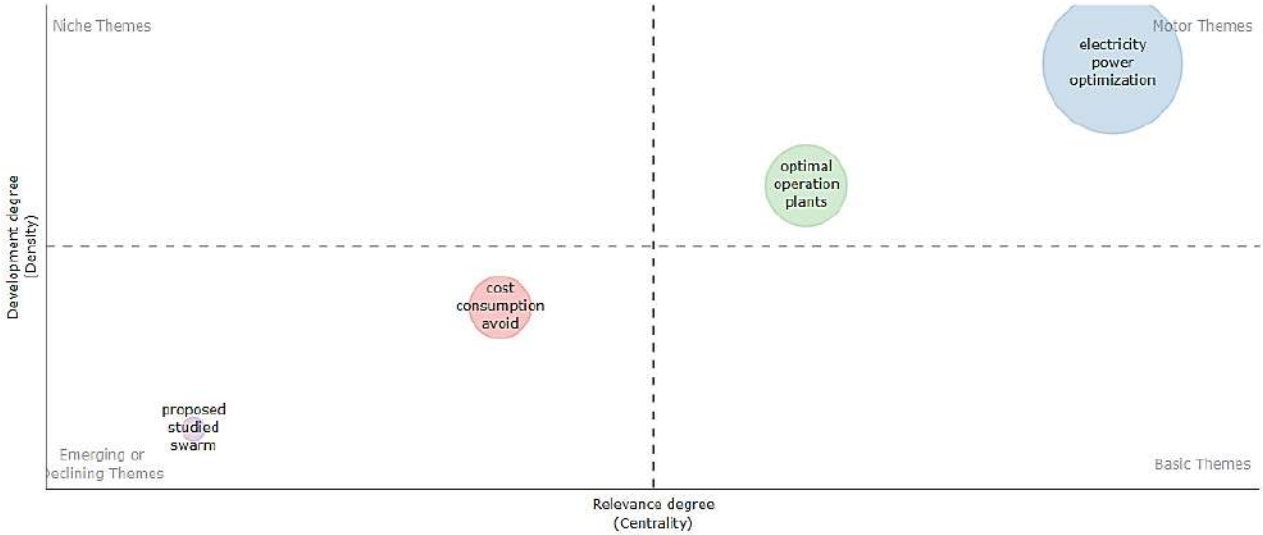

Fig 12. Thematic map in the abstract field.

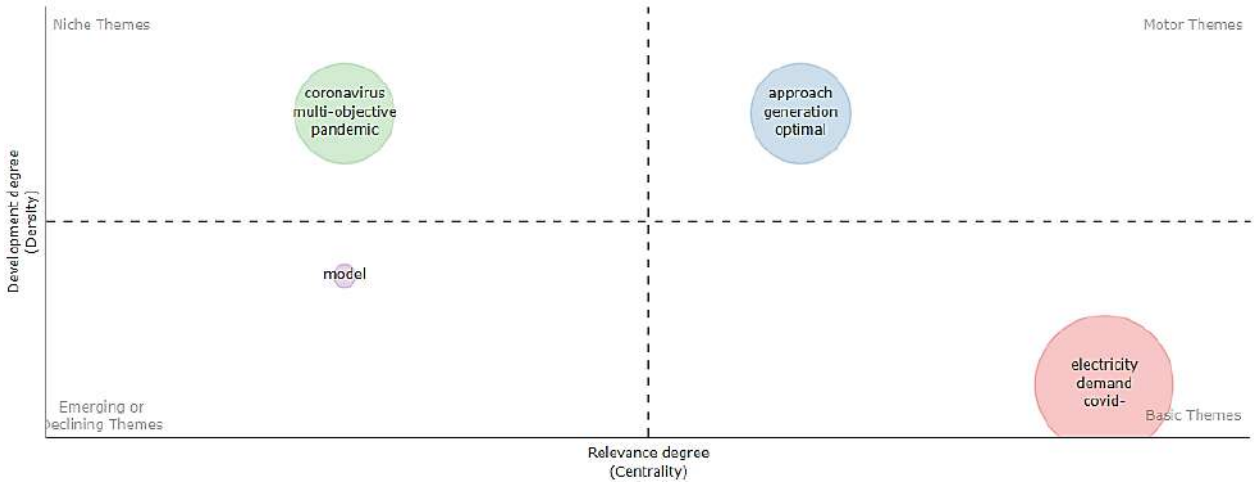

Fig 13. Thematic map in the title field.

Research Landscape on Optimization Modelling to Electricity Strategy Business during Covid-19 Pandemic

1. Discussion of Solution Handling Electricity Business Strategies During the Covid-19 Pandemic Using OROM Articles' Evolution Between 2019-2021++

This section discusses the study and analysis of the role and contribution of OROM in optimal decision-making strategies during pandemics. In addition, this section examined models and optimization methods that can be discussed to ensure company policies such as energy transition, customer service improvement, green boosters, and others continue to run on the agenda. Finally, Table XI summarizes literature studies on aspects of electricity business strategy, problems that must be solved during the Covid-19 pandemic, joint conditions, and OROM solutions and contributions.

Nowadays, machine learning-based methods have become popular in solving many real problems. In this review of literature, there are three studies, namely, Ceylan [6], Gulati *et al.* [21], and Elkamel *et al.* [31], which implement machine learning in forecasting the amount of electricity demand in various countries.

The electricity demand impact of Covid-19 in Turkey is studied in Ceylan [6]. The study compares machine learning methods in estimating the short-term impact of Covid-19 on the economy with Turkey's daily electricity consumption data (from March 16th, 2020, until June 1st, 2020). This study used various machine learning algorithms based on functions and trees in WEKA software as essential learning for time series forecasting. Forecasting using function-based algorithms relies on mathematical models, while tree-based learning models utilize a tree structure to make predictions. GPR (Gaussian Process Regression), SMOReg (Sequential Minimal Optimization Regression, XNV (Correlated Nyström Views), and LR (Linear Regression from function-based models and tree models M5P (M5P) and REPTree (Reduced Error Pruning Tree) from tree-based models are used. The results obtained in Ceylan [6] are as follows. First, in May 2020, the electricity demand was decreasing significantly. In this case, demand fell by about 17% compared to 2019. Second, the most remarkable reduction in electricity use occurred at the weekend, with a 34.7% reduction compared to the year 2019 with the same period. Third, the SMOreg model outperformed the GPR, XNV, LR, M5P, and REPTree models in forecasting electricity consumption during the Covid-19 lockdown period. Ceylan [6] show that the SMOreg method can be a firm and robust method for short-term approximation of electricity needs in any disaster (i.e., pandemics, collapsing economies, etc.).

Gulati *et al.* [21] analyzed the effects of the Covid-19 outbreak on the industrial, rural, agricultural, and urban sectors of the electricity load of Haryana state, India. The insistence that the electric power system forecast the electricity load to prevent waste is carried out due to restrictions imposed by the government on the condition of Covid-19. They apply the approach of classical machine learning, namely LR (Linear Regression), SVR (Support Vector Regression), DTR (Decision Tree Regression), RFR (Random Forest Regression), and ANN. Forecasting considers short-term and long-term data involving "lockdown" conditions. The input data is normalized to weigh all characteristics evenly. The complete dataset is split into two main parts - a subset for training and another for testing, with a ratio of 70 to 30. For the purposes of this study, the Artificial Neural Network (ANN) utilizes only three hidden layer sizes. The model was compiled using Adam's optimizer with a learning rate of 0,01 and trained over 1000 epochs.

Early termination is done to avoid overfitting, and the model's accuracy is evaluated using specific mean square errors (MSEs). ANN performance is better than the remaining method based on the results obtained. However, Random Forest Regressor outperforms ANN in some cases.

Another study using machine learning was conducted by Elkamel *et al.* [31]. The accuracy of load demand forecasting during the Covid-19 pandemic is critical to power generation scheduling and unit commitment (UC) issues. Elkamel *et al*. [31] explored the effects of the Covid-19 pandemic on electricity demand by analyzing data sourced from the Florida Department of Health. In Ramadan and Helmi [25], unit commitment (UC) problems are stated as a bounded-variable mixed-integer linear programming (BVMILP) model. The purpose of UC's concern is to minimize the operational costs of production units across scheduling ranges. The Long Short Term Memort (LSTM) block, a more complex RNS model, was proposed in this study. The LSTM system is used for forecasting and classification tasks; the construction of the entire system. In formulating and developing the model, electricity data were collected per hour and the number of Covid-19 cases in Florida, then compared electricity needs per month in 2019 and 2020. There are 24 generating units in the proposed UC issue. Features of coal-fired power plants, gas power plants, hydroelectric power plants, hydroelectric and nuclear power plants, actual load consumption, minimum and maximum power output, and average generating costs are obtained from the Electric Power Research Institute (2015). The proposed methods were evaluated against two alternative approaches - the Multilayer Perceptron (MLP) and the Support Vector Machine (SVM) - based on three criteria: mean absolute error (MAE), mean fundamental percentage error (MAPE), and root mean square error (RMSE). Inaccurate electrical load predictions are better achieved through the use of Long Short-Term Memory (LSTM) modeling than other benchmark methods such as Support Vector Machines (SVM) and Multilayer Perceptron (MLP).

In Peñaranda *et al.* [27], the Recurrent Neural Network (RNN) using a Long Short Term Memory (LSTM) is applied in the forecasting of one case of learning the effect of different operating strategies on the incomes from BESS operation.

In addition to implementing machine learning-based methods, researchers combine this method with other methods, or hybrids, as done by Lu *et al*. [22]. A hybrid model combines ICEEMDAN, MOGWO, and SVM to predict electricity demand in the United States every day during the pandemic. The analysis results indicate that the proposed model is promising.

The other optimization methods adopted in the research we studied are heuristic, meta-heuristic, or a hybrid of its methods. For example, Casaravilla *et al.* [23] utilize

parameterizable genetic optimization to determine the optimal technology and operation cost in the given series of infrastructures. Ramadan and Helmi [25] implement a bio-inspired optimization technique, MRFO (Manta Ray Foraging Optimization), to look for a feasible reconfigured D.N. with the least amount of power losses and an optimized voltage profile enhancement.

Research on methods of analysis and forecasting electricity demand using hybrid methods for cases in China was studied by He *et al.* [24]. Static causality tests, cointegration analysis, and Granger causality tests were employed to investigate the causal relationship between electricity demand and various factors, such as GDP, population, energy mix, industrial composition, and urban development. Hence, these factors' direct and indirect causes are investigated with path-coefficient analysis. In He *et al.* [24], a method of improvement from Chicken Swarm Optimization (CSO) based on Simulated Annealing, Simulated Annealing CSO (SA-CSO), was suggested to achieve optimal weighting factor of three different models for predicting electricity demand. Those forms are linear multiple, exponential, and quadratic. The model was trained using historical data from 1980 to 2011, and its accuracy was validated using data from 2012 to 2016. Mean Absolute Percentage Error (MAPE) was used to evaluate the model's performance on the test set. To evaluate the performance of the proposed method, three other methods: Chicken Swarm Optimization (CSO), Particle Swarm Optimization (PSO), and Genetics Algorithm (GA), were selected as a comparison to prove their effectiveness. Based on He *et al.* [24], the proposed SA-CSO algorithm outperformed other algorithms, which showed that improvements from CSO-based Simulated Annealing were valid. Based on these trials, the following better method after SA-CSO is CSO.

Other optimization aspects obtained: the use of lexicographic optimization to solve problems formed in multi-objective models such as in Alvarez [26]; the use of a Flexible Fuzzy Goal Programming Approach in the Multi-objective Optimization Model for Optimal Mix of Power Generation as in Khan *et al.* [29]; the development of a nonlinear programming optimization model (namely HIDROTERM model) can be applied for mapping out functioning of the hydrothermal system in the Brazilian hydrothermal system as in Lima *et al*. [32].

2. Benchmarking in Handling the Impact of Pandemics on The World's Electricity Business Sources' Analysis

The coronavirus outbreak has hit all lines of the utility business, including electricity. In 2020 many countries will experience an economic slowdown. The impact on the electricity business is felt and responded to in various countries. This section is given in Table XI, presenting different aspects of electricity studied from multiple countries and alternative solutions offered. Based on PRISMA results obtained by several countries that provide optimization methods as an alternative solution to problems arising from the effects of the Covid-19 pandemic on electricity. However, this table is also given a study that does not involve optimization in the solution (without an asterisk mark). Studies involving optimization and applied to case studies of certain countries are described in Table XI as well.

In 2018, the population of India reached 1.353 billion people, and it became the world's second-most populous country, with a GDP of 2.726 trillion USD. India's improved electricity sector will be crucial to its economic growth. The sudden surge in electricity demand patterns since the spread of Covid-19 (the closure of various industries and people insisting on staying at home) resulted in increased domestic consumption and declining industrial consumption. India's energy consumption plunged significantly in March after the "Janta Curfew" notice. Gulati *et al.* [21] conduct a week's electricity load forecasting to determine the required electricity load, thus helping to plan regional power systems and prevent unnecessary waste of power. In Gulati *et al.* [21], Machine Learning and Artificial Neural Network (ANN) algorithms are used. Khan *et al.* [29] conducted a study aimed at achieving one of the objectives set by the Indian government to reduce emission levels, increase the capacity of renewable sources, and improve hydro and nuclear status that must be carried out, as well as technical and financial parameters. In 2021, an analysis and assessment of India's socio-economic sustainability's optimal power generation cost system were conducted. The research offers the Flexible Fuzzy Goal Programming approach in determining optimally combined power generation for socio-economic sustainability.

The United States is the country that consumes energy, the second-largest in the world. It is the most affected in the pandemic (as of May 29th, 2020, accounting for several infected people in around 30% of the world) [22]. Therefore, the criteria must be met for the electricity provider department, which is inaccurately allocating resources, to become more complex. Thus, accurate prediction of electricity demand in electricity management is significant. Lu *et al.* [22] developed a predicting model of electricity consumption that can be applied well during pandemic times, which considers the accuracy of predictions and does not ignore stability. In Lu *et al.* [22], Hybrid prediction systems involving data processing, modeling, and optimization are applied.

Social isolation in Uruguay led to a decrease in demand for electrical energy (about 6%) and a more significant reduction in fuel consumption derived from petroleum occurring globally. This implies a drop-in fuel prices due to the impossibility of reducing supply suddenly. Consequently, these condone can pose severe problems for decision-makers, for example: regarding the expansion of plants, either because projected demand is delayed over a period of time and there will be a surplus or that income risks expected by investors do not come due to depressed marginal markets. Casaravilla *et al*. [23] analyzed the impact of sudden changes in electricity demand and fuel prices on the electricity industry. Lu *et al*. [22] proposed a simple model for Plant Investment Planning.

In China's "New Normal" phase, there are concerns about the electricity supply surplus, particularly in the northwest and northeast. In addition, ongoing reforms to the electricity system bring uncertainty and challenge the electricity supply and demand balance. Thus, it is still imperative and necessary to have precise estimation of electricity demand. He *et al*. [24] conducted a study on estimating electricity

TABLE XI
COMPARISON TABLE OF EACH COUNTRY RELATED TO THE ASPECTS OF ELECTRICITY STUDIED AND ALTERNATIVE SOLUTIONS OFFERED

No	Country	Electrical Aspects Studied	Alternative Solutions	Reference
1.	Japan	Review changes in monthly electricity demand generation and electricity grid needs.	The discovery of a pattern of reduced electricity demand without a significant impact.	D'Alessandro *et al.* [5]
2.	Polish	Observe a rapid change in electricity demand.	A study on the effects of pandemics on energy usage profiles variation and entity volumes.	Malec *et al.* [4]
3.	Turkey*	Accurate prediction of electricity demand when lockdown is applied.	Compared to electricity predictions, test the demand for fossil fuels and renewable energy at the time of lockdown.	Ceylan *et al.* [6]
4.	Romanian	Analyze changes in electricity consumption. and their relationship to economic growth during pandemics.	Recommended use of NRES (electricity powered by coal) that can be adjusted to economic needs.	Iancu *et al.* [7]
5.	Spanish	Review and enhance econometric models to assess the influence of the Covid-19 pandemic and forecast the behavior of dynamic electricity markets during such situations.	It is advisable to include more statistical data to review more complex aspects of the issue and the application of proposed models for data in other countries.	Norouzi *et al.* [8]
6.	Indonesia	Analyzing the activities that caused the increase in electricity bills during the pandemic in Indonesia.	During the Covid-19 pandemic, it is necessary to raise public awareness about conserving electricity and regularly monitoring household energy consumption.	Al-Hakim *et al.* [16]
7.	Indonesia	Analyzing consumer protection of electricity users after paying against the sudden increase in PLN (State Electricity Company in Indonesia) electricity bills during the Covid-19 pandemic.	There wishes to be a revision of the Consumer Protection Law. Therefore, electricity consumers who experience an increase of 50 percent to 100 percent should report to PLN for clarification.	Hasiholan and Tampi [17]
8.	Indonesia*	Avoiding surges in electricity prices for the characteristics of a variety of different buildings.	Design pre-cooling models for air conditioning and use CLC bricks for buildings with standard room and weather walls.	Marwan and Marwan [28]
9.	India*	Reviewing the pattern of electricity demand, namely changes in domestic consumption and industrial power consumption, especially involving certain factors.	Forecasting the required electrical load. Alternative solutions to Gulati *et al.* (2021) utilize Machine Learning and Artificial Neural Network (ANN) algorithms.	Gulati *et al.* [21]
10.	India*	Examine and assess the optimal power generation cost system for India's socio-economic sustainability.	The use of a flexible fuzzy goal programming approach is proposed for achieving optimal combined power generation with a focus on socio-economic sustainability.	Khan *et al.* [29]
11.	The United States*	Analyze resource allocation and electricity management to predict electricity demand.	Develop a well-applied electricity consumption prediction model during pandemic times, which considers the accuracy of predictions and does not neglect stability.	Lu *et al.* [22]
12.	Uruguay*	Examine the effects of an abrupt change in the demand for electricity and the cost of fuels utilized in thermal power stations on the electricity industry.	Propose a simple model for plant investment planning with risks due to rare severe events.	Casaravilla *et al.* [23]
13.	China*	Review the accurate estimation of electricity demand in the "New Normal" phase to determine the balance of electricity supply and demand.	Perform a causality analysis of the effect between electricity demand and several factors that are considered influential and utilizes the Simulated Annealing-Chicken Swarm Optimization method on forecasting	He *et al.* [24]
14.	Argentina*	Evaluate the adaptability of electric power system operations to changing conditions systems for the prevention of the Covid-19 pandemic.	Use multi-objective formulations to increase flexibility in the operation of electric power systems.	Alvarez [26]
15.	Brazil*	Reviewing the Covid-19 pandemic impact on hydrothermal systems in Brazil.	A recommended strategy is to plan the efficient reduction of high-priced thermal plants and recover water levels from reservoir storage and the productivity of complex hydro systems.	Lima *et al.* [32]
16.	Florida*	Reviewing the significant effects on electricity load demand profiles and unit commitment issues during the Covid-19 pandemic.	Examined how Covid-19 has affected both electricity demand and unit commitment issues using a Machine Learning: Long-short-term memory-based approach.	Elkamel *et al.* [31]
17.	General*	Review optimal reconfiguration for vulnerable intelligent grid networks under insured operating conditions.	The restructuring of the distribution network (DN) guarantees better system characteristics.	Ramadan and Helmi [25]

in China by taking into account factors such as economic development, population, added value of secondary industries, proportion of primary energy consumption from coal, and urbanization.

In He *et al.* [24], it is recommended to involve other factors that may affect electricity demand, for example electricity prices, environmental effects, policy effects, and so forth, for better forecasting models.

Ramadan and Helmi [25] observed the effect of the lockdown situation globally due to the Covid-19 pandemic on energy demand. Vulnerable power grid operations, especially on isolated microgrids or large-scale intelligent grids, can be prominently avoided by proposing optimally reconfigurable networks. Distribution network reconfiguration ensures better system characteristics under normal or incurable conditions. Three operations cases were studied and analyzed: common conditions (or standard cases), load variations, and contingency line outages. Manta Ray Foraging Optimization is proposed in Ramadan and Helmi [25]. Ramadan and Helmi gave new methods involving the Covid-19 pandemic's impact on the operation of large-scale electricity systems [25].

Alvarez [26] studies the increased adjustability in Argentina's electric power systems operation. The case study was conducted in mitigation efforts during the Covid-19 pandemic. Paper Alvarez [26] offers a multi-objective formulation that improves the operation of electric power systems in complex circumstances (due to pandemics). In Alvarez [26], lexicographic optimization is proposed. Two test cases with Argentine Electrical System data were simulated.

Research related to electricity during the Covid-19 pandemic in Colombia was performed by Peñaranda *et al* [27], which is related to the storage of grid-scale battery energy for arbitration goals. Peñaranda *et al.* [27] review the determination of appropriate arbitration strategies that allow owners of battery energy storage systems (BESS) to get maximum economic benefits while supporting the Colombian electricity market. Four different strategies for arbitrage, including Mirror arbitration, back-to arbitrage, and statistically based operating systems, are utilized to ascertain the best-performing strategies for BESS, which will take part in the Colombian market. In addition, the problem of Optimization of Mixed Integer Linear Programming (MILP) was formulated to determine optimal BESS operation, including a method for battery degradation modeling that relies on the linear upper piecewise approach technique.

The Covid-19 pandemic hit various countries, including Brazil, due to sudden reductions in energy demand and other impacts. Hydropower has become Brazil's primary electricity supply source, with a significantly increased participation share of thermal and wind power plants. A planned adaptation strategy is indispensable to dealing with declining demand. Lima *et al*. [31] emphasized the importance of devising an effective strategy that integrates the reduction of output from the most expensive thermal plants and replenishes water levels from reservoirs and enhances productivity in complex hydro systems. In Lima *et al*. [31], hydrothermal models were used in trade-off and adaptation strategies, and nonlinear programming optimization models for planning Brazilian hydrothermal systems were utilized for Lima *et al.* [31].

Researchers from Indonesia, Marwan and Marwan [28] observed that electricity bills in the midst of the Covid-19 pandemic are increasingly associated with warming weather. This is because many consumers use air conditioning for a long time at the same time during this period. In 2021, pre-cooling models for air conditioners were designed to avoid a surge in electricity prices on different building characteristics. It is expected that users will implement the proposed model and use Cellular Lightweight Concrete (CLC) bricks on the walls to save energy for buildings with certain rooms and weather.

IV. Conclusions and Future Research

The SLR has been conducted in this study by implementing the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) steps. This study was conducted to obtain information on the contribution of Optimization Mathematical Modeling and Operations Research in measuring the impact of Covid-19 on the world's electricity business strategy. Based on a review of existing articles, electricity demand is the most discussed topic related to the impact of the world's electricity business utility during the Covid-19 pandemic. Factors affecting electricity demand include electricity prices, environmental effects, policy effects, GDP, population, energy structure, industrial structure, and urbanization. Based on the study, many researchers analyze the electricity consumption data. It can be concluded that when some policies are taken by the government related to handling Covid-19, the consumption of electricity by households, Industrial, and business customers changes. There are significant changes in certain conditions.

It is recommended to conduct further research, especially related to electricity demand forecasting in Indonesia, using the optimization methods studied in the previous literature. The pre-tests on factors that may affect electricity demand are strongly suggested. In addition, we recommend considering the importance of data uncertainty, as in Yao and Yao [32]. In many situations, uncertainties must be considered. Thus, Robust Optimization is good to be proposed for handling the uncertainties; see [33], [34], and [35].

References

[1] Hillier and Lieberman, "Introduction to Operations Research," 7th ed. New York: McGraw-Hill, 2001.

[2] A. M. Caunhye, X. Nie, and S. Pokharel, "Optimization models in emergency logistics: A literature review," *Socio-Economic Planning Sciences*, vol. 46, no. 1, pp. 4-13, 2012.

[3] X. A. Tingting, G. B. Weijun, L. C. Yanxue, and Q. D. Fanyue, "Impact of the Covid-19 Pandemic on the reduction of electricity demand and the integration of renewable energy into the power grid," *Journal of Renewable and Sustainable Energy*, vol. 13, no. 2, pp. 026304, 2021.

[4] M. Malec, G. Kinelski, and M Czarnecka, "The impact of Covid-19 on electricity demand profiles: A case study of selected business clients in Poland," *Energies*, vol. 14, no. 17, pp. 5332, 2021.

[5] K. D'Alessandro, A. Chapman, and P. Dargusch, "The Impact of Covid-19 on Electricity Demand and Generation in Japan," *Sustainability*, vol. 13, no. 19, pp. 10836, 2021.

[6] Z. Ceylan, "The impact of COVID-19 on the electricity demand: a case study for Turkey," *International Journal of Energy Research*, vol 45, no 9, pp13922-13039, 2021.

[7] I. A. Iancu, C. P. Darab, and, S. D. Cirstea, "The Effect of the Covid-19 Pandemic on the Electricity Consumption in Romania," *Energies*, vol. 14, no. 11, pp. 3146, 2021.

[8] N. Norouzi, G. Z. Zarazua de Rubens, P. Enevoldsen, and F Behzadi. A, "The impact of COVID-19 on the electricity sector in Spain: An econometric approach based on prices," *International Journal of Energy Research*, vol. 45, no. 4, pp. 6320-6332, 2021.

[9] T. Naegler, C. Sutardhio, A. Weidlich, and T. Pregger, "Exploring long-term strategies for the german energy transition - A review of multi-Sector energy scenarios," *Renewable and Sustainable Energy Transition*, vol. 1, pp. 100010, 2021.

[10] N. Naval and J. M. Yusta, "Virtual power plant models and electricity markets - A review," *Renewable and Sustainable Energy Reviews*, vol. 149, pp. 111393, 2021.

[11] A. Navon, R. Machlev, D. Carmon, A. E. Onile, J. Belikov, and Y Levron, "Effects of the Covid-19 Pandemic on energy systems and electric power grids—A review of the challenges ahead," *Energies*, vol. 14, no. 4, pp. 1056, 2021.

[12] M. L. Abdulrahman, K. M. Ibrahim, A. Y. Gital, F. U. Zambuk, B. Ja'afaru, Z. I. Yakubu, and, A. Ibrahim, "A Review on Deep Learning with Focus on Deep Recurrent Neural Network for Electricity Forecasting in Residential Building," *Procedia Computer Science*, vol. 193, pp. 141–154, 2021.

[13] T. Ahmad and D. Zhang, "A critical review of comparative global historical energy consumption and future demand: The story told so far," *Energy Reports*, vol. 6, pp. 1973–1991, 2020.

[14] M. Y Naz., M. Bou-Rabee, S. Shukrullah, A. Ghaffar, A. Gungor, and, S. A. Sulaiman, "A review of hybrid energy technologies tenets, controls and combinational strategies," *Cleaner Engineering and Technology*, vol. 5, pp. 100340, 2021.

[15] G. N. D. De Doile, P. R. Junior, L. C. S. Rocha, I Bolis., K. Janda, and L. M. C. Junior, "Hybrid wind and solar photovoltaic generation with energy storage systems: A systematic literature review and contributions to technical and economic regulations," *Energies*, vol. 14, no. 20, pp. 1–22, 2021.

[16] R. R. Al Hakim, A. Muchsin, and F. S. Lestari, "Analysis of Increases in Electricity Bills During the Covid-19 Pandemic Based on Consumptive Behavior of Electrical Energy in Indonesia," *Jurnal Cafetaria*, vol. 2, no. 1, pp. 25-35, 2021.

[17] J. Hasiholan and M. M. Tampi, "Consumer Protection of Postpaid Electricity Users Against Sudden Increases in PLN Electricity Bills During the Covid-19 Pandemic (Study of Electricity Increases for the April-May and June 2020 Periods)," *Jurnal Hukum Adigama*, vol. 4, no. 1, pp. 210-232, 2021.

[18] J. P. Matthew and D. Moher, "Evaluations of the uptake and impact of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) Statement and extensions: a scoping review," vol. 6, no. 1, pp. 263, 2017.

[19] J. J. Riva, K. M. P. Malik, S. J. Burnie, A. R. Endicott, and J. W. Busse, "What is your research question? An introduction to the PICOT format for clinicians," *Commentary*, vol. 56, no. 3, pp. 167-171, 2012.

[20] H. Dervis, "Bibliometric Analysis using Bibliometric an R Package," *Journal of Scientometric*, vol. 8, no. 3, pp. 156-160, 2019.

[21] P. Gulati, A. Kumar, and R. Bhardwaj, "Impact of Covid19 on Electricity Load in Haryana (India)," *Int J Energy Res*, vol. 45, no. 2, pp. 3397–3409, 2021.

[22] H. Lu, X. Ma, and M. Ma, "A Hybrid Multi-Objective Optimizer-Based Model for Daily Electricity Demand Prediction Considering COVID-19," *Energy*, vol. 219, pp. 119568, 2021.

[23] G. Casaravilla, R. Chaer, and X. Caporale, "Planning of Generation Investments with Risks of Severe Infrequent Events," *In 2020 IEEE PES Transmission & Distribution Conference and Exhibition-Latin America (T&D LA); IEEE: Montevideo, Uruguay*, pp. 1–6, 2020.

[24] Y. He, M. Wang, F. Guang, and W. Zhao, "Research on the Method of Electricity Demand Analysis and Forecasting: The Case of China," *Electric Power Systems Research*, vol. 187, pp. 106408, 2020.

[25] H. S. Ramadan and A. M. Helmi, "Optimal Reconfiguration for Vulnerable Radial Smart Grids under Uncertain Operating Conditions," *Computers & Electrical Engineering*, vol. 93, no. 107310, 2021.

[26] G. E Alvarez, "A Multi-Objective Formulation of Improving Flexibility in the Operation of Electric Power Systems: Application to Mitigation Measures during the Coronavirus Pandemic," *Energy*, vol. 227, no. 120471, 2021.

[27] A. F. Peñaranda, D. Romero-Quete, and C. A. Cortés, "Grid-Scale Battery Energy Storage for Arbitrage Purposes: A Colombian Case," *Batteries*, vol. 7, no. 3, pp. 59, 2021.

[28] M. Marwan and M. D. Marwan, "Designing a Pre-Cooling Model for Air Conditioning to Avoid an Electricity Price Spike for Different Building Characteristics," *Journal of King Saud University - Engineering Sciences*, no. S1018363921000969, 2021.

[29] M. F. Khan, A. Pervez, U. M. Modibbo, J. Chauhan, and I. Ali, "Flexible Fuzzy Goal Programming Approach in Optimal Mix of Power Generation for Socio-Economic Sustainability: A Case Study," *Sustainability*, vol. 13, no. 15, pp. 8256, 2021.

[30] M. Elkamel, A. Ahmadian, and Q. P. Zheng, "Impact of Coronavirus Disease 2019 on Electricity Demand and the Unit Commitment Problem: A Long–Short-Term Memory-Based Machine Learning Approach," *Engineering Optimization*, pp. 1–18, 2021.

[31] S. C. P. Lima, R. C. Zambon, M. T. L. Barros, and, W. W. Yeh, "G. Impacts of the Covid-19 Pandemic on the Brazilian Hydrothermal System," *World Environmental and Water Resources Congress 2021, American Society of Civil Engineers: Virtual Conference*, pp. 1092–1102, 2021.

[32] Y. Yao and H. Yao, "Finite-time Control of Complex Networked Systems with Structural Uncertainty and Network Induced Delay," *IAENG International Journal of Applied Mathematics,* vol. 51, no. 3, pp508-514, 2021.

[33] A. Ben-Tal and A. Nemirovski, "Robust optimization–methodology and applications," *Mathematical Programming*, vol. 92, no. 3, pp. 453– 480, 2002.

[34] D. Chaerani, S. P. Dewanto, and E. Lesmana, "Robust optimization modelling with applications to industry and environmental problems." In *Journal of Physics: Conference Series*, vol. 893, no. 1, pp. 012065. IOP Publishing., 2017.

[35] Diah Chaerani, R.A. Agustini, and E. Rusyaman, "Adjustable Robust Maximum Flow Problem with Parametric Ellipsoidal and Polyhedral Uncertainty Set," *IAENG International Journal of Applied Mathematics,* vol. 51, no. 1, pp82-91, 2021.