Basic Ai Models For Electric Load Forecasting: Bibliometric Analysis Approach From Scopus

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Abstract

Artificial intelligence (AI) has revolutionized the field of electricity load forecasting, which is crucial for efficient power system planning and operation. The growing integration of renewable energy sources, particularly with their intermittent nature, has further highlighted the need for accurate load forecasting to optimize system performance and enhance grid stability. AI methods, such as neural networks and machine learning, have emerged as effective tools to address the complexity and nonlinearity of electric load data, outperforming traditional approaches. This paper uses a bibliometric analysis approach with the SCOPUS database, examining publications from 1997 to 2023 to analyze research trends in basic AI approaches for load forecasting. The analysis of 72 publications shows a notable rise in interest post-2018, particularly in short-term and very short-term load forecasting. Key countries leading this research include China, India, Indonesia, Australia, and the USA, reflecting their growing energy demands and efforts to integrate AI with smart grids and renewable energy systems. Recent trends show an increasing exploration of novel methods such as ensemble learning and Bayesian optimization to enhance model accuracy and stability. Future studies should explore more advanced AI techniques to better address the evolving challenges of load forecasting in the context of increasingly complex power systems.

Research purpose:
This paper aims to analyse research trends in basic artificial intelligence approaches for load forecasting in the following aspects: the number of publications over time, the key countries, the main authors

Research motivation:
Artificial intelligence (AI) has revolutionized the field of electricity load forecasting, which is crucial for efficient power system planning and operation. The growing integration of renewable energy sources, particularly with their intermittent nature, has further highlighted the need for accurate load forecasting to optimize system performance and enhance grid stability. Investigating the current application of AI in electricity load forecasting is essential to identify future trends in this area.

Research design, approach, and method:
In this study, bibliometric analysis was employed to investigate global scholarly interest in applying AI to electrical load forecasting. Data was extracted from the Scopus database, examining publications from 1997 to 2023. The analysis was conducted using Biblioshiny, VOSviewer, and Microsoft Excel to assess performance metrics, keyword co-occurrence, and international scientific collaboration.

Main findings:
The research finds increasing attention to AI-based electric load forecasting from 1997 to 2023, with a notable spike in publication productivity after 2018. Analysing 72 publications, the study highlights significant contributions from China, India, Indonesia, Australia, and the USA, driven by rising energy demand. Advanced techniques like LSTM, deep learning, and ensemble learning have gained prominence since 2017, showing improvements in accuracy and efficiency for short-term load forecasting in smart grid systems.

Practical/managerial implications:
AI-based load forecasting can significantly support power system operation by providing more accurate predictions, especially with the rise of renewable energy integration. Bibliometric analysis shows a growing interest in the research topic of adopting basic AI techniques, such as neural networks and machine learning, to help power companies optimize energy distribution, reduce operational costs, and enhance grid stability. Considering AI models in load forecasting is necessary for countries with an increasing portion of renewable energy in their power systems.

Keywords: Bibliometric, Load forecasting, Artificial intelligence, AI, Forecasting method

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1. INTRODUCTION

As the world transitions to renewable energy sources, many consumers have opted to incorporate renewable energy into their consumption. The intermittent nature of renewables such as solar energy has heightened the importance of accurate load forecasting. Precise load forecasting can help reduce resource wastage (Hsu et al. 2020). Consequently, artificial intelligence (AI) has been employed for load forecasting to enhance predictive performance and improve the accuracy of results.

The ability of artificial intelligence (AI) to process vast amounts of data and learn iteratively has transformed numerous industries. AI has become a cornerstone in forecasting applications, including weather, business, and production demand. Notably, AI plays a pivotal role in predicting electricity load, a critical component for effective power system planning and operation (Dhillon et al. 2016).

Load forecasting plays a pivotal role in ensuring the stable and efficient operation of a power system. Predicting electricity demand with accuracy at any given moment is essential for system dispatch activities, including generating unit operating schedule optimization, system security, economic planning, and effective energy management (Singh, Singh, and Tripathy 2012). The non-storability of electricity necessitates a near-instantaneous balance between generation and consumption. Therefore, load forecast data must be highly accurate, especially in the spot electricity market. Through the analysis of historical data and influencing factors, forecasting models help power systems predict electricity demand accurately, thereby supporting timely and effective dispatch decisions (Pallonetto, Jin, and Mangina 2022). System dispatch based on load forecasting not only helps minimize the risk of overload or power shortage but also optimizes electricity generation costs. By prioritizing the use of low-cost and flexible power sources, the power system can reduce operating costs and enhance competitiveness (Jawad et al. 2020). In addition, load forecasting also supports the planning of power system development, ensuring that it meets the growing demand for electricity in the future.

To ensure the reliability of forecasts, with the ability to process large datasets and provide quick and accurate results, artificial intelligence (AI) has been rapidly adopted and has become a popular method for electricity load forecasting. Recent research has focused on electricity load forecasting using AI methods. Literature indicates that electricity load forecasting is susceptible to the nonlinear characteristics of influencing factors (Guo, Niu, and Chen 2006), or caused by the complexity of electricity load data (255), resulting in forecast errors. Surveys show that only a 1% error in forecasting can lead to economic losses. To overcome this situation, researchers have used AI methods and have achieved better results compared to traditional forecasting methods (Jha et al. 2021; Singh et al. 2012).

The literature on artificial intelligence that falls under this research's purview uses conventional neural networks or fundamental machine learning techniques like ANN, LSTM, fuzzy neural network (FNN), wavelet neural network (WNN), etc. The first published document in 1997 examined the stability of neural networks (Lowe 1997). By 2023, there were a total of 72 reliable documents on this topic. Notably, in 2018, the number of publications increased significantly compared to the previous period. From 2018 to 2023, the number of publications each year ranged from 9 to 11, indicating that this is an emerging topic and has received more attention from the author community.

The author KOPRINSKA has the most published research in the dataset. KOPRINSKA has collaborated with other scholars to research various AI methods such as wavelet neural networks (Rana and Koprinska 2013), maximum length weighted nearest neighbor (Colombo, Koprinska, and Panella 2015) and then continued to develop further research on convolutional neural networks (Koprinska, Wu, and Wang 2018). The two co-authors BENAOUDA DJAMEL and MURTAGH FIONN both researched Neuro-wavelet approach (Benaouda and Murtagh 2007, n.d.). The two authors JEENANUNTA CHAWALIT and PHYO PYAE P. jointly researched deep learning models (Phyo, Jeenanunta, and Hashimoto 2019), and then continued to delve deeper into deep neural network (Phyo and Jeenanunta 2016).

The majority of AI-based load forecasting methods are concentrated on short-term (Dhillon et al. 2016; Wang et al. 2009) and very short-term forecasting (Singh and Dwivedi 2022). This alignment with the evolving power grid is driven by the need for accurate and timely forecasts to support the increased flexibility in energy generation, distribution, and management that is anticipated in the future power system. As stated in (Jetcheva, Majidpour, and Chen 2014), the future power grid is expected to provide unprecedented flexibility, necessitating an ability to perform accurate short-term small-scale electricity load and generation forecasting.

The first published research on AI-based forecasting methods described a method for estimating and characterizing data, along with the complexity of models suitable for forecasting repetitive time series. The study examined the stability of the model using neural networks and yielded promising results (Lowe 1997). To address practical issues such as small sample sizes, nonlinearity, multidimensionality, and local minima, support vector machines (SVM) have been employed, resulting in good performance and fast computation speed (Ma 2008). However, the application of this method for electricity load forecasting remains scarce (Guo et al. 2006) due to its high complexity.

Subsequently, artificial neural networks (ANNs) emerged as a promising AI tool. (Velasco et al. 2022) suggested that ANN models with flexible backpropagation training algorithms have great potential for short-term forecasting, especially for predicting consumption in the next hour. Initially, simple ANNs were developed, and researchers conducted a comprehensive analysis of the ANN design space and implemented various training programs. Results indicated that ANN-based models improved accuracy by 29% (Ortiz-Arroyo, Skov, and Quang Huynh n.d.). ANNs were further enhanced with algorithms such as Weight and bias initialization, reducing processing time (Kumar and Tripathi 2019), or with the support of MATLAB, resulting in a model with an R-value of 0.988, a mean absolute deviation of 0.104, and a mean squared error of 0.27 (Samuel et al. 2020).

With the advancement of computer science, neural networks such as DNN, CNN, and RNN (Adewuyi et al. 2019) have been developed and applied to electricity load forecasting, achieving higher accuracy.

Long short-term memory (LSTM) networks have gained significant attention from researchers. LSTM is capable of forecasting complex univariate electric load time series with strong non-stationarity (Ermatita et al. 2019) and can effectively extract load features (Jiang et al. 2018). Numerous studies have demonstrated the effectiveness of LSTM in outperforming traditional forecasting methods in the challenging peak load forecasting problem, surpassing deep belief networks (DBN) (Phyo et al. 2019). Ongoing research continues to explore the advantages and disadvantages of this technique (Kanwar, Agrawal, and Manoranjitham 2023).

A comprehensive study on the application of basic AI models in electricity load forecasting is currently lacking. This research aims to fill this gap by conducting a systematic literature review of load forecasting using data from the Scopus database. The study provides a global overview of basic AI models for electricity load forecasting and the challenges associated with new research. This review will assist researchers in identifying potential research directions.

Specifically, this study aims to address the following research questions (RQ):

> RQ1: How has the number of publications on electric load forecasting using artificial intelligence evolved over time?
>
> RQ2: What are the important countries in electric load forecasting using artificial intelligence methods?
>
> RQ3: What are the main author keywords and trends in research on electric load forecasting using artificial intelligence?

2. RESEARCH METHODS

2.1 Bibliometric analysis

Bibliometric analysis is a statistical technique that assesses and measures the influence of scientific publications, providing valuable insights into the progress and patterns within a specific study domain. This approach entails gathering and examining bibliographic data from several databases, including Scopus, Web of Science, Google Scholar, and Semantic Scholar (Donthu et al. 2021). A key objective of bibliometric analysis is to quantify the output and impact of scholars, organizations, and countries while also charting the connections across various study topics and detecting developing patterns. Overall, bibliometric analysis is a potent instrument for both researchers and policymakers, providing a comprehensive and numerical evaluation of the scientific environment and promoting a more profound comprehension of the dynamics within various research fields.

This study uses bibliometric analysis to examine global scholarly interest in applying AI to electrical load forecasting through studies found in the Scopus database.

2.2 Database, keywords and search strategies

Extracted data are obtained from Scopus, Web of Science database, which are well-regarded, reliable, and the largest databases for publishing and citation of literature. In this study, Scopus was used for data extraction. The approach for collecting the database followed the parameters specified in the Preferred Reporting Items for Systematic Reviews and MetaAnalyses (PRISMA) paper (Figure 1) (Moher et al. 2009).

PRISMA has been widely adopted by researchers to collect data in various fields, such as education (Hallinger and Chatpinyakoop, 2019) and tourism (Szpilko, 2017). In the field of forecasting, many scholars have utilized PRISMA for data analysis and collection (Saraiva and Yoshizaki, 2024). PRISMA enables authors to explicitly detail all search and screening steps.

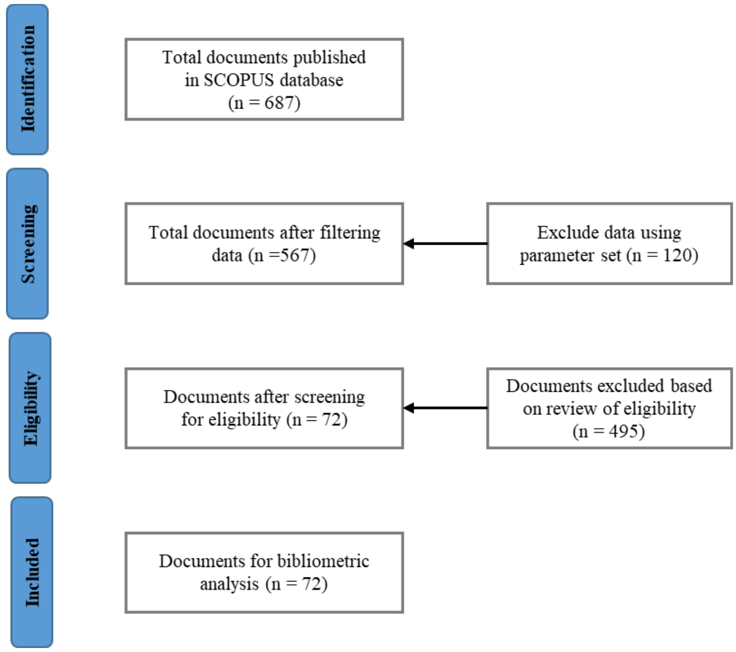

Figure 1: Data collect based on the PRISMA Process

To accomplish the goal of identifying research that applies AI to load forecasting, the keywords "electricity load forecasting" and its variant "electricity load forecast" were used for the initial search in March 2024. Executing the query Article title, Abstract, and Keyword shows that there are 687 documents that match. The search scope is not limited to the earliest study; however, the search is limited to 2023 only. Other criteria used to narrow the search scope include Language (English), Document type (Article and Conference paper), Subject area (Engineering, Energy, Computer Science, Decision Sciences). After this step, 120 documents were eliminated, and 567 documents were retained for the next step. Finally, the authors performed a literature review to identify studies using Basic AI for load forecasting, resulting in 72 relevant papers.

Table 1: Main query string used for document database collection.

Step	Query string	Results
1	TITLE-ABS-KEY ("electricity load forecasting" OR "electricity load forecast")	687
2	TITLE-ABS-KEY ("electricity load forecasting" OR "electricity load forecast") AND (LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "ENER") OR LIMIT-TO (SUBJAREA , "DECI")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp")) AND (LIMIT-TO (LANGUAGE , "English")) AND (EXCLUDE (PUBYEAR , 2024))	567
3	Document titles, abstracts, and full texts were scanned to identify publications using Basic AI in load forecasting.	72

2.3 Software and methods of analysis

Data analysis was conducted using the Biblioshiny package, Microsoft Excel, and VOSviewer software modules. Both the Biblioshiny package and the Excel utility are used to conduct performance analysis. Furthermore, the VOSviewer and the Biblioshiny program, a widely used bibliometric software package for science mapping, provide support in answering the question. Analysis of performance centers on the trajectory of growth, geographical distribution, and the most notable author, influential work, or important source.

Co-authorship analysis shows international scientific collaboration. Countries are considered nodes in this analysis when they co-author an article. The dataset lists papers, authors, nations, and other relevant data. Assessing author keyword co-occurrence frequency is the best way to find common study fields. In bibliometrics, co-occurrence keyword analysis identifies patterns and relationships between terms within a corpus of scientific literature. By examining the frequency with which certain keywords appear together, researchers can uncover hidden associations and identify important concepts in a specific research field. Co-occurrence keyword analysis provides insights into the interconnectedness of ideas and assists in identifying emerging trends and research clusters. This technique aids in literature review, supports decision-making, and facilitates knowledge discovery. By understanding the co-occurrence relationships between keywords, researchers can gain a deeper understanding of the underlying structure and dynamics of a research field.

3. RESULT AND DISCUSSION

3.1 The number of publications

On the topic of "Load forecast methods using AI," to date, 72 articles have been identified in the Scopus database, with the earliest publication dating back to 1997. Among these articles, conference papers constitute the majority with 46 publications, accounting for 63.89% of the dataset, while journal articles comprise the remaining 26 publications, representing 36.11%.

Figure 2 illustrates the total number of publications by year on this topic from 1997 to 2023. Overall, this dataset exhibits a relatively low Annual Growth Rate (AGR) of only 8.33% per year. The first identified publication, titled "Complexity Modelling and Stability Characterization for Long-Term Iterated Time Series Prediction" (Lowe 1997), appeared in 1997 and introduced the initial approach of using neural networks for electricity load forecasting. However, it was not until 8 years later that the next publication on this topic emerged, featuring the application of a simple ANN-based prediction model (Ortiz-Arroyo et al. n.d.). The number of annual publications remained low in subsequent years and only experienced significant growth starting in 2018.

When combined with the data illustrated in Figure 2, it is evident that the trend in the number of publications on this topic from 1997 to 2023 can be divided into two main periods: 1997–2017 and from 2018 onward. During the first period, from 1997 to 2017, the topic received relatively little attention, with an average of only two publications per year. There was even a period from 1998 to 2004 where no publications on this topic were found. The second period, from 2018 onward, witnessed a dramatic surge in the number of publications, accounting for 72.22% of the total number of publications in the dataset. In recent years, this topic has garnered increasing interest from scholars, with a broader range of AI-based approaches and various neural network models being explored and applied to load forecasting in journal articles. Thus, it can be argued that fundamental AI methods in load forecasting are becoming increasingly crucial in modern energy management. Early models, such as Artificial Neural Networks, have paved the way for the development of more complex approaches, such as deep learning, which better meet the growing demands of electricity load forecasting.

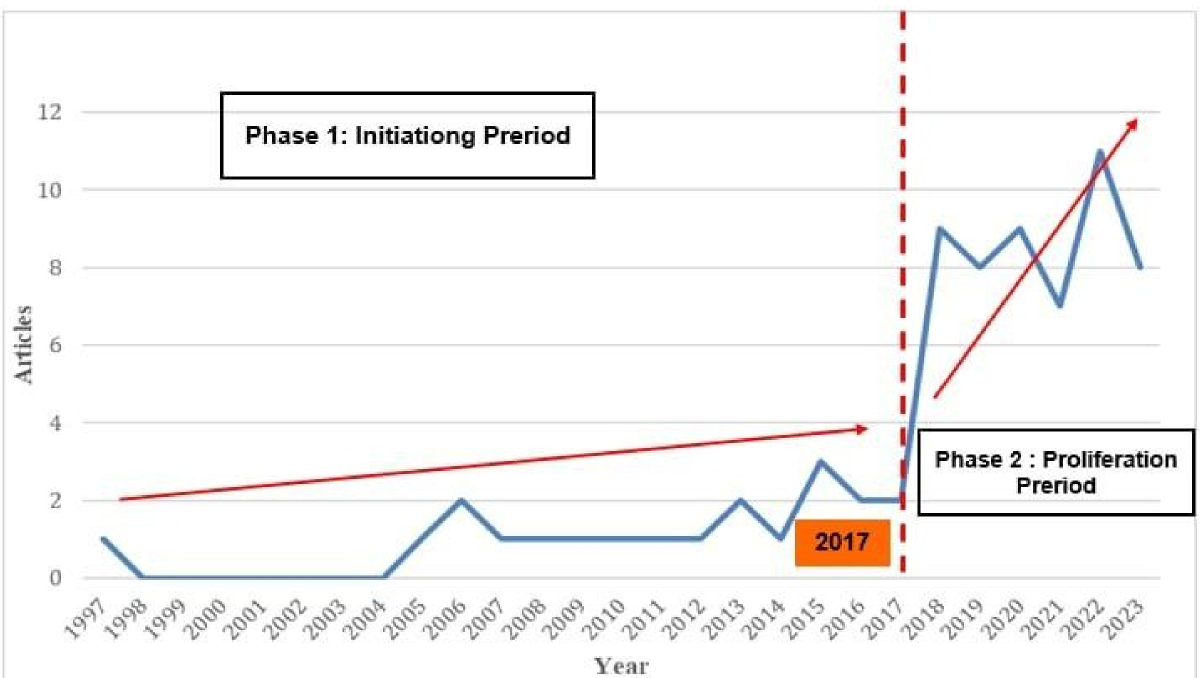

Figure 2: Number of publications 1997-2023.

3.2 Analysis of important authors

There are 206 authors who have contributed to this topic, yet only 9 authors have contributed more than two publications. This indicates that although the topic has garnered widespread interest with a large number of participating authors, the contributions are dispersed, and the level of specialization varies among the authors. Only a small number of authors have conducted in-depth research on this subject.

A bibliometric analysis of the important authors is provided in Table 2, which shows the top 10 most influential authors in this field, based on the number of publications and total citations. KOPRINSKA IRENA is the only author with 3 publications - the most prolific author on this topic. Additionally, KOPRINSKA IRENA ranks first in total citations, establishing as the most significant contributor to the subject. Koprinska's works demonstrate various AI approaches to load forecasting, exhibiting diversity in the types of neural networks applied (Colombo et al. 2015; Koprinska et al. 2018; Rana and Koprinska 2013). Another notable finding is that the other authors with two publications tend to collaborate within the same research groups. BENAOUDA DJAMEL and MURTAGH FIONN co-authored papers on the Neuro-wavelet approach (Benaouda and Murtagh 2007, n.d.), while the two publications by JEENANUNTA CHAWALIT and PHYO PYAE P. are also joint works (Phyo et al. 2019). The other authors with two publications also belong to the same research group (Wang et al. 2023). Together, the present findings confirm that authors who have conducted extensive research in this field tend to focus on a specific approach, with their subsequent publications building on the initial approach introduced in their earlier works.

Table 2: Top 10 impact author based on h_index

TT	Author	h_index	TC	NP	PY_start
1	KOPRINSKA IRENA	3	129	3	2013
2	BENAOUDA DJAMEL	2	12	2	2006
3	MURTAGH FIONN	2	12	2	2006
4	JEENANUNTA CHAWALIT	2	49	2	2019
5	PHYO PYAE P.	2	49	2	2019
6	LI FUCUN	2	8	2	2020
7	SHEN JUN	2	8	2	2020
8	YONG BINBIN	2	8	2	2020
9	ZHOU QINGGUO	2	8	2	2020
10	ADEWALE ADEYINKA	1	7	1	2020

3.3 Analysis of important journals

On the other hand, the analysis of important journals brings many new findings. A total of 55 journals have contributed to this topic, with 36 of them starting to publish on the subject from 2018 onwards, representing 65.45% of the total journals in the dataset. This discovery also corroborates the findings from the analysis of publications by time, indicating that interest in this topic has significantly increased from 2018 onwards.

Table 3 below presents the top 10 important journals, analysed using bibliometric methods, all of which belong to the fields of energy, computer science, and related areas. These journals have published numerous works focusing on smart grid systems, energy forecasting, and efficient energy management. Particularly, conferences such as ICSG, ICPS, and SmartGridComm emphasize the application of AI, including neural networks, in predicting electricity load demand. According to Table 3, the leading journal is “ENERGY AND BUILDINGS,” which ranks highest in terms of both the number of publications and total citations, with 3 publications and 158 citations. This journal has been a long-standing contributor to the topic, with its first publication identified in 2014. "LECTURE NOTES IN COMPUTER SCIENCE" shares the same number of papers on this topic as "ENERGY AND BUILDINGS," with 3 publications, yet it has garnered considerably less attention, receiving only 13 citations, despite initiating this topic earlier, in 2013. In terms of average citations per year, the two leading journals are “ENERGY AND BUILDINGS” and “PROCEEDINGS OF THE INTERNATIONAL JOINT CONFERENCE ON NEURAL NETWORKS.” These two journals entered the topic of "Basic AI methods for load forecasting" relatively early, in 2014 and 2015, and their contributions continue to attract significant attention. Additionally, this metric reveals that “ADVANCES IN INTELLIGENT SYSTEMS AND

COMPUTING" is an emerging journal with great potential in this field, with an average citation count of 6.2, ranking third.

Table 3: Top 10 impact sources base h_index

	Source	h_index	TC	NP	PY_start	Average
1	ENERGY AND BUILDINGS	3	158	3	2014	15,8
2	ADVANCES IN INTELLIGENT SYSTEMS AND COMPUTING	2	31	2	2019	6,2
3	LECTURE NOTES IN COMPUTER SCIENCE (INCLUDING SUBSERIES LECTURE NOTES IN ARTIFICIAL INTELLIGENCE AND LECTURE NOTES IN BIOINFORMATICS)	2	13	3	2013	1,18
4	PROCEEDINGS OF THE INTERNATIONAL JOINT CONFERENCE ON NEURAL NETWORKS	2	122	2	2015	13,56
5	2015 3RD INTERNATIONAL ISTANBUL SMART GRID CONGRESS AND FAIR, ICSG 2015	1	5	1	2015	0,56
6	2017 7TH INTERNATIONAL CONFERENCE ON COMPUTER AND KNOWLEDGE ENGINEERING, ICCKE 2017	1	9	1	2017	1,29
7	2017 7TH INTERNATIONAL CONFERENCE ON POWER SYSTEMS, ICPS 2017	1	45	1	2018	7,5
8	2020 IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS, CONTROL, AND COMPUTING TECHNOLOGIES FOR SMART GRIDS, SMARTGRIDCOMM 2020	1	2	1	2020	0,5
	2020 INTERNATIONAL SYMPOSIUM ON COMMUNITY-CENTRIC SYSTEMS, CCS 2020	1	2	1	2020	0,5
10	4TH INTERNATIONAL SYMPOSIUM ON ENVIRONMENT FRIENDLY ENERGIES AND APPLICATIONS, EFEA 2016	1	13	1	2016	1,625

3.4 Analysis of important documents

The Bibliometric method provides an analysis of the most significant documents within this dataset, as detailed in Table 4 below. These publications predominantly employ diverse models for short-term load forecasting, aligning with the recent advancements in machine learning, where models are continuously developed to accommodate complex data variations. Notably, the most influential documents are recent, except for "Neural Network Model Ensembles for Building-Level Electricity Load Forecasts"(Jetcheva et al. 2014) published in 2014 (Period 1). Despite its age, this study remains highly influential in shaping AI and machine learning applications in energy management, as it is frequently cited in discussions of advanced computational models. Otherwise, "Deep Learning for Load Forecasting with Smart Meter Data: Online Adaptive Recurrent Neural Network,"(Fekri et al. 2021) published in 2021 (Period 2), has gained the highest citation count (155), reflecting the growing interest in smart grids and smart meter data. This trend is likely to continue, as energy demand data becomes increasingly complex, particularly with the integration of renewable energy sources that exhibit inherent instability.

Table 4: Top 10 impact documents based on total citations

TT	Paper	Author	PY_start	TC	TC per year
1	Deep learning for load forecasting with smart meter	Fekri, Mohammad Navid; Patel, Harsh; Grolinger,	2021	155	38.75

	data: Online Adaptive Recurrent Neural Network	Katarina; Sharma, Vinay			
2	Neural network model ensembles for building-level electricity load forecasts	Jetcheva, Jorjeta G.; Majidpour, Mostafa; Chen, Wei-Peng	2014	143	13.00
3	A deep learning model for short-term power load and probability density forecasting	Guo, Zhifeng; Zhou, Kaile; Zhang, Xiaoling; Yang, Shanlin	2018	135	19.29
4	Convolutional Neural Networks for Energy Time Series Forecasting	Koprinska, Irena; Wu, Dengsong; Wang, Zheng	2018	117	16.71
5	An evaluation of Bayesian techniques for controlling model complexity and selecting inputs in a neural network for short-term load forecasting	Hippert, Henrique S.; Taylor, James W.	2010	82	5.47
6	Short-term electricity load forecasting with machine learning	Madrid, Ernesto Aguilar; Antonio, Nuno	2021	56	14.00
7	Forecast electricity demand in commercial building with machine learning models to enable demand response programs	Pallonetto, Fabiano; Jin, Changhong; Mangina, Eleni	2022	49	16.33
8	Electricity load forecasting using fuzzy logic: Short term load forecasting factoring weather parameter	Mukhopadhyay, P.; Mitra, G.; Banerjee, S.; Mukherjee, G.	2018	45	6.43
9	International Journal of Electrical and Electronic Engineering and Telecommunications	Phyo, Pyae P.; Jeenanunta, Chawalit; Hashimoto, Kiyota	2019	40	6.67
10	Machine Learning Based Cost Effective Electricity Load Forecasting Model Using Correlated Meteorological Parameters	Jawad, Muhammad; Nadeem, Malik Sajjad Ahmed; Shim, Seong-O; Khan, Ishtiaq Rasool; Shaheen, Aliya; Habib, Nazneen; Hussain, Lal; Aziz, Wajid	2020	38	7.60

3.5 Country Scientific Production

Analysis according to the Country Scientific Production of Bibliometric studies shows the top 10 countries as detailed in Table 5 below. Among a total of 250 author citations in the dataset, the top 10 countries with the highest number of author citations include China, India, and Indonesia, accounting for 190 citations, or 76% of the total, representing a significant portion of the overall author citations. These countries encompass both developed and developing nations across various continents. Notably, the top five leading countries—China, India, Indonesia, Australia, and the USA—share commonalities regarding their energy sectors and load demands.

Leading the research in AI for load forecasting, studies from China focus on the utilization of deep neural networks and the integration of AI with smart grid systems. We speculate that this emphasis may be attributed to China's robust advancements in clean energy and renewable energy, which have significantly motivated the research of AI in load management (Zhang et al. 2017)(Zeng, Li, and Zhou 2013). Researchers in India predominantly concentrate on applying load forecasting models to enhance grid performance, which appears to be driven by the country's ongoing modernization of its grid infrastructure and efforts to improve system efficiency to meet increasing demand (Archana, Shankar, and Singh 2022). Indonesian research primarily revolves around the application of AI for managing energy systems in regions with weak infrastructure, reflecting the reality that Indonesia's energy infrastructure remains underdeveloped, particularly in remote and rural areas (Bank 2020)(Anon 2022)(IRENA 2020). Conversely, Australia focuses on integrating AI with renewable energy systems, such as solar and wind energy, due to its substantial potential in renewable energy (Kut et al. 2024)(Hollis and Wilkinson 2022).

These countries, characterized by high and rapidly increasing energy demands driven by economic growth and urbanization, are also facing pressures to reduce carbon emissions in recent years (Li and Gou 2024). Consequently, these nations are transitioning towards the use of renewable energy sources rather than traditional energy sources. However, one of the barriers to utilizing renewable energy is its inherent instability. It is important to highlight that traditional load forecasting methods may be constrained by this characteristic; thus, transitioning to AI-based forecasting methods will facilitate more efficient and accurate power system operation (Aribowo, Muslim, and Basuki 2020), ensuring a balance between supply and demand. This may explain the recent surge in research on AI-based load forecasting approaches in these countries.

3.6 Top 10 countries

The table 5 shows the number of authors involved in studies about the use of basic AI in forecasting electricity demand. The data provides insights into the geographical distribution and participation of authors in this research area. China and India have the highest frequencies, with 45 and 42 occurrences, respectively, indicating their significant contributions to this field. Indonesia follows with 18 instances, indicating a growing interest in this topic. Australia, the USA, Nigeria, Pakistan, the UK, and Turkey have moderate frequencies ranging from 15 to 11 instances, highlighting the global interest and collaboration in this domain. Spain completes the list with 10 occurrences. These findings indicate an international interest in utilizing basic AI in electricity demand forecasting, with China and India leading the research efforts.

Table 5: Top 10 important countries

TT	Region	Freq
1	CHINA	45
2	INDIA	42
3	INDONESIA	18
4	AUSTRALIA	15
5	USA	13
6	NIGERIA	12
7	PAKISTAN	12
8	UK	12
9	TURKEY	11
10	SPAIN	10

3.7 Science mapping of co-authors

The Scopus dataset on the topic of "Basic AI methods for load forecast" includes 241 authors, but only 3 are single-authored. A further novel finding is that the co-authors per document is 3.5, and international co-authorships percent stand at 20.83%. This indicates strong collaboration at both national and international levels, leading to a diverse and dynamic research network in this field.

We also describe the results of science mapping of co-authors using VOSviewer (as shown in Figure 3), which illustrates strong collaborative relationships among author groups and the contributions of key authors. The map reveals the presence of several tightly knit author clusters, such as those of Koprinska Irena and Jeenanunta Chawalit, who are heavily involved in collaborative work and have a significant presence in the network. The map further highlights Koprinska Irena as a highly influential author, with large node size indicating both the number of publications and this author's extensive collaborations with other researchers. Another author, Li Cucun, also demonstrates broad collaborative connections but within different clusters, suggesting a division between different research directions or author communities.

From the color gradient on this map, it is clear that there has been a noticeable increase in collaboration since 2018, indicated by the green and yellow hues on the chart. This suggests that this research field has attracted growing attention from scientists, particularly in recent years. Another promising finding is the time-based distribution trend depicted in the map: Authors such as Li Cucn, represented by darker blue hues, have been active for a longer period, contributing significantly to the field over time. Meanwhile, more recent contributors, like Jeenanunta Chawalit, indicated by green and yellow hues, have emerged in recent years and already established substantial collaborations in a relatively short period, indicating the rise of new research directions or discoveries. The green and yellow clusters, primarily emerging from 2018 onwards, show an increasing number of researchers joining and publishing in this field. This trend may reflect the growing demand and interest in topics such as artificial intelligence (AI) and load forecasting amid the context of rapidly increasing energy demand.

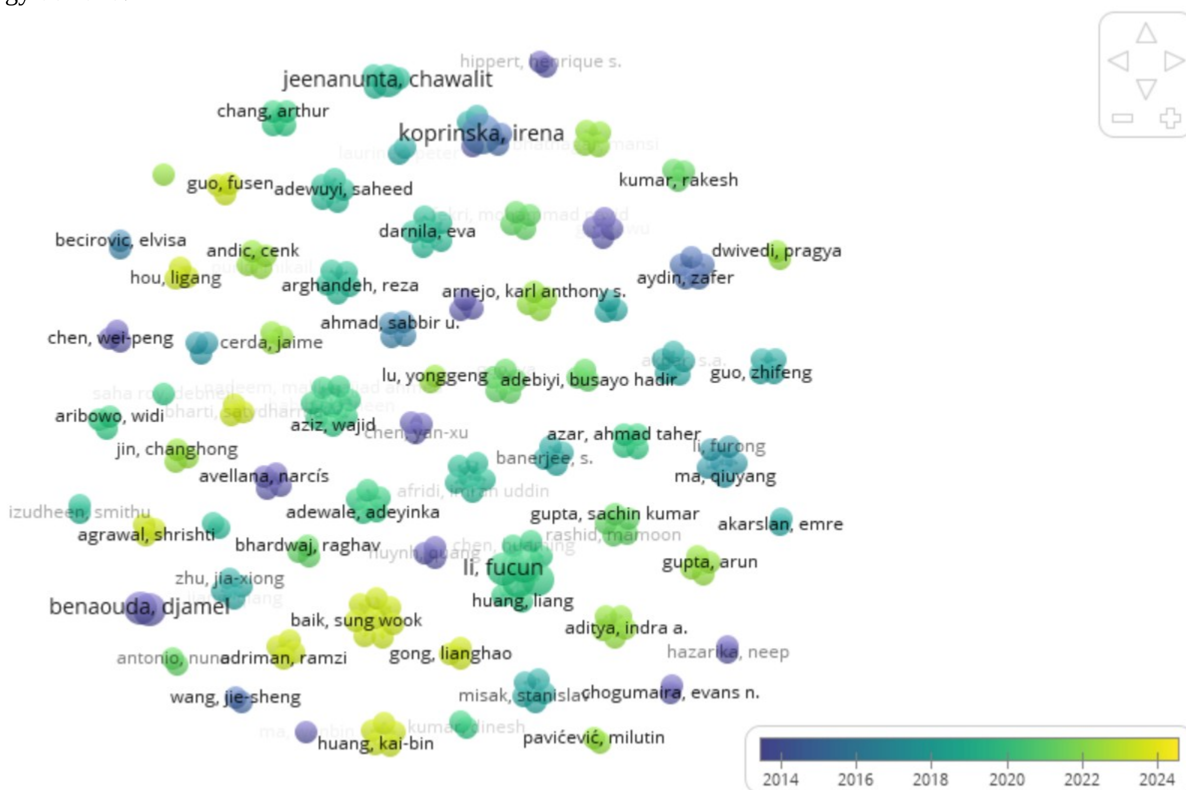

Figure 3: Science mapping: co-author

3.8 Science mapping of author keywords

Figure 4 provides an overview of the author keywords related to the topic "Basic AI models in electric load forecasting." The keywords are represented by nodes, with node size indicating the frequency of each keyword's occurrence in the literature. "Electric load forecasting" is the largest and central keyword, showing strong connections to several other terms, particularly "machine learning" and "neural network," which are the two main AI techniques in electric load forecasting. Additionally, keywords such as "deep learning algorithm" are linked to both "smart grid" and "forecast," reflecting the trend of integrating AI with smart grid systems can help somewhat forecast electricity demand accurately. The keyword analysis results demonstrate the diversity of approaches, with the strong connections between keywords reflecting the integration and interaction of various AI techniques in electric load forecasting.

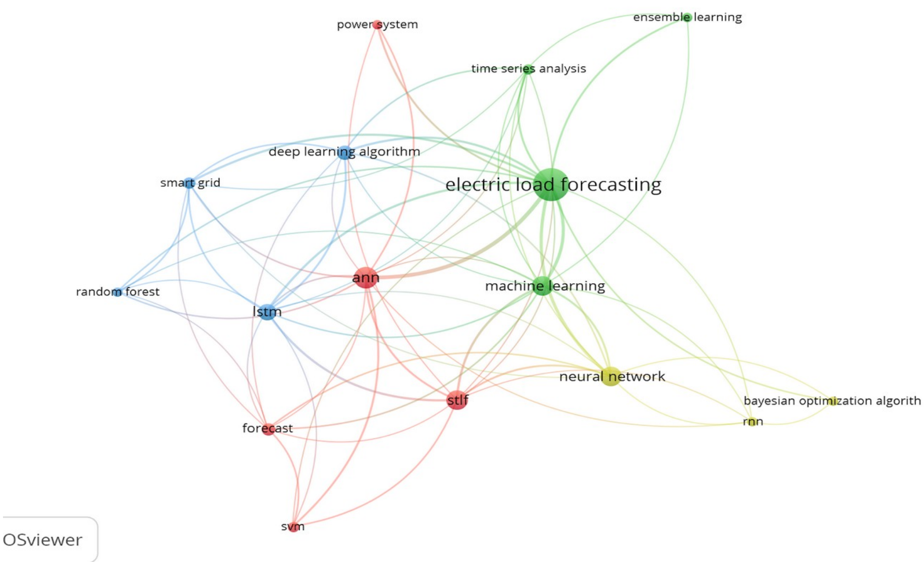

Figure 4: Science mapping: co-occurrence keywords

As shown in Figure 4, the mapping reflects significant advancements in load forecasting, especially with AI support. Early-studied keywords, represented by dark blue nodes such as "LSTM" and "deep learning algorithm," demonstrate that research into these techniques began around 2017. These terms are strongly linked to keywords like "smart grid" and "forecast," indicating early efforts to integrate advanced neural networks and AI technologies for electric grid management and demand forecasting. Green and yellow nodes such as "ensemble learning" and "bayesian optimization algorithm" highlight that these methods have garnered increased research attention recently, particularly during 2020-2021. These keywords represent newer approaches being explored to enhance the accuracy and efficiency of load forecasting models.

From the insights gathered from these scientific mappings, it becomes evident that the energy forecasting trend is evolving, with a strong emphasis on integrating smart grids. Keywords like "smart grid," "power system," and "forecast" underscore the growing importance of utilizing AI for managing and optimizing energy supply and demand. The prevalence of terms like "LSTM" and "neural network" highlights the dominance of deep learning techniques in time series analysis for energy demand forecasting, where predictive accuracy relies heavily on past data. Recent keywords such as "ensemble learning," "bayesian optimization algorithm," and "RNN" (recurrent neural network), which have emerged in the past few years (green and yellow nodes), suggest an ongoing exploration of novel machine learning techniques aimed at improving the stability and precision of load forecasting models. Improving load forecasting models has a significant impact on the efficient operation of power systems. This can be seen as a means to optimize energy utilization, enabling the development of more effective energy-saving policies. Enhanced load forecasting also addresses carbon emission challenges, contributing to better environmental management. Consequently, it can be argued that these advancements lead to an increasing demand from nations for the development of smarter energy solutions through the aid of AI, fostering a more sustainable and efficient energy landscape.

By analysing the dataset on the topic of “Basic AI models for load forecasting,” it can be inferred that AI techniques like LSTM and deep learning are gradually replacing traditional methods in load forecasting like ARIMA, linear regression,... (Jetcheva et al. 2014)(Singh et al. 2012). Technologies such as neural networks, machine learning, and deep learning, developed early on, continue to be widely applied. The increase in the number of publications on Scopus since 2018 clearly reflects the growing research interest in electric load forecasting, aligned with the global rise of AI and smart energy. AI is increasingly being integrated into renewable energy sources like wind and solar power, enhancing the accuracy of load forecasting and optimizing energy supply (Hsu et al. 2020). Integrating smart grids and AI, especially in countries like the USA, has significantly improved the optimization of power systems, ensuring stable and efficient electricity distribution (Hosseini, Hooshmand, and Sharma 2018). LSTM and ANN are pioneering methods, but newer approaches like Bayesian Optimization and Ensemble Learning have gained significant attention since 2020, aiming to improve both the accuracy and efficiency of load forecasting. Overall, these research aspects illustrate the evolution of load forecasting, from early basic artificial neural networks to the current advanced AI methods, often integrated with renewable energy. The surge in publication numbers after 2018 further evidences the rapid development of this field globally.

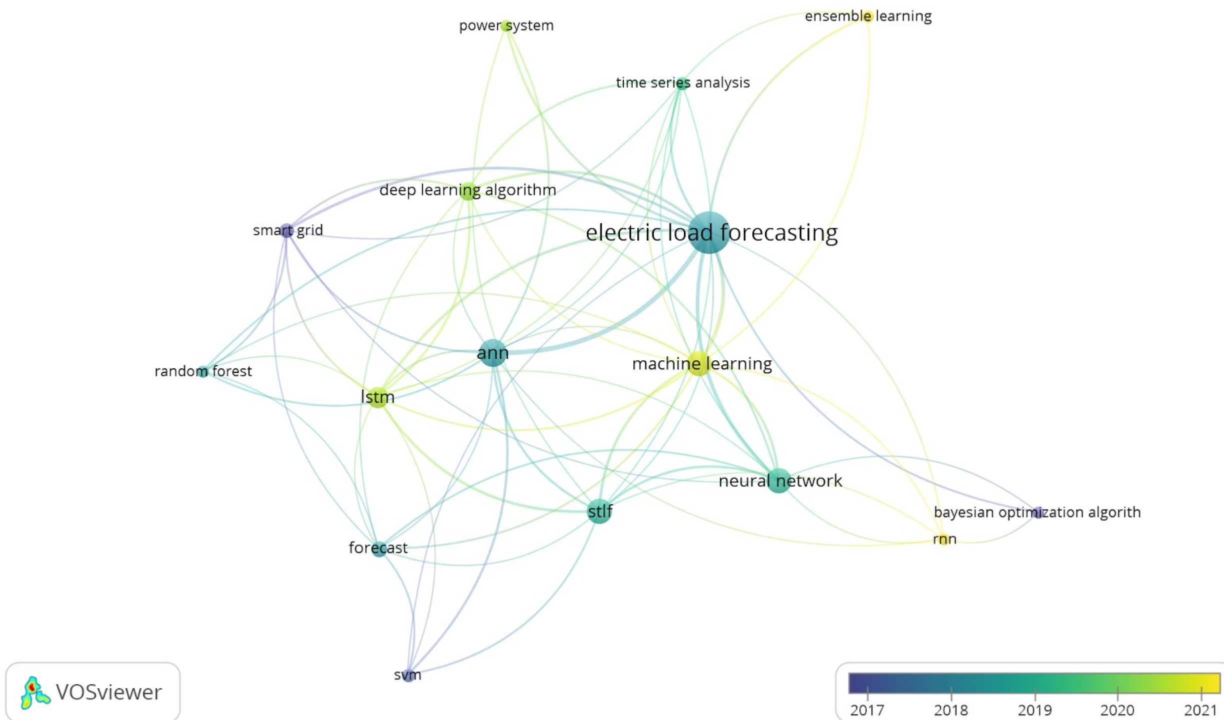

Figure 5: Science mapping: co-occurrence keywords (based on time)

4. CONCLUSION

This research reviews simple artificial intelligence (AI) methods for electric load forecasting from 1997 to 2023. Over the past 26 years, this topic has seemed to attract more and more attention from scholars, especially the increase in publication productivity in 2018. The documents focus on traditional and basic AI models, aiming to improve the performance and accuracy of electric load forecasting.

The topic of electric load forecasting using AI has recorded 72 publications from 1997 to 2023, with 63.89% being conference papers and 36.11% journal articles. Between 1997 and 2017, the field saw slow growth, but after 2018, the number of publications spiked, indicating increasing interest in advanced AI techniques like deep learning and neural networks in energy management, particularly for short-term load forecasting.

Bibliometric analysis shows that 10 leading countries account for 76% of authorship in this research, with China, India, Indonesia, Australia, and the USA leading the charge. These countries face rising energy demand and carbon emission pressures, which drive their focus on integrating AI with smart grids and renewable energy to optimize load management and grid performance.

Keyword analysis within the "Basic AI models in electric load forecasting" topic reveals that “Electric load forecasting” is the central keyword, strongly connected with “machine learning” and “neural network.” Advanced techniques such as “LSTM” and “deep learning algorithm” have been prominent since 2017, highlighting the incorporation of AI into smart grid systems. More recent trends emphasize novel methods like “ensemble learning” and “Bayesian optimization,” aimed at enhancing the accuracy and efficiency of load forecasting models.

Although the research provides a comprehensive overview of basic AI models in load forecasting, several limitations remain. Firstly, the data is restricted to Scopus, potentially omitting results from other databases like Web of Science, IEEE, or Google Scholar. Secondly, there is a lack of detailed geographic analysis; AI models may vary across commercial regions or continents, but the study only addresses key countries without considering broader geographic factors. Lastly, the focus on basic AI models might overlook advancements like hybrid models or deep learning, which could better address future load forecasting needs. Future research should explore more advanced AI techniques to capture recent developments in this field.

Limitations

However, like any research, this study has its limitations (Vuong, 2020). The research approaches the topic by reviewing literature related to the use of basic AI for electricity load forecasting. Consequently, it may overlook crucial materials concerning the application of basic AI to Energy demand forecasting, Power consumption prediction, Electric load prediction, Energy load forecasting, Electricity demand projection, Load demand forecasting, Power usage forecasting, Load forecasting in power systems, etc. Moreover, the sample size of 72 documents is relatively small, which could potentially affect the reliability of the analysis results.

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