



AI in Accelerating the Creation of Renewable Energy Sources. Bibliometric Analysis

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Abstract. In recent years, one of the most pressing issues facing society is the protection and conservation of our planet's resources. The United Nations 2030 Agenda for Sustainable Development, adopted by 193 countries in 2015, defines a global model for sustainable development. According to the agendas guidelines, the modernisation efforts of highly developed countries should be focused on the eradication of poverty in all its forms, while pursuing a set of economic, social and environmental goals. Energy management, the acquisition and use of renewable energy sources, innovation and attention to environmental sustainability are some of the agenda's goals. This trend includes innovations to create renewable energy sources, which are managed and monitored using artificial intelligence (AI) solutions. Therefore, the aim of this article is to highlight the importance of AI in accelerating renewable energy creation. As a research method, we used bibliometric analysis based on a set of publications from the Scopus database to achieve the stated objective. The VOSviewer programme was also used to analyse the collected bibliographic data on publications. The research shows that authors are increasingly interested in AI and renewable energy topics in recent years, as evidenced by the growing number of publications in this area.

Keywords: Artificial Intelligence · sustainability · renewable energy sources

1 Introduction

Caring for natural resources is one of the key premises of the UN resolution. Thus, of the 17 goals defined in the document, almost half directly or indirectly refer to the need to create solutions to increase the protection of natural resources and care for the sustainable use of ecosystems and environmental protection. Economic development based only on economic calculation and the criterion of profitability has led to the devastation of natural resources and an imbalance in the biological balance of the entire planet. Awareness of this threat has led to

the adoption of the UN Sustainable Development Agenda, developed in 2015, by 193 countries.

Consequently, it is becoming increasingly important to extract natural resources without devastating the environment. One of the most important problems of the modern world is to ensure adequate energy resources and energy security. Therefore, in line with sustainable development trends, a very important direction of economic dynamisation is the effort to create and manage both industrial and individual installations of renewable energy sources [2, 3, 6, 10, 16].

This process is not possible without the use of modern ICT solutions. Moreover, AI solutions are increasingly being applied to large industrial installations such as photovoltaic or windmill farms that provide energy for businesses or conurbations. The use of this class of IT solutions is justified by the need to anticipate energy demand in the short and long term and to manage the volume of energy generation and storage [1, 7, 13, 17]. This problem is all the more important given that current technological solutions do not allow energy to be stored in a way that will be cost-effective, which means that the ability to monitor demand in terms of acquisition, consumption and potential storage is a significant financial issue [4, 20].

Expectations of optimising energy production in correlation with energy demand are driving numerous investments in the implementation of advanced information technology into the processes of energy production and consumption management. The creation of smart grids, the Internet of Things or the use of AI solutions and machine learning algorithms are currently standard [5, 9, 12, 15, 19, 21]. Strong links are also being made between urban energy sources [11] or the concept of zero waste [14] and the popular approach of the smart city [18].

Therefore, we believe that a bibliometric analysis in the above-mentioned subject area is an extremely important research issue. The bibliometric analysis will be the first stage of the research work planned by us on the use of AI solutions in the management of generation and monitoring of renewable energy resources. We have observed a growing interest in the above-mentioned topics, both in the context of published scientific papers as well as reports and industry and popular science studies.

Therefore, the aim is to present the general results of a bibliometric analysis of the scientific literature on the use of AI tools in the management of renewable energy sources. The research method used was bibliometric analysis conducted on the resources of the Scopus database. The VOSviewer programme was used to visualise the results of the analysis. The article presents only a small part of the analysis, which shows quantitative trends in the publications as well as the identification of countries where the authors most frequently address this topic in their articles.

2 Research Questions

(RQ1) What is the publication trend in the area of application of AI to accelerate renewable energy sources?

- (RQ2) What is the publication trend in the area of application of AI to accelerate renewable energy sources in Business, Management and Accounting sciences?
 (RQ3) From which countries do papers related to AI and renewable energy originate?

3 Methodology

We decided to use bibliometric analysis as a research method. The present research was carried out according to the procedure presented below in the form of a numbered list:

1. Defining the research questions (RQ1-RQ3) → They have been developed based on the literature review and own knowledge of publication trends. The questions relate to the area of applying artificial intelligence to accelerate the development of renewable energy sources.
2. Defining the keywords - “artificial intelligence” OR “AI”, “renewable energ*” → Three keywords have been defined, one of which is an abbreviation. The “*” in the third keyword will replace a number of characters at any point in a word.
3. Selection of the scientific publication database for bibliometric analysis in Scopus → We decided to choose the Scopus database because it is the most recognisable database containing up-to-date and trusted research and data that can be useful for academic work.
4. Development of the first version of the query - TITLE-ABS-KEY (“artificial intelligence” OR “AI”) AND “renewable energ*”) → The first search we constructed is generic and was entered into the database to achieve an overall picture of the study area.
5. Development of the second version of the query with restriction to the Business, Management & Accounting area - TITLE-ABS-KEY (“artificial intelligence” OR “AI”) AND “renewable energ*”) AND (LIMIT-TO (SUBJAREA , “BUSI”)) → In the second search, one area-related narrowing was introduced in order to relate the study area to the field of management.
6. Entry of both queries into the Scopus database → Both queries were entered into the database and the analysis began.
7. Analysis of the number of publications in all and individual years for both searches → The results of this stage have been presented in the charts.
8. Part of bibliographic coupling for both searches - analysis of the countries from which the publications originated → The countries were analysed in terms of the number of documents, and this was presented in the visualisations developed in VOSviewer.
9. Development of conclusions based on the collected results → The summary, conclusions, as well as the concept for further research are described at this stage.

The results of the research carried out will be presented later in the article.

4 Results

Research using bibliometric analysis was carried out from 10-14.07.2023 using data from the Scopus database. Among the techniques used in the bibliometric analysis was the use of science mapping [8], and within the science mapping we focused on the bibliographic coupling part, which in this case includes the analysis of countries. Furthermore, in order to present the overall status of the number of papers in the field of AI and renewable energy sources, we analysed the total number of publications, the number of papers published in each year.

Following the research methodology presented, we entered two defined queries into the Scopus database and obtained a certain number of documents. In the case of the first query, this number was 2288 documents. Due to the relevance of the field of management of all environmental changes, as well as the need to manage projects related to the application of AI in accelerating the creation of renewable energy sources, an inclusion criterion in the Scopus database was selected - subject area as Business, Management & Accounting. The second search yielded 105 papers. The results show a significant difference in the number of documents after selecting a subject area.

The number of publications per year was then analysed for both searches. Looking at the first search (Fig. 1), between 1994 and 2005 only a few authors addressed the topic described. Since about 2007, however, the number of publications has increased. The highest number of publications combining the field of AI and renewable energy sources was recorded in 2022, with 505 papers in the Scopus database. It is reasonable to assume that the number of papers published in 2023 would also increase if the analysis were carried out in December of that year.

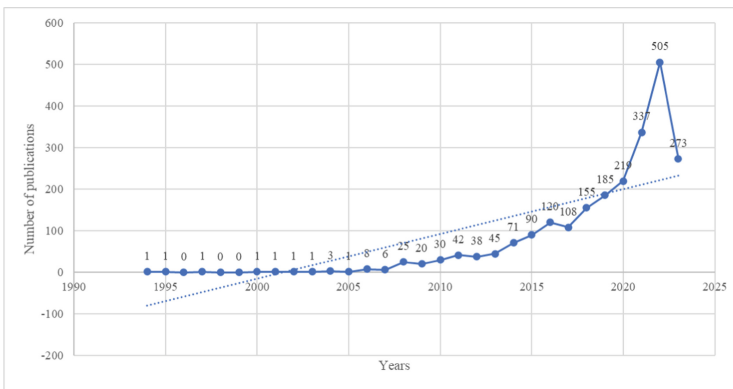


Fig. 1. Number of publications per year for the first search (1994–2023).

In the second graph, which is based on publications from the second search, considering only the subject area - Business, Management & Accounting (Fig. 2),

an increasing trend is also noticeable. Between 2019 and 2022, at least 11 papers per year were produced on AI and renewable energy sources in the selected subject area. In 2023, 12 papers on the subject area have already been produced; given that this bibliometric analysis is carried out in July, it is likely that there will be more publications at the end of this year than in 2022.

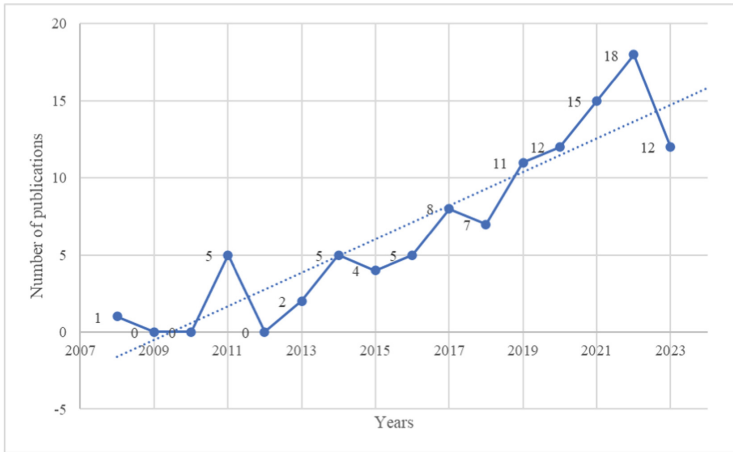


Fig. 2. Number of publications per year for the second search (1994–2023).

First part of the bibliographic coupling carried out is the analysis of the countries from which the collected documents originate. For the first search, publications came from 140 countries. We defined the following restrictions for the countries to be displayed: minimum number of documents of a country - 5, minimum number of citations of a country - 0. As a result of the conditions applied, 68 countries were displayed (Fig. 3).

The largest number of publications collected in the first search came from India (441 documents). This is followed by countries such as China (329 documents), United States (222 documents), United Kingdom (144 documents) and Germany (102 documents). The rest of the countries produced less than 100 documents in the selected area. Considering citations, China (7651 citations), United States (5334 citations) and India (4438 citations) accumulated the most.

The countries from which the documents for the second search originated were then analysed. We also defined some conditions for the analysis: minimum number of documents of a country - 5, minimum number of citations of a country - 0. Of the 46 countries, 9 met the indicated criteria (Fig. 4).

As with the first search, the largest number of publications comes from India (20 documents). The United States came second (11 documents), followed by China (9 documents), Netherlands and Germany (8 documents each). Publications from the United States (345 citations), China (223 citations), United

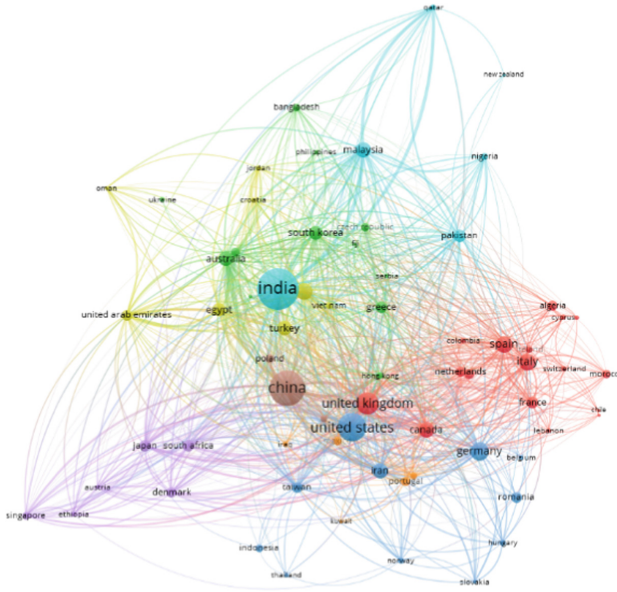


Fig. 3. Countries of documents for the first search.



Fig. 4. Countries of documents for the second search.

Kingdom (220 citations) and Netherlands (211 citations) accumulated the most citations.

Due to limitations in the number of pages of this article, we plan to conduct further parts of the bibliographic coupling, which will deal with the analysis of documentary sources, authors of documents and organizations.

5 Conclusions

By carrying out a bibliometric analysis, the following objective - to present the general results of a bibliometric analysis of the scientific literature on the use of AI tools in the management of renewable energy sources - was achieved.

It is apparent that the topic is important and research centres in many countries are addressing it. Among the countries at the forefront of research into the use of AI and the creation of renewable energy sources, the triad of 3 countries - India, China, USA - is clearly visible. In addition, among the publications cited, it is worth pointing out that the countries indicated are at the forefront. In addition, citations were supplemented by the Netherlands, Germany.

Therefore, we will undertake further research to determine which centres are leading in their research, as well as to determine whether leading representatives of the analysed topic can be identified. Further research aims to identify which research centres can be collaborated with. Furthermore, we aim to conduct further research, including determining whether there are any research gaps in the current state of knowledge.

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