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Artificial Intelligence and Renewable Energy Utilization

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Abstract. *This article shows the role that digital intelligence has on renewable energy, based on literature underpinnings. Therefore, the methodological research is based on literature review to demonstrate the link between artificial intelligence and renewable energy, with a focus on global sustainable development strategies in this field. The main findings reveal the fact that we must take advantage of the opportunities offered by artificial intelligence on energy, in general, and renewable energy, in particular. Referring to literature, it is constantly expanding due to the importance of the development of renewable energy for researchers but also for the population, being many parties interested in this field. The aim of the study is to highlight the relationship between renewable energy and artificial intelligence. Therefore, with the help of artificial intelligence and energy innovations, the population enjoys renewable energy that exists in its many forms (solar panels or photovoltaic panels, water, or wind energy and so on). To put in a nutshell, the research considered in this article reflects the impact of artificial intelligence on renewable energy as part of supporting the achievement of sustainable economic development.*

Keywords: artificial intelligence, renewable energy, sustainable economy, energy resources, sustainable development, energy efficiency.

Introduction

Artificial intelligence (AI) plays a key role in the integration of renewable energy (RE) sources into the grid, supporting the process of sustainable development of the countries. AI has a major impact in contemporary society and especially in technological and digital progress. Modern computer systems, based on artificial intelligence, help the consumption of renewable energy to lead to financial efficiency and protect the environment (Abdalla et al., 2021). Machine learning optimizes energy efficiency and is increasingly common in RE integration around the world. With an efficient energy system, investments are optimized and renewable energy production increases.

The greatest benefits of this type of energy are the local character of the energy resources (opportunity of extraction at the point of use), independence of the weather, and no negative impact on the natural environment (Marks-Bielska et al., 2020). Climate change negatively impacts humanity and raises concerns to lead businesses and especially industrial sectors to improve their social responsibility level (Hafezi & Alipour, 2020).

Starting from the hypothesis that artificial intelligence is strongly related to the efficiency of renewable energy, in this article I proposed to check if this hypothesis is accepted or rejected, based on literature underpinnings.

The utilization of renewable energy offers many significant advantages over traditional fossil fuels, including being environmentally friendly, sustainable, and safe (Abdul et al., 2022).

On this frame of facts and references, *the main objective of this paper* is to investigate the role that artificial intelligence plays in the optimal implementation and use of energy resources from renewable sources (Dellosa & Palconit, 2022). The importance of the topic comes from the reality that shows that the technologies with which the energy efficiency from renewable sources

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is achieved, are based on artificial intelligence software. Artificial Intelligence could assist in achieving the future goals of the RE. (Jha et al., 2017)

The role of the digital economy is extremely valuable in supporting the construction of smart grids that help optimize the consumption and integration of renewable energy (Zheng & Wong, 2024). Moreover, hydrogen is expected to be a key fuel in the global energy transition, that an increase of hydrogen production from renewable energy (RES) is especially important from the point of view of further sustainable development (Mendrela et al., 2024). Digital technology can improve the intelligence of the grids and realize the large-scale access and consumption of renewable energy (Shahbaz et al., 2022).

With the help of energy knowledge, AI software firms can overcome certain obstacles due to the advancement of new energy technologies. The escalation of renewable energy adoption on a global scale over recent decades represents a transformative shift in power generation, highlighting a concerted move toward more sustainable energy sources (Hassan et al., 2024). Even from the design stage, AI systems can be thought of in automating routine and organized operations. Through this, people will begin to address possible energy challenges in the future. Moreover, artificial intelligence has led to the improvement of energy quality, to the efficiency of consumption as well as to transparency in the use of RE sources.

The structure of the paper includes: Part 2 deals with the literature review and reviews the news in the field. Part 3 presents the methodology, part 4 presents a bibliometric analysis using selected keywords, with the Web of Science database as the official source and discusses the main findings, part 5 presents the research conclusions.

2. Literature review

Although the relationship between renewable energy and economic performance has attracted the interest of researchers in recent years, most of the analysis has focused on economic growth, which does not reflect the quality of standards of living (Soukiazis et al., 2019).

Moreover, renewable energy projects are becoming essential in the energy mixes of most of the countries (Ahmed & Shimada, 2019). Big data and artificial intelligence (AI) have received significant attention in the recent years from research communities and the energy industry (Mazzeo et al., 2021).

AI represents an advanced field of engineering and computer science that focuses on creating smart or intelligent devices or machines (Dellosa & Palconit, 2021), and systems that perform operations similar to human learning and decision-making (Castro & New, 2016). AI is used in almost each type of the RE (wind, solar, geothermal, hydro, ocean, bio, hydrogen and hybrid) for the design, optimization, estimation, management, distribution, and policy (Jha et al., 2017).

Artificial intelligence comes with methodologies and techniques for a machine, robot or device, to understand the information collected and processed. Machines are configured to automatically advance with the information available and act on the corresponding inputs from the environment (Dellosa & Palconit, 2021).

The broad objectives of sustainable development goal (SDG) can be classified as follows (Bose, 2017):

- optimum resource utilization;
- higher energy efficiency;
- higher system reliability;

- higher system security;
- economical electricity distribution to consumers (Mishra et al., 2020).

Globally, the production of renewable energy is growing rapidly (Drechsler et al., 2017). The correct allocation of renewable power plants remains one of the priority problems that requires a strict solution because the area where to produce energy from renewable sources is very controversial.

Environmental pollution has become a significant concern of nations. International organizations, local authorities, and social activists try to achieve the SDGs to protect the environment. Even so, the SDG cannot be met without recognizing the role of advanced technology applications (Khan & Nasir, 2023).

The use of renewable energy and the promotion of technological innovations have a positive impact on the quality of life by reducing the energy poverty that affects the economies of the EU, in different proportions, regardless of the specific weather conditions of each country (Noja et al., 2022).

Renewable energy sources have gained a great deal of coverage in the past centuries as a possible remedy for the decline of energy production and the predictions of accelerated environmental issues (Wang et al., 2017).

Given the sizeable importance of companies from the energy sector, and the economic, social, and environmental implications generated by their activity, an in-depth assessment of the relationship between financial performance and Corporate Social Responsibility (CSR) initiatives becomes essential for this sector (Noja et al., 2023).

Thus, innovative storage solutions can also be enabled in the future by electric vehicles. Electric vehicles can potentially impact profile costs, since these vehicles are both consumers of electricity and mobile battery storage facilities, able to change their consumption pattern relatively easily, hence also providing a special use-case for demand response (Boza & Evgeniou, 2021).

Given the increasingly frequent climate changes, measures are required to combat possible problems. These actions must be taken urgently to reduce the risk of escalating and to ensure an improvement artificial intelligence is called upon. The generation of renewable energy should be highlighted as a sustainable energy and alternative to traditional energy; as a result, it can meet the nascent demand for energy (Yi et al., 2023).

Increased changes in the climate and ecosystems call for sustainable economic development, where economic growth should be compatible with the environment goals (Martinho & Mourao, 2020). Problems with energy supply and use are related not only to global warming, but also to such environmental concerns as air pollution, acid precipitation, ozone depletion, forest destruction, and emission of radioactive substances (Dincer, 2000).

Therefore, the transition from classic energy sources to the supply of renewable energy requires calculations, analyses, forecasts and evaluations of resources, appropriate technologies and, of course, some high-performance systems that manage to correctly integrate energy from renewable sources by satisfying demands with the profile appropriate time (Østergaard et al., 2020).

The variety of renewable energy sources is continuously expanding. Part of them is renewable sources, such as wind and solar. This is one more reason why the potential of renewable energy is substantial. Also, in some regions and countries, the share of renewable energy has increased substantially over time the last couple of decades (Lund, 2007).

3. Methodology

A literature review of highly regarded journals and reviews of related study reports in recent years was conducted to obtain significant results from artificial intelligence (AI) studies (Dellosa & Palconit, 2021), particularly in the field of energy. The method used to achieve the objective of this study is bibliometric analysis of literature underpinnings, performed with the VOSviewer software. The obtained results allow the analysis of homogeneous groups called clusters, as regards the main keywords used in their research by other authors.

4. Results and discussions

Through a bibliometric analysis we managed to highlight numerous details available in the specialized literature. The analysis performed in this part of the article is based on the results generated using the VOSviewer software with which the maps were obtained.

The main findings of the research are represented in Figures 1 and 2. By using the VOSviewer software, a cluster analysis was performed on homogeneous groups, using the following 2 keywords: renewable energy and artificial intelligence. For these keywords used, 3,516 results were found from the Web of Science Core Collection.

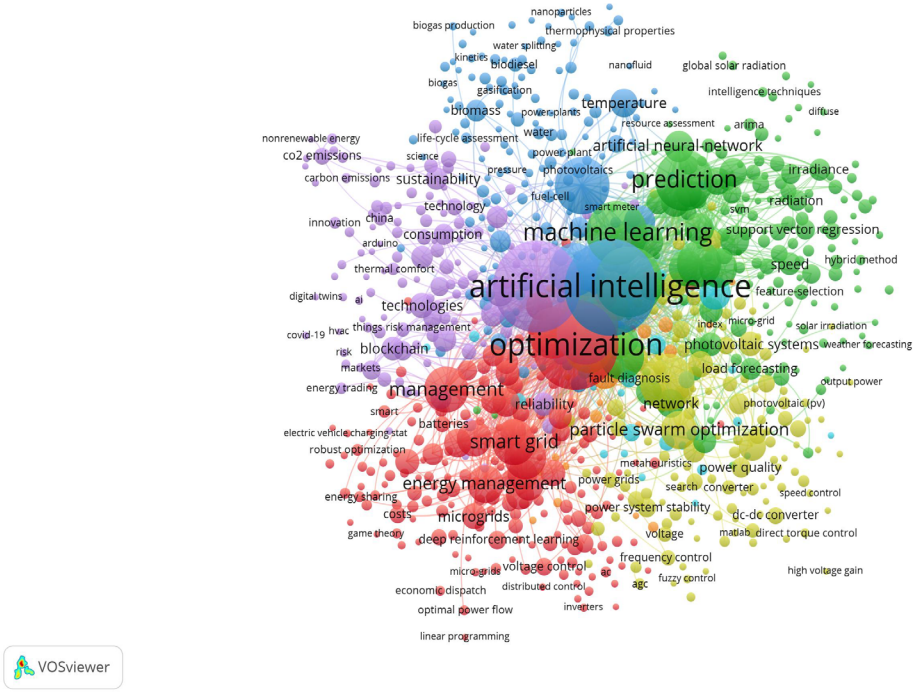

Figure 1. Bibliometric analysis of the of the co-occurrence of keywords approached in the WoS Core Collection articles related to artificial intelligence and renewable energy

Source: Created by author in VOSviewer tool, using Web of Science Core Collection database.

In Figure 1 is presented bibliometric analysis of the of the co-occurrence of keywords approached in the WoS Core Collection articles related to artificial intelligence and renewable energy. For the two keywords used, "renewable energy" and "artificial intelligence", 3516 articles from the Web of Science Core Collection database were used. Through the VOSviewer program, 5 clusters were obtained for homogeneous groups of data. The most analyzed topics by specialized literature are: artificial intelligence, machine learning, optimization, prediction, network etc. In the

first group of homogeneous data, highlighted in blue, we notice that artificial intelligence has been addressed in the specialized literature often together with keywords such as: fuel cell, biomass, photovoltaics etc. In the second group of homogeneous data, highlighted in purple, we notice that artificial intelligence has been addressed in the literature often together with keywords such as: technologies, consumption, sustainability, things risk management, innovation, technology etc. In the third group of homogeneous data, highlighted in green, we notice that machine learning has been addressed in the specialized literature often together with keywords such as: prediction, neural-network, support vector regression or speed. In the fourth group of homogeneous data, highlighted in red, we notice that optimization has been addressed in the specialized literature often together with keywords such as: management, smart grid, energy management, microgrids, costs, robust predictions etc. In the last group of homogeneous data, highlighted in yellow, we notice that network has been addressed together with the following keywords: network, fuzy control, particle swarm optimization, power quality, photovoltaic systems or power grids.

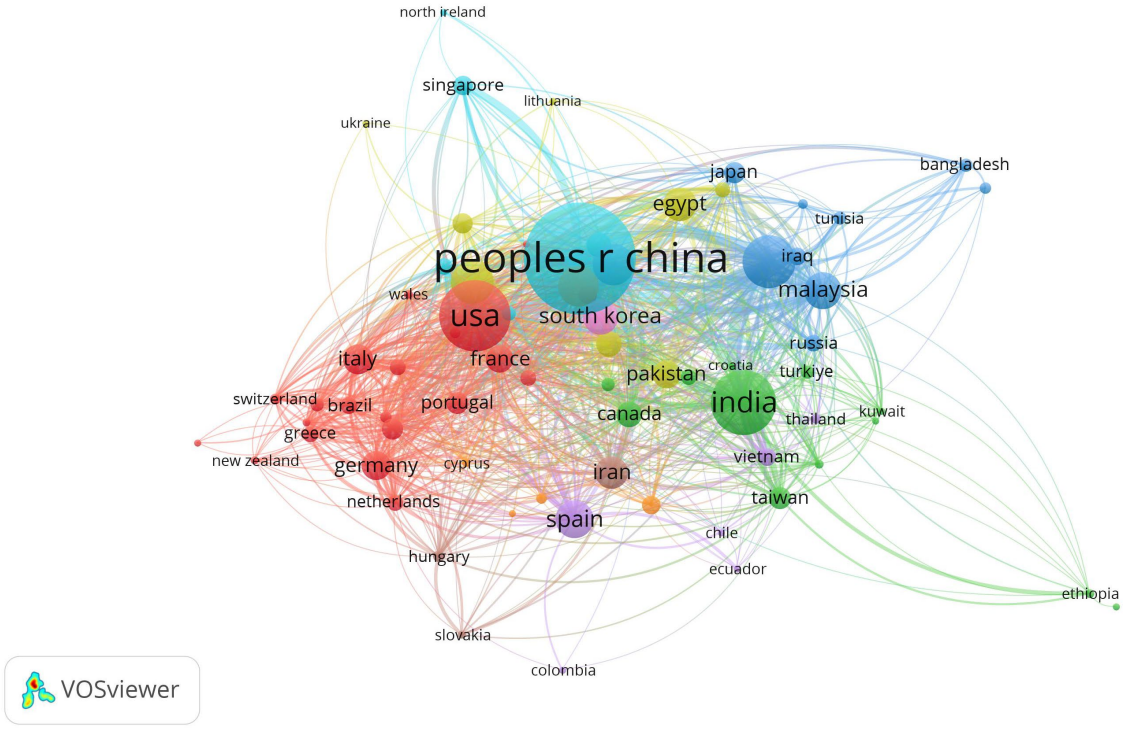

Figure 2. Bibliometric analysis of the co-authorship of keywords approached in the WoS Core Collection articles related to artificial intelligence and renewable energy

Source: Created by author in VOSviewer tool, using Web of Science Core Collection database.

In Figure 2 is presented bibliometric analysis of the co-authorship of keywords approached in the WoS Core Collection articles related to artificial intelligence and renewable energy. As in Figure 1, the bibliometric analysis of co-author keywords was generated as a result of processing the 3516 articles belonging to the WoS Core Collection related to artificial intelligence and renewable energy. Following the processing of which we obtained homogeneous groups of data, which show the origin of the authors who published most often on the topic of renewable energy or artificial intelligence.

From Figure 2, we notice that the authors who published articles about artificial intelligence or renewable energy mainly come from the following countries: China, the United States of America (USA), India, South Korea, Iraq, France, Spain, Iran, Canada etc. In red, we see that the homogeneous group of data created shows that the area with the most articles is the USA. Also, in this group we find states such as: Italy, France, Portugal, Switzerland, Brazil, Greece, Germany, Cyprus, New Zealand, the Netherlands, Hungary.

5. Conclusion

The present article covered the current trends in the field of artificial intelligence in the use of renewable energy.

The technologies that achieve energy efficiency from renewable sources are based on artificial intelligence software. In the energy sector, challenges constantly arise for the efficiency of energy storage and production from renewable sources, which is why management teams turn to artificial intelligence to monitor and control an optimal level of results. Considering these challenges and the importance of the production and use of renewable energy whose efficiency increases thanks to artificial intelligence, this topic is much analyzed and written more and more on this topic.

Findings of this research proved that the hypothesis regarding the importance of artificial intelligence on renewable energy is accepted, being supported by the numerous studies in this field.

This research aimed to carry out a literature review, complemented by a bibliometric analysis, on the themes of "artificial intelligence" and "renewable energies". I referred to the VOSviewer software for bibliometric analysis and the Web of Science platform (as a major source of our observed references), from which 3,516 articles were identified from this scientific platform.

The findings validate the proposed research objective, namely the literature is vast and long researched. The authors who researched topics such as artificial intelligence or renewable energy come from areas such as: China, USA, India, South Korea, Iraq, France, Spain, Iran, Canada etc. Also, the co-occurrence of theme keywords such as: artificial intelligence, machine learning, optimization, prediction, smart grid etc.

To put in a nutshell, this article examined the importance of artificial intelligence on renewable energy and also the implications on the development of the sustainable economy.

As limitations of the research, we can consider the fact that only one database, Web of Science, was studied. And as future research directions, the use of other relevant international databases, such as Scopus or PubMed would be recommended (moreover, a future research can also be extended to the relationship with the medical side and its influences).

References

Abdul, D., Wenqi, J., & Tanveer, A. (2022). Environmental stewardship: Analyzing the dynamic impact of renewable energy, foreign remittances, and globalization index on China's CO2 emissions. *Renewable Energy*, *201*, 418-425.

Abdalla, A. N., Nazir, M. S., Tao, H., Cao, S., Ji, R., Jiang, M., & Yao, L. (2021). Integration of energy storage system and renewable energy sources based on artificial intelligence: An overview. *Journal of Energy Storage*, *40*, 102811.

Ahmed, M. M., & Shimada, K. (2019). The effect of renewable energy consumption on sustainable economic development: Evidence from emerging and developing economies. *Energies*, *12*(15), 2954.

Bose, B. K. (2017). Artificial intelligence techniques in smart grid and renewable energy systems—some example applications. *Proceedings of the IEEE*, *105*(11), 2262-2273.

Boza, P., & Evgeniou, T. (2021). Artificial intelligence to support the integration of variable renewable energy sources to the power system. *Applied Energy*, *290*, 116754.

Castro, D., & New, J. (2016). The promise of artificial intelligence. *Center for Data Innovation*, *115*(10), 32-35.

Dellosa, J. T., & Palconit, E. C. (2021, September). Artificial Intelligence (AI) in renewable energy systems: A condensed review of its applications and techniques. In *2021 IEEE International Conference on Environment and Electrical Engineering and 2021 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe)* (pp. 1-6). IEEE.

Dellosa, J., & Palconit, E. V. (2022). Resource assessment of a floating solar photovoltaic (FSPV) system with artificial intelligence applications in Lake Mainit, Philippines. *Engineering, Technology & Applied Science Research*, *12*(2), 8410-8415.

Dincer, I. (2000). Renewable energy and sustainable development: a crucial review. *Renewable and sustainable energy reviews*, *4*(2), 157-175.

Drechsler, M., Egerer, J., Lange, M., Masurowki, F., Meyerhoff, J., & Oehlmann, M., 2017 Efficient and equitable spatial allocation of renewable power plants at the country scale. Nature Energy 2, 1-9.

Hafezi, R., & Alipour, M. (2020). Energy Security & Sustainable Development. *Affordable and Clean Energy: Encyclopedia of the UN Sustainable Development Goals; Springer: Cham, Switzerland*.

Hassan, Q., Algburi, S., Sameen, A. Z., Tariq, J., Al-Jiboory, A. K., Salman, H. M., ... & Jaszczur, M. (2024). A Comprehensive Review of International Renewable Energy Growth. *Energy and Built Environment*.

Jha, S. K., Bilalovic, J., Jha, A., Patel, N., & Zhang, H. (2017). Renewable energy: Present research and future scope of Artificial Intelligence. *Renewable and Sustainable Energy Reviews*, *77*, 297-317.

Khan, K. I., & Nasir, A. (2023). Application of artificial intelligence in solar and wind energy resources: a strategy to deal with environmental pollution. *Environmental Science and Pollution Research*, 30(24),1-15.

Lund, H. (2007). Renewable energy strategies for sustainable development. *energy*, *32*(6), 912-919.

Marks-Bielska, R., Bielski, S., Pik, K., & Kurowska, K. (2020). The importance of renewable energy sources in Poland's energy mix. *Energies*, *13*(18), 4624.

Martinho, V. D., & Mourão, P. R. (2020). Circular economy and economic development in the European Union: a review and bibliometric analysis. *Sustainability*, *12*(18), 7767.

Mazzeo, D., Herdem, M. S., Matera, N., Bonini, M., Wen, J. Z., Nathwani, J., & Oliveti, G. (2021). Artificial intelligence application for the performance prediction of a clean energy community. *Energy*, *232*, 120999.

Mendrela, P., Stanek, W., & Simla, T. (2024). Thermo-ecological cost–System evaluation of energy-ecological efficiency of hydrogen production from renewable and non-renewable energy resources. *International Journal of Hydrogen Energy*, *50*, 1-14.

Mishra, M., Nayak, J., Naik, B., & Abraham, A. (2020). Deep learning in electrical utility industry: A comprehensive review of a decade of research. *Engineering Applications of Artificial Intelligence*, *96*, 104000.

Noja, G. G., Cristea, M., Pirtea, M. G., Panait, M., Drăcea, R. M., & Abrudan, D. (2023). Drivers of firms' financial performance in the energy sector: a comparative approach between the conventional and renewable energy fields. *Engineering Economics*, *34*(2), 205-222.

Noja, G. G., Cristea, M., Panait, M., Trif, S. M., & Ponea, C. Ș. (2022). The impact of energy innovations and environmental performance on the sustainable development of the EU countries in a globalized digital economy. *Frontiers in Environmental Science*, *10*, 934404.

Østergaard, P. A., Duic, N., Noorollahi, Y., Mikulcic, H., & Kalogirou, S. (2020). Sustainable development using renewable energy technology. *Renewable energy*, *146*, 2430-2437.

Shahbaz, M., Wang, J., Dong, K., & Zhao, J. (2022). The impact of digital economy on energy transition across the globe: The mediating role of government governance. *Renewable and Sustainable Energy Reviews*, *166*, 112620.

Soukiazis, E., Proenca, S., & Cerqueiraa, P. A. (2019). The interconnections between renewable energy, economic development and environmental pollution: A simultaneous equation system approach. *The Energy Journal*, *40*(4), 1-24.

Wang, S., Zhou, A., Yang, M., Sun, L., Hsu, C. H., & Yang, F. (2017). Service composition in cyber-physical-social systems. *IEEE Transactions on Emerging Topics in Computing*, *8*(1), 82-91.

Yi, S., Raghutla, C., Chittedi, K. R., & Fareed, Z. (2023). How economic policy uncertainty and financial development contribute to renewable energy consumption? The importance of economic globalization. *Renewable Energy*, *202*, 1357-1367.

Zheng, M., & Wong, C. Y. (2024). The impact of digital economy on renewable energy development in China. *Innovation and Green Development*, *3*(1), 100094.