

THE POWER OF DIGITAL TECHNOLOGIES IN SOLAR ENERGY STORAGE PERFORMANCE

IORGOVAN DANIELA

PH.D. STUDENT, UNIVERSITY OF CRAIOVA, DOCTORAL SCHOOL OF ECONOMICS

“EUGENIU CARADA”, CRAIOVA, ROMANIA

e-mail: iorgovandaniela@yahoo.com

Abstract

Digital technologies are advancing at an astonishing rate. With the help of these new technologies, it has been possible to increase the production of solar energy, which leads to lower costs for the population for electricity bills. But more important than the fact that electricity is produced is the fact that it must be captured. Efficient energy storage allows it to be kept in optimal conditions so that it can be used to its maximum potential for users. Creating the conditions for a sustainable life is very important, starting from sustainable production to sustainable consumption. In this article, the relationship between digital technologies and solar energy storage is fundamental. This article aims to delve deeper into a topic of major interest to the population and researchers. The research method used is based on bibliometric analysis of 2 keywords of interest in this article, namely: digital technologies and solar energy storage. The keywords were used to create a bibliometric analysis with the VOSviewer software. The analysis of 240 articles resulted in the Bibliometric Analysis Map. The articles were collected from the Web of Science database. As a result of the research carried out, the connection between digital technologies and solar energy storage is observed.

Keywords: power, solar energy, performance, sustainable development

1. Introduction

Efficient energy storage is a central link in a modern energy process. As the population approaches the modern trend of using artificial intelligence, it is observed how this type of consumerism guides us to adapt to new technologies. Some have only heard of heat pumps while others have come to own them.

The evolution of investments and strategies for implementing digital energy storage technologies facilitates the shift to greater use of renewable, clean and renewable energy sources.

Solar energy plays a key role in the global transition to renewable energy sources. Recently, digital technologies have begun to profoundly transform the way solar energy is produced, monitored, distributed and consumed. This process is part of a broader phenomenon known as the digitalization of the energy sector.

Deeply decarbonized energy systems depend on advances in materials science and battery technology to overcome the threats of intermittency from wind and solar power (Kittner, Lill, & Kammen, 2017).

The REPowerEU strategy aims to double grid-connected solar power from 2020 levels to 320GW. Furthermore, this plan targets nearly 600GW by 2030 (Festa, 2025).

The contribution that artificial intelligence makes to the development of new technologies represents a huge boost to innovation. Technology is advancing day by day, and studies and research are being conducted to develop thermodynamic models with which to increase the performance of energy storage from green energy sources.

2. Paper body

Concentrated solar power (CSP) is used to harness solar energy for the purpose of generating electricity (Onu & Mbohwa, 2019).

A study shows that, (Meibodi. S., 2025) depending on the temperature of the space heating installations, energy storage systems can achieve a solar fraction of up to 100% for winter heating, eliminating the need for non-renewable energy sources.

Another study brings quantitative evidence to policymakers to develop strategies aimed at balancing energy transition (Bergougui et al., 2025).

A representative study (Cetina-Quiñones et al., 2023) shows the importance of the solar drying process, solar radiation, as well as wind, humidity and ambient temperature.

Another study shows (Geng, Zhang, Sun, 2025) us that the performance and feasibility of a hybrid renewable energy system for buildings in isolated areas, integrating solar photovoltaic (PV) panels, a ground source heat pump (GSHP) or wind turbines. Thermochemical adsorption systems can store significant amounts of energy (Ren et al., 2025). Low-carbon and renewable energy systems are being sought to meet winter heating demand, such as the Power-to-Hydrogen (PtH2) system to meet seasonal demand (Petkov, & Gabrielli, 2019).

Solar-assisted heat pumps have a promising future. They have impressed with their energy-saving performance. Also, Zhang & Zhang say that the environmental protection that heat pumps offer leads to sustainable development. Pumped thermal energy storage (PTES) is an electrical energy storage system that converts electrical energy into thermal energy, which is subsequently converted into electricity. The green supply chain is strongly influenced by innovations in renewable energy (McTigue & Ma, 2025).

There is increasing discussion about the future of work in the context of demographic changes and technological advances (Ciucă et al., 2025).

New technologies influence all sectors, which is why, with the help of the implementation of digital technologies on railways powered by renewable energy, an increase in energy efficiency is observed (Tairab et al., 2023). The essential components are analyzed using energy measurement correction methods, through Coulombic efficiency (CE) estimation techniques and SOC estimation using efficiency algorithms (Chen & Fang, 2024).

With a world full of uncertainties of all kinds, the issue of apathy regarding energy crises arises.

A future global energy crisis has only one solution: achieving an advanced, bidirectional, self-healing, interoperable, and predictive digital energy system (Dorji et al., 2023). Smart grids (SGs) represent a key factor in the energy transition, helping to integrate renewable and conventional energy sources through the use of advanced digital technologies. (Campana et al., 2025).

For thorough security, such a system obviously needs cyber protections to mitigate malicious attacks.

Establishing sustainable energy systems facilitates the reduction of negative environmental impacts through resource efficiency and technological innovations (Huang & Tan, 2025).

Figure 1 further shows that a bibliometric analysis of co-occurrence was carried out using the VOSviewer application software.

For this bibliometric analysis, 240 articles extracted from the WoS Core Collection database were used. VOSviewer shows 6 clusters, more precisely, homogeneous groups of data, which resulted for the keywords "digital technologies" and "solar energy storage".

3. Conclusions

New digital technologies have revolutionized the way photovoltaic systems are designed, planned and installed, contributing to increased efficiency, reduced costs and faster and more accurate implementation.

Digital technologies are a huge enabler and catalyst for the sustainable development of solar energy. They enable a more efficient integration of renewables into the energy infrastructure and give users control, transparency and efficiency. As innovation continues, digitalization will play a key role in achieving global climate and energy goals. Digital technologies help monitor, increase efficiency, control and integrate stored solar energy into electrical grids.

Energy storage monitoring and management are more effective if the batteries have a better state of charge, voltage, or temperature. Also, the lifespan of the batteries used in solar energy storage influences their charging or discharging. There are more and more practical studies that analyze the technical characteristics, the times for different stages or the technical indicators that could be improved to increase the efficiency of solar energy storage. Many studies focus on investigating the performance of hybrid renewable energy systems for remote buildings in isolated regions, by implementing solar photovoltaic (PV) panels. To achieve the transition to renewable energy, improved deployment strategies are needed.

With the help of bibliometric analysis, the importance of a topic such as energy storage for researchers in the field can be observed. Through the co-occurrence of keywords, the 6 identified clusters can be observed. The chosen keywords show how important research on solar energy storage is for the specialized literature in relation to digital technologies.

4. References

- Bergougui, B., Murshed, S. M., Shahbaz, M., Zambrano-Monserrate, M. A., Samour, A., & Aldawsari, M. I. (2025). Towards secure energy systems: Examining asymmetric impact of energy transition, environmental technology and digitalization on Chinese city-level energy security. *Renewable Energy*, 238, 121883
- Campana, P., Censi, R., Ruggieri, R., & Amendola, C. (2025). Smart Grids and Sustainability: The Impact of Digital Technologies on the Energy Transition. *Energies*, 18(9), 2149.
- Cetina-Quiñones, A. J., Arıcı, M., Cisneros-Villalobos, L., & Bassam, A. (2023). Digital twin model and global sensitivity analysis of an indirect type solar dryer with sensible heat storage material: An approach from exergy sustainability indicators under tropical climate conditions. *Journal of Energy Storage*, 58, 106368.
- Chen, F., & Fang, G. (2024). Harnessing digital twin and IoT for real-time monitoring, diagnostics, and error correction in domestic solar energy storage. *Energy Reports*, 11, 3614-3623.
- Ciucă, V., Iordan, M., Lincaru, C., & Chilian, M. N. (2025). Viitorul muncii în contextul schimbărilor demografice și al avansului tehnologic: perspective din România. In *Viitorul muncii în contextul schimbărilor demografice și al avansului tehnologic: perspective din România: Ciucă, Vasilica, Iordan, Marioara, Lincaru, Cristina, Chilian, Mihaela Nona*. București: Institutul European din România.
- Dorji, S., Stonier, A. A., Peter, G., Kuppasamy, R., & Teekaraman, Y. (2023). An extensive critique on smart grid technologies: Recent advancements, key challenges, and future directions. *Technologies*, 11(3), 81
- Festa, A. (2025). THE EUROPEAN GREEN DEAL AND THE JUST TRANSITION IN THE EUROPEAN UNION: AIMS AND SOCIAL ASPECTS OF THE “FIT FOR 55” PACKAGE. *Revue Européenne du Droit Social*, 67(2), 33-48

- Geng, C., Zhang, T., & Sun, W. (2025). Hybrid solar, wind, and geothermal power generation combined with energy storage for sustainable energy management in remote buildings. *Journal of Energy Storage*, 123, 116655.
- Huang, S., & Tan, H. (2025). Evaluating the effects of green supply chain, digital technologies, and energy prices on renewable energy innovations: A way forward for an emerging economy. *Energy Economics*, 141, 108038.
- Kittner, N., Lill, F., & Kammen, D. M. (2017). Energy storage deployment and innovation for the clean energy transition. *Nature Energy*, 2(9), 1-6.
- McTigue, J., & Ma, Z. (2025). Analysis of pumped thermal energy storage using particle media integrated with concentrating solar power. *Solar Energy*, 292, 113436.
- Meibodi, S. S., Ma, Z., Roskilly, A. P., & Bao, H. (2025). Dynamic modelling and performance analysis of compressor-assisted thermochemical sorption for seasonal solar thermal energy storage. *Chemical Engineering Science*, 301, 120739.
- Onu, P., & Mbohwa, C. (2019, November). Concentrated solar power technology and thermal energy storage: a brief overview of nascent sustainable designs. In *2019 7th International Renewable and Sustainable Energy Conference (IRSEC)* (pp. 1-4). IEEE.
- Petkov, I., & Gabrielli, P. (2019, November). An uncertainty and sensitivity analysis of Power-to-Hydrogen as a seasonal storage option in a district multi-energy system. In *Journal of Physics: Conference Series* (Vol. 1343, No. 1, p. 012103). IOP Publishing
- Ren, J., Cao, X., Zhou, X., Wu, L., Zhao, N., & Zhang, P. (2025). Experimental study on the heat storage and release performance of an open adsorption thermal storage system for solar energy storage. *Journal of Energy Storage*, 123, 116817
- Tairab, A. M., Wang, X., Zhang, Z., Hao, D., Abdelrahman, M., Salman, W., & Ali, A. (2023). The Nexus of IoT technology: A renewable multi-module energy harvester for self-powered on railway. *Sustainable Materials and Technologies*, 38, e00752
- Zhang, X. M., & Zhang, Y. R. (2013). The Performance of Thermal Storage Tank in Solar Energy System. *Advanced Materials Research*, 724, 97-100.