



Intelligent Technologies for Sustainable Energy Transitions and System Reliability

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ABSTRACT

The evolution towards renewable energy is progressing rapidly. However, at the same time, it creates more complicated systems. Various intelligent technologies, for example, artificial intelligence, machine learning, digital twins, and advanced forecasting, can help to overcome all the problems with renewable energy technologies. Thus, this paper reviews the role of these technologies in sustainable development and focuses on the following topics: forecasting of renewable energy supply, optimization of the electric grid, demand management, energy storage, predictive maintenance, and stability of systems. Recognize advancements in technology, advantages from operations, obstacles to implementation, and current research trends. Renewable energy contributed approximately 92.5% of the global power capacity in 2024, indicating the need for enhanced flexibility and smarter operation of systems. On the other hand, data centers consumed nearly 1.5% of global electricity, which reflects the growing energy demand of information infrastructure. According to what has been analyzed, intelligent systems may facilitate predicting, operational coordinating, utilizing equipment, and making instant decisions, but efficiency benefits vary significantly depending on system arrangement. With this in view, it becomes apparent that future transitions in energy production will need to include integrated use of intelligent technologies along with storage, flexible demand, smart grids, reliable and secure data systems, and relevant regulations in order to provide sustainable and reliable energy systems.

1. Introduction

The transition from energy systems relying on fossil fuels to those based on renewable sources and low-emission sources has become an important aspect of international efforts for mitigating climate change, achieving energy security, and progressing in sustainable development [Kyriakarakos, 2025]. The use of the renewable technologies, such as solar photovoltaic, wind energy, hydro energy, bioenergy, and many others is gaining popularity with the decline of prices for different technologies, as well as growing ambitions of the countries when it comes to decarbonization [Wyrwicka, 2023]. In 2024, renewable energy was responsible for around 92.5% of the amount of new capacity in the electricity sector, which indicates the scale and speed of development of this sector [Campana, 2025, Tasnia, 2026]. However, the increase in penetration of renewables brings other issues as the generation based on solar and wind energy depends largely on meteorological conditions and is, therefore, variable and uncertain [Cavus, 2025]. These traits can complicate supply-demand balancing, frequency regulation, voltage management, reserve planning, and grid congestion management. Traditionally, conventional power systems were built around centralized and dispatchable generation [Kabeyi, 2023]. Availability of power, increasingly decentralized, information-intensive, and characterized by interactions from distributed generation, battery storage, electric vehicles, prosumers, flexible loads, and interconnecting energy markets is evolving right now [Hossain, 2024]. Compliance with these conditions will require even faster inspection, monitoring, optimization, and controls than traditional operational procedures can always institute. Intelligent technologies have thus emerged as important enabling mechanisms in the management of increasing complex energy systems [Duer, 2022, Lu, 2020].

Advanced technologies such as AI, machine learning, deep learning, reinforcement learning, digital twins, smart meters, advanced sensors, and control systems enables to convert enormous amount of energy data and environmental information into

useful decisions [Campana, 2025, Hossain, 2022]. AI-based forecasting allows to predict renewable energy generation and electricity demand, while intelligent optimization will help to manage generation and storage processes as well as load management [Carley, 2020]. Predictive maintenance will help to discover equipment malfunctions while digital twins will enable real-time assessment of the equipment [Qazi, 2019]. However, despite being a use of technology, digitalization alone is not enough to secure sustainability or reliability. Smart technologies are reliant on good sets of data, communication infrastructure, computing capabilities, cybersecurity, interoperability, and regulated governance systems [Ullah, 2025]. Also, the emergence of AI technologies brings a significant sustainability challenge since the computing infrastructure necessary for modern digital products consumes a lot of power [Cavus, 2025]. By 2024, data centers accounted for around 1.5% of electrical power consumption worldwide, and this number keeps growing substantially. Under these circumstances, the evaluation of intelligent technologies should assess both their advantages in terms of working capabilities and their disadvantages in terms of technical, environmental, and institutional aspects [Telukunta, 2017, Dincer, 2015]. This review thus investigates the role of intelligent technologies in sustainability transitions and the reliability of systems. Furthermore, it highlights the main challenges in implementation and provides relevant priority topics for research in the field of safe, efficient, transparent, and adaptable intelligent energy systems [Rahman, 2021].

2. Methodology

This study employed a systematic narrative approach to analyze the impact of intelligent technologies on sustainable energy transitions and reliability of power systems. It involved the use of peer-reviewed articles, review papers, and reports from reputable institutions, especially recent literature related to artificial intelligence, machine learning, smart grids, renewable energy forecasting, digital twins, demand response, energy storage, predictive maintenance, and resilience of energy systems [Strielkowski, 2021]. The study also took into account studies that focused on use of intelligent technologies in renewable integration, operational flexibility, forecasting, optimization, reliability, or resilience. In addition, reports from global power organizations were utilized to find contemporary trends in energy transition and digitalization. The evidence collected was categorized into renewable forecasting and integration, smart grid management, flexibility in demand and storage, predictive maintenance and resilience, and obstacles to implementation [Kittner, 2017]. A real meta-analysis was avoided, and instead of it, comparative qualitative synthesis helped to distinguish the similarities in technological advantages and disadvantages, research gaps, and ways of transition to sustainable and reliable energy systems [Newaz, 2022].

3. Results and Discussion

3.1 Intelligent Forecasting and Renewable Energy Integration

The Precise forecasting is regarded as one of the functions of advanced technologies in renewables-heavy power systems as presented in Figure 1. For solar and wind generation, there is a direct link to the weather, which means that quick changes in solar irradiation, temperature, cloud cover, and wind can cause a difference between forecasted and real power outputs [Osman, 2022]. By using machine learning and deep learning technologies it is possible to analyze historical generation data, meteorological records, satellite data, and real-time sensor data to unveil nonlinear relations that are hard to uncover with conventional statistical methods [Kroposki, 2017]. Deep neural networks, recurrent architecture, ensemble learning, and hybrid forecasting approaches are becoming more and more popular in short- and mid-term forecasting of solar and wind generation [Ullah, 2025, Hossain, 2025]. Better forecasts allow system operators to manage generation and coordinate storage better, reduce reserve needs, and be aware of times with excess or shortage of renewable while AI, therefore, plays an important role in linking weather uncertainty to operational choices [Parmentola, 2021]. Its role increases as in 2024 renewable energy made up about 92.5% of global power capacity addition. The bigger the share of variable renewable electricity is the greater consequences forecasting errors may bring to the system [Farghali, 2023, Imon, 2025]. Therefore, intelligent forecasting should be paired with probabilistic uncertainty assessment instead of being utilized merely as a point forecaster. Reliable use of technology demands also relevant geographic data and continuous model updates, as climate change and equipment degradation can affect the performance of the model [Kalair, 2020].

Intelligent Forecasting in Renewable Energy



Figure 1. Intelligent Forecasting and Renewable Energy Integration

3.2 Smart Grids, Automated Control, and System Reliability

Digital grids encompass sensing, communications, computing, and automated control and enable more detailed insights into the electricity supply system. Smart meters, phasor measurement units, supervisory control systems, and AI tools can enhance situational awareness of energy transmission and distribution systems [Motlagh, 2020]. They serve as an invaluable asset to the operator by enabling detection of unusual operating conditions, prediction of congestion, optimization of energy flow, and faster responses to any disturbances occurring in the networks [Imon, 2025]. Operations based on AI are especially important for systems relying on renewable energy as traditional rules of operation may be ineffective due to simultaneous fluctuations of supply and demand. Using reinforcement learning and sophisticated optimization methods, it is possible to manage distributed energy resources while respecting operational constraints [Tabor, 2018]. The application of digital twins, an additional intelligence layer is provided due to generation of virtual model of electrical systems or a single asset and assessment of various alternatives regarding operations as presented Figure 2. Despite the benefits digitalization can bring to the sphere, it can generate new uncertainties in terms of reliability [Parmentola, 2021, Mohanty, 2016]. Communication breakdowns, wrong information received from sensors, overly generalized algorithms, and cyber-attacks can easily spread through advanced connected systems of electrical grid [Howlader, 2026]. Consequently, implementation of smart control system should complete existing protection systems instead of replacing them. The need in that is growing since the demand for electricity from data centers is increasing: the world demand for electricity consumed by data centers increased by 17% in 2025 [Kumar, 2017].

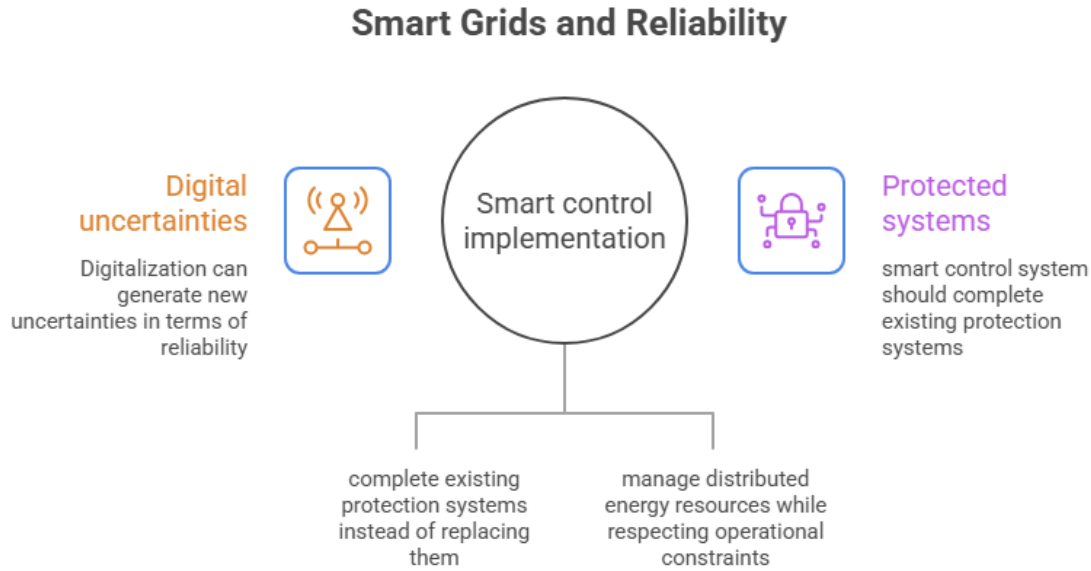


Figure 2. Smart Grids, Automated Control, and System Reliability

3.3 Demand-Side Intelligence and Energy Storage Optimization

Demand flexibility and the ability to store energy are key balancing components in systems that rely on highly inconsistent power from renewable sources as summarized in Table 1. Demand-response systems are clever as they rely on data from smart meters, electricity tariffs, weather and behavioral patterns of customers to determine when electricity usage can be changed without changing the customer needs significantly [Sayed, 2023]. Forecasting methods and machine learning algorithms provide information about future electricity consumption, help identify flexible loads and provide the basis for automated scheduling in buildings, industries, EV charging networks, and distributed energy systems. Storage is complementary to power demand flexibility because it can take up excess power from renewable sources and provide energy at times of low generation or high demand [Akhtaruzzaman, 2025, Mensah, 2019]. Artificial intelligence-enabled battery management systems can optimize charging and discharging schedules by considering factors such as renewable forecasts, state of charge, battery degradation, electricity pricing as well as grid demands at the same time [Mourtzis, 2022]. Such coordination can make it possible to reduce renewable curtailment and to enhance the usage of existing infrastructure. The continuous increase in electricity demands created by the digital infrastructure opens new opportunities for intelligent flexibility [Hossain, 2025]. Once the needed market drivers and regulation measures are in place, these resources will be able to provide grid services rather than solely act as back-up capacity. Nevertheless, that will require the introduction of standardized mechanisms for communication, transparent market regulations, the establishment of consumer incentives, and development of measures which protect batteries from too much cycling [Brauns, 2020, Selvam, 2024].

Table 1. Demand-Side Intelligence and Energy Storage Optimization

Aspect	Role	Major Benefit
Demand Response	Shifts electricity use using smart-meter, price, weather, and consumer data.	Reduces peak demand and improves grid flexibility.
ML & Forecasting	Predicts demand and identifies flexible energy loads.	Enables efficient and automated energy management.
Energy Storage	Stores excess renewable energy for later use.	Reduces energy wastage and supports supply during high demand.
AI-Based Battery Management	Optimizes battery charging and discharging based on demand, price, and battery condition.	Improves battery efficiency and lifespan.
Digital Infrastructure	Provides new opportunities for intelligent demand flexibility.	Enhances the use of flexible energy resources.
Policy & Regulation	Supports market mechanisms, consumer incentives, and battery protection.	Enables reliable and sustainable grid services.

3.4 Predictive Maintenance, Resilience, and Asset Management

Nowadays, intelligent technologies are changing the landscape of power system maintenance – from reactive or scheduled techniques to condition-based and predictive methods as presented in Figure 3. Sensors that are placed on transformers and other equipment such as wind turbines, solar power installations, and battery systems can be used for continuous detection of temperature, vibration, current, and voltage [Hossain, 2023]. Machine learning models that analyze data from these sensors are capable of detecting abnormal behavior and recognizing patterns in time to prevent breakdowns [Zhang, 2023]. Digital twins enhance the process by integrating real-time measurements with physical or data models, enabling operators to simulate degradation and evaluate asset performance under different operating scenarios [Strielkowski, 2021, Hossain, 2025]. This capability is critical, particularly as electricity networks deal with stress due to electrification, distributed generation, harsh weather, and new high-density loads. Nevertheless, predictive systems have a tendency to rely on incomplete data and to be unfamiliar with rare events. Models trained merely on “normal” operating conditions might therefore perform inadequately when dealing with extreme occurrence. Thus, applications focusing more on resilience think of connecting AI analytics with physical knowledge, scenario modeling, risk information, and robust emergency response actions [Ullah, 2025].

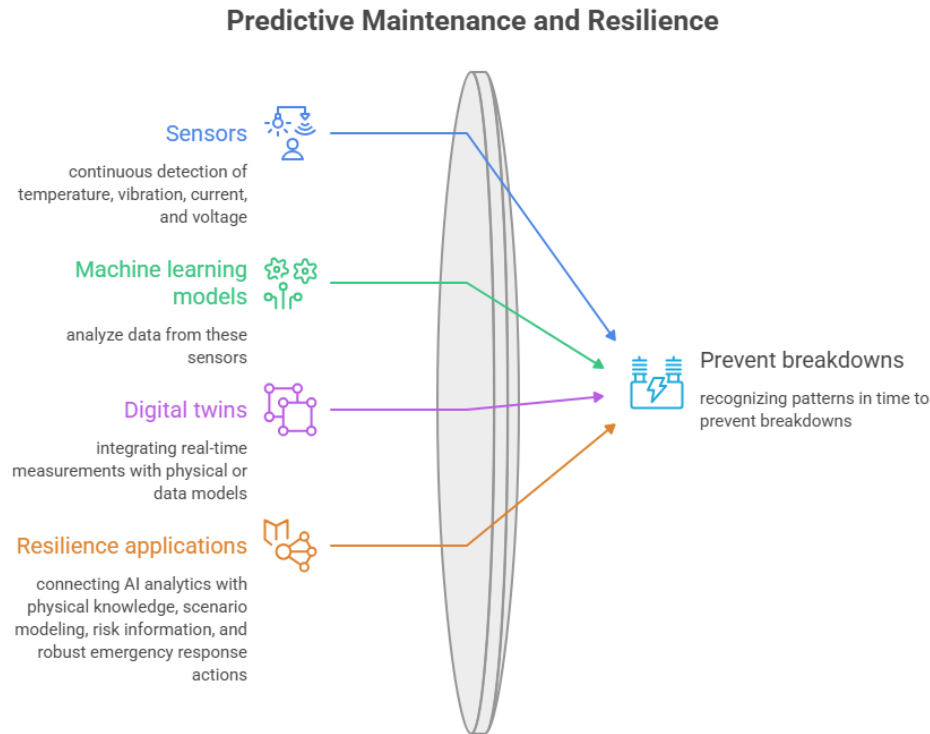


Figure 3. Predictive Maintenance, Resilience, and Asset Management

3.5 Implementation Challenges and Sustainable Digitalization

Intelligent energy technologies have promise, they have obstacles in terms of technicalities, costs, institutions, and the environment. Data fragmentation is one major issue creating hurdles for utilities, distributed generators, customers, and technology providers as they use different platforms [Rathor, 2020]. Further, differences in data formats and insufficient sharing of information prevent the application of artificial intelligence models from one region to another and between electricity networks. Algorithmic opacity is another issue because operators must be able to understand when and why automated tools recommend certain actions [Tabor, 2018]. Due to millions of devices contributing to the digital surface of power systems, the significance of cybersecurity increases dramatically. In addition, as consumption data is collected from households and companies, different privacy issues become relevant [Breyer, 2022]. Therefore, proper management requires ensuring cybersecurity by design, secure data transferring, model validation, identification of responsibilities, and secure privacy. Hence, AI can improve the efficiency of power systems and generate extra demands for electricity. Therefore, in the process of digitalization, the net energy and ecological benefit of smart applications have to be evaluated.

4. Conclusion

The rise of intelligent technologies has enabled sustainability in the energy transition process through the electricity systems becoming more dependent on variable renewable technologies, decentralization of electricity generation, and energy storage systems. Their best asset consists of altering complex energy data into quick decisions which enhance the flexibility and reliability of the electricity systems. Nevertheless, the intelligent technologies cannot support sustainable transition by themselves. The limitations related to information systems, security problems, interoperability of process, and infrastructure make it impossible. Therefore, future energy systems need to integrate intelligent technologies with the modernization of the physical grid, energy storage, flexibility in demand, strong cybersecurity, and effective regulatory principles. This coordinated development can ensure that digital intelligence advances the transition toward safe, stable, and low-carbon energy systems instead of hindering it.

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References

- [1] Akhtaruzzaman, M., Barman, S. C., Hossain, M. A., Ahmad, M., & Ali, R. A. (2025). Cloud enabled AI smart energy infrastructure for industrial and utility applications. *International Conference on Energy Conservation and Efficiency (ICECE)*, 1–6. <https://doi.org/10.1109/icece69114.2025.11272935>
- [2] Brauns, J., & Turek, T. (2020). Alkaline water electrolysis Powered by Renewable Energy: a review. *Processes*, 8(2), 248. <https://doi.org/10.3390/pr8020248>
- [3] Breyer, C., Khalili, S., Bogdanov, D., Ram, M., Oyewo, A. S., Aghahosseini, A., Gulagi, A., Solomon, A. A., Keiner, D., Lopez, G., Ostergaard, P. A., Lund, H., Mathiesen, B. V., Jacobson, M. Z., Victoria, M., Teske, S., Pregger, T., Fthenakis, V., Raugei, M., . . . Sovacool, B. K. (2022b). On the History and Future of 100% Renewable Energy Systems Research. *IEEE Access*, 10, 78176–78218. <https://doi.org/10.1109/access.2022.3193402>
- [4] 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. <https://doi.org/10.3390/en18092149>
- [5] Carley, S., & Konisky, D. M. (2020). The justice and equity implications of the clean energy transition. *Nature Energy*, 5(8), 569–577. <https://doi.org/10.1038/s41560-020-0641-6>
- [6] Cavus, M. (2025). Advancing Power Systems with Renewable Energy and Intelligent Technologies: A Comprehensive Review on Grid Transformation and Integration. *Electronics*, 14(6), 1159. <https://doi.org/10.3390/electronics14061159>
- [7] Dincer, I., & Acar, C. (2015). A review on clean energy solutions for better sustainability. *International Journal of Energy Research*, 39(5), 585–606. <https://doi.org/10.1002/er.3329>
- [8] Duer, S., Rokosz, K., Zajkowski, K., Bernatowicz, D., Ostrowski, A., Woźniak, M., & Iqbal, A. (2022). Intelligent systems supporting the use of energy devices and other complex technical objects: modeling, testing, and analysis of their reliability in the operating process. *Energies*, 15(17), 6414. <https://doi.org/10.3390/en15176414>
- [9] Farghali, M., Osman, A. I., Mohamed, I. M. A., Chen, Z., Chen, L., Ihara, I., Yap, P., & Rooney, D. W. (2023). Strategies to save energy in the context of the energy crisis: a review. *Environmental Chemistry Letters*, 21(4), 2003–2039. <https://doi.org/10.1007/s10311-023-01591-5>
- [10] Hossain, A., Oyeboode, D., Imon, K. a. A., Faisal, S. M. W., & Vayyala, R. (2025). Analyzing how MIS can optimize the distribution of energy in smart grids, focusing on data-driven decision-making processes. *Journal of Smart Internet of Things*, 2025(1), 31–42. <https://doi.org/10.2478/jsiot-2025-0004>
- [11] Hossain, M. A. (2025). Residual stress mitigation and distortion control in laser powder bed fusion components for High-Reliability Engineering applications. *American Journal of Advanced Technology and Engineering Solutions*, 01(02), 173–215. <https://doi.org/10.63125/1b3nyj37>
- [12] Hossain, M. A., & Bhuiyan, M. A. A. (2025). Digital twin-based process optimization and defect prediction in metal additive manufacturing for critical mechanical components. *Brit. J. Multidiscip. Stud.* 3(2), 57–72.
- [13] Hossain, M. A., Dangol, S., Hasan, D. W., & Badugu, D. (2023). Thermal Performance Study of Additively Manufactured Compact Heat Exchangers for Industrial Energy Systems. *Journal of Mechanical, Civil and Industrial Engineering*, 4(4), 86–103.
- [14] Hossain, M. S., & Rahman, M. A. (2022). Integration of solar thermal energy and solar electricity generation for sustainable power production. *Central Asian Journal of Theoretical and Applied Science*. <https://doi.org/10.51699/cajotas.v3i5.1696>
- [15] Hossain, M. S., Patel, U., & Chadni, F. H. (2024). Key factors affecting high-voltage insulation performance: Evidence from environmental contamination, partial discharge, and preventive maintenance. *Applied IT & Engineering*, 2(1), 1–16. <https://doi.org/10.25163/engineering.2110771>
- [16] Howlader, M. N., Chowdhury, S., Imon, K. a. A., Khan, G. J., Mehedi, M. K. H., Rabbi, M. F., Islam, A., & Alif, S. a. Z. (2026). Design and implementation of a low-cost IoT-enabled dual-axis photovoltaic tracking system with experimental and simulation-based validation. *Journal of Electrical Systems and Information Technology*, 13(1). <https://doi.org/10.1186/s43067-026-00351-z>
- [17] Imon, K. a. A., Chowdhury, B. S., Robbani, M. S., Rahman, M. A., Ahmed, N., & Anonto, H. Z. (2025). Advanced nonlinear state estimation of degrading battery systems via unscented kalman filtering. *IEEE PES Conference on Innovative Smart Grid Technologies - Middle East (ISGT Middle East)*, 1–5. <https://doi.org/10.1109/isgtmiddleeast65737.2025.11314288>
- [18] Imon, K. a. A., Robbani, M. S., Chowdhury, B. S., Arthey, A. G., Ahmed, N., & Amin, N. (2025). Lightweight Kalman filtering for battery pack SOC estimation: A Bar-Delta approach. *International Conference on Computer and Information Technology (ICCIT)*, 4555–4560. <https://doi.org/10.1109/iccit68739.2025.11491411>
- [19] Kabeyi, M. J. B., & Olanrewaju, O. A. (2023). Smart grid technologies and application in the sustainable energy transition: a review. *International Journal of Sustainable Energy*, 42(1), 685–758. <https://doi.org/10.1080/14786451.2023.2222298>
- [20] Kalair, A., Abas, N., Saleem, M. S., Kalair, A. R., & Khan, N. (2020). Role of energy storage systems in energy transition from fossil fuels to renewables. *Energy Storage*, 3(1). <https://doi.org/10.1002/est2.135>
- [21] Kittner, N., Lill, F., & Kammen, D. M. (2017). Energy storage deployment and innovation for the clean energy transition. *Nature Energy*, 2(9). <https://doi.org/10.1038/nenergy.2017.125>
- [22] Kroposki, B., Johnson, B., Zhang, Y., Gevorgian, V., Denholm, P., Hodge, B., & Hannegan, B. (2017). Achieving a 100% Renewable Grid: Operating Electric Power Systems with Extremely High Levels of Variable Renewable Energy. *IEEE Power and Energy Magazine*, 15(2), 61–73. <https://doi.org/10.1109/mpe.2016.2637122>
- [23] Kumar, D., Zare, F., & Ghosh, A. (2017). DC Microgrid Technology: system architectures, AC grid interfaces, grounding schemes, power quality, communication networks, applications, and standardizations aspects. *IEEE Access*, 5, 12230–12256. <https://doi.org/10.1109/access.2017.2705914>
- [24] Kyriakarakos, G. (2025). Artificial intelligence and the energy transition. *Sustainability*, 17(3), 1140. <https://doi.org/10.3390/su17031140>
- [25] Lu, Y., Khan, Z. A., Alvarez-Alvarado, M. S., Zhang, Y., Huang, Z., & Imran, M. (2020). A Critical review of sustainable energy Policies for the promotion of renewable energy sources. *Sustainability*, 12(12), 5078. <https://doi.org/10.3390/su12125078>
- [26] Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Social Sciences*, 5(1). <https://doi.org/10.1080/23311886.2019.1653531>

- [27] Mohanty, S. P., Choppali, U., & Kougiannos, E. (2016). Everything you wanted to know about smart cities: The Internet of things is the backbone. *IEEE Consumer Electronics Magazine*, 5(3), 60–70. <https://doi.org/10.1109/mce.2016.2556879>
- [28] Motlagh, N. H., Mohammadrezaei, M., Hunt, J., & Zakeri, B. (2020). Internet of things (IoT) and the energy sector. *Energies*, 13(2), 494. <https://doi.org/10.3390/en13020494>
- [29] Mourtzis, D., Angelopoulos, J., & Panopoulos, N. (2022). A Literature Review of the Challenges and Opportunities of the Transition from Industry 4.0 to Society 5.0. *Energies*, 15(17), 6276. <https://doi.org/10.3390/en15176276>
- [30] Newaz, A. A. H., Al Imon, K. A., Jahan, R., & Tanvir, I. K. (2022). Advanced Motor Design and Optimization for High-Efficiency Industrial Applications. *Metallurgical and Materials Engineering*, 28(4), 697–713.
- [31] Osman, A. I., Chen, L., Yang, M., Msigwa, G., Farghali, M., Fawzy, S., Rooney, D. W., & Yap, P. (2022). Cost, environmental impact, and resilience of renewable energy under a changing climate: a review. *Environmental Chemistry Letters*, 21(2), 741–764. <https://doi.org/10.1007/s10311-022-01532-8>
- [32] Parmentola, A., Petrillo, A., Tutore, I., & De Felice, F. (2021). Is blockchain able to enhance environmental sustainability? A systematic review and research agenda from the perspective of Sustainable Development Goals (SDGs). *Business Strategy and the Environment*, 31(1), 194–217. <https://doi.org/10.1002/bse.2882>
- [33] Qazi, A., Hussain, F., Rahim, N. A., Hardaker, G., Alghazzawi, D., Shaban, K., & Haruna, K. (2019). Towards Sustainable Energy: A Systematic review of renewable energy sources, technologies, and public opinions. *IEEE Access*, 7, 63837–63851. <https://doi.org/10.1109/access.2019.2906402>
- [34] Rahman, M. A., & Hossain, M. S. (2021). Intelligent optimisation for power system stability: A comparative expert-survey analysis of artificial neural networks, particle swarm optimisation, genetic algorithms, fuzzy logic, and hybrid AI approaches. *Journal of Primeasia*, 2(1), 1–16. <https://doi.org/10.25163/primeasia.2110773>
- [35] Rathor, S. K., & Saxena, D. (2020b). Energy management system for smart grid: An overview and key issues. *International Journal of Energy Research*, 44(6), 4067–4109. <https://doi.org/10.1002/er.4883>
- [36] Sayed, E., Olabi, A., Alami, A., Radwan, A., Mdallal, A., Rezk, A., & Abdelkareem, M. (2023). Renewable energy and energy storage systems. *Energies*, 16(3), 1415. <https://doi.org/10.3390/en16031415>
- [37] Selvam, A. P., & Al-Humairi, S. N. S. (2024). Environmental impact evaluation using smart real-time weather monitoring systems: a systematic review. *Innovative Infrastructure Solutions*, 10(1). <https://doi.org/10.1007/s41062-024-01817-7>
- [38] Strielkowski, W., Civiń, L., Tarkhanova, E., Tvaronavičienė, M., & Petrenko, Y. (2021). Renewable Energy in the Sustainable Development of Electrical Power Sector: A review. *Energies*, 14(24), 8240. <https://doi.org/10.3390/en14248240>
- [39] Tabor, D. P., Roch, L. M., Saikin, S. K., Kreisbeck, C., Sheberla, D., Montoya, J. H., Dwaraknath, S., Aykol, M., Ortiz, C., Tribukait, H., Amador-Bedolla, C., Brabec, C. J., Maruyama, B., Persson, K. A., & Aspuru-Guzik, A. (2018). Accelerating the discovery of materials for clean energy in the era of smart automation. *Nature Reviews Materials*, 3(5), 5–20. <https://doi.org/10.1038/s41578-018-0005-z>
- [40] Tasnia, R., & Hossain, M. S. (2026). Investment barriers and financing solutions for critical energy infrastructure projects. *Pacific Journal of Advanced Engineering Innovations*, 3(1), 89–96. <https://doi.org/10.70818/pjaei.v03i01.0246>
- [41] Telukunta, V., Pradhan, J., Agrawal, A., Singh, M., & Srivani, S. G. (2017). Protection challenges under bulk penetration of renewable energy resources in power systems: A review. *CSEE Journal of Power and Energy Systems*, 3(4), 365–379. <https://doi.org/10.17775/cseejpes.2017.00030>
- [42] Ullah, M. S., Hossain, M. S., & Ullah, S. M. E. (2025). Wireless power transfer adoption in smart renewable energy networks: A quantitative study of awareness, perceived benefits, technical barriers, and renewable integration. *Energy Environment and Economy*, 3(1), 1–13. <https://doi.org/10.25163/energy.3110770>
- [43] Wyrwicka, M. K., Więcek-Janka, E., & Brzeziński, Ł. (2023). Transition to Sustainable Energy System for Smart Cities—Literature review. *Energies*, 16(21), 7224. <https://doi.org/10.3390/en16217224>
- [44] Zhang, X., Fu, X., Xue, Y., Chang, X., & Bai, X. (2023). A review on basic theory and technology of agricultural energy internet. *IET Renewable Power Generation*, 18(7), 1318–1331. <https://doi.org/10.1049/rpg2.12808>