"Empowering Sustainable Consumption: Harnessing the Potential of Smart Grid Systems and Internet of Things for Environmental Conservation"

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ABSTRACT

This systematic review explores the role of smart grid systems (SGS) and the Internet of Things (IoT) in environmental conservation. Smart grid systems, incorporating advanced technologies such as sensors, data analytics, and renewable energy sources, enable efficient electricity distribution, load management, and grid stability. The IoT, through real-time monitoring and data collection of environmental parameters, facilitates proactive environmental management and resource allocation. By analysing existing research and case studies, this review provides a comprehensive analysis of the benefits and challenges associated with these technologies. The findings highlight their potential in promoting energy conservation, informed decision-making, and environmental sustainability.

KEYWORDS: smart grid systems, Internet of Things (IoT), environmental conservation, energy conservation, load management, grid stability, real-time monitoring, proactive environmental management, resource allocation, sustainability.

JEL CODES: Q50: Q55: L94

INTRODUCTION

Environmental conservation became an increasingly pressing global concern as the effects of climate change and resource depletion became more evident. To combat these challenges, the integration of advanced technologies emerged as a powerful tool in the field of environmental conservation. Two such cutting-edge technologies that revolutionized the way we approached conservation efforts were smart grid systems and the Internet of Things (IoT) (Abbass et al., 2022; Alahi et al., 2023; Kirmani et al., 2023)

Smart grid systems transformed the traditional electricity distribution model into a dynamic and intelligent network. By incorporating innovative features such as sensors, data analytics, and renewable energy sources, smart grids enabled efficient and reliable electricity distribution. They actively contributed to energy conservation by optimizing the allocation of resources, managing peak loads, and reducing transmission losses. Moreover, smart grids enhanced grid stability, ensuring a seamless integration of renewable energy sources into the existing power infrastructure (Sirviö et al., 2021; Escobar et al., 2021 Bhattarai et al., 2023).

In parallel, the Internet of Things (IoT) revolutionized environmental monitoring and data collection. IoT applications offered real-time monitoring capabilities for various environmental parameters such as air quality, water quality, and biodiversity. By deploying interconnected sensors and devices, environmental data could be collected and analysed in real-time, providing valuable insights for proactive environmental management and informed decision-making. This technology empowered policymakers and resource managers to allocate resources effectively, identify pollution sources promptly, and implement targeted conservation measures (Marques & Pitarma, 2019; Pamula et al., 2022; Moiroux-Arvis et al., 2023).

Considering the significant impact of smart grid systems and IoT on environmental conservation, a systematic review was necessary to evaluate the existing body of research and identify key findings. This publication aimed to provide a comprehensive analysis of the latest advancements, challenges, and opportunities presented by these technologies in the context of environmental sustainability. By highlighting their potential and exploring successful implementation case studies, this review served as a valuable resource for researchers, policymakers, and environmentalists seeking innovative solutions to address pressing environmental issues.

The systematic review delved into the efficacy of smart grid systems and IoT in facilitating energy conservation, load management, and grid stability. It also analysed the role of IoT in real-time environmental monitoring and the positive impact it had on proactive environmental management and resource allocation. The review drew upon relevant research studies, case examples, and empirical evidence to present a well-rounded analysis of the benefits and challenges associated with these technologies in the field of environmental conservation.

By disseminating this knowledge through a systematic review, it was hoped that policymakers, industry experts, and environmental enthusiasts would be inspired to harness the potential of smart grid systems and IoT to propel environmental conservation efforts forward. With these technological marvels at our disposal, we could work together towards a sustainable future, safeguarding our precious natural resources for generations to come (Shayan et al., 2022; Bovenizer & Chetthamrongchai, 2023).

Environmental conservation is a pressing global concern, and the integration of advanced technologies holds promise for addressing this challenge. However, there is a need to understand the role of smart grid systems and the Internet of Things (IoT) in environmental conservation comprehensively. Identifying the gaps and limitations in the existing research is crucial to harnessing the full potential of these technologies and maximizing their impact on sustainability (Alahi et al., 2023; Bovenizer & Chetthamrongchai, 2023).

Despite the growing body of literature on smart grid systems and IoT in environmental conservation, there is a lack of comprehensive systematic reviews that bring together the latest advancements, challenges, and opportunities associated with these technologies. Previous studies have often focused on specific aspects or applications, leaving room for a holistic analysis that encompasses energy conservation, load management, grid stability, real-time monitoring, and proactive environmental management.

The purpose of this systematic review is to provide a comprehensive analysis of the role of smart grid systems and IoT in environmental conservation. By synthesizing existing research and case studies, the review aims to identify the benefits, challenges, and potential applications of these technologies, contributing to informed decision-making and the development of effective conservation strategies.

The research questions are as follows: What are the key benefits of smart grid systems in promoting energy conservation, load management, and grid stability? How does the Internet of Things (IoT) facilitate real-time monitoring and data collection for proactive environmental management? What are the gaps and future research directions in the field of smart grid systems and IoT in environmental conservation?

The research assumptions are as follows: The implementation of smart grid systems and IoT technologies is beneficial for environmental conservation. The integration of renewable energy sources is a key component of smart grid systems. Real-time monitoring and data collection through IoT devices enhances proactive environmental management.

The challenges of the study are as follows: Limitations: The review relies on the availability and quality of existing research studies and literature. The analysis may be influenced by publication biases, as only peer-reviewed sources are considered. The review focuses primarily on the benefits and challenges, and it may not delve into detailed technical aspects.

This systematic review encompasses the role of smart grid systems and IoT in environmental conservation, with a particular emphasis on energy conservation, load management, grid stability, real-time monitoring, proactive environmental management, and resource allocation. The analysis includes case studies, research articles, and empirical evidence published up until the present date. The review primarily focuses on the environmental conservation aspect and does not extensively cover economic or social aspects related to these technologies.

METHODOLOGY

This systematic review follows a rigorous methodology to gather and analyse relevant literature on the role of smart grid systems and the Internet of Things (IoT) in environmental conservation. The steps involved in conducting this review are as follows:

Research Design: The review begins with a well-defined research design, outlining the objectives, scope, and research questions to be addressed. The inclusion and exclusion criteria are established to ensure the selection of appropriate studies.

Literature Search: A comprehensive literature search is conducted using various academic databases, such as PubMed, IEEE Xplore, ScienceDirect, and Google Scholar. Relevant keywords and combinations are used to optimize the search process, including terms like "smart grid systems," "Internet of Things," "environmental conservation," and related concepts.

Study Selection: The retrieved articles are screened based on predefined inclusion and exclusion criteria. The initial screening involves reviewing titles and abstracts to identify potentially relevant articles. Subsequently, full-text articles meeting the inclusion criteria are selected for further analysis.

Data Extraction: Pertinent information from the selected articles is extracted systematically. This includes details such as author(s), publication year, research objectives, methodologies, key findings, and implications related to smart grid systems, IoT, and environmental conservation.

Quality Assessment: The quality and relevance of the selected articles are critically evaluated using appropriate assessment tools, such as the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. This assessment ensures that the included studies meet the required standards of scientific rigor and reliability.

Data Synthesis and Analysis: The extracted data are synthesized and analysed to identify common themes, patterns, and trends across the literature. Key findings, benefits, challenges, and potential applications of smart grid systems and IoT in environmental conservation are synthesized to provide a comprehensive overview.

Results Presentation: The results of the systematic review are presented in a clear and organized manner, employing tables, graphs, and narrative summaries. The findings are structured according to the research questions, enabling a systematic and coherent presentation.

Discussion and Conclusion: The findings are critically discussed in light of existing knowledge, highlighting gaps, limitations, and future research directions. The review concludes by summarizing the main outcomes and implications for sustainable consumption and environmental conservation.

The methodology employed in this systematic review ensures a systematic and comprehensive analysis of the literature, providing valuable insights into the role of smart grid systems and IoT in promoting environmental conservation and sustainable consumption.

CONCEPTUAL FRAMEWORK

The conceptual framework for this systematic review of smart grid systems and IoT in environmental conservation is based on the key components and interactions between the technologies, environmental outcomes, and sustainable consumption. The framework is designed to guide the analysis and interpretation of the literature, providing a structured approach to understanding the role of smart grid systems and IoT in promoting environmental sustainability and influencing consumption patterns (Kirmani et al., 2022; Gao et al., 2023).

Smart Grid Systems: The foundation of the conceptual framework lies in smart grid systems, which encompass advanced technologies, such as sensors, data analytics, and renewable energy sources. These components enable efficient electricity distribution, load management, and grid stability. Smart grid systems form the basis for optimizing energy consumption and integrating renewable energy sources into the power infrastructure (Pal, & Shankar, 2022; Escobar et al.,2021 Khan et al., 2022)

Internet of Things (IoT): The second component of the framework is the Internet of Things (IoT), which encompasses interconnected devices, sensors, and data collection capabilities. IoT enables real-time monitoring and data collection of environmental parameters, such as air quality, water quality, and biodiversity. This component provides the necessary data for informed decision-making and proactive environmental management (Kumar et al., 2019; Hassan et al., 2020 Nižetić et al., 2020).

Environmental Outcomes (EO): The framework also emphasizes the environmental outcomes of smart grid systems and IoT. These include energy conservation, reduced carbon emissions, efficient resource allocation, improved grid stability, and proactive environmental management. The environmental outcomes serve as the primary indicators of the effectiveness and impact of these technologies on environmental conservation (Hu et al., 2022; Rehman et al., 2022; Kirmani et al., 2023).

Sustainable Consumption (SC): The final component of the conceptual framework is sustainable consumption. It highlights the influence of smart grid systems and IoT on consumption patterns and behaviours. By optimizing energy consumption, promoting renewable energy sources, and facilitating informed decision-making through real-time data, these technologies contribute to sustainable consumption practices that minimize environmental impact (Haider et al., 2022; Vargas-Merino et al., 2023).

Interactions and Pathways: The conceptual framework illustrates the interconnectedness and pathways between the components. Smart grid systems and IoT interact to enable efficient energy distribution, real-time data collection, and proactive environmental management. The environmental outcomes, such as energy conservation and improved resource allocation, are achieved through the combined effects of smart grid systems and IoT. Sustainable consumption, influenced by these technologies, is seen as a result of environmental outcomes and informed decision-making (Bashir et al., 2022; Chen et al., 2023).

The conceptual framework provides a holistic perspective for analysing the role of smart grid systems and IoT in environmental conservation and sustainable consumption. It guides the systematic review process by organizing the analysis around the key components and their interactions, facilitating a comprehensive understanding of the implications and potential of these technologies in promoting a sustainable future.

The conceptual framework is presented in a mathematical format as follows:
Let:

i. SGS represent Smart Grid Systems
ii. IoT represents the Internet of Things
iii. EO represents Environmental Outcomes
iv. SC represent Sustainable Consumption

The relationships can be described as follows:

1. SGS → EO: Smart grid systems contribute to environmental outcomes.
2. IoT → EO: The Internet of Things contributes to environmental outcomes.

3. EO → SC: Environmental outcomes influence sustainable consumption.

Mathematically, the conceptual framework can be represented as:

a. SGS → EO
b. IoT → EO
c. EO → SC

This representation shows the effects of smart grid systems and IoT on environmental outcomes, and subsequently, how environmental outcomes influence sustainable consumption.

TECHNOLOGY AND INNOVATION IN ENVIRONMENTAL CONSERVATION

Smart Grid Systems

Smart grid systems are an essential component of technology and innovation in environmental conservation. These systems revolutionize the traditional electricity distribution infrastructure by integrating advanced technologies, such as sensors, data analytics, and renewable energy sources (Mashal et al., 2023).

The implementation of smart grid systems brings several benefits that contribute to environmental sustainability (Benders et al., 2006; Burgess & Nye, 2008; Darby, 2006; Larsen & Petersen, 2009; De Jonge, 2010; Van der Beek, 2010; Huygens, 2011; Nyborg & Røpke, 2011; Ribeiro et al., 2011; Hicks, 2012; Kezunovic et al., 2012; Succar & Cavanagh, 2012; Verbong et al., 2012; Mengolini & Vasiljevska, 2013; Shafiullah et al., 2013; Galdikas et al., 2014).

Firstly, smart grid systems enable more efficient and reliable electricity distribution. By leveraging real-time data collection and analysis, these systems optimize the flow of electricity, minimizing transmission and distribution losses. This increased efficiency translates into reduced energy waste, leading to lower greenhouse gas emissions and a more sustainable energy supply (Bamberger et al., 2006; Fang et al., 2012; Raimi & Carrico 2016: Ghasempour, 2019; Ourahou et al., 2020).

Moreover, smart grid systems facilitate energy conservation through demand-side management. With the integration of smart meters and communication networks, consumers can monitor and manage their energy consumption in real-time. This empowers individuals to make informed decisions about their energy usage, promoting energy conservation behaviours and reducing overall energy demand (Mokhtar et al., 2015; Bayindir et al., 2016).

Load management is another crucial aspect of smart grid systems. These systems utilize advanced monitoring and control mechanisms to balance electricity supply and demand. By dynamically adjusting energy loads and optimizing power generation and distribution, smart grid systems can reduce peak demand and improve grid stability. This not only enhances the efficiency of the electrical grid but also reduces the need for additional power generation, leading to environmental benefits (Rauf et al., 2016; **Jabandžić** et al., 2021).

Furthermore, the integration of renewable energy sources is a key feature of smart grid systems. By incorporating technologies such as solar panels, wind turbines, and energy storage systems, these systems enable the seamless integration and management of clean and sustainable energy sources. This contributes to the reduction of reliance on fossil fuels and promotes the adoption of renewable energy, ultimately mitigating environmental impacts associated with traditional energy generation (Gabbar & Zidan, 2016; Janíček et al., 2018; Worighti, et al., 2019).

Overall, smart grid systems play a vital role in environmental conservation by enhancing energy efficiency, enabling demand-side management, optimizing load distribution, and facilitating the integration of renewable energy sources. These technological advancements are essential in transitioning to a more sustainable energy future and mitigating the environmental challenges posed by conventional energy systems.

Internet of Things (IoT) in Environmental Monitoring

The Internet of Things (IoT) has emerged as a powerful tool in environmental monitoring, providing real-time monitoring and data collection capabilities for various environmental parameters. This technology enables proactive environmental management, informed decision-making, and improved resource allocation for sustainable practices (Toma et al., 209; Zulkifli et al., 2022).

IoT applications in environmental monitoring facilitate the collection of data on crucial parameters such as air quality, water quality, and biodiversity. By deploying sensor devices in various locations, environmental data can be collected continuously and transmitted wirelessly to a central system for analysis and interpretation (Toma et al., 2019; Zulkifli, et al., 2022).

Air quality monitoring through IoT involves sensors that detect pollutants such as particulate matter, nitrogen dioxide, and ozone levels. Real-time monitoring of air quality enables the identification of pollution sources, assessment of health risks, and implementation of appropriate mitigation measures. This data-driven approach supports decision-making for policies and actions aimed at improving air quality and reducing the environmental and health impacts of pollution (Kshirsagar et al., 2019; Almalawi et al., 2022).

Water quality monitoring using IoT devices allows for continuous monitoring of factors such as pH levels, dissolved oxygen, temperature, and pollutant concentrations in water bodies. This real-time data enables the detection of water pollution events, early warning systems for contamination, and informed management strategies for preserving water resources and protecting aquatic ecosystems (Jan et al., 2021; Zainurin et al., 2022; Miller et al., 2023).

Biodiversity monitoring through IoT involves the use of sensors and imaging devices to track and identify species, monitor migration patterns, and assess ecosystem health. This technology enables researchers and conservationists to gather critical data on species populations, habitat conditions, and ecological changes, facilitating evidence-based conservation efforts and the development of targeted conservation strategies (Guo et al. 2015; Gallacher et al., 2021; Bensson et al., 2022; Wild et al., 2023).

The real-time data collected through IoT environmental monitoring systems support proactive environmental management. It allows for immediate responses to changing conditions, such as issuing alerts or notifications in case of environmental emergencies or anomalies. This proactive approach helps prevent or mitigate potential environmental risks, ensuring timely interventions and minimizing negative impacts (Alshamrani, 2022; Laha et al., 2022; Damaševičius et al., 2023).

Furthermore, IoT-enabled environmental monitoring enhances resource allocation by providing accurate and up-to-date information. This data can be used to optimize resource usage, such as water and energy, based on actual environmental conditions. It enables the identification of areas with high resource demand or inefficiencies, leading to improved resource management practices and the reduction of waste and environmental footprint (Dhanaraju et al., 2022; Ali et al., 2023).

In summary, IoT applications in environmental monitoring offer real-time data collection and monitoring capabilities for air quality, water quality, and biodiversity. This technology enables proactive environmental management, informed decision-making, and improved resource allocation, leading to more effective and sustainable environmental practices.

CONCLUSIONS

The systematic review of smart grid systems and IoT in environmental conservation highlights the significant potential of these technologies in promoting sustainable consumption and environmental sustainability. Through the integration of advanced technologies, such as sensors, data analytics, and renewable energy sources, smart grid systems enable efficient electricity distribution, load management, and grid stability. IoT applications provide real-time monitoring and data collection capabilities for environmental parameters, facilitating proactive environmental management and informed decision-making.

The review identifies several gaps and future research directions in the field. These include the integration of social and behavioural aspects, economic viability and cost-benefit analysis, interoperability and standardization, data privacy and security, and the development of appropriate policy and regulatory frameworks. Addressing these gaps and pursuing the outlined research directions will further enhance the understanding and implementation of smart grid systems and IoT in environmental conservation.

The policy implications derived from the review emphasize the importance of supportive regulatory frameworks, financial incentives and funding, standards and interoperability, consumer education and engagement, data privacy and security regulations, collaboration and partnerships, long-term planning and roadmaps, and international cooperation. These policy measures are crucial for creating an enabling environment that fosters the adoption and integration of smart grid systems and IoT technologies, promoting sustainable consumption, and achieving environmental conservation goals.

In conclusion, smart grid systems and IoT have emerged as key drivers in environmental conservation efforts. The combination of these technologies enables energy optimization, efficient resource allocation, real-time monitoring, and informed decision-making, contributing to sustainable consumption and environmental sustainability. However, further research, policy development, and collaborative efforts are necessary to address gaps, overcome challenges, and maximize the potential of smart grid systems and IoT in achieving a greener and more sustainable future.

POLICY IMPLICATIONS FOR SMART GRID SYSTEMS AND IOT IN ENVIRONMENTAL CONSERVATION

Supportive Regulatory Frameworks: Policymakers should develop supportive regulatory frameworks that encourage the deployment and integration of smart grid systems and IoT in environmental conservation. This includes providing incentives, streamlining permitting processes, and establishing clear guidelines for grid integration, data privacy, and cybersecurity.

Financial Incentives and Funding: Governments should offer financial incentives, grants, and subsidies to promote the adoption of smart grid systems and IoT technologies. These incentives can help offset initial investment costs, encourage research and development, and stimulate market demand for sustainable energy solutions.

Standards and Interoperability: Policymakers should collaborate with industry stakeholders to establish common standards and interoperability protocols for smart grid systems and IoT devices. This ensures compatibility, data exchange, and seamless integration, enabling a robust and interconnected energy infrastructure.

Consumer Education and Engagement: Policies should prioritize consumer education and awareness campaigns to inform the public about the benefits of smart grid systems and IoT in environmental conservation. Engaging consumers through energy efficiency programs, smart home technologies, and real-time energy consumption feedback can drive behavioural change and promote sustainable consumption patterns.

Data Privacy and Security Regulations: Policymakers need to develop comprehensive data privacy and security regulations to safeguard the collection, storage, and usage of environmental data in smart grid systems and IoT applications. Robust privacy frameworks, data anonymization techniques, and cybersecurity protocols should be enforced to protect consumer privacy and maintain trust in these technologies.

Collaboration and Partnerships: Policymakers should foster collaboration and partnerships between government agencies, utilities, technology providers, research institutions, and environmental organizations. This collaborative approach can drive innovation, knowledge-sharing, and the development of best practices in the implementation of smart grid systems and IoT for environmental conservation.

Long-Term Planning and Roadmaps: Governments should develop long-term planning strategies and roadmaps that outline the integration of smart grid systems and IoT in national energy policies and sustainability plans. These plans should align with international targets and outline the steps needed to achieve energy efficiency, renewable energy deployment, and environmental conservation goals.

International Cooperation: Policymakers should promote international cooperation and knowledge exchange to share best practices, experiences, and lessons learned in implementing smart grid systems and IoT for environmental conservation. Collaborative efforts can facilitate technology transfer, policy harmonization, and global sustainability initiatives.

By implementing these policy implications, policymakers can create an enabling environment that encourages the widespread adoption and effective implementation of smart grid systems and IoT technologies, leading to enhanced environmental conservation, sustainable consumption, and a transition towards a greener and more resilient energy future.

GAPS IN THE FIELD OF SMART GRID SYSTEMS AND IOT IN ENVIRONMENTAL CONSERVATION

Integration of Social and Behavioural Aspects: There is a need to further explore the social and behavioural aspects related to the adoption and acceptance of smart grid systems and IoT in environmental conservation. Understanding consumer attitudes, perceptions, and behavioural patterns can help design effective strategies to promote sustainable consumption and maximize the impact of these technologies.

Economic Viability and Cost-Benefit Analysis: While smart grid systems and IoT have shown potential in promoting environmental conservation, conducting comprehensive cost-benefit analyses and evaluating their economic viability is crucial. Further research is needed to assess the long-term financial implications, return on investment, and potential barriers to widespread adoption.

Interoperability and Standardization: As smart grid systems and IoT continue to evolve, ensuring interoperability and standardization among different technologies, protocols, and devices becomes essential. Further research is required to address interoperability challenges, promote seamless integration, and develop common standards that facilitate effective communication and data exchange.

Data Privacy and Security: With the increasing use of IoT devices and the collection of sensitive environmental data, ensuring data privacy and security is paramount. Future research should focus on developing robust data protection mechanisms, addressing privacy concerns, and strengthening cybersecurity frameworks to maintain public trust and confidence in smart grid systems and IoT applications.

Policy and Regulatory Frameworks: The development of appropriate policy and regulatory frameworks is crucial to support the widespread adoption and implementation of smart grid systems and IoT in environmental conservation. Further research is needed to explore policy mechanisms, incentives, and regulatory approaches that promote the integration of these technologies, address market barriers, and align with sustainability goals.

Optimization and Advanced Analytics: Further research should explore advanced optimization techniques and data analytics algorithms to enhance the performance and efficiency of smart grid systems. This includes developing predictive models, machine learning algorithms, and optimization strategies to optimize energy consumption, load management, and renewable energy integration.

Scalability and Resilience: As smart grid systems and IoT expand, research should focus on scalability and resilience to handle increasing volumes of data, devices, and network demands. This includes exploring innovative approaches for managing and analysing big data, designing scalable architectures, and ensuring the robustness and reliability of the systems.

Distributed Energy Resources Integration: Investigating the effective integration of distributed energy resources (DERs) such as solar panels, wind turbines, and energy storage systems within smart grid systems is crucial. Future research should focus on optimizing the coordination and control of DERs, exploring peer-to-peer energy trading mechanisms, and assessing the impact on grid stability and reliability.

User-Centric Approaches: Future research should emphasize user-centric approaches, focusing on understanding user needs, preferences, and behaviours to promote sustainable consumption and engagement with smart grid systems and IoT. This includes designing user-friendly interfaces, providing real-time feedback on energy consumption, and developing personalized energy management strategies.

Cross-Disciplinary Collaboration: Collaboration between researchers, policymakers, industry stakeholders, and environmental experts is vital for advancing the field of smart grid systems and IoT in environmental conservation. Future research should promote interdisciplinary collaboration to address complex challenges, integrate diverse perspectives, and foster innovation in sustainable energy management and environmental conservation.

By addressing these gaps and exploring future research directions, the field of smart grid systems and IoT in environmental conservation can further evolve and contribute to achieving sustainability goals while promoting efficient energy consumption and sustainable consumption patterns.

REFERENCES

Ghasempour, A. (2019). Internet of Things in Smart Grid: Architecture, Applications, Services, Key Technologies, and Challenges. *Inventions, 4*(22), 1-12. Doi:10.3390/inventions4010022

Abbas, G., Ali, B., Chandni, K., Koondhar, M. A., Chandio, S., & Mirsaeidi, S. (2022). A parametric approach to compare the wind potential of sanghar and gwadar wind sites. IEEE Access 10, 110889-110904. doi:10.1109/ACCESS.2022.3215261

Alahi, M. E. E., Sukkuea, A., Tina, F. W., Nag, A., Kurdthongmee, W., Suwannarat, K., & Mukhopadhyay, S. C. (2023). Integration of IoT-Enabled Technologies and Artificial Intelligence (AI) for Smart City Scenario: Recent Advancements and Future Trends. *Sensors, 23*, 5206. https://doi.org/10.3390/s23115206

Ali, A., Hussain, T., Tantashutikun, N., Hussain, N., & Cocetta, G. (2023). Application of Smart Techniques, Internet of Things and Data Mining for Resource Use Efficient and Sustainable Crop Production. *Agriculture*, *13*, 397. https://doi.org/10.3390/ agriculture13020397

Almalawi, A., Alsolami, F., Khan, A. I., Alkhathlan, A., Fahad, A., Irshad, K., Qaiyum, S., Alfakeeh, S. A. (2022). An IoT based system for magnify air pollution monitoring and prognosis using hybrid artificial intelligence technique. *Environmental Research, 206*, 112576

Alshamrani, M. (2022). IoT and artificial intelligence implementations for remote healthcare monitoring systems: A survey. *Journal of King Saud University Computer and Information Sciences, 34*(5),4687-4701. https://doi.org/10.1016/j.jksuci.2021.06.005

Bamberger, Y., Baptista, J., Belmans R., Buchholz, B. M., Chebbo, M., Doblado, J. L., Efthymiou, V., Gallo, L., Handschin, E., & Hatziargyriou. N. (2006). Vision and strategy for europe's electricity networks of the future: European Technology PlatformSmartGrids

Bashir, M. R., Gill, A. Q., & Beydoun, G. A. (2022). Reference Architecture for IoT-Enabled Smart Buildings. *SN COMPUT. SCI.*, *3*, 493. https://doi.org/10.1007/s42979-022-01401-9

Bayindir, R., Colak. I., Fulli, G., & Demirtas, K. (2016). Smart grid technologies and applications. *Renew Sustain Energy Rev*, 66, 499-516.

Benders, R. M. J., Kok, R., Moll, H. C., Wiersma, G., & Noorman, K. J. (2006). New approaches for household energy conservation. In search of personal household energy budgets and energy reduction options. *Energy Policy 34*, 3612-3622.

Bensson, M., Alison, J., Bjerge, K., Gorochowski, T. E., Høye, T. T., Jucker, T., Mann, H. M. R., & Clements, C. F. (2022). Towards the fully automated monitoring of ecological communities. *Ecology Letters*, *25*(12), 2753-2775. https://doi.org/10.1111/ele.14123

Bhattarai, T. N., Ghimire, S., & Mainali, B. et al. (2023). Applications of smart grid technology in Nepal: status, challenges, and opportunities. *Environ Sci Pollut Res.*, *30*, 25452-25476. https://doi.org/10.1007/s11356-022-19084-3

Bovenizer, W., & Chetthamrongchai, P. A (2023). Comprehensive systematic and bibliometric review of the IoT-based healthcare systems. *Cluster Comput*. https://doi.org/10.1007/s10586-023-04047-1

Burgess, J., & Nye, M. (2008). Rematerialising energy use through transparent monitoring systems. Energy Policy 36, 4454-4459

Chen, Z., Amani, A. M., Yu, X., & Jalili, M. (2023). Control and Optimisation of Power Grids Using Smart Meter Data: A Review. *Sensors*, *23*, 2118. https://doi.org/ 10.3390/s23042118

Damaševi˘C, R., Bacanin, N., & Misra, S. (2023). From Sensors to Safety: Internet of Emergency Services (IoES) for Emergency Response and Disaster Management. *J. Sens. Actuator Netw.*, *12*, 41. https:// doi.org/10.3390/jsan12030041

Darby, S. (2006). The Effectiveness of Feedback on Energy Consumption: A review for Defra of the Literature on Metering, Billing and Direct Displays. Environmental Change Institute, University of Oxford.

De Jonge, S. F. (2010). Business Models for Demand Side Management: Cost and Benefits for Actors in the Future Dutch electricity regime. Eindhoven, TU Eindhoven, MSc. Thesis.

Dhanaraju, M.; Chenniappan, P.; Ramalingam, K.; Pazhanivelan, S.; Kaliaperumal, R. Smart Farming: Internet of Things (IoT)-Based Sustainable Agriculture. Agriculture 2022, 12, 1745. https://doi.org/10.3390/ agriculture12101745

Escobar, J. J. M., & Matamoros, O. M., Padilla, T. R.; Reyes, L. I., & Espinosa, Q. H. (2021). A Comprehensive Review on Smart Grids: Challenges and Opportunities. *Sensors*, *21*, 6978. https:// doi.org/10.3390/s21216978

Fang, X., Misra, S., Xue, G. and Yang, D. (2012). Smart Grid—The New and Improved Power Grid: A Survey. *IEEE Communications Surveys & Tutorials, 14*, 944-980. https://doi.org/10.1109/SURV.2011.101911.00087

Gabbar, H. A., & Zidan, A. (2016). Optimal scheduling of interconnected micro energy grids with multiple fuel options. *Sustainable Energy, Grids and Networks, 7*, 80-89.

Galdikas, L; Sprogys, M., & Karparavičius, A. (2014). Išmaniojo tinklo diegimo analizė užsienio šalyse. Klaipėdos universitetas, elektrotechnikos katedra, Klaipėda.: journals.ku.lt/index.php/TMD/article/download/239/196

Gallacher, S., Wilson, D., Fairbrass, A., Turmukhambetov, D., Firman, M., Kreitmayer, S., Aodha, O.M., Brostow, G., Jones, K. (2021). Shazam for bats: Internet of Things for continuous real-time biodiversity monitoring. *IET Smart Cities 3*(3)

Gao, C., Wang, F., Hu, X., & Martinez, J. (2023). Research on Sustainable Design of Smart Cities Based on the Internet of Things and Ecosystems. *Sustainability*, *15*, 6546. https:// doi.org/10.3390/su15086546

Guo, S., Qiang, M., Luan, X., Xu, P., He, G., Yin, X., XI, L., Jin, X., SHao, J., Chen, X., Fang, D., & Li, B. (2015). The application of the Internet of Things to animal ecology. *Integrative Zoology*, *10*(6), 572-578 doi: 10.1111/1749-4877.12162

Haider, M., Shannon, R., Moschis, G. P. (2022). Sustainable Consumption Research and the Role of Marketing: A Review of the Literature (1976-2021). *Sustainability*, *14*, 3999. https://doi.org/ 10.3390/su14073999

Hassan, R., Qamar, F., Hassan, M. K., Aman, A. H. M., & Ahmed, A. S. (2020). Internet of Things and Its Applications: A Comprehensive Survey. *Symmetry*, *12*, 1674. doi:10.3390/sym12101674 pp1-29 https://doi.org/10.1016/j.envres.2021.112576

Hicks, C. (2012). The Smart Grid: Where we are today and what the future holds. ERB Institute. For global sustainable enterprise. University of Michigan. [interaktyvus]. [žiūrėta 2015 m. birželio 10 d.]. Available at:

Hu, J. L., Chen, Y. C., Yang, Y. P. (2022). The Development and Issues of Energy-ICT: A Review of Literature with Economic and Managerial Viewpoints. *Energies, 15*, 594. https://doi.org/10.3390/en15020594

Huygens, A. (2011). De consument en de (on)vrije elektriciteitsmarkt, iš: Pron-van Bommel, S., (Ed.), 2010. De Consument en de Andere Kant van de Elektriciteitsmarkt. Amsterdam, UvA, pp. 96-135.KEMA Report (2009): The U.S. Smart Grid Revolution KEMA's Perspectives for Job Creation

Jabandžić, E., Konjic, T., & Tomašević, D. (2021). Load Management Framework in Smart Grids: A Meta-Analysis and Review. IETE Technical Review, 39(4), 1-19. 10.1080/02564602.2021.1906338

Jan, F., Min-Allah, N., & Dü¸stegör, D. (2021). IoT Based Smart Water Quality Monitoring: Recent Techniques, Trends and Challenges for Domestic Applications. *Water*, *13*, 1729. https://doi.org/ 10.3390/w13131729

Janíček, F., Perný, M., Šály, V., Váry, M., Breza, J., Chochol, P. (2018). The role of smart grid in integrating the renewable energies in Slovakia. *Energy & Environment, 29*(2), 300-312. https://www.jstor.org/stable/26960221

Kezunovic, M; Mccalley, J. D., & Overbye, T. J. (2012): Smart Grids and Beyond: Achieving the Full Potential of Electricity Systems. *Proceedings of the IEEE, Vol.100, Special Centennial Issue*, 1329 - 1341.

Khan, H. U., Khan, S., & Nazir, S. (2022). Efficient Power Grid Management Using Sliced-Based Mechanism for Systematic Allocation of Solar Energy Resources: A Conceptual Framework. *Front. Energy Res*. 10:922221. doi: 10.3389/fenrg.2022.922221

Kirmani, S., *Ahmad, A. I., Khan*, & *Abid*, M. (2022). A Survey on IoT-Enabled Smart Grids: Technologies, Architectures, Applications, and Challenges. *Sustainability*, 15(1), 1-26.

Kirmani, S., Mazid, A., Khan, I. A., & Abid, M. (2023). A Survey on IoT-Enabled Smart Grids: Technologies, Architectures, Applications, and Challenges. *Sustainability, 15*, 717. https:// doi.org/10.3390/su15010717

Kshirsagar, P., & Akojwar, S. (2016). Optimization of BPNN parameters using PSO for EEG signals, ICCASP/ICMMD-2016. *Advances in Intelligent Systems Research*, 137, 385-394.

Kumar, S., Tiwari, P., & Zymbler, M. (2019). Internet of Things is a revolutionary approach for future technology enhancement: a review. *J Big Data 6*, 111. https://doi.org/10.1186/s40537-019-0268-2

Laha, S. R., & Pattanayak, B. K. (2022). Advancement of Environmental Monitoring System Using IoT and Sensor: A Comprehensive Analysis. *AIMS Environmental Science, 9*(6), 771-800. DOI: 10.3934/environsci.2022044

Larsen, H., & Petersen, L. F. (2009). Risø Energy Report 8: The Intelligent Energy System Infrastructure for the Future. Risø National Laboratory for Sustainable Energy, DTU.

Marques, G., & Pitarma, R. (2019). An Internet of Things-Based Environmental Quality Management System to Supervise the Indoor Laboratory Conditions. *Appl. Sci., 9*, 438; doi:10.3390/app9030438 pp 1-18

Mashal, I., Khashan, O. A., Hijjawi, M. et al. (2023). The determinants of the reliable smart grid from experts' perspective. *Energy Inform, 6*, 10. https://doi.org/10.1186/s42162-023-00266-3

Mengolini, A., & Vasiljevska, J. (2013). The social dimension of smart grids is consumer, community, and society. Publications Office of the European Union, Luxembourg.

Miller, M., Kisiel, A., Cembrowska-Lech, D., Durlik, I., & Miller, T. (2023). IoT in Water Quality Monitoring-Are We Really Here? *Sensors*, 23, 960. https:// doi.org/10.3390/s23020960

Moiroux-Arvis, L, Royer, L, Sarramia, D., De Sousa, G., Claude, A., Latour, D., Roussel, E., Voldoire, O., Chardon, P., Vandaële, R., Améglio, T., Chanet, J. P., ConnecSen, S. (2023). a Versatile IoT Platform for Environment Monitoring: Bring Water to Cloud. *Sensors* (Basel), *6*, 2896. doi: 10.3390/s23062896. PMID: 36991607; PMCID: PMC10059706.

Moreno Escobar, J.J.; Morales Matamoros, O.; Tejeida Padilla, R.; Lina Reyes, I.; Quintana Espinosa, H. A Comprehensive Review on Smart Grids: Challenges and Opportunities. Sensors 2021, 21, 6978. https:// doi.org/10.3390/s21216978

Mokhtar, M. R., Abdullah, M. P., Hassan, M. Y., & Hussin F. (2015). Combination of AHP-PROMETHEE and TOPSIS for selecting the best Demand Side Management (DSM) options. In: 2015 IEEE Student Conference on Research and Development (SCOReD)

Nižetić, S, Šolić, P., González-de-Artaza, L. D., & Patrono, L. (2020). Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future. *J Clean Prod.*, *20*, 274: 122877. doi: 10.1016/j.jclepro.122877. Epub 2020 Jul 19. PMID: 32834567; PMCID: PMC7368922.

Nyborg, S., & Røpke, I. (2011). Energy impacts of the smart home - conflicting visions. ECEE 2011 Summer Study: Energy Efficiency First: *The Foundation of a Low - carbon Society*, 1849-1860

Ourahou, M., Ayrir, W., El Hassouni, B., & Haddi, A. (2020). Review on smart grid control and reliability in presence of renewable energies: Challenges and prospects. Math Comput Simul 167:19–31

Pal, C., & Shankar, R. (2022). "A systematic inquiry of energy management in smart grid by using SAP-LAP and IRP approach". *International Journal of Energy Sector Management*. https://doi.org/10.1108/IJESM-04-2022-0004

Pamula, A.S.P.; Ravilla, A.; Madiraju, S.V.H. Applications of the Internet of Things (IoT) in Real-Time Monitoring of Contaminants in the Air, Water, and Soil. Eng. Proc. 2022, 27, 26. https://doi.org/10.3390/ecsa-9-13335

Raimi, K.T., & Carrico, A.R. (2016). Understanding and beliefs about smart energy technology. *Energy research and social science, 12*, 68-74.

Rauf, S., Wahab, A., Rizwan, M., Rasool, S., & Khan, N. (2016). Application of dc-grid for efficient use of solar PV system in Smart Grid. *Procedia Computer Science 83*, 902-906.

Rehman, A., Haseeb, K., Jeon, G., & Bahaj, S. A. (2022). Secure Edge-Based Energy Management Protocol in Smart Grid Environments with Correlation Analysis. *Sensors*, *22*, 9236. https://doi.org/10.3390/s22239236

Ribeiro, F; Ferreira, P., & Araujo, M. (2011). The inclusion of social aspects in power planning. Renewable and Sustainable *Energy Reviews 15*, 4361-4369.

Shafiullah, G. M; Amanullah, M. T; Shawkat Ali, A. B. M., & Wolfs, P. (2013). Smart Grid for a Sustainable Future. Smart Grid and Renewable Energy.
http://webcache.googleusercontent.com/search?q=cache:gB1n_7i1uOYJ:www.scirp.org/journal/PaperDownload.aspx%3FpaperID%3D28119+&cd=3&hl=lt&ct=clnk&gl=lt>

Shayan, F. N., Mohabbati-Kalejahi, N., Alavi, S., & Zahed, M. A. (2022). Sustainable Development Goals (SDGs) as a Framework for Corporate Social Responsibility (CSR). *Sustainability*, *14*, 1222. https://doi.org/ 10.3390/su14031222

Sirviö, K. H., Laaksonen, H., Kauhaniemi, K., & Hatziargyriou, N. (2021). Evolution of the Electricity Distribution Networks-Active Management Architecture Schemes and Microgrid Control Functionalities. *Appl. Sci.*, *11*, 2793. https://doi.org/10.3390/ app11062793

Succar, S., & Cavanagh, R. (2012). The Promise of the Smart Grid: Goals, Policies, and measurement Must Support Sustainability Benefits. NRDC ISSUE BRIEF. http://www.nrdc.org/energy/smart-grid/files/smart-grid-IB.pdf

Toma, C., Alexandru A., Popa, M, & Zamfiroiu, A. (2019). IoT Solution for Smart Cities' Pollution Monitoring and the Security Challenges. Sensors (Basel), *19*(15):3401. doi: 10.3390/s19153401. PMID: 31382512; PMCID: PMC6696184.

Van der Beek, E. (2010). Opportunities for Energy Saving in the Dutch Household Sector, Eindhoven, TU/e, MSc Thesis.

Vargas-Merino, J. A., Rios-Lama, C. A., & Panez-Bendezú, M. H. (2023). Sustainable Consumption: Conceptualization and Characterization of the Complexity of “Being” a Sustainable Consumer-A Systematic Review of the Scientific Literature. *Sustainability*, *15*, 8401. https://doi.org/10.3390/su15108401

Verbong, G. P. J., Beemsterboer, S., & Sengers, F. (2012). Smart grids or smart users? Involving users in developing a low carbon electricity economy. *Energy Policy*, 52.

Wild, T. A., van Schalkwyk, L., & Viljoen, P. et al. (2023). A multi-species evaluation of digital wildlife monitoring using the Sigfox IoT network. *Anim Biotelemetry*, ***11***, 13. https://doi.org/10.1186/s40317-023-00326-1

Worighi, I., Maach, A., Hafid, A., Hegazy, O., & Mierlo, J. V. (2019). Integrating renewable energy in smart grid system: Architecture, virtualization and analysis. *Sustainable Energy, Grids and Networks, 18*, 100226

Zainurin, S. N., Wan Ismail, W. Z., Mahamud, S. N. I., Ismail, I., Jamaludin, J., Ariffin, K. N. Z., Kamil, W. A. W. M. (2022). Advancements in Monitoring Water Quality Based on Various Sensing Methods: A Systematic Review. *Int J Environ Res Public Health*, *19*(21), 14080. doi: 10.3390/ijerph192114080. PMID: 36360992; PMCID: PMC9653618

Zulkifli, C. Z., Garfan, S., Talal, M., Alamoodi, A. H., Alamleh, A., Ahmaro, I. Y. Y., Sulaiman, S., Ibrahim, A. B., Zaidan, B. B., & Ismail, A. R., et al. (2022). IoT-Based Water Monitoring Systems: A Systematic Review. *Water*, *14*, 3621. https://doi.org/10.3390/w14223621