Journal of Artificial Intelligence, Machine Learning and Neural Network
Vol. 05, No. 01, Jan-June 2025
ISSN: 2799-1172, DOI: 10.55529/jaimlnn.51.14.27

Research Paper

A study on the role of artificial intelligence and renewable energy technologies in building a sustainable future

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Article Info

Article History:
Received: 17 January 2025
Revised: 02 April 2025
Accepted: 11 April 2025
Published: 28 May 2025

Keywords:
Artificial Intelligence
Renewable Energy
Sustainability
Energy Efficiency
Smart Grids

ABSTRACT

AI and renewable energy technologies have already emerged as leading drivers of sustainability, with a focus accelerating around global energy demand and climate change at the forefront of contemporary problems. This concept is mainly new as this research is related to AI revolutionary role in improving efficiency of renewable energy generation, distribution and consumption to reduce environmental pollution. AI analytics and smart grids and systems automate energy use, integrating solar, wind, and other renewable sources into the grid more smoothly. AI-based energy predictions and fault detection are also critical actions that bring first-world grid reliability and cost savings. The report identifies, through case studies and emerging trends, the untapped potential of the synergy between Renewable Energy and AI as a transformative force for advancing the sustainable, low-carbon development agenda. They show the potential of power to decarbonize the energy sector, to create economic sustainable growth, to address compact non environmental challenges.

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1. INTRODUCTION

This study aims to draw attention to the importance of studying the future of artificial intelligence applications in particular, and the Fourth Industrial Revolution and its aftermath in general, especially green artificial intelligence as a means and an attempt to extrapolate, anticipate and predict its effects. This new revolution has had effects on the level of production, financial markets, business and the economy, as well as scientific, health and other effects. The Fourth Industrial Revolution also pushed to reduce the time difference between the theoretical and applied sides. Given that man still has creativity, the ability to think, write, language, practice art and other activities that distinguished him from other beings on the surface of the Earth, the fear of the so-called control of artificial intelligence over the human mind is unjustified, because the main problem lies in what lies behind the movement of these applications from humans themselves, and then the world will not witness a conflict between human intelligence and artificial intelligence, but will be through their alliance together to achieve human goals in the end in the battle to acquire the power of the present and the future [1].

These changes are both radical directions for the energy requirements of any future world, as increasing anxiety over climate change, energy security and environmental sustainability pushes a worldwide transformation of energy options to renewables. With dependence on fossil fuels conflicting with both greenhouse gases and ecological habitats, government, industry, and researchers worldwide are struggling to make these renewable energy technologies a reality. Especially since renewable energy sources (solar, wind, hydropower, etc.) so far have so many downsides to energy intermittency, storage limits, grid integration, and more [2]. The advent of AI is a promising and transformative technology that can help in overcoming these barriers and further enhance the efficiency, reliability, and scalability of RES .With this wide range of processes, AI-powered solutions such as predictive analytics, machine-learning algorithms, and smart grid technologies, make real-time energy forecasting, demand-response optimization, and self-managing systems all possible. This results in improved energy capture, lower costs, and better decision-making in renewable energy.This study explores how AI applications can be integrated with renewable energy technologies and can be made practical in terms of an environmentally friendly future. The objective of this study is to identify the main applications, initiatives and trends in artificial intelligence helping the transition to a low carbon economy in an economically and environmentally sustainable manner.

The global economy since the Industrial Revolution has been built largely on fossil fuels, the burning of which has driven a steep increase in greenhouse gas emissions — mostly carbon dioxide. These emissions have disturbed Earth climate balance hence causing global warming and climate change. Climate change has serious implications, including sea-level rise, high-impact weather events including hurricanes and disruptions of ecological systems. These effects represent considerable threats to human health, economic stability, and environmental sustainability [3].

They are addressing such urgent problems through international accords, for example, the Kyoto Protocol and the Paris Accord, with a focus on reducing emissions and increasing uptake of renewable energy. But progress has lagged and world temperatures have continued to rise, underscoring the need for faster action. A fast, and huge, and however graceful shift is urgently needed to renewable power sources to keep away from the worst impacts of local weather change. The fundamental shifts needed for such a green transition demand heavy investments in R&D; policy advocacy, and bolstered international cooperation. This is important, as energy conservation and efficiency can help lower the total amount of energy consumed (and therefore, the carbon emissions generated) by a community. Already in this fight, countries have to exchange the best practices and solutions that work. Despite strides already in climate action, the scale of the challenge remains daunting. Even if all of the current commitments were fulfilled — which experts are skeptical of — the rise in global temperature is still on track to exceed the targets established in the Paris Agreement, leading to increased climate risks. That highlight the imperative for more decisive and urgent action to protect the planet for future generations."[4].

Ever since 2000, global carbon dioxide (CO_2) emissions have never stopped climbing, reaching an all-time high in 2021. In 36 selected countries, average annual growth rates of CO_2 emissions over the period between 2000 and 2021 have been estimated at 1.7% according to the International Energy Agency. It is worth mentioning that, China's CO_2 emissions increased from 5,425 metric tons to 15,632 metric tons and 5.2 percent annually. Conversely, the United Kingdom managed to decrease its from 700 metric tons to 425 metric tons, annihilating at an annual rate of 2.3%, as the two extremes among the countries studied. Those diverging trends reveal different levels of success in fighting climate change.

But the rise in total emissions underscores the unsustainable development trajectories of many countries documents the trend of carbon emissions in the countries shown in Figure 1.

To comprehend the determinants of these diverging trends, the study focuses on the influence of artificial intelligence, green human capital, renewable energy consumption, geopolitical risks, natural resources dependency, Information and communication technology (ICT), and institutional quality on CO_2 emissions. This approach analyzes these variables to identify effective strategies for reducing emissions and creating a sustainable future [5].

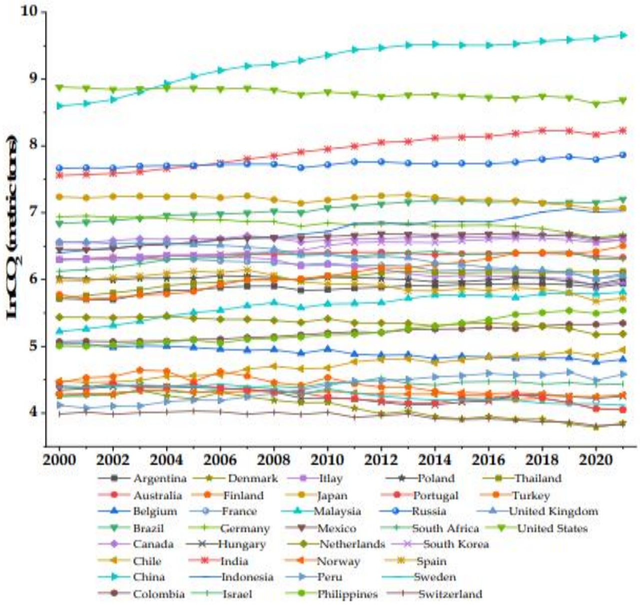

Figure 1. The Image Documents the Trend of Carbon Emissions in the Countries.

Industry 4.0 era where with AI we are a game changer in multiple industry and will solve some of the challenging problems of the world. It's most crucial application is towards the environment and carbon emissions. AI can enable sustainability gains by optimizing energy use in companies, increasing the efficiency of supply chains, and accelerating the shift to renewable energy technologies [6]. But for all its benefits, AI's energy-hoovering processes — especially during the training of large language models — have raised concerns about its impact on the environment. The massive amount of compute needed for training, operating, and maintaining AI systems is a major source of carbon emissions. While multiple studies have highlighted the ways in which A.I. has been beneficial in reducing CO_2 emissions, fewer have looked at its negative environmental effect. Estimated a single large AI model can create some 626,000 pounds in C02 emissions on training — five times the emissions produced over the life of an average American car. Further you would know that, according to other data from the Shift Project, the share of the digital sector to global CO_2 emissions increased from 2.5% in 2013 to 3.7% in 2018, with a frightening annual growth rate of 4%. One reason for this trend is reliance on AI solutions: they indeed require a lot of energy and are creating rising greenhouse gases, at the same time AI technologies become more widespread [7].

However, as AI applications grow, it is still early to integrate sustainability into its development and production processes. AI-computation 'carbon footprint' can also be addressed with higher energy efficiency computing practices, data center utilization of renewable energy sources such as wind and solar power; with future green AI techniques. Finding a balance between the potential of AI to promote sustainability while also, at the same time, its environmental harms will be critical to ensuring that the technology delivers a more sustainable future [8].

2. RELATED WORK

The integration of artificial intelligence (AI) and renewable energy technologies has attracted increased attention in the past several years because it may provide groundbreaking solutions to the pressing world problems of climate change and sustainable development. It's no surprise many studies focused on the game-changing role AI could play in helping to integrate renewables into the energy system, drive efficiency and accelerate our shift towards clean energy.

Artificial intelligence (AI) technologies, like machine learning, deep learning and predictive analytics, have been actively used for energy forecasting, resource management, and system maintenance. For instance, [9] that showed how the use of neural networks led to accurate and satisfactory solar and wind energy generation forecasts, contributing to the integration of the renewables in the network of the countries. Similarly, investigated the possibility of reinforcement learning algorithms for the purpose of optimizing energy storage systems, and the consequent degree of approximation of non-renewable back-up needs.

Recent publications on the impact of artificial intelligence (AI) on renewable energy systems and sustainability have been growing significantly in the last few years. As the world's demand for energy continually rises and the effects of climate change become more acute, AI-powered tools are leveraged to facilitate planning, deploying, and operating renewable energy sources, like solar, wind, hydro, and bioenergy.

It has been demonstrated in some publications, how the AI can improve the efficiency and reliability of renewable energy sources. For example, [10] showed that the machine learning algorithms could accurately forecast the solar and wind energy generation, with the primary implication for grid availability and energy planning. [2] Investigated deep learning in wind turbine predictive maintenance to reduce downtime and operational expenses. In addition to the technical optimization, AI can also find application in energy management and smart grid systems. [11] Investigated AI demand response methods in connected smart grids that 169 play a significant role in energy load balance in real-time and enhancement of RE infrastructure agility. These improvements will not only lead to energy efficiencies, but will also be employed to reduce carbon dioxide emissions by encouraging less use of fossil fuels.

Furthermore, AI also contributes to sustainability beyond energy systems and environmental monitoring, carbon tracing, as well as climate models are among the areas that can be developed thanks to [12] emphasized the role of AI in climate action where AI can support better evidence-based policy-making and adaptive resource management. More broadly, AI in agri- culture, waste management, and urban planning are other examples for how it contrib-utes to the SDGs. In parallel with AI, renewable energy solutions have also developed. According to IRENA's report (2023), development of advanced photovoltaics, battery ener-gy storage and hydrogen fuel cells are examples for key innovations for decar-bonising highly energy intensive and greenhouse gas emission releasing sectors. Work such as [13] are also providing interesting stories towards the 100% RE system integration that highlight the inclusion of AI to handle complexity and variability.

Despite progress, there are some missing pieces in the literature on how AI and renewable energy in combination and synergistically contribute to holistic sustainable futures. Although many of the works focus only on AI or renewables separately there have been much less efforts in the intersection of both of them and how they can add value to society in socio-eco-environment terms. Furthermore, there is a lack of (sub) national and policy studies, especially in the developing country context, where sustainable transitions are most required. Our study builds up on this emergent literature by bringing together cross-disciplinary lenses to envision how AI and renewable energy technologies combined can enable sustainability objectives, as well as comprehend barriers to implementation, novel routes to innovating and policy lessons.

3. METHODOLOGY

1. Improve Energy Efficiency

Artificial intelligence plays a key role in improving energy efficiency through graphical analysis and big data analysis techniques. Artificial intelligence systems rely on analyzing current data to predict energy usage patterns and identify gaps and waste. For example, artificial intelligence can improve the performance of cooling, heating and lighting systems in buildings, significantly reducing energy consumption.

2. Accelerating Innovation in Renewable Energy Technologies

Artificial intelligence contributes to accelerating the pace of innovation in the field of renewable energy technologies such as solar and wind energy. Artificial intelligence relies on the analysis of atmospheric data and weather forecasting to improve the efficiency of these systems and increase their productivity. In addition, artificial intelligence technologies are used in optimizing the design of wind turbines and solar panels, making them more effective and efficient.

3. Management of Smart Electrical Networks

Artificial intelligence plays a pivotal role in the management of smart electrical networks by optimizing energy distribution and reducing waste. Smart systems rely on artificial intelligence to effectively analyze energy demand and distribution, which contributes to reducing power outages and improving the sustainability of the grid.

4. Reduce Carbon Emissions

By improving energy efficiency and accelerating innovation in renewable energy technologies, artificial intelligence contributes to reducing carbon emissions [14], [15] Companies and organizations rely on artificial intelligence to analyze carbon emissions and identify ways to reduce them, contributing to achieving the Sustainable Development Goals and addressing climate change.

5. Applications in Transport and Logistics

Artificial intelligence also plays an important role in improving the efficiency of transportation and logistics. Intelligent transportation systems rely on artificial intelligence to optimize flight schedules and avoid congestion, reducing fuel consumption and carbon emissions. In addition, artificial intelligence technologies are used to improve fleet management and reduce waste in logistics operations. Artificial intelligence shows its great potential in the development of clean energy and the promotion of environmental sustainability. From improving energy efficiency and accelerating innovation in renewable energy technologies, to managing smart electric grids and reducing carbon emissions, artificial intelligence plays a pivotal role in achieving a sustainable future. [14] Investing in artificial intelligence technologies and their applications in the field of clean energy is a crucial step towards addressing the challenges of climate change and ensuring the sustainability of the planet for future generations.

With the increasing demands of data analysis brought on by improvements in supercomputing, Artificial Intelligence (AI) has behaved like a parasite, boosting the throughput of materials discovery by several orders of magnitude. AI is applied in various fields including energy, environmental science, material science, management and economics. Again, AI had recently been significant for the discovery and implementation of clean energy technologies and materials. Those AI-driven advances in materials design and discovery had moved it a lot closer to the what we refer to as a fourth paradigm [16],[17]. The broader field of machine learning (ML), which stands out as one of the most beneficial subfields of AI, has made huge gains in predicting material properties, designing new materials, and optimizing existing ones. Machine Learning (ML) algorithms are broadly divided to 3 types: supervised learning, unsupervised learning and reinforcement learning. In contrast to supervised learning, where the input-output relationship is known from the start (the training data has labels), in unsupervised learning only input data is used [18]. Typical supervised learning models are ordinary least squares regression (OLSR), support vector regression (SVR), Gaussian process regression (GPR), kernel ridge regression (KRR) and decision trees (DT).

Table 1 was show the methodological Overview of the Study conversely, unsupervised learning works with unlabelled data in hopes of finding hidden structures, with clustering and dimensionality reduction techniques as prevalent examples. Even artificial neural network (ANN), deep learning, and other AI-based approaches gained popularity in this field too, where those approaches can manage complex datasets in a more flexible manner [19].

Table 1. Methodological Overview of the Study.

Component	Description
Purpose of the Study	To examine how AI and renewable energy technologies contribute to achieving sustainability goals.
Data Sources	Peer-reviewed journal articles, policy reports, industry whitepapers, and expert opinions.
Time Frame	Related work from 2013 to 2024, with an emphasis on recent technological and policy developments.
Sampling Technique	Purposive sampling of sources relevant to AI applications, renewable energy innovations, and sustainability.
Data Collection Methods	Systematic Related work using academic databases (e.g., Scopus, Web of Science) and semi-structured interviews with professionals in energy, AI, and environmental policy.
Data Analysis Method	Thematic content analysis to identify trends, challenges, and impact pathways of AI and renewable energy technologies.
Validity and Reliability	Triangulation of multiple data sources and peer debriefing to ensure credibility and consistency.
Ethical Considerations	Informed consent for interview participants; data confidentiality and adherence to research ethics.

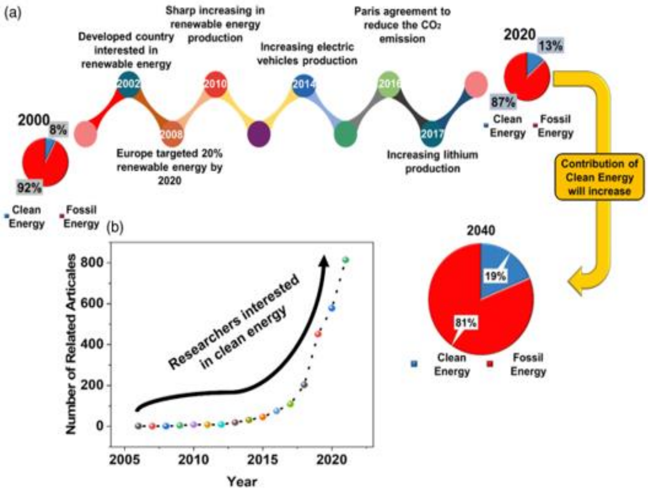

Figure 2. Showing the Contribution of Clean Energy to the Total Energy Produced in the World and the Number of Articles Published [18].

The AI-the people use to discover material is dramatically reduce the development time compared to the traditional laboratory of trial and error. These traditional experimental techniques rely heavily on researchers' intuition and long testing durations, both of which are vulnerable to human error. Computational simulations can aid experimental work, but are heavily dependent on micro- and nano-scale architectures, so it is still difficult to predict how the material properties will be affected when assembled. In addition, these simulations require substantial compute power and costly infrastructure. In contrast, AI-empowered material discovery provides a cost-effective and fast alternative to alleviate the limiting factors imposed by traditional methods.

Figure 2 showing the contribution of clean energy to the total energy produced in the world and the number of articles published [20].

Each one has its pros and cons for AI-based solutions D Only deep learning (DL)—an enhancement of deep neural networks algorithms—enables material informatics (DM). Gains in computational power, along with access to large data sets have made deep learning useful in real-world applications ranging from self-driving cars to materials research. Advantages of deep learning: First, it automates feature engineering: deep learning algorithms learn to extract dominant features in data without requiring labor intensive work that can save time, why not also discovering new features. This would be a holy grail in any ML task and eventually brings significant accuracy and reliability compared to regular ML models as deep learning is capable to work with tons of training data. Third, it is more able to handle big data, and could offer faster cycles of material development. Large, high-quality datasets are often hard to come by and one of the most difficult obstacles in deep learning.

AI acts as a catalyst to create clean energy solutions and as AI progress continues to advance through, we can likely expect an even more extensive integration of AI within material science and innovation, which ultimately will accelerate, enhance quality and reduce costs for advancement of clean energy and other applications [21].

4. RESULTS AND DISCUSSION

To the urban future, AI and green tech are a great contribution to the sustainable and intelligent city. We report empirical results based on the comprehensive empirical analysis that highlight the various roles of AI and green technology in the construction of smart green cities. By gathering, analyzing, and making sense of huge amounts of data, this work sets out to shed light on the implications, challenges, and possible affordances of this way that generative technologies are intertwined. AI-powered application and AI domain-specific application are major advances in smart city systems have integrated artificial intelligence technologies in them. AI-based technologies addressing waste management & resource management optimization, energy efficiency & transportation sustainability, and energy optimization will thrive in an urban environment. Dynamic responses to environmental conditions and evolving user needs to achieve end-user expectations are the hallmarks of such intelligent infrastructure which is referred to as a smart city powered by predictive analytics and machine learning [22].

AI and green technology work together to provide a fresh age of collaborative product development in which both paths flexibly pull the potential of the other to the first trailing another. Now, artificial intelligence complements green technology, relying on big data to deliver actionable recommendations for effective resource optimization and environmental protection. The purpose of this statement is to highlight how one will learn how to apply AI to transform the renewable energy sector, through optimization algorithms which can an analytic solution of production-"value" data, from renewables assets, to control demand models allowing for optimal scheduling of usage patterns, condenser, the latest techniques, will be justifiable, in the decision making process, that will save the plant, energy and emissions, while providing low impact daily output.

In addition, the socio-economic consequences of the application of AI and green technologies in intelligent communities are also presented in this article. But sustainable innovations also promote economic growth and create jobs, while in turn improving residents' quality of life through better access to key services and infrastructure. However, to unlock such benefits several challenges need to be overcome including cyber security vulnerabilities, data privacy risks, technical interoperability and ethical challenges. To effectively implement AI-enabled sustainable solutions, it will be key to face these challenges and create strong legislative framework and policy reforms [23].

Artificial Intelligence (AI) – Use Case in Smart Town Development

With the development of smart towns worldwide, AI is becoming a design feature for smart towns and a future for efficiency and innovation for urban centres. Here are some flavors used to apply AI for urban living, urban work, energy management, transportation, etc — we propose these insights via empirical research and the case studies that demonstrate the power of AI to alter urban realities as we know them. Energy Management & Efficiency AI is showcasing its prowess in several domains, one of the most prominent ones being energy management. These AI-powered systems are then trained on the intricate and massive datasets, allowing them to produce predictive analytics, delivering hyper-accurate insights into upcoming energy demand. This empowers local authorities to scale energy generation and supply dynamically for maximum efficiency and zero waste. Performance lay in the demand-response system through Ai by analytical methods, we can broaden the renewable energy sources—solar markets, and wind-turbine markets—put them together according to production needed in the current energy demand environment, thus improving the efficiency of the industry while reducing carbon emissions compliance and dependence on fossil energy [24].

More importantly, AI again plays a prominent role in transforming transportation systems in smart towns. Intelligent Traffic Management system uses an AI algorithm to process real-time traffic data from various sources, such as sensors, cameras, GPS devices, to improve traffic flow, reduce congestion, and improve safety. AI-equipped traffic management systems might analyze general traffic movements and, based on historical data, can predict traffic behavior, proactive steps can be taken to mitigate the same, through changing the signalling timings or by suggesting alternate paths based on how the situation demands. Finally, AI is going to transform urban transport with the next era of innovation topics like autonomous vehicles in urban settings, ensuring safer, more streamlined and sustainable travels.

AI is enabling the transformation of public safety, from transport to policing in smart towns. AI systems trained for this very function can utilize data, such as social media feeds, Internet of Things sensors and public records or data associated with human activity, processing large sets of information and identifying trends relevant to the risk of, and even criminal activity. That data-driven approach helps town administrators allocate resources more effectively, reduce emergency response times and enhance public safety in general. Improving the engagement of citizens, making them a part of city administration adds value and brings more effectiveness to the use of AI in the smart city solution [25].

Green Technology Integration of Smart and Sustainable Towns

Green technology will play a key role in developing smart and sustainable communities and will lead to greener urban frameworks and planning. The next part lists what green techs are included in smart towns and their significant boons.

Integrating renewables into smart town energy systems for a seamless and non-disruptive approach is one of the key components of vectorial™ integration of green technology. Solar optical panels, wind turbines, and hydropower generators are increasingly deployed into urban environments, harvesting energy gifted to us in abundance by the natural world. By embracing these renewable sources smart towns reduce their reliance on fossil fuels, reduce greenhouse gas emissions, and improve energy resilience against price volatility and supply disruptions.

Smart transportation technology associated with energy-efficient modes of transport is another area that is majorly propelling transformation of smart town's mobility. Sustainable energy sources lead the world's energy resources while clean energy-powered electric vehicles (EVs) become the dominant mode of transport, supported by widespread charging infrastructure and smart grid integration. Likewise, urban initiatives like bike-sharing, pedestrian-friendly designs and intelligent transportation systems create lively, livable communities — and they fight traffic-snarling congestion and improve public health by cutting down on air pollution.

Community engagement and education around green technologies is a key component in their adoption and acceptance. Sustainable attitudes also help when locals are involved in the programs. Halblivaid They also conduct public outreach, workshops and educational campaigns about the importance of green technologies and sustainable living. There is no contradiction of the latter, in fact, because they go hand in hand, as local sustainability programs, grassroots movement or community-led initiatives actually model that a joint action creates the sense of a "collective responsibility for environmental stewardship" or fosters the vision of how sustainable development and thriving self-sustained communities could look like.

As a result, the integration of green technology and AI on smart city solutions generate a web of an optimized urban structure that not just improves living within smart cities but also mitigates their effects on the surroundings, setting a paradigm for tomorrow living designs in urban civilization [26].

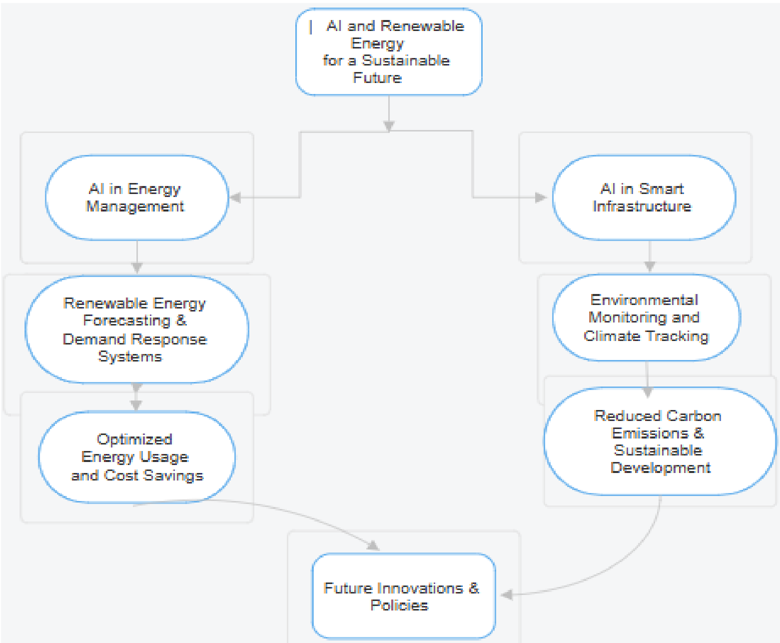

Figure 3. Future of Sustainable Development.

AI integrating renewable-based energy systems requires very high upfront capital.AI, energy storage and other technologies can support sustainability efforts. In the below Flowchart AI of Renewable energy and Sustainable Development shown in Figure 3

The following are some of the major findings from our study:

- Predictions of needs and real-time supply adjustments powered by AI improve energy conservation.
- AI in smart grids results in an energy balance (less wastage, better storage)
- Predictive maintenance based on AI ensures higher productivity of renewable energy systems with a lower OPEX.
- Energy Finance Automation of Buildings
- Environmental monitoring enabled through AI for real-time tracking of pollution and climate-related data the detailes are in Table 2.
- AI-enabled energy forecasting has enabled greater openness for solar, wind and hydro energy.
- Second AI Improving Grid Stability by Balancing Supply from Variable Renewable Energy Sources
- Advanced such as microgrids can be integrated thanks to AI energy systems.

- B. Socio-Economic and Environmental Benefits Realized
- AI + renewable energy = more green tech jobs
- It helps to decrease our reliance on fossil fuels, which reduces carbon emissions and mitigates climate change.
- Energy and infrastructure Php226, 0794. 07 trillion generated and efficiency savings Services AI systems and autonomy is pushing, pulling, refining, optimizing.
- The Future Insight and its Opportunities and Challenges Data privacy, cybersecurity, and regulatory frameworks in need of improvement for AI adoption to happen without friction.

Table 2: Summary of Key Findings – Role of AI and Renewable Energy in Sustainability.

Key Area	Findings	Examples/Technologies	Implications for Sustainability
AI in Energy Optimization	AI enhances energy efficiency through predictive analytics and real-time control.	Smart grids, demand forecasting, energy load balancing	Reduced energy waste and improved grid stability.
AI in Renewable Energy Forecasting	Improves the accuracy of solar and wind energy predictions.	ML algorithms, satellite data analysis	Better integration of renewables into the grid; reduced reliance on fossil fuels.
Automation in Energy Management	AI automates energy distribution and resource allocation.	IoT sensors, AI-based control systems	More efficient use of energy in industrial and residential settings.
Renewable Energy Adoption Trends	Increased deployment of solar, wind, and bioenergy supported by AI systems.	Solar PV, offshore wind, smart inverters	Accelerated transition to low-carbon energy sources.
AI for Smart Infrastructur e	Enables smart cities through integration of renewable energy and data systems.	AI in building energy management, EV charging	Sustainable urban planning and reduced carbon footprint.
Environment al Impact Monitoring	AI supports monitoring and reduction of environmental degradation.	Satellite imagery, drone-based AI analysis	Improved environmental policy decisions and faster response to issues.
Challenges Identified	Data privacy, high implementation costs, lack of policy standardization.	N/A	Need for stronger regulation and investment in R&D.
Policy & Governance Role	Strategic policy needed to foster AI and renewables integration.	National AI strategies, green energy incentives	Encourages responsible development and long-term sustainable practices.

5. CONCLUSION

In the researcher paper we have emphasized the disruptive nature of Artificial Intelligence (AI) and Renewable Energy Technologies for a sustainable tomorrow. These technologies help Smart Cities and Communities with energy efficiency, resource management and significantly minimizes their devices adverse environmental impact [27].

AI thus serves as the perfect enabler for sustainability innovation, from energy management, smart transportation to transformative public services. Utilizing predictive analytics and machine learning, Ai helps improve efficiency across renewable energy systems ensuring that when sun, wind and hydropower are available, they're put to viable use. Solutions for Intelligent Transport powered by AI help reduce congestion and emissions, but these are just the tip of the iceberg for clean, efficient mobility.Deep decarbonization will not occur, however, without extensive low-carbon technology adoption. They will be essential to filling the voids of phase-out of fossil fuel, for example renewable energy technologies. Green energy is demonstrating its capacity to power increasingly large cities, from solar panels to wind farms, to smart grids —without the environmental toll of fossil fuels. Also, merging AI along with renewable energy optimizes energy consumption, which incorporates resilience and sustainability into urban infrastructure [28]. But there is still much room to run on the full potential of these technologies. The fold in organizations can challenge traditional concepts of rights and boundaries While this 'fault' line in the system will need strong regulatory support, delivery minds to be considerate of things like data privacy, cyber security, policy frameworks, and tech interop for smooth integration and ethical deployment; awareness and public participation by stakeholders will also be very critical.Written by Shabina SahirWritten by [22], yet AI and renewable energy technologies institute a broad range of synergistic effects that can yield new campuses, intelligence, and improvements that ignite responsibility, sustainability, and the smart future as well. Such developments allow cities and communities to make strides towards their environmental goals, reduce carbon footprints, and build smarter, greener, more livable places for the future generations [29].

Acknowledgments

Special thanks to the president of the northern Technical University, Professor Dr. Alyaa Abbas Al-Attar for her continuous support to provide what is the best and outstanding. I would like to thank my wife [Zainab Mohammed Abdulkarim] for being a great supervisor and supporter throughout this project.

Funding Information

This study, did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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Zainab Mohammed Abdulkareem		✓		✓		✓		✓	✓	✓	✓	✓		✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

Conflict of Interest Statement

There is no conflict of interest.

Informed Consent

We have obtained informed consent from all the individuals included in this study.

Ethical Approval

That the research followed all national rules and institutional policies, and was approved by the Council of the Medical Technical Institute-Kirkuk - Iraq.

Data Availability

The data supporting the results of this study are available from the corresponding author, [Mahdi Fadil Khaleel], upon reasonable request.

REFERENCES

[1] D. J. Davidson, 'Exnovating for a renewable energy transition', Nat Energy, vol. 4, no. 4, pp. 254-256, 2019. doi.org/10.1038/s41560-019-0369-3

[2] R. York, 'Do alternative energy sources displace fossil fuels?', Nat Clim Chang, vol. 2, no. 6, pp. 441-443, 2012. doi.org/10.1038/nclimate1451

[3] D. P. Tabor, 'Accelerating the discovery of materials for clean energy in the era of smart automation', Nat Rev Mater, vol. 3, no. 5, pp. 5-20, 2018. doi.org/10.1038/s41578-018-0005-z

[4] Y. Bai, T. Zhang, Y. Zhai, Y. Jia, K. Ren, and J. Hong, 'Strategies for improving the environmental performance of nickel production in China: Insight into a life cycle assessment', J Environ Manage, vol. 312, 2022. doi.org/10.1016/j.jenvman.2022.114949

[5] S. Jiang, 'Environmental impacts of lithium production showing the importance of primary data of upstream process in life-cycle assessment', J Environ Manage, vol. 262, 2020. doi.org/10.1016/j.jenvman.2020.110253

[6] A. Agrawal and A. Choudhary, 'Deep materials informatics: Applications of deep learning in materials science', MRS Commun, vol. 9, no. 3, pp. 779-792, 2019. doi.org/10.1557/mrc.2019.73

[7] D. A. Notter, Contribution of Li-ion batteries to the environmental impact of electric vehicles. ACS Publications, 2010. doi.org/10.1021/es903729a

[8] M. Fetanat, 'Machine learning for advanced design of nanocomposite ultrafiltration membranes', Ind Eng Chem Res, vol. 60, no. 14, pp. 5236-5250, 2021. doi.org/10.1021/acs.iecr.0c05446

[9] R. Pollice, 'Data-driven strategies for accelerated materials design', Acc Chem Res, vol. 54, no. 4, pp. 849-860, 2021. doi.org/10.1021/acs.accounts.0c00785

[10] M. Fetanat, M. Keshtiara, R. Keyikoglu, A. Khataee, R. Daiyan, and A. Razmjou, 'Machine learning for design of thin-film nanocomposite membranes', Sep Purif Technol, vol. 270, 2021. doi.org/10.1016/j.seppur.2021.118383

[11] A. Agrawal and A. Choudhary, 'Deep materials informatics: Applications of deep learning in materials science', MRS Commun, vol. 9, no. 3, pp. 779-792, 2019. doi.org/10.1557/mrc.2019.73

[12] G. Chaney, A. Ibrahim, F. Ersan, D. Çakır, and C. Ataca, 'Comprehensive study of lithium adsorption and diffusion on Janus Mo/WXY', ACS Appl Mater Interfaces, vol. 13, no. 30, pp. 36388-36406, 2021. doi.org/10.1021/acsami.1c05508

[13] M. Kunitski, 'Double-slit photoelectron interference in strong-field ionization of the neon dimer', Nat Commun, vol. 10, no. 1, 2019. doi.org/10.1038/s41467-018-07882-8

[14] J. Schmidt, M. R. G. Marques, S. Botti, and M. A. L. Marques, 'Recent advances and applications of machine learning in solid-state materials science', NPJ Comput Mater, vol. 5, no. 1, 2019. doi.org/10.1038/s41524-019-0221-0

[15] X. Chen, X. Liu, X. Shen, and Q. Zhang, 'Applying machine learning to rechargeable batteries: from the microscale to the macroscale', Angewandte Chemie, vol. 133, no. 46, pp. 24558-24570, 2021. doi.org/10.1002/ange.202107369

[16] K. Medkova, P. Lähteenaro, and M. Virtanen, 'Renewable Energy Sources Enabling a Clean Energy Transition in Industry', LAB Sustainability Annual Review.
[17] S. Dale, "BP statistical review of world energy," BP Plc: London, UK, pp. 14-16, 2021.
[18] J. Dunn, M. Slattery, A. Kendall, H. Ambrose, and S. Shen, 'Circularity of lithium-ion battery materials in electric vehicles', Environ Sci Technol, vol. 55, no. 8, pp. 5189-5198, 2021. doi.org/10.1021/acs.est.0c07030
[19] R. Pollice, 'Data-driven strategies for accelerated materials design', Acc Chem Res, vol. 54, no. 4, pp. 849-860, 2021. doi.org/10.1021/acs.accounts.0c00785
[20] W. Wen, S. Yang, P. Zhou, and S. Z. Gao, 'Impacts of COVID-19 on the electric vehicle industry: Evidence from China', Renewable and Sustainable Energy Reviews, vol. 144, 2021. doi.org/10.1016/j.rser.2021.111024
[21] Q.-J. Hong, J. Schroers, D. Hofmann, S. Curtarolo, M. Asta, and A. Van De Walle, 'Theoretical prediction of high melting temperature for a Mo-Ru-Ta-W HCP multiprincipal element alloy', NPJ Comput Mater, vol. 7, no. 1, 2021. doi.org/10.1038/s41524-020-00473-6
[22] J. C. Barbosa, R. Gonçalves, C. M. Costa, and S. Lanceros-Mendez, 'Recent advances on materials for lithium-ion batteries', Energies (Basel), vol. 14, no. 11, 2021. doi.org/10.3390/en14113145
[23] A. Azzo, 'Advanced Methods for Identifying Counterfeit Currency: Using Deep Learning and Machine Learning', NTU Journal of Engineering and Technology, vol. 3, no. 3, 2024. doi.org/10.56286/ntujet.v3i3.944
[24] Q.-J. Hong, J. Schroers, D. Hofmann, S. Curtarolo, M. Asta, A. Van De Walle, npj Comput. Mater. 2021, 7, 1. doi.org/10.1038/s41524-020-00473-6
[25] H. Abid, M. Kissaoui, A. Raihani, and M. H. Zaggaf, 'Energy management in autonomous hybrid electric vehicles: A review', in E3S Web of Conferences, 2025. doi.org/10.1051/e3sconf/202560100083
[26] J. Dunn, M. Slattery, A. Kendall, H. Ambrose, S. Shen, Environ. Sci. Technol. 2021, 55, 5189. doi.org/10.1021/acs.est.0c07030
[27] C. M. Costa and S. Lanceros-Mendez, Smart and functional materials for lithium-ion battery. MDPI, 2021. doi.org/10.3390/en14227713
[28] X. Chen, T. Hou, K. A. Persson, and Q. Zhang, 'Combining theory and experiment in lithium-sulfur batteries: Current progress and future perspectives', Materials Today, vol. 22, pp. 142-158, 2019. doi.org/10.1016/j.mattod.2018.04.007
[29] D. M. Hameed and R. R. O. Al-Nima, 'High-Performance Character Recognition System Utilizing Deep Convolutional Neural Networks', NTU Journal of Engineering and Technology, vol. 3, no. 4, pp. 42-51, 2024. doi.org/10.56286/ntujet.v3i4.1086

How to Cite: Mahdi Fadil Khaleel, Zainab Mohammed Abdulkareem. (2025). A study on the role of artificial intelligence and renewable energy technologies in building a sustainable future. Journal of Artificial Intelligence, Machine Learning and Neural Network (JAIMLNN), 5(1), 14–27. https://doi.org/10.55529/jaimlnn.51.14.27

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