Published 2024-11-06 emsajpublishers.org/ijcces



APPLICATION OF ARTIFICIAL INTELLIGENCE AND DATA SCIENCE IN GREEN ENERGY TECHNOLOGIES FOR CLIMATE ADAPTATION IN NIGERIA

[1]Nwosu, Ifeoma Chidimma, [2]Udegbunam, Ifeoma Priscilla, [3]Udeoba, Catherine Ekenma

[1-3] Department of Public Administration, Faculty of Management Sciences. Nnamdi Azikiwe University Awka, Anambra state.

Corresponding Author: Nwosu, Ifeoma Chidimma: ic.nwosu@unizik.edu.ng; Department of Public Administration, Faculty of Management Sciences. Nnamdi Azikiwe University Awka, Anambra state.

ABSTRACT

This study examined the application of Artificial Intelligence (AI) and Data Science in advancing green energy technologies for climate adaptation in Nigeria. It aims to assess Nigeria's climate adaptation needs in response to environmental challenges, evaluate the effectiveness of green energy technologies in addressing climate change, investigate the role of AI and Data science in the context, and identify barriers to their adoption. Employing a qualitative research design, the study utilizes content analysis of various sources, including academic literature and policy documents, to gain a comprehensive understanding of the interplay between AI, data science, green energy, and climate adaptation. Nigeria faces diverse and pressing climate adaptation needs, including desertification, coastal erosion, and irregular rainfall patterns, which significantly impact agricultural productivity and socio-economic stability. Despite its vast renewable energy potential, the country remains heavily reliant on fossil fuels, exacerbating greenhouse gas emissions and limiting sustainable energy development. The integration of AI and data science in green energy technologies offers transformative solutions, including optimization of energy systems, smart grid deployment, predictive maintenance, and enhanced energy efficiency. However, the adoption of AI in Nigeria's green energy sector is hindered by challenges such as inadequate data and infrastructure, financial constraints, lack of technical expertise, regulatory barriers, and socio-cultural resistance. To overcome these obstacles, the study recommends launching national data standardization programs, pursuing international financial support, expanding educational initiatives, engaging policymakers for clearer regulations, and conducting public awareness campaigns. These strategies aim to foster an environment conducive to harnessing AI's potential in promoting sustainable energy practices and enhancing climate resilience in Nigeria.

Keywords: Artificial Intelligence, Data Science, Green Energy Technologies, Climate Adaptation, Sustainable Development

Author Biographies

I. C Nwosu, Department of Public Administration, Faculty of Management Sciences. Nnamdi Azikiwe University Awka, Anambra state.

She is a dedicated and captivating scholar with outstanding teaching abilities and knowledge of management, public and corporate administration, and development. Committed to using efficient lecturing strategies to increase learning and engagement both within and outside of the classroom and talented at promoting the growth and development of students, the public sector, and business companies by offering advice and support. She is ardent supporter of sustainable renewable energy and climate change mitigation, encouraging awareness and preventative measures both inside and outside of the academic community. Email: ic.nwosu@unizik.edu.ng Orcid number: 0009-0008-7553-4441

I. P Udegbunam, Department of Public Administration, Faculty of Management Sciences. Nnamdi Azikiwe University Awka, Anambra state.

Ifeoma Priscilla Udegbunam is a lecturer in the Department of Public Administration Awka, Anambra State Nigeria. She majors in the area of Human Resources Personal Management with research interests in personality. She has published many journal articles. She is an interesting scholar with zeal and determination to break new frontiers and broaden horizons in Personal Management across the globe. Email: pi.udegbunam@unizik.edu.ng

C.E Udeoba, Department of Public Administration, Faculty of Management Sciences. Nnamdi Azikiwe University Awka, Anambra state.

Udeoba, Catherine Ekenma is a lecturer in the Department of Public Administration, Nnamdi Azikiwe University Awka, Anambra State Nigeria. She has distinguished herself in expanding the frontiers of knowledge through teaching and research. She is a member of Chattered Institute of Local Government and Public Administration of Nigerian. She has authored a number of conference papers in reputable local and international journals. Email: ce.udeoba@unizik.edu.ng

Introduction

Climate change is one of the most pressing global challenges of the 21st century, with far-reaching impacts on ecosystems, economies, and human societies (Abbass et al., 2022). Nigeria, Africa's most populous nation and largest economy, is particularly vulnerable to the effects of climate

change due to its diverse geography, reliance on agriculture, and significant energy demands (United State Agency for International Development, 2023). The country faces a multitude of climate-related issues, including extreme weather events such as droughts and floods, rising temperatures, and changing rainfall patterns. These challenges threaten key sectors like agriculture, water resources, health, and energy infrastructure, thereby affecting food security, livelihoods, and overall economic stability. As a developing nation, Nigeria's ability to adapt to these challenges is critical for its long-term sustainability and development (Adamaagashi, Nzechie, Obiorah & Idakwoji, 2023). In response to these challenges, the adoption of green energy technologies has gained momentum as a crucial strategy for climate adaptation and mitigation worldwide (Nwosu, Abasili, Unoma & Nwokike, 2024). Green energy technologies, including solar, wind, hydroelectric, and biomass energy, provide sustainable alternatives to fossil fuels by harnessing natural resources that are renewable and abundant. Unlike fossil fuels, which release significant amounts of greenhouse gases during combustion, these technologies generate energy with minimal carbon emissions, thereby playing a crucial role in mitigating climate change. By reducing dependence on non-renewable energy sources, green technologies not only decrease environmental pollution but also contribute to long-term energy security (Ang, Salem, Kamarol, Das, Nazari & Prabaharan, 2022). However, the successful implementation of these technologies requires more than just their adoption; it demands optimization, efficient management, and resilience to the dynamic nature of climate change (Lucas, 2024).

Artificial Intelligence (AI) and Data Science with its advanced computational capabilities, offers transformative solutions that can significantly enhance the efficiency, reliability, and adaptability of green energy systems (Ukoba, Olatunji, Adeoye, Jen & Madyira, 2024). By enabling predictive maintenance, AI helps in identifying potential failures before they occur, ensuring continuous

operation. Moreover, AI can optimize energy distribution and consumption by analyzing vast amounts of data in real-time, leading to more effective use of resources. AI-driven models can predict and adapt to changing environmental conditions, allowing green energy systems to remain resilient in the face of unpredictable climate patterns. Thus, AI not only supports the integration of green technologies but also ensures they operate at their highest potential, contributing to a more sustainable and climate-resilient future (Lucas, 2024).

Data Science plays a complementary role by enabling the extraction of actionable insights from the vast datasets generated by green energy technologies. It involves the application of statistical methods, machine learning algorithms, and data analytics to process, analyze, and visualize data, thereby facilitating informed decision-making (Ullah et al., 2024). In the context of green energy, Data Science can be utilized to model energy consumption patterns, forecast energy demand, optimize resource allocation, and monitor the performance of energy systems. By leveraging on data science techniques, stakeholders can gain a deeper understanding of energy usage trends, identify inefficiencies, and implement targeted interventions to enhance the sustainability and resilience of energy infrastructure (Khaleel & Jebrel, 2024; University of Illinois Chicago, 2024).

The integration of AI and Data science into green energy technologies holds the potential to revolutionize how Nigeria and other countries address the challenges posed by climate change (Greif, Kimmig, El Bobbou, Jurisch & Ovtcharova, 2024). This research explored the application of AI and Data science in green energy technologies for climate adaptation in Nigeria, focusing on understanding how these technologies can drive the adoption, optimization, and resilience of green energy systems. The study aims to provide detailed understanding into the role of AI and Data

Science in enhancing the effectiveness of green energy systems in responding to the impacts of climate change and contributing to Nigeria's sustainable development goals.

Study Objectives:

The following research objectives were formulated to guide this study;

- To assess Nigeria's climate adaptation needs in response to environmental challenges.
- To evaluate the use of green energy technologies in addressing climate change in Nigeria.
- To investigate the role of artificial intelligence and data science in advancing green energy technologies in Nigeria.
- To identify the challenges hindering the adoption of AI and data science in Nigeria's green energy sector.

Method

For this study, we adopted a ***scoping review approach,*** which is particularly valuable for achieving our research goals and providing a comprehensive understanding of the relationship between artificial intelligence (AI), data science, green energy technologies, and climate adaptation in Nigeria. A scoping review is a flexible and systematic method that enables the collection, examination, and synthesis of secondary data from various reliable sources. This approach is well-suited for mapping key concepts, identifying gaps in existing research, and collating broad yet relevant information to offer a detailed overview of the research topic. The scoping review approach was selected because it is ideal for ***exploratory research*** where the objective is not only to summarize existing knowledge but also to identify the extent, range, and nature of the available evidence. To ensure the accuracy and reliability of the findings, we sourced secondary data

exclusively from ***reputable academic repositories, government databases,*** and ***international organizations' reports.*** These sources provided peer-reviewed articles, policy papers, technical reports, and case studies that are directly relevant to the research objectives. The academic databases used include ***Google Scholar, IEEE Xplore, Scopus, and Doaj etc.***, which are widely recognized for their comprehensive and credible collections of scholarly works. Careful attention was paid to avoid irrelevant or outdated documents by setting clear ***inclusion and exclusion criteria*** during the literature search. The search focused on publications from ***2015-2024,*** ensuring that the data reflected current advancements in AI, data science, green energy, and climate adaptation. Only English-language documents were considered, and we excluded any sources that were not directly related to the research scope or lacked credibility.

Conceptual Clarification

Artificial Intelligence, Date Science, Green Energy and Climate Adaptation

Sheikh, Prins & Schrijvers (2023) described Artificial Intelligence (AI) as a sophisticated technology designed to replicate and execute complex human skills. This encompasses a wide range of functions such as problem-solving, learning, reasoning, and understanding natural language. By leveraging on algorithms and data, AI systems can mimic human cognitive processes, making them capable of performing tasks that traditionally required human intelligence. This includes everything from recognizing patterns and making decisions to engaging in conversations and adapting to new information. Dignum (2019) offers a broad view of Artificial Intelligence (AI) by defining it as a computational artifact essentially a product of human engineering and design that emulates human-like cognitive functions. This definition encompasses AI systems that are crafted to replicate or simulate various aspects of human thought processes

and behaviors. In essence, AI is not merely a set of algorithms or machines, but rather constructs that strive to exhibit or mimic the ways humans think, reason, and act. This perspective highlights AI's role in bridging the gap between human cognition and machine execution, aiming to create systems that can perform tasks in ways that align with human expectations and practices. Huawei Technologies Co., Ltd. (2023) describes artificial intelligence (AI) as an emerging field of technological science focused on the development and application of theories, methods, and technologies designed to emulate, enhance, and advance human intelligence. AI encompasses a broad range of activities aimed at creating systems and solutions that can perform tasks typically requiring human cognition, such as problem-solving, learning, and decision-making. This involves not only the simulation of human-like reasoning and perception but also the continuous improvement of these capabilities to create more sophisticated and efficient intelligent systems.

According to Sarker (2021), data science is a broad and varied field that serves as an umbrella term for a variety of advanced techniques and methodologies. These include data analytics, which involves examining raw data to draw conclusions about that information; data mining, which focuses on discovering patterns and relationships within large datasets; and machine learning, which refers to the development of algorithms that allow computers to learn from and make predictions or decisions based on data. Deep learning, a subset of machine learning, employs neural networks with multiple layers to analyze complex patterns in data. In addition to these, data science also integrates elements of statistics, which provides the foundational mathematical tools necessary for data analysis and interpretation. The primary goal of data science is to extract meaningful insights or valuable knowledge from datasets, which can then be transformed into actionable business strategies. This transformation process enables organizations to make informed decisions, optimize operations, and ultimately drive growth and innovation.

Van (2023) defines data science as the systematic study of data aimed at extracting meaningful insights that can be leveraged for business decision-making and strategic planning. This field is inherently multidisciplinary, drawing on a rich combination of principles and practices from various domains, including mathematics, statistics, artificial intelligence, and computer engineering. Mathematics and statistics provide the foundational tools for modeling and understanding data patterns, enabling data scientists to quantify relationships and test hypotheses. Artificial intelligence and machine learning, on the other hand, introduce sophisticated algorithms that can automate data analysis processes, detect intricate patterns, and make predictions with minimal human intervention.

Meanwhile, computer engineering ensures that the data infrastructure encompassing data storage, processing, and retrieval systems is robust, scalable, and capable of handling the immense volumes of data generated in today's digital age. Through this comprehensive approach, data scientists are equipped to explore and address a range of critical questions. For instance, they can analyze historical data to understand what happened in the past (descriptive analytics), investigate the underlying causes of observed trends (diagnostic analytics), forecast future outcomes based on current data (predictive analytics), and suggest actionable strategies to achieve desired results (prescriptive analytics). This iterative process not only enhances the accuracy of business forecasts but also drives innovation, optimizes operations, and contributes to informed decision-making across various sectors.

On the other hand, according to National Grid (2024), green energy refers to energy derived from sources and methods that have minimal or no adverse impact on the natural environment. This form of energy is generated through renewable sources such as solar, wind, hydro, and geothermal

power, which do not produce harmful emissions or pollutants. By harnessing these sustainable resources, green energy contributes to reducing greenhouse gas emissions, mitigating climate change, and preserving ecosystems. This approach contrasts with conventional energy sources like fossil fuels, which can deplete natural resources and harm the environment. Green energy promotes a cleaner, more sustainable future by emphasizing environmental stewardship and resource conservation. Green energy sources are derived directly from natural processes and phenomena (Jaiswal, Chowdhury, Yadav, Verma, Dutta, Jaiswal, SangmeshB, & Karuppasamy, 2022). For instance, solar energy harnesses the sun's rays, wind energy captures air flow, hydro energy utilizes water flow in rivers or tides, and geothermal energy taps into Earth's internal heat (Kalyani, Dudy & Pareek, 2015). These sources are inherently renewable because they are continuously replenished by nature, making them available on demand. Unlike fossil fuels, which are finite and deplete over time, green energy sources can be generated repeatedly and sustainably, providing a consistent and eco-friendly supply of power. Mitchell (2022) defines green energy, or renewable energy, as energy derived from sources that are naturally replenished on a human timescale. This includes resources such as sunlight, wind, rain, tides, geothermal heat, and biomass. Unlike fossil fuels, which take millions of years to form and are finite, renewable energy sources are sustainable and can be replenished naturally and continuously. As these resources are not depleted when used, they contribute to reducing greenhouse gas emissions and environmental impact, making them crucial in addressing climate change and promoting sustainable development (Holechek, Geli, Sawalhah & Valdez, 2022).

Fankhauser (2017) described climate adaptation as a strategic process aimed at adjusting to the effects of climate change. The goal of adaptation is to reduce the negative impacts and capitalize on any positive opportunities presented by changing climate conditions. This involves

implementing measures that improve resilience to adverse climate impacts, such as extreme weather events, rising sea levels, and shifting climate patterns, while also taking advantage of any potential benefits, such as longer growing seasons or new economic opportunities. Adaptation strategies can include infrastructure improvements, policy changes, and community-based initiatives designed to enhance overall preparedness and flexibility in the face of climate variability and change.

Overview of Climate Adaptation Needs in Nigeria

Nigeria's climate adaptation needs are both diverse and urgent. The country confronts a range of severe environmental challenges that necessitate comprehensive and tailored strategies for effective climate adaptation. One of the most pressing issues is desertification, which predominantly affects the northern regions of Nigeria (Audu & Adie, 2018). Desertification is the process by which fertile land becomes desert as a result of drought, deforestation, or inappropriate agriculture. This phenomenon not only depletes the land's productivity but also exacerbates food insecurity and disrupts local economies. Efforts to combat desertification in Nigeria involve reforestation projects, sustainable land management practices, and the promotion of drought-resistant crops. In the southern regions, Nigeria is grappling with coastal erosion and flooding. Coastal erosion threatens the integrity of shorelines, leading to the loss of valuable land and damage to infrastructure (Molua et al., 2021). Flooding, exacerbated by heavy rainfall and poor drainage systems, further compounds the problem by causing property damage, displacing communities, and straining emergency response resources. Adaptation strategies in these areas include the construction of sea walls, improved urban drainage systems, and the restoration of wetlands to absorb excess water. Nigeria experiences irregular rainfall patterns, which

significantly impact agricultural productivity. Agriculture is a critical sector for the Nigerian economy, providing livelihoods for a large proportion of the population (Tajudeen, Omotayo, Ogundele & Rathbun, 2022). Variability in rainfall affects crop yields and can lead to both droughts and flooding, further complicating food security and rural incomes. To address these challenges, adaptation measures such as the development of weather-resistant crop varieties, improved irrigation systems, and enhanced climate forecasting services are essential.

These challenges have profound socio-economic implications, especially for vulnerable populations reliant on natural resources for their livelihoods. For instance, communities that depend on agriculture or fishing are particularly susceptible to environmental changes, which can exacerbate poverty and food insecurity. The adverse effects of resource depletion and environmental degradation not only undermine their economic stability but also disrupt their social fabric (Okeke, 2024; Enete & Amusa, 2010). As these populations face increased difficulties in securing their basic needs, the broader socio-economic impacts can include heightened inequality and reduced quality of life. According to Abu & Rayhan (2023), effective climate adaptation strategies are essential for addressing the multifaceted impacts of climate change. These strategies aim to enhance resilience against climate-related risks and uncertainties. The integration of artificial intelligence (AI) in green energy technologies is identified as a pivotal component in these strategies. AI can significantly enhance the efficiency and effectiveness of green energy systems by optimizing energy production, improving resource management, and facilitating innovative solutions for climate adaptation (Abu & Rayhan, 2023). Through advanced data analytics, predictive modeling, and automation, AI technologies contribute to the development of sustainable energy solutions that are crucial for mitigating climate impacts and fostering environmental resilience.

Green Energy Technologies in Nigeria

Nigeria possesses an abundance of renewable energy resources, making it one of the most promising countries in Africa for clean energy development. The country is richly endowed with solar energy, particularly in its northern regions, where sunlight is abundant throughout the year, providing a significant potential for solar power generation. Wind energy is another renewable resource, with notable wind speeds in certain areas like the northern and coastal regions, suitable for wind farms. Nigeria's numerous rivers and water bodies offer substantial opportunities for hydroelectric power, with the potential for both large-scale and small-scale hydro projects (Amadi, Madu, Ojuka, & Igbogidi, 2024). Additionally, the country has significant biomass resources from agricultural and forestry residues, which can be harnessed for bioenergy. These resources, if fully exploited, can play a crucial role in diversifying Nigeria's energy mix, reducing dependency on fossil fuels, and contributing to climate change mitigation efforts. The International Renewable Energy Agency (2023) highlighted the vast potential these resources offer for sustainable energy development in Nigeria.

Despite this potential, Nigeria's energy sector continues to rely heavily on fossil fuels, particularly oil and gas, as the primary sources of energy. This dependency not only limits the development and adoption of renewable energy technologies but also significantly contributes to the emission of greenhouse gases, such as carbon dioxide and methane (Obada et al., 2024). These emissions exacerbate the global challenge of climate change, leading to adverse environmental impacts like rising temperatures, erratic weather patterns, and increased frequency of extreme weather events. The continued reliance on fossil fuels undermines efforts to transition to a more sustainable energy system that could mitigate these effects (Obada, et al., 2024). However, recent initiatives have

sought to expand the use of green energy technologies to address the dual challenges of increasing energy demands and environmental degradation. In particular, solar power has emerged as a prominent solution due to Nigeria's abundant solar irradiance. The country's high levels of solar radiation provide a substantial opportunity for harnessing solar energy, which is increasingly recognized for its potential to reduce dependence on fossil fuels and lower greenhouse gas emissions (Chanchangi et al., 2022). This growing focus on solar energy is driven by both technological advancements and policy support, aiming to create a more sustainable and resilient energy infrastructure.

Ugwu, Ozor, & Mbohwa (2022) highlighted that these projects are not only feasible but also crucial for diversifying energy sources and promoting sustainable development in various regions. The integration of AI into green energy technologies can significantly enhance their efficiency, reliability, and scalability. AI-driven algorithms and models can optimize energy production and consumption by predicting demand patterns and adjusting operations in real-time. This leads to more efficient use of resources and reduces waste. Additionally, AI can improve the reliability of green energy systems by identifying and addressing potential issues before they cause system failures. For scalability, AI enables the seamless integration of diverse energy sources and technologies, facilitating the expansion of green energy solutions across different regions and applications (Onwusinkwue, Osasona, Ibrahim, Anyanwu, Dawodu, Obi & Hamdan, 2024).

Application of Artificial Intelligence and Date Science in Green Energy

In recent years, the urgency to address climate change has intensified, prompting nations around the world to explore innovative solutions for reducing greenhouse gas emissions and enhancing climate resilience. Nigeria, like many other countries, faces significant challenges related to energy

consumption and climate adaptation. The integration of Artificial Intelligence (AI) and data science into green energy technologies presents a transformative opportunity to address these challenges (Okonkwo & Okonkwo, 2024).

Optimization of Energy Systems*:* AI plays a pivotal role in optimizing energy systems, which is crucial for the effective integration and management of renewable energy sources. Traditional energy management systems often struggle with balancing supply and demand, particularly in regions with variable renewable resources such as solar and wind energy. AI algorithms address this challenge by analyzing historical consumption patterns and current usage trends to predict energy demand with high accuracy (Ukoba, Olatunji, Adeoye, Jen & Madyira, 2024). For example, machine learning models can forecast solar and wind energy generation based on weather data, thereby improving the planning and management of energy grids. This predictive capability enables more effective energy distribution, reducing waste and enhancing overall system reliability. In addition to optimizing energy generation, AI assists in managing energy storage systems. Predictive algorithms can determine the optimal times to store or release energy, ensuring that supply and demand are balanced more effectively (Ukoba, Olatunji, Adeoye, Jen & Madyira, 2024). This capability is particularly beneficial in areas with intermittent renewable energy sources, where precise management of energy storage can mitigate fluctuations and enhance grid stability.

Smart Grids and Energy Management*:* The deployment of AI-powered smart grids represents a significant advancement in energy management. Smart grids provide real-time monitoring and control of energy flow, which is essential for reducing energy losses and enhancing the reliability of the energy supply. In Nigeria, where power outages and inconsistent electricity supply are

prevalent, the adoption of smart grids can address these issues by optimizing the balance between energy supply and demand (Olatunde, Okwandu, Akande, & Sikhakhane, 2024). AI technologies enable smart grids to integrate renewable energy sources such as solar and wind into the national grid more effectively (Kaur, Kumar & Singh, 2024). By continuously analyzing data on energy supply and consumption, AI can adjust grid operations to accommodate fluctuations in renewable energy generation. This integration supports the transition to more sustainable energy solutions, benefiting both the economy and the environment. Furthermore, smart grids enhance the stability of the power supply, which is crucial for supporting economic development and improving the quality of life for citizens.

***Predictive Maintenance**:* Another critical application of AI in green energy technologies is predictive maintenance. Predictive maintenance involves using AI to forecast equipment failures before they occur, allowing for proactive interventions and reducing downtime. This capability is especially important for maintaining the uninterrupted operation of renewable energy systems, which are often located in remote areas with limited access to maintenance services (Szleter, 2024).

***Energy Efficiency**:* AI also contributes to energy efficiency by optimizing energy consumption in buildings and industrial processes. Sophisticated AI algorithms analyze real-time usage patterns and dynamically adjust energy settings to minimize waste. For instance, in buildings, AI systems can regulate heating, ventilation, and air conditioning (HVAC) based on occupancy and weather forecasts. In industrial settings, AI can fine-tune machinery operations to reduce energy consumption (World Economic Forum, 2024).

***Climate Risk Assessment and Adaptation Planning**:* AI-driven models are increasingly important in climate risk assessment and adaptation planning. These models utilize machine learning

algorithms and extensive datasets to evaluate the risks posed by climate change. By analyzing historical climate data, current environmental conditions, and predictive simulations, AI can identify regions most vulnerable to climate impacts such as flooding, droughts, and heat-waves (Jain et al., 2023). AI's ability to forecast climate variability and its potential consequences allows for the development of targeted adaptation strategies (Jain, Dhupper, Shrivastava, Kumar & Kumari, 2023). For example, AI models can recommend specific green energy solutions tailored to the needs of vulnerable regions, optimizing resource allocation and enhancing resilience. This data-driven approach ensures that adaptation plans are based on comprehensive insights, facilitating more effective responses to climate challenges.

Challenges and Barriers to AI Adoption in Nigeria

Adelaja (2020) discussed the promising potential of artificial intelligence (AI) in advancing green energy technologies, particularly in Nigeria. However, despite these opportunities, several challenges impede its widespread adoption. These challenges include:

Lack of Data and Infrastructure: The successful deployment of artificial intelligence (AI) in green energy technologies is heavily dependent on the availability of high-quality data and robust infrastructure (Adelaja, 2020; EMRCInfo, & EMRCInfo, 2024). In Nigeria, however, the lack of reliable data and adequate infrastructure represents a major challenge. High-quality, accurate, and comprehensive data is essential for training AI models and ensuring their effectiveness. In Nigeria, the absence of reliable data on energy consumption, renewable resources, and environmental conditions hampers the ability of AI systems to make informed decisions and predictions (Adelaja, 2020; Amadi, Madu, Ojuka & Igbogidi, 2024). Inconsistent data collection practices, data gaps, and outdated information further exacerbate the issue, making it difficult to develop and implement

AI solutions effectively. Also, AI applications require a solid technological foundation, including advanced computing resources, data storage facilities, and network connectivity. In Nigeria, inadequate infrastructure, such as limited access to high-speed internet, insufficient data centers, and outdated hardware, undermines the ability to support sophisticated AI technologies (Adelaja, 2020; Abdulrazaq, 2015). These infrastructure limitations not only affect the performance and scalability of AI solutions but also hinder the integration of AI into existing energy systems.

Financial Constraints: **Financial Constraints:** The deployment of artificial intelligence (AI) technologies in green energy projects necessitates a significant financial outlay for several key components. This includes the acquisition and maintenance of advanced hardware and software, which are essential for running complex AI algorithms and processing large datasets (Adelaja, 2020). Additionally, investing in skilled personnel such as data scientists, AI specialists, and system engineers is crucial for developing, implementing, and managing AI systems effectively. Limited financial resources can therefore create a barrier to adopting AI in green energy initiatives, as organizations may struggle to allocate sufficient funds for these critical investments. This constraint can delay or prevent the integration of AI technologies that are vital for enhancing the efficiency and impact of green energy solutions (Adelaja, 2020).

Technical Expertise: **Technical Expertise**: The effective deployment of artificial intelligence (AI) in green energy technologies necessitates a high level of specialized knowledge and technical skills. In Nigeria, there is a significant shortage of professionals with expertise in AI, which impedes the advancement and practical application of AI-driven solutions. This gap in technical expertise affects the development, integration, and optimization of AI technologies in the green

energy sector, limiting the potential benefits and innovations that could be achieved (Adelaja, 2020).

Regulatory and Policy Barriers: Regulatory and policy barriers can significantly hinder the progress of AI and green energy technologies. When regulations and policies are unclear or absent, it creates an environment of uncertainty that deters both innovation and investment. For AI, the lack of specific guidelines can lead to concerns about data privacy, security, and ethical use, making it difficult for businesses to develop and deploy AI solutions confidently (Adelaja, 2020).

Social/Cultural Barriers: These barriers stem from entrenched habits, attitudes, and cultural norms that influence behavior and decision-making. Habits and traditional practices can obstruct the adoption of new technologies or methods, as individuals may be resistant to change. Attitudes shaped by culture and social norms often dictate risk perception, with some groups viewing new innovations or changes as threats rather than opportunities. Cultural beliefs can also affect willingness to engage with new systems, as they may conflict with established values or practices (Adelaja, 2020).

Conclusion

The integration of Artificial Intelligence (AI) into green energy technologies represents a transformative approach to addressing climate adaptation challenges in Nigeria. As the country confronts severe climate impacts such as desertification, coastal erosion, and irregular rainfall

patterns, the need for innovative and resilient solutions becomes increasingly critical. AI offers promising capabilities to enhance the efficiency, reliability, and scalability of green energy systems, which are essential for mitigating climate change and promoting sustainable development. AI's role in optimizing energy systems through predictive analytics, smart grid management, and predictive maintenance is vital for improving the performance and stability of green energy technologies. By accurately forecasting energy demand and managing resources effectively, AI can ensure that renewable energy sources such as solar, wind, and hydro power are utilized to their full potential.

Recommendations and Future Directions

To harness the full potential of AI in green energy technologies for climate adaptation, the following recommendations are proposed:

- Launch a national program to standardize and improve data collection across the energy sector, incorporating modern technologies to gather and manage data on energy consumption, renewable resources, and environmental conditions. This initiative should involve collaboration between government agencies, private sector, and research institutions to ensure comprehensive and high-quality data availability for AI applications.
- Pursue financial support from international organizations and development agencies focused on green energy and AI. Establish partnerships with global tech companies and financial institutions to secure funding and resources, helping to overcome the high costs associated with AI deployment in green energy projects.
- Develop and expand educational programmes and training initiatives focused on AI and green energy technologies. Partner with universities and online platforms to offer

specialized courses and certifications, aiming to build a skilled workforce equipped to handle AI technologies and innovations in green energy.

- Engage with policymakers to create comprehensive and clear regulations that address both AI and green energy sectors. Ensure that these regulations cover data privacy, security, and ethical issues, while also providing incentives and support to encourage innovation and investment.
- Launch targeted public awareness campaigns to educate and inform the general public about the benefits and opportunities of AI and green energy technologies. Focus on changing perceptions and addressing cultural misconceptions to foster a more supportive environment for technology adoption.

References

Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., & Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research, 29*(29), 42539–42559. https://doi.org/10.1007/s11356-022-21123-9

Abdulrazaq, K. (2015). Challenges of e-government implementation in the Nigerian public service. *Journal of Writing in Creative Practice, 1*(4), 45–56. https://doi.org/10.1386/wcp.1.4.45_1

Abu, R., & Rayhan, S. (2023). *The* role of artificial intelligence in climate change mitigation and adaptation. CBECL's R&D Lab. https://doi.org/10.13140/ RG.2.2.10346.70087/1

Adamaagashi, I., Nzechie, O., Obiorah, J., & Idakwoji, A. A. (2023). Analyzing the critical impact of climate change on agriculture and food security in Nigeria. *International Journal of Agricultural and Environmental Sciences*, *9*(4), 1–27. https://doi.org/10.56201/ijaes.v9.no4.2023.pg1.27

Adelaja, A. O. (2020). Barriers to national renewable energy policy adoption: Insights from a case study of Nigeria. *Energy Strategy Reviews, 30*, 100519. https://doi.org/10.1016/j.esr.2020.100519

Amadi, H. N., Madu, M. C., Ojuka, O. E., & Igbogidi, O. N. (2024). Renewable energy in Nigeria: Prospects and challenges. *European Journal of Advances in Engineering and Technology*, *11*(4), 51-60.https://www.researchgate.net/publication/380147954_Renewable_Energy_in_Nigeria_Prospects_and_Challenges

Amadi, H. N., Madu, M. C., Ojuka, O. E., & Igbogidi, O. N. (2024). Renewable energy in Nigeria: Prospects and challenges. *European Journal of Advances in Engineering and Technology*, *11*(4), 51-60.https://www.researchgate.net/publication/380147954_Renewable_Energy_in_Nigeria_Prospects_and_Challenges

Ang, T.-Z., Salem, M., Kamarol, M., Das, H. S., Nazari, M. A., & Prabaharan, N. (2022). A comprehensive study of renewable energy sources: Classifications, challenges and suggestions. *Energy Strategy Reviews, 43*, 100939. https://doi.org/10.1016/j.esr.2022.100939

Audu, I. A., & Adie, L. A. (2018). Desertification in Northern Nigeria: Causes and consequences. *Environmental Studies, 1*(2), 20–37.

Chanchangi, Y. N., Adu, F., Ghosh, A., Sundaram, S., & Mallick, T. K. (2022). Nigeria's energy review: Focusing on solar energy potential and penetration. *Environment, Development and Sustainability, 25*(2014). https://doi.org/10.1007/s10668-022-02308-4

Dignum, V. (2019). What Is Artificial Intelligence?. In: Responsible Artificial Intelligence. Artificial Intelligence: Foundations, Theory, and Algorithms. Springer, Cham. https://doi.org/10.1007/978-3-030-30371-6_2

EMRCInfo, & EMRCInfo (2024, January 29). Transforming Renewable Energy Using Artificial Intelligence - EMRC. *EMRC* -. https://www.energymrc.ng/transforming-renewable-energy-using-artificial-intelligence/

Enete, A. A., & Amusa, T. A. (2010). Challenges of agricultural adaptation to climate change in Nigeria: A synthesis from the literature. *Field Actions Science Reports, 4*. http://journals.openedition.org/factsreports/678

Fankhauser, S. (2017). Adaptation to climate change. *Annual Review of Resource Economics, 9*(1), 1-36. https://doi.org/10.1146/annurev-resource-100516-033554

Greif, L., Kimmig, A., El Bobbou, S., Jurisch, P., & Ovtcharova, J. (2024). Strategic view on the current role of AI in advancing environmental sustainability: A SWOT analysis. *Discover Artificial Intelligence*, 4(45). https://doi.org/10.1007/s44163-024-00146-z

Holechek, J. L., Geli, H.M.E., Sawalhah, M.N. & Valdez, R. A (2022). Global Assessment: Can Renewable Energy Replace Fossil Fuels by 2050? *Sustainability*, *14*, 4792. https://doi.org/10.3390/su14084792

Huawei Technologies Co., Ltd.. (2023). A General Introduction to Artificial Intelligence. In: Artificial Intelligence Technology. Springer, Singapore. https://doi.org/10.1007/978-981-19-2879-6_1

International Renewable Energy Agency (2023). Renewable energy roadmap: Nigeria. https://energy.gov.ng/reports/IRENA_REMap_Nigeria_2023.pdf

Jain, H., Dhupper, R., Shrivastava, A., Kumar, D., & Kumari, M. (2023). AI-enabled strategies for climate change adaptation: Protecting communities, infrastructure, and businesses from the impacts of climate change. *Computational Urban Science*, *3*(25). https://doi.org/10.1007/s43762-023-00100-2

Jain, H., Dhupper, R., Shrivastava, A., Kumar, D., & Kumari, M. (2023). AI-enabled strategies for climate change adaptation: Protecting communities, infrastructure, and businesses from the impacts of climate change. *Computational Urban Science*, *3*(25). https://doi.org/10.1007/s43762-023-00100-2

Jaiswal, K. K., Chowdhury, C. R., Yadav, D., Verma, R., Dutta, S., Jaiswal, K. S., SangmeshB, & Karuppasamy, K. S. K. (2022). Renewable and sustainable clean energy development and impact on social, economic, and environmental health. *Energy Nexus, 7*, 100118. https://doi.org/10.1016/j.nexus.2022.100118

Kalyani, V. L., Dudy, M. K., & Pareek, S. (2015). Green energy: The need of the world. *Journal of Management Engineering and Information Technology (JMEIT)*, *2*(5), 1-26.

Kaur, S., Kumar, R., & Singh, K. (2024). Smart grids and solar energy: Role of artificial intelligence in grid management. In *Futuristic trends in renewable & sustainable energy* (pp. 97-118). IIP Series. https://doi.org/10.58532/V3BDRS1P1CH8

Khaleel, M., & Jebrel, A. (2024). *Artificial intelligence in computer science*. *International Journal of Electrical Engineering and Sustainability (IJEES)*, 2(2), 01-21. https://ijees.org/ index. php/ijees/indexVolume2/Number2/April-June2024/Pages01-21

Lucas, M. (2024). The role of AI in climate change mitigation and environmental monitoring. https://doi.org/10.13140/RG.2.2.21153.38247

Mitchell, D. (2022). Significance of green energy. *Global Journal of Petroleum Research & Alternative Fuels, 1*(1), 003-004. https://creativecommons.org/ licenses/by-nc-nd/4.0/

Molua, O. C., Ukpene, A. O., Vwavware, J. O., Nwachuku, D. N., & Osuhor, P. O. (2021). Geophysical assessment of coastal erosion in Nigeria's coastal regions: Strategies for protection and management. *International Journal of Research and Innovation in Science Engineering and Technology, 1*(2), 39-49. DOI: https://doi.org/10.55529/ijrise.12.39.49

National Grid (2024). What is green energy*?* https://www.nationalgrid.com/stories/energy-explained/what-is-green-energy

Nwosu, I.C., Abasili, K.N. Unoma, N.G. & Nwokike, C.E. (2024). Community implementation of green energy technologies for climate change adaptation in Nigeria. International Journal of Contemporary Academic Research, 5(1)37-52.

Obada, D. O., Muhammad, M., Tajiri, S. B., Kekung, M. O., Abolade, S. A., Akinpelu, S. B., & Akande, A. (2024). A review of renewable energy resources in Nigeria for climate change mitigation. *Case Studies in Chemical and Environmental Engineering, 9*, 100669. https://doi.org/10.1016/j.cscee.2024.100669

Okeke, C. U. (2024, February 5). Community Resilience: Integrating Local Approaches into Nigeria's Climate Change Adaptation Agenda. *APRI*. https://afripoli.org/community-resilienceintegrating-local-approaches-into-nigerias-climate-change-adaptation-agenda

Okonkwo, G., & Okonkwo, G. (2024, August 7). Energy Efficiency and the Role of Artificial Intelligence (AI) - EMRC. *EMRC* -. https://www.energymrc.ng/energy-efficiency-and-the-role-of-artificial-intelligence-ai/

Olatunde, T. M., Okwandu, A. C., Akande, D. O., & Sikhakhane, Z. Q. (2024). The impact of smart grids on energy efficiency: A comprehensive review. *Engineering Science & Technology Journal, 5*(4), 1257–1269. https://doi.org/10.51594/estj/v5i4.1016

Onwusinkwue, S., Osasona, F., Ibrahim, I. A., Anyanwu, A. C., Dawodu, S. O., Obi, O. C., & Hamdan, A. (2024). Artificial intelligence (AI) in renewable energy: A review of predictive maintenance and energy optimization. *World Journal of Advanced Research and Reviews, 21*(1), 2487-2799. https://doi.org/10.30574/wjarr.2024.21.1.0347

Sarker, I.H. (2021). Data science and analytics: an overview from data-driven smart computing, decision-making and applications perspective. *SN COMPUT. SCI.* **2**, 377. https://doi.org/10.1007/s42979-021-00765-8

Sheikh, H., Prins, C., Schrijvers, E. (2023). Artificial Intelligence: Definition and Background. In: Mission AI. Research for Policy. Springer, Cham. https://doi.org/10.1007/978-3-031-21448-6_2

Szleter, P. (2024, June 13). Practical applications of AI-powered predictive maintenance for renewable energy infrastructure. *Forbes Technology Council.*

Tajudeen, T. T., Omotayo, A., Ogundele, F.O. & Rathbun, L.C. (2022). The effect of climate change on food crop production in Lagos State. Foods,11(24):3987. doi: 10.3390/foods11243987. PMID: 36553731; PMCID: PMC9778574.

Ugwu, C. O., Ozor, P. A., & Mbohwa, C. (2022). Small hydropower as a source of clean and local energy in Nigeria: Prospects and challenges. *Fuel Communications, 10,* 100046. https://doi.org/10.1016/j.jfueco.2021.100046

Ukoba, K., Olatunji, K. O., Adeoye, E., Jen, T.-C., & Madyira, D. M. (2024). Optimizing renewable energy systems through artificial intelligence: Review and future prospects. *Energy & Environment*, *0*(0). https://doi.org/10.1177/0958305X241256293

Ukoba, K., Olatunji, K. O., Adeoye, E., Jen, T.-C., & Madyira, D. M. (2024). Optimizing renewable energy systems through artificial intelligence: Review and future prospects. *Energy & Environment*, *0*(0). https://doi.org/10.1177/0958305X241256293

Ullah, I., Adhikari, D., Su, X., Palmieri, F., Wu, C., & Choi, C. (2024). Integration of data science with the intelligent IoT (IIoT): Current challenges and future perspectives. *Digital Communications and Networks*. https://doi.org/10.1016/j.dcan.2024.02.007

United State Agency for International Development (2023, November 29). Nigeria Climate Change Country Profile. Fact Sheet U.S. Agency For International Development. https:// www. usaid.gov/climate/country-profiles/Nigeria

University of Illinois Chicago (2024, May 07). What is (AI) Artificial Intelligence? Online Master of Engineering. https://meng.uic.edu/news-stories/ai-artificial-intelligence-what-is-the-definition-of-ai-and-how-does-ai-work/#:~:text=Artificial%20 Intelli ge nc e%20(AI) %20works%20by,%2C%2 0perception%2C%20and% 20 language % 20 understanding.

Van, G. B. (2023). Data science. in: data in context. the enterprise engineering series. Springer, Cham. https://doi.org/10.1007/978-3-031-35539-4_15

World Economic Forum. (2024, July 22). AI and energy: Will AI help reduce emissions or increase demand? Here's *what to know*. https://www.weforum.org/agenda/2024/07/ai-energy-emissions-demand/