Article

Not peer-reviewed version

Smart Supply Chains for a Sustainable Future: Qualitative Insights into AI Applications in Renewable Energy

Olivia Roberts *

Posted Date: 7 May 2025

doi: 10.20944/preprints202505.0468.v1

Keywords: supply chain management; artificial intelligence; sustainability; operational efficiency; resilience; innovation

Article

Smart Supply Chains for a Sustainable Future: Qualitative Insights into AI Applications in Renewable Energy

Olivia Roberts

Independent Researcher; olivia.roberts1789@hotmail.com

Abstract: This paper seeks to explore the implementation of artificial intelligence (AI) within renewable energy supply chains for the impact on operational efficiency, resilience, and sustainability. Given the focus on transforming the entire world towards an effective supply chain using sustainable energy sources, there is strong interest in how AI can aid the optimization of supply chain processes. From the study, ultimately from the qualitative research done through in-depth interviews with industry experts, key themes that relate to what AI can provide the production system related to forecasting accuracy, resource allocation, and real time decision making. Findings show that in addition to reducing the operational cost, AI also enables the adaptability of supply chains and increases its responsiveness to fluctuation on energy demand and external disturbance. Additionally, the study insists that AI will assist in the reduction of emissions, minimization of waste, and supporting the circular economy improvement. However, advantages like low cost of implementation, lack of standardization, concerns about the ethical process of data privacy, as well as lack of skilled manpower, still pose challenges to wider adoption. This research highlights the need for organizations to make the first stride to resolve these issues by investing the necessary means of training and mediated standards for the integration of AI. Finally, this paper provides some meaningful lessons on the possible effects of AI to the renewable energy supply chain, and it is likely that the success of implementing AI can result in important benefits on operational performance and directly contribute to a more sustainable renewable energy landscape. Combination of AI technologies allows for increasing organization competitiveness and insignificant participation in global movement away from dirty energy and towards cleaner energy future.

Keywords: supply chain management; artificial intelligence; sustainability; operational efficiency; resilience; innovation

---

1. Introduction

The application of artificial intelligence (AI) to renewable energy systems and supply chains is a major disruptive innovation in the practice of energy systems and supply chains worldwide, enabling unparalleled opportunities to create sustainability, efficiency and resilience of global energy systems. Recently, the global energy landscape is continuously increasing its usage of renewable energy whose major categories include solar, wind, hydropower, or biomass (Adhikary & Bhandari, 2020). The adoption of renewables has has been very successful, however, managing the simplest renewable energy supply chains presents a daunting complexity. The energy generation in these supply chains is very highly variable in energy generation, very dependent on weather conditions, and requires real-time decision making to ensure stability and reliability (Ai & Ding, 2021). According to this, machine learning, predictive analytics, and optimization algorithms are rising as strong tools able to improve the efficiency and effectiveness in the incorporation of renewable energy to the supply chain in this context. However, AI has demonstrated the potential to enhance demand forecasting, energy storage optimization and logistics in the renewable energy supply chains, tackling some of the key problems in the energy sector (Babu & Kannan, 2020). Dynamic and uncertain

 doi:10.20944/preprints202505.0468.v1

renewable energy supply chains imply that generation is susceptible to fluctuations which need to be monitored, observed and controlled in real time. Predictive models driven by AI can help energy providers in anticipating demand and supply pattern with higher accuracy and even waste reduction as it reduces unutilized (Alavi & Jabarzadeh, 2020). Additionally, AI has been essential in minimizing the deployment of energy storage systems, like batteries, that go a long way in balancing supply and demand. With the use of AI algorithms, decision makers can decide on the best ways for the storage and distribution of renewable energy and avoid energy losses and improve grid reliability (Botta & Crespi, 2020). Coordination across multiple stakeholders (energy producers, energy distributors, energy consumers), which are necessary for integrating renewable energy into supply chains, is further introduced into the integration process. Being of this complexity, it requires the use of intelligent systems capable of managing huge amounts of data and helpful insights (Asimakopoulos & Koutitas, 2021). This is made possible by AI as it provides advanced analytics, and the decision support tool to the stakeholders to take informed decisions, which are based on real time data (Emon, 2025). For example, AI powered platforms can monitor the performance of the renewable energy systems, pinpoint the possible bottlenecks and suggest corrective actions to achieve uninterrupted functioning of the system (Chakraborty, Saha, 2021). Especially in systems of decentralized energy supply, where multiple small source renewable plants generate the total supply, these capabilities are of special value. By providing AI tools, the distributed energy resources (DERs) can be integrated into the grid and energy can be efficiently allocated, distributed to where it is most wanted (Gupta & Singh, 2020). Yet it only takes a momentary environmental event like extreme weather to threaten supply chains formed by renewable energy, and even more lethal if supply chain disruptions are caused by, for instance, supply shortages or cyberattacks. Proactive risk management as well as real-time management of disruptions is shown to have been very promising by the application of AI in strengthening supply chain resilience (Giannakis & Papadopoulos, 2016). As an example, the AI algorithms can analyze historical data to identify patterns and tendencies that will provide energy providers an opportunity to mitigate before any issues arise (Choudhury & Khatun, 2021). Moreover, AI can facilitate the development of adaptive supply chain strategies to enable organizations to quickly adapt to changing environments and maintain continuity in the energy supply (Khan & Emon, 2025). This is important as climate change leads to more extreme events (including more frequency and more intensity) of extreme weather events that are challenging for the renewable energy systems (Fathabadi, 2021). Likewise, the synergy between artificial intelligence (AI) and renewable energy goes even further than that to enable sustainability in supply chain operations. Finally, the use of AI empowers organizations to minimize their energy consumption and waste so that they can reach sustainability goals (Bhatia & Joshi, 2021). One such example is AI powered tools that can identify the inefficiencies in energy usage and recommend how the consumption of energy can be brought down in the supply chain (Khan & Hasan Emon, 2024). By doing so, this not only reduces greenhouse gas emissions, but also greatly reduces the operational cost, which makes it a perfect win-win scenario for businesses, as well as for the environment (Ghadimi & Ranjbar, 2021). Furthermore, AI can help integrate principles of circular economy into renewable energy supply chains by enhancing tracking and tracking of materials across their lifecycle (Apostolou & Christou, 2022). Optimizing materials recycling and reuse, including rare earth metals, used in solar panels and wind turbine production, which are crucial for sustainable energy production, is also included in this. Despite the large advantages of AI on renewable energy supply chains, there are also many disadvantages and some limitations that must be addressed. The biggest challenge is the non-standardization and no interoperability of different AI systems, which makes it difficult to implement such systems in existing supply chain infrastructures. Additionally, as most of the AI technologies are deployed, they might involve huge investments in hardware, software, and skilled personnel, rendering it a barrier to smaller organizations or operating in underdeveloped regions (Babu & Kannan, 2020). Along with ethical concerns regarding data privacy and security; use of applied AI means processing huge amounts of sensitive data (Chakraborty & Saha, 2021). To address these challenges, it will be imperative to work together with government, industry stakeholders and academia to draft out best practices and standards for the use of AI in renewable energy supply chains in a manner beyond looking at pitch black cycles of life. Since then, there have been recent

 doi:10.20944/preprints202505.0468.v1

advancements in AI technologies that have opened more doors for their use in renewable energy systems. For instance, deep learning and neural network algorithms have capability to enhance the predictability of weather forecasting that will support the optimization of renewable energy performance (Adhikary & Bhandari, 2020). These AI tools provide energy providers with precise predictions of weather conditions which would help to predict energy generation fluctuations and provide a stable supply of energy to meet demand (Asimakopoulos & Koutitas, 2021). Other than that, AI driven optimization models have been employed to improve the design and operation of renewable energy supply chains with significant cost savings and efficiency improvements (Ai & Ding, 2021). Finally, the transformative effect that AI can have to the renewable energy sector and also in the supply chain management are evidenced by these innovations. Besides these technological improvements, AI cannot be looked over as an enabler of collaboration and innovation in the renewable energy sector. Using AI powered platforms, knowledge sharing and collaboration among stakeholders can take place in a more effective manner so that they work together more to find solutions for common problems and to strive for common goals (Bhatia & Joshi, 2021). These include the usage of AI tools for developing the digital twins of the renewable energy systems wherein the stakeholders can perform the simulation to explore the differing scenarios and possible solutions to the problem in a virtual environment (Alavi & Jabarzadeh, 2020). Both approaches contribute to a more efficient renewable energy supply chain and provide better conditions for innovation of innovative solutions of complex problems. Meanwhile, there has been more emergent research on the fundamental role of AI in integrating renewable energy supply chain. For instance, recent studies aimed at applying AI in the task of optimizing energy storage and distribution systems, as well as in elevating the scale of renewable energy technologies (Emon & Khan, 2024; Emon et al, 2025). Moreover, studies on the use of AI for enhancing the resilience and sustainability of energy supply chains in a context of rising environmental and economic uncertainties were conducted by researchers (Rahmana et al., 2024). These findings reinforce the need for using AI to tackle increasingly challenging issues for the renewable energy sector and will help enable new processes for growth and innovation (Emon et al., 2024). AI and renewable energy and their integration in supply chains represent a change of paradigm when it comes to energy system management and operation. AI technologies help organizations to design more efficient, more robust and more orgainically sustainable renewable energy supply chains, on the road to a more sustainable and fairer energy future. At the same time, however, we will have to go further in addressing the challenges and the limitations we encounter in applying AI. With subsequent research and development in this area, the link between AI and green energy is likely to play a major part in charting the global energy path in accordance with the energy transition away from a low carbon economy.

2. Literature Review

Driven by the necessity to resolve the global sustainability issues as well as the necessity to optimize the energy systems, the integration of artificial intelligence into the renewable energy supply chains has been of intense interest in the recent years. Solar, wind, hydroelectric power, among others, are huge renewable energy sources that can both reduce carbon emissions and meet increased energy demand. Yet, owing to the inherent variability and unpredictability of these energy sources, supply chain management suffers from the use of the advanced tools and technologies. It has been proved that AI plays a role in overcoming these challenges and offers innovative solutions to enhance efficiency, reliability and resilience of renewable energy systems to supply chains (Hsu & Chen, 2018). Through machine learning, predictive analytics, and optimization algorithm, AI helps in the data driven decision making thus supporting the energy systems in the dynamic change over time conditions and optimization in the supply chain (Nascimento & Ferreira, 2020). Demand forecasting and resource optimization are one of the main ways where AI has been enhancing the renewable energy supply chain. Demand forecasting is critical for matching energy and demand within energy systems where a high percentage of the energy comes from renewable sources (Khan et al., 2024). Through using historical data and real time information, predictive models based on AI are able to anticipate fluctuations in the energy demand, thus, allowing supply chains to allocate resources effectively and reducing waste (Jain & Sharma, 2020). In addition, these models are well

 doi:10.20944/preprints202505.0468.v1

suited to address the intermittency of renewable energy generation such as the variability of the generation of solar, wind; generation that depends on the weather. Also, the resource allocation including energy storage and distribution network is further assisted using AI-based optimization techniques, which are able to provide renewable energy to the end users reliably (Manogaran & P. A., 2021). For instance, AI algorithms can also place energy storage systems, such as batteries, so that they are more effective in reducing loads on the incoming line from the grid while limiting transmission losses (Liu & Zhao, 2020). What's more, AI contributes to the improvement of integration of renewable energy into the already existing energy grids and supply chain infrastructures. Usually, renewable energy systems are decentralized characterized by many small scale producers generating part of the overall supply of energy. These coordination challenges occurring in the context of this decentralization are particularly pronounced in: the coordination of the flow of energy between producers, distributors, and consumers. To address these challenges, AI technologies offer real time analytics and the decision support it provides for the stakeholders to coordinate their activities efficiently (Kumar and Kumar, 2020). Energy supply from distributed energy resources can be accommodated on the grid using the AI-powered platforms, and so what was once noisy, and unpredictable generation can truly be smoothed out. Furthermore, these platforms are used for grid management which in turn monitors energy flows, detects potential bottleneck, and proposed corrective measures for maintaining operational efficiency (Li & Huang, 2021). As opposed to operational efficiency, AI's potential to improve renewable energy supply chains also includes the aspects of resilience and sustainability. Supply chain management is highly concerned with resilience, which is especially true for the renewable energy sector, where all disruptions can be caused by excessive weather events, shortages of the supply, and cybersecurity threats. Proactive risk management is a capability of AI that investigates history of data and predict possible vulnerability and disruption. Thus, for instance, algorithms of AI could evaluate the effect of weather patterns on energy generation and suggest mitigation risk mitigation strategies (e.g. by spreading energy source or increasing capacity of storage). (Makhathini & Mkhwanazi, 2021) Apart from resilience, AI maintains the sustainability of the renewable energy supply chain through energy performance optimization and reduction of waste (Emon & Khan, 2024). By using AI-driven systems that monitor energy consumption patterns and point out the inefficiencies, organizations can put aside targeted measures to reduce its energy waste and emissions of greenhouse gases (Marra & Orazem, 2020). They are the capabilities matching the global sustainability goals and they support the transition to the low carbon economy (Pandey & Sharma, 2020). There is another area that is another critical area — where the design and operating processes of renewable energy supply chains are being driven by AI — and this is totally another critical area, where AI is basically picking the five out of the top 10 sites. Since AI-driven optimization models are well promising, supply chain performance has been enhanced by the allocation of resource, cost and operation flexibility enhancement (Pappas & Koutsou, 2021). In particular, these models are powerful to tackle the difficulty of complex renewable energy supply chain incorporating many interdependent processes and stakeholders. For instance, the scheduling of energy production and distribution activities for example, may be optimized using AI algorithms to minimize resource use and delays (Khedhiri & Mhenni, 2021). Similarily, AI helps performers to invent distant forms of design through digital twin of the physical system designed, which shape stakeholders to simulate different scenarios and assess their efficiency on the supply chain performance (O'Neill & Goldsworthy, 2021). Digital twins can help gain valuable insights in the behavior of renewable energy systems for data driven decision making, for overall supply chain efficiency (Raza & Ahmed, 2020). There are surprisingly few benefits of AI in renewable energy supply chains along with several significant challenges and limitations which must be taken care of. Lack of standardization and interoperability among AI systems is also one of the main challenges when entering implementation of AI systems in the existing supply chain infrastructure. In case of AI technologies, it may require many investments in hardware, software and manpower, which is not always possible with small or developing organization (Naji & Asadi, 2021). Moreover, because of the use of AI, the use of data is massive, hence, ethical considerations related to data privacy and security should not be ignored (Rahman & Rashed, 2021). To address these challenges, we envision the adoption of policies, standards, and best practices to use AI in the

 doi:10.20944/preprints202505.0468.v1

responsible way in the renewable energy supply chain (Hsu and Chen, 2018) that needs to be done by collaborative efforts among the governments, industry stakeholders and academic institutions (Emon & Khan, 2025). Renewable energy systems were conducted (Khan & Emon, 2024; Khan et al, 2025). Researchers have also investigated the use of AI in providing increased supply chain transparency and traceability, as it is important to establish trust relationships of stakeholders thereby ensuring sustainability of renewable energy operations (Fuada et al., 2024). These findings emphasize the salience of employing AI in promoting collaboration and innovation among stakeholders in the renewable energy sector by enhancing capabilities for collaboration and innovation among stakeholders to realize their shared objectives (Khan et al., 2024). An additional facility that AI can provide in integrating circular economy principles in renewable energy supply chains is to drive sustainability and resource efficiency. If you want to follow it, you ensure the materials are recycled and reused from the beginning of their lifecycle across the entire life cycle, avoiding waste and preserving natural resources. Using AI, materials utilized in things like solar panels and wind turbines like rare earth metals can be better tracked and managed to make sure they are recycled and reused appropriately (Nascimento & Ferreira,2020). The principle of circular economy is incorporated into supply chain operations and AI aids to design sustainable energy systems with reduced environmental footprint as well as ensuring long term resource sustainability (Pandey & Sharma, 2020). Additionally, machine learning and other AI technologies have also showed great promise of improved scale of renewable energy systems across the renewable energy supply chains. Patterns and trends can be recognized in large amounts of data by the machine learning algorithms, helping organizations scale their operations up without any errors (Liu & Zhao, 2020). As an example, AI tools can block solar panels and wind turbines at the optimal location based on maximizing energy generation and minimizing costs (Jain & Sharma, 2020). However, these capabilities are extremely useful as the need for renewable energy steadily rises, necessitating supply chains to adjust to more sophisticated and bigger levels of complexity and scale (Li & Huang, 2021). Integrating AI to renewable energy supply chains is a disruptive transition of how energy supply chains are governed and exercised. Through innovation to the solution of demand forecasting, resource optimization, resilience and sustainability, AI provides significant leverage to overcome major and highly critical challenges in renewable energy systems and achieve greater efficiency and reliability. Yet proper addressing of the challenges and limitations with which AI will need to be harnessed to fully deliver its promise and to do so in a responsible and ethical way remains to be done. With the growing prosperity of this field by research and development, the synergy of AI and renewable energy will be an important force in writing the energy writing of the world and the conduct of the global energy transition towards a more sustainable and shielded energy future.

3. Materials and Method

The methodology of the research was qualitative and explored the combination of artificial intelligence, as a new technology, with renewable energy, a traditional one, in the supply chains. As a methodological approach, I decided it was appropriate, as it could provide in depth insight into participants' experience, perceptions and the complex landscape of the subject matter. The objective of the study involved understanding of the use of AI technologies in renewable energy supply chains to increase efficiency, sustainability and resiliency, as well as barriers to deployment of these technologies. The purpose of this research was to get details on the things under study, rich descriptive of the phenomenon under investigation. Through semi structured interviews, data were collected with purposive sample of 30 participants based on their expertise and involvement in related fields of supply chains management, artificial intelligence and renewable energy. Industry professionals, researchers, policymakers and technology developers who have direct experience in using AI in renewable energy supply chains were participating in the workshop. This purposive sampling made sure to attract the study by various perspectives and insights from the people that are very good about the subject area. To recruit participants, messages were sent through email and professional platforms, as well as through academic institutions and industry associations. It focused on the major themes of AI and integration of renewable energy supply chains, and the semi structured interviews were designed so that there would be free flow of experience and opinion of

 doi:10.20944/preprints202505.0468.v1

the participants. To achieve consistency across interviews, open ended questions were used addressing how AI benefits vs challenges renewable energy supply chains; specific how AI is being used and case examples; as well as opportunities for innovation and improvement related to future innovation and improvement. In addition, participants were asked to add anything that they themselves believe to be relevant to the research topic at hand. Although the interviews were conducted face-to-face or online video-based interviews depending on the participant's availability and preference. The participants were consented to audio recording via audio recording and transcription of each interview for accurate data capture. Interviews also taken place with detailed field notes of nonverbal cues, contextual information, first impressions taken. The data were analyzed through the examination of recorded interviews that were transcribed verbatim to achieve a thorough analysis. The process of data analysis went in the direction of a thematic approach; it coded the transcriptions in order to identify recurring patterns, themes and categories. Then, manually, first coding was conducted, and then, emerging codes were reviewed and refined iteratively until they are reflective enough to the data. The research objectives were addressed, and broader topics were formed through organizing themes into categories which lend meaning to the role of AI in renewable energy supply chains. All throughout the research process, the research was strictly adhered to ethical considerations to ensure that the rights on confidentiality of the participants were met. Before data collection, participants were given standardized detailed information on the study, its purpose, methods and possible implications. All participants gave informed consent to participate and took part in the promise that their data would be anonymized and use for only research. Participants were also told that they had the right to withdraw from the study at any time without any negative impact. The study was carried out under the auspices of ethical approval from the relevant institutional review board, to conform to the standards and guidelines of established ethical practice. Several measures including triangulation, member checking, peer debriefing, etc., were taken to improve data reliability and validity. The cross-referencing of the interview data with relevant literature and publicly available case studies were utilized for the triangulation which validates the findings and draws attention to possible discrepancies. To verify the accuracy and the area of the interpretation, member checking was conducted by sharing preliminary findings with a subset of participants. Peer debriefing was performed with colleagues and with experts in the field to review the process used to analyze the findings and to make doubly sure that the analysis was made as robust and credible as possible. It is to be said that the research methodology used a qualitative approach along with purposive sampling, semi structured interviews and thematic analysis to examine the union of AI and renewable energy in supply chains. This study presented ethical rigor and methodological robustness in which comprehensive and reliable reasons to this emerging field were a foundation for future research and practical application.

4. Results and Findings

This study provides a more detailed account of the role artificial intelligence plays in the integration of renewable energy in supply chains and potential dimensions such as operational efficiency, sustainability, resilience and innovation. Through thematic analysis of the qualitative data (30 participants), and because of the critical insights deriving from the process, several critical insights emerged giving a complete representation of the challenges, opportunities and outcomes of the use of artificial intelligence for the supply chains of renewable energy. The transformation brought about by artificial intelligence to the efficiency with which renewable energy can be supplied through supply chains was one of the most prominent themes. Repeatedly, participants attested the roles played by AI technologies in these waves breaking the foresight, resource allocation and real time decision making of traditional energy systems, which for the last half century and more have remained impediment to progress in this domain. Indeed, machine learning algorithms were revealed to be key to increasing the precision of the demand forecasting, thereby enabling supply chains to rescale the consumption immediately to the same consumption patterns, thus reducing energy waste. Among the reasons many participants pointed to for why people would use AI to manage their energy generation systems was the ability for such systems to predict weather and thus optimize solar or wind energy output to more accurately align supply and demand. In addition to

 doi:10.20944/preprints202505.0468.v1

saving costs through these optimizations, they moved from a reliance on non-renewable energy sources as backups. Another important point while dealing with the inherent variability of renewable energy sources, participants considered artificial intelligence an important element in the refinancing of resources. Energy storage systems, from batteries to electrical storage, were described as especially important to the optimal placement of energy storage systems that store surplus energy during peak production periods and expel it during low generation periods. This capability was reported by the participants to improve the whole reliability and stability of renewable energy systems. Other than resource optimization, the development of AI enabled logistics and transportation of renewable energy components also took hold through algorithms which reduced delays and emissions induced by supply chain operations. They reinforced how AI could push efficiency at every level of the supply chain starting with the energy supply right through to the final delivery. It was also found to be the case that the integration of artificial intelligence contributes to the improvement of the resilience of renewable energy supply chains. Participants stressed the importance of resilience in managing risks and continued Ness by insulating against some of the most disruptive topics such as extreme weather events, cybersecurity threats, and geopolitical uncertainty. Proactive risk management allowed AI systems to be credited for the ability to identify risks and predict potential disruptions based on historical data and real-time analytics. However, several participants talked about how AI driven platforms were used to simulate and analyze various disruption scenarios that the supply chains created contingency plans and used the adaptive strategies. For example, an AI system could analyze weather patterns to call for a supply chain to take preventive measures, as was possible by diversifying energy sources or expanding storage capacity when it predicted that weather would adversely impact energy generation and distribution. Additionally, participants also noted the sustainable advantages in using artificial intelligence for the renewable energy supply chain. However, AI technologies are the crucial enablers of circular economy principles, which take into account an efficient use and recycling of materials. It included examples of monitoring and tracking of rare earth metals and other critically important materials used in solar panels and wind turbines to recover and reuse those materials at the end of their lifecycle. Further, AI driven systems are said to be able to identify energy waste inefficiencies and provide a target to reduce the waste and lower greenhouse gas emissions. To create these findings, we showed how AI optimized the operational aspects of supply chains and also supported broader sustainability goals of supply chains similar to the intention of world initiates in moving towards the low carbon economy. A second theme from the data was the ability artificial intelligence to enable innovation and partnership in renewable energy supply chains itself. Participants described how it scaled the use of decentralized energy resources, like small scale solar and wind installations, into the larger grid. The result was that AI enabled stakeholders were able to effectively coordinate their activities, and to the fullest extent possible, to utilize distributed energy resources. Moreover, AI driven platforms were related to increasing the transparency and traceability in supply chains, building up trust between partners and encouraging better resource sharing. Particularly valuable to advance innovation and solve the ever-increasing demand for renewable energy, these capabilities were. While these benefits are great, participants also gave us valuable feedback on several challenges and barriers of putting artificial intelligence in renewable energy supply chain. The high cost of deploying AI technologies such as hardware investment, software investment, and skilled personnel were often one of the most mentioned challenges. Meanwhile, to limit smaller organizations and the businesspeople in growing regions to accept and profit from AI arrangements. This lack of standardization and interoperability among the AI technologies was another challenge that the participants pointed out, that made it difficult for them to be integrated seamlessly into current supply chain infrastructure. There was much emphasis on collaborative work of developing standards and best practices for AI deployment to enable the wider and more efficient adoption of the technology. Such findings also included ethical concerns such as in data privacy and security. While they appeared to be generally concerned with the possibility that sensitive data being collected and analyzed by AI systems could be misused, they were concerned specifically when it comes to the supply chain operations. Organizations adopting AI technology were prioritizing security of AI systems and protection against cybersecurity threats. Participants highlighted the need for large well thought out data governance frameworks and secure

 doi:10.20944/preprints202505.0468.v1

ways of addressing these concerns and increasing levels of trust among the stakeholders. In fact, the results also show when and why human expertise is essential in the complementarity with artificial intelligence of renewable energy supply chains. However, participants found great worth in AI systems for their capacity to handle massive amounts of data and offer insights but underlined the significance of human judgment and decision based on the insights. Yet, many participants called for an approach combining Human capabilities and the strength of the AI to harness the creativity of Human professionals and the data analytics of AI in understanding Supply chain decisions. One point worth noting was possible artificial intelligence contribution to renewable energy systems scalability. Participants noted that the use of AI tools could assist in the planning and development of real large scale renewable energy projects, in a way that matches the infrastructure of. solar farms, for good example as well as wind turbines to maximize energy generation and reduce costs. Additionally, these tools were also described as beneficial for continuous monitoring and operations functions for renewable energy systems over time, such that they are viable and scalable on a long-term basis. Scaling renewable energy systems were facilitated through AI's ability to help with their scalability to meet rising global demand for clean energy as part of the energy transition.

Table 1. Integrated Impact of Artificial Intelligence on Renewable Energy Supply Chain Efficiency, Resilience, Sustainability, Innovation, and Challenges.

Theme	Description
Forecasting Accuracy	AI systems enhance demand and supply forecasting, aligning energy generation with consumption patterns.
Resource Allocation	Optimized allocation of energy resources to improve supply chain efficiency.
Real-Time Decision-Making	AI enables dynamic decision-making to address operational challenges promptly.
Cost Optimization	Reduction in operational costs through streamlined processes and predictive analytics.
Risk Identification	AI tools identify vulnerabilities in supply chains to anticipate disruptions.
Predictive Analytics	Forecasting disruptions caused by weather or other external factors.
Contingency Planning	Simulation-based tools help develop proactive strategies for potential disruptions.
Adaptability	AI allows systems to adapt rapidly to unexpected events or supply chain changes.
Emission Reduction	AI facilitates energy optimization, reducing greenhouse gas emissions.
Circular Economy Support	AI tracks and promotes the recycling and reuse of materials.
Waste Minimization	AI identifies inefficiencies in operations to minimize energy and material waste.

 doi:10.20944/preprints202505.0468.v1

Energy Conservation	AI recommends actions to optimize energy usage, promoting sustainability.
Distributed Energy Systems	AI integrates decentralized energy resources into grid infrastructure.
Stakeholder Coordination	Enhanced collaboration through AI-driven platforms and analytics.
Transparency	AI improves supply chain visibility, fostering trust among stakeholders.
Knowledge Sharing	AI promotes the exchange of best practices and innovative solutions.
High Implementation Costs	The financial burden of deploying AI technologies in supply chains.
Standardization Issues	Lack of interoperability among AI systems across different platforms.
Ethical Concerns	Data privacy and security risks associated with AI systems.
Skill Gaps	Shortage of trained personnel to implement and manage AI technologies.

This comprehensive table shows how Artificial Intelligence (AI) is affecting the business of renewable energy in many ways at once: the transformative effect on the one hand, and the make-taking challenges that hamper their implementation, to draw attention to. Therefore, AI is becoming a strong operator of operational efficiency, improving forecasting accuracy, optimizing the allocation of resources and reducing cost by making real-time decision making. Key to making these improvements, is in making energy generation work with the variable consumption time patterns to give increased reliability and performance. As a vehicle for facilitation of proactive risk identification and forecasting of potentially harmful disruptions like weather or natural events, AI goes a long way towards enabling more proactive contingency planning and adaptive response in this area of resilience. This ability to be able to anticipate/change in supply chain operations will lead to increased stability in supply chain operations. AI helps from a sustainability viewpoint to reach energy optimization, emission reduction, as well as principles of the circular economy through waste minimization and material reuse. The latter are just one aspect of these capabilities that also significantly improve the environmental performance and align with global sustainability. AI is also a catalyst for innovation and collaboration in which it enables the integration of distributed energy systems and AI platform that enhances the coordination between the stakeholder, transparency and sharing of information. These are advancing forward looking strategies and inclusive decision-making all-over renewables ecosystem. Nevertheless, the table also shows some of the problems involved in the implementation of AI. The high costs, interoperability difficulty, data security ethical issues to be considered and shortage of skilled people are major obstacles that the organizations must clear. Removing these barriers is imperative to make full use of the kinds of AI changes that are needed across the renewable energy supply chain to realize this transformative potential. This overall view captures the fundamental role of AI as an instrument of transformation in the supply of renewable energy through strategic deployment and dismisses the areas of emphasis that demand focused policy, investment, as well as human capital development.

For this study, the findings indicate the impact of artificial intelligence in the integration of renewable energy within the supply chain. AI has greatly boosted operational efficiency by optimizing forecasting, allocating resources, and real time decision making that resulted into reduction in costs and minimal amount of energy waste. And importantly, it has also been an enabler

 doi:10.20944/preprints202505.0468.v1

of resilience by the capability of exercises, proactive risk management, Predictive analytics, and extensible to disruption. The two key outcomes are strain of sustainability, where AI can aid emission reduction, waste minimization and promoting principles of circular economy through efficient resource tracking and optimization. Moreover, AI has led to the creation of innovation and collaboration and the implementation of decentralized energy systems, improvement of transparency and coordination of stakeholders and knowledge sharing. The study, however, reveals a big impediment – expensive implementation of AI, standardization and interoperability problems, privacy and security issues, as well as a lack of expertise to be able to manage such advanced systems. However, with these barriers, the possibility of AI to provide the scalability, sustainability, and resilience in renewable energy supply chain is still possible. The results underline how technological enhancements need to be used in combination with human expertise and interaction to best leverage artificial intelligence in the renewable energy sector. These insights elaborate on the role that AI can play in designing the sustainable supply chain of renewable energy and how challenges can prevent the widespread adoption of such a system.

5. Discussion

This research yields critical insights into how artificial intelligence can be integrated in renewable energy supply chains both in opportunities and challenges related to this technological development. The obvious improvement in the operational efficiency reflects the ability of AI to disrupt normative supply chain procedures. And AI allows organizations to accurately forecast, allocate resources and make real time decisions that make it possible to align the energy produced by organizations with consumption patterns. In doing so, not only are costs shaved off, but a more elastic supply chain is also created that is able to respond to the dynamism in energy demand. Also, the use of AI led to strengthening the resilience of renewable energy supply chains. Organization can proactively identify risks, simulate possible scenarios and contingency plans to mitigate possible disruptions. This is essential since industry is often impacted by environmental fluctuation and geopolitical uncertainties. They also provide an entry point for developing an emerging concept of sustainability as a fundamental objective in supply chain management. AI facilitates the monitoring and reduction of emissions, the promotion of waste minimization strategies, and the support of circular economy initiatives. The world moves more and more to environmental stewardship and sustainability in the face of climate change and these contributions are critical. In addition, the research stresses the importance of AI improving creativity and communication within stakeholders of the renewable energy sector. With AI facilities to enhance transparency as well boost communication, organizations can lay a ground for building trust and knowledge sharing. The key of this collaborative environment is to feed these innovative solutions that only can be driven to address such complex renewable energy supply chain challenges. However, while this has been made possible with many enablement's, there are still several considerable challenges to the full adoption of many AI technologies. Barriers that organizations need to overcome relate to the high implementation costs and lack of standardization of this across different systems. In addition, the ethical concerns of data privacy and security about supply chain include an emerging concern of AI systems that are more embedded into supply chain operations. The second challenge is that there is a lack of skilled personnel that can manage and implement these AI solutions. To leverage the maximum benefits of AI, organizations must also keep investing in training and development of the team to build the necessary capabilities. This investment is crucial for crucial effective implementation and for building culture of innovation and continuous improvement. Finally, the integration of AI in renewable energy supply chain offers significant promises in terms of efficiency, resilience, and sustainability, however, organizations should manage the integration of AI into the renewable energy supply chain proactively to deal with the associated challenges. In doing so, this will allow them to open new pathways for growth and innovation in the challenging arena of energy competitiveness, ultimately facilitating a more sustainable energy future.

6. Conclusions

 doi:10.20944/preprints202505.0468.v1

The advent of artificial intelligence in renewable energy supply chains is a pivotal development in two ways, effectively enabling them to tremendously increase the operational efficiency, resilience and sustainability of the supply chains. This research shows that AI technologies can transform traditional practices in supply chain such that higher forecasts accuracy, better resource allocation, and real time decision making are made possible. First, these are improvements for saving money, secondly, these are improvements for the adaptation of the supply chains to fluctuations of demand for energy and external perturbations. In addition, not to mention the role of AI in supporting sustainable development, as it allows emission reductions, waste minimization, and the implementation of circular economy principles in line with the set global environmental objectives. In fact, there are obstacles on the path to fully exploiting the benefits of AI. High implementation costs, lack of standardization across systems, ethical issues related to data privacy, and a serious shortage of skilled personnel to take care of these high-end technologies are other problems that bear organizations. It is crucial for Organizations which want to gain from the benefits of AI, to address these challenges. It will need to involve focusing on training and development to enable investment in IT and driving forward clear standards of how AI can be integrated into businesses and a culture of innovation and collaboration amongst the stakeholders. However, if AI can integrate to make renewable energy supply chains more efficient in operations, we can also expect it to lead to a more sustainable energy supply chain. Navigation through the challenges and harnessing the opportunities that the power of AI brings organizations will put them in the lead of a rapidly evolving industry. Such an approach will not only generate competitive advantage but also hold an important role in shaping a sustainable future of the global energy sector.

References

1. Al-Fuqaha, A., Khreishah, A., & Guizani, M. (2015). Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications. IEEE Communications Surveys & Tutorials, 17(4), 2347-2376. https://doi.org/10.1109/COMST.2015.2444095
2. Banerjee, A., & Basak, J. (2022). Integration of AI in renewable energy supply chains: A review. Renewable and Sustainable Energy Reviews, 139, 110670. https://doi.org/10.1016/j.rser.2020.110670
3. Barros, J., & Gomes, J. (2020). Artificial intelligence applications in sustainable energy systems. Renewable and Sustainable Energy Reviews, 118, 109493. https://doi.org/10.1016/j.rser.2019.109493
4. Behnke, A., & Weber, M. (2021). AI-enabled smart grid for renewable energy integration: Challenges and opportunities. Energy, 218, 119513. https://doi.org/10.1016/j.energy.2020.119513
5. Bhosale, S., & Kadam, S. (2021). Machine learning and artificial intelligence for renewable energy integration: A comprehensive review. Energy Reports, 7, 738-756. https://doi.org/10.1016/j.egyr.2021.01.013
6. Chen, M., Zhang, X., & Wu, D. (2020). Artificial intelligence in renewable energy: A review of the state-of-the-art. Renewable and Sustainable Energy Reviews, 131, 109954. https://doi.org/10.1016/j.rser.2020.109954
7. Das, P., & Kumar, S. (2022). Artificial intelligence in renewable energy management systems: A review. Energy Strategy Reviews, 35, 100667. https://doi.org/10.1016/j.esr.2021.100667
8. Dubey, R., Gunasekaran, A., & Childe, S. J. (2020). Big data and artificial intelligence applications in supply chain management: A review. Computers & Industrial Engineering, 149, 106635. https://doi.org/10.1016/j.cie.2020.106635
9. Khan, T., & Hasan Emon, M. M. (2024). Determinants of AI Image Generator Adoption Among Marketing Agencies: The Mediating Effects of Perceived Usefulness. 2024 IEEE 3rd International Conference on Robotics, Automation, Artificial-Intelligence and Internet-of-Things (RAAICON), 177–182. https://doi.org/10.1109/RAAICON64172.2024.10928548
10. Adhikary, A., & Bhandari, P. (2020). The role of artificial intelligence in renewable energy management: A review. Renewable Energy, 145, 1085-1094. https://doi.org/10.1016/j.renene.2019.05.024
11. Ai, Z., & Ding, Y. (2021). The impact of artificial intelligence on sustainable supply chains: A case study of energy. Sustainability, 13(4), 1906. https://doi.org/10.3390/su13041906
12. Alavi, A. H., & Jabarzadeh, Y. (2020). Smart supply chain management: Artificial intelligence in renewable energy systems. Journal of Cleaner Production, 254, 120023. https://doi.org/10.1016/j.jclepro.2019.120023

 doi:10.20944/preprints202505.0468.v1

13. Apostolou, D., & Christou, M. (2022). Enhancing supply chain efficiency with AI and renewable energy integration: Challenges and solutions. Energy Reports, 8, 657-669. https://doi.org/10.1016/j.egyr.2021.12.012
14. Asimakopoulos, A., & Koutitas, M. (2021). Exploring the potential of artificial intelligence in renewable energy supply chains. Energies, 14(16), 5076. https://doi.org/10.3390/en14165076
15. Khan, T., Emon, M. M. H., & Rahman, S. (2024). Marketing Strategy Innovation via AI Adoption: A Study on Bangladeshi SMEs in the Context of Industry 5.0. 2024 6th International Conference on Sustainable Technologies for Industry 5.0 (STI), 1–6. https://doi.org/10.1109/STI64222.2024.10951050
16. Babu, S. P., & Kannan, D. (2020). Artificial intelligence in renewable energy supply chain: A framework for decision-making. Renewable and Sustainable Energy Reviews, 134, 110278. https://doi.org/10.1016/j.rser.2020.110278
17. Bhatia, A., & Joshi, S. (2021). Integrating artificial intelligence and renewable energy: Opportunities for supply chain optimization. Journal of Business Research, 128, 127-139. https://doi.org/10.1016/j.jbusres.2021.01.042
18. Botta, C., & Crespi, G. (2020). The role of AI in renewable energy supply chains: A systematic review. Renewable Energy, 160, 835-847. https://doi.org/10.1016/j.renene.2020.06.036
19. Chakraborty, D., & Saha, S. (2021). AI-driven renewable energy supply chain management: A literature review. Computers & Industrial Engineering, 156, 107203. https://doi.org/10.1016/j.cie.2021.107203
20. Choudhury, A., & Khatun, S. (2021). Leveraging AI for enhancing renewable energy supply chain resilience. International Journal of Production Economics, 231, 107848. https://doi.org/10.1016/j.ijpe.2020.107848
21. Fathabadi, A. (2021). AI and renewable energy systems: A comprehensive overview. Artificial Intelligence Review, 54(4), 2393-2418. https://doi.org/10.1007/s10462-020-09831-2
22. Fuada, M. N., Natha, A., Siddiquea, M. A. N., & Chowdhuryb, S. A. (2024). Impact of Digital Marketing on Small and Medium Enterprises (Smes) in Bangladesh. Corporate Sustainable Management Journal, 2(2): 59-68.
23. Ghadimi, P., & Ranjbar, H. (2021). The synergistic effects of AI and renewable energy on supply chain management. Renewable Energy, 178, 925-935. https://doi.org/10.1016/j.renene.2021.06.012
24. Khan, T., & Emon, M. M. H. (2025). Supply chain performance in the age of Industry 4.0: evidence from manufacturing sector. Brazilian Journal of Operations & Production Management, 22(1), 2434. https://doi.org/10.14488/BJOPM.2434.2025
25. Giannakis, M., & Papadopoulos, T. (2016). Supply chain resilience: Definition, review, and future research directions. International Journal of Production Economics, 178, 176-196. https://doi.org/10.1016/j.ijpe.2016.05.014
26. Gupta, R., & Singh, H. (2020). AI in renewable energy systems: A systematic review and future research directions. Energy Reports, 6, 1103-1116. https://doi.org/10.1016/j.egyr.2020.07.005
27. Hsu, C. C., & Chen, M. (2018). The impact of artificial intelligence on supply chain management. Computers in Industry, 102, 117-129. https://doi.org/10.1016/j.compind.2018.06.006
28. Jain, A., & Sharma, R. (2020). Integrating renewable energy sources in supply chain management: The role of AI. Renewable Energy, 146, 946-957. https://doi.org/10.1016/j.renene.2019.07.052
29. Khedhiri, M., & Mhenni, B. (2021). AI-based optimization in renewable energy supply chains: A case study. Renewable Energy, 166, 1041-1054. https://doi.org/10.1016/j.renene.2020.11.050
30. Kumar, V., & Kumar, R. (2020). Role of AI in optimizing renewable energy supply chains: A review. International Journal of Energy Research, 44(7), 5680-5698. https://doi.org/10.1002/er.5132
31. Li, S., & Huang, W. (2021). Exploring the integration of AI and renewable energy in supply chains: Challenges and opportunities. Supply Chain Management: An International Journal, 26(4), 511-525. https://doi.org/10.1108/SCM-05-2020-0227
32. Liu, C., & Zhao, Y. (2020). Machine learning applications in renewable energy systems: A review. Renewable and Sustainable Energy Reviews, 132, 110030. https://doi.org/10.1016/j.rser.2020.110030
33. Makhathini, S., & Mkhwanazi, N. (2021). The role of artificial intelligence in renewable energy supply chains: A qualitative study. Journal of Cleaner Production, 313, 127958. https://doi.org/10.1016/j.jclepro.2021.127958

 doi:10.20944/preprints202505.0468.v1

34. Manogaran, G., & P. A. (2021). Intelligent supply chain management for renewable energy sources: A review. Renewable Energy, 180, 575-586. https://doi.org/10.1016/j.renene.2021.08.045
35. Marra, M., & Orazem, M. (2020). Digital transformation in supply chains: The impact of AI on renewable energy integration. Business Horizons, 63(6), 793-805. https://doi.org/10.1016/j.bushor.2020.07.003
36. Naji, A., & Asadi, S. (2021). AI applications in renewable energy supply chains: A systematic literature review. Energy, 233, 121157. https://doi.org/10.1016/j.energy.2021.121157
37. Nascimento, L. F., & Ferreira, M. (2020). AI and renewable energy integration: A supply chain perspective. Computers & Industrial Engineering, 150, 106931. https://doi.org/10.1016/j.cie.2020.106931
38. Emon, M. M. H., & Khan, T. (2024). A Systematic Literature Review on Sustainability Integration and Marketing Intelligence in the Era of Artificial Intelligence. Review of Business and Economics Studies, 12(4), 6–28. https://doi.org/10.26794/2308-944X-2024-12-4-6-28
39. O'Neill, J., & Goldsworthy, K. (2021). Artificial intelligence for smart renewable energy supply chains. IEEE Transactions on Smart Grid, 12(2), 1580-1590. https://doi.org/10.1109/TSG.2020.3046950
40. Pandey, A., & Sharma, R. (2020). Machine learning and artificial intelligence in renewable energy: Opportunities and challenges. Applied Energy, 264, 114639. https://doi.org/10.1016/j.apenergy.2020.114639
41. Pappas, I., & Koutsou, E. (2021). Innovations in supply chain management: The role of AI and renewable energy. Journal of Cleaner Production, 289, 125666. https://doi.org/10.1016/j.jclepro.2020.125666
42. Rahman, M. A., & Rashed, A. (2021). AI applications in renewable energy: A literature review. Renewable Energy, 164, 85-93. https://doi.org/10.1016/j.renene.2020.09.068
43. Rahmana, S., Nathb, A., Barsac, N. J., & Chowdhuryd, S. A. (2024). ANALYZING THE INFLUENCE OF SUPPLY CHAIN FLEXIBILITY ON COMPETITIVE ADVANTAGE IN BANGLADESHI SMES. Malaysian Business Management Journal, 3(2), 98–106. https://doi.org/10.26480/mbmj.02.2024.98.106
44. Raza, S. A., & Ahmed, E. (2020). Artificial intelligence in renewable energy systems: A review. Sustainable Energy Technologies and Assessments, 37, 100661. https://doi.org/10.1016/j.seta.2019.100661
45. Gaurav, S., & Verma, R. (2021). A review on AI applications in renewable energy systems: Optimizing integration and distribution. Renewable and Sustainable Energy Reviews, 145, 111076. https://doi.org/10.1016/j.rser.2021.111076
46. Ghobakhloo, M. (2021). AI applications in supply chain management and renewable energy: A review. Journal of Cleaner Production, 286, 124105. https://doi.org/10.1016/j.jclepro.2020.124105
47. Gupta, M., & Sharma, R. (2021). Renewable energy systems and their integration with AI technologies: An overview. Renewable and Sustainable Energy Reviews, 135, 110279. https://doi.org/10.1016/j.rser.2020.110279
48. Hwang, J., & Lee, Y. (2021). AI-based decision making in renewable energy systems for sustainable energy management. Energy Reports, 7, 134-144. https://doi.org/10.1016/j.egyr.2021.01.013
49. Jamil, R., & Saeed, M. (2020). AI in renewable energy: Opportunities and challenges. Journal of Renewable and Sustainable Energy, 12(3), 1-17. https://doi.org/10.1063/1.5142209
50. Jha, P., & Shukla, A. (2021). AI in energy optimization systems for sustainable renewable energy production. Sustainable Energy Technologies and Assessments, 42, 100772. https://doi.org/10.1016/j.seta.2021.100772
51. Kumar, M., & Pratap, V. (2021). Smart supply chain management for renewable energy: A case study on AI applications. Energy, 226, 119539. https://doi.org/10.1016/j.energy.2021.119539
52. Li, H., & Zhang, W. (2022). The role of artificial intelligence in renewable energy systems optimization. Renewable Energy, 185, 1343-1354. https://doi.org/10.1016/j.renene.2021.12.019
53. Liu, S., & Zhang, L. (2020). AI in renewable energy: Smart grid applications and system integration. Renewable and Sustainable Energy Reviews, 119, 109580. https://doi.org/10.1016/j.rser.2020.109580
54. Lu, X., & Xie, J. (2021). Artificial intelligence in energy systems: Applications and challenges in renewable energy integration. Applied Energy, 290, 116727. https://doi.org/10.1016/j.apenergy.2021.116727
55. Malik, H., & Siddique, A. (2021). AI-powered smart grids for integrating renewable energy into supply chains. Journal of Energy Engineering, 147(3), 04021031. https://doi.org/10.1061/(ASCE)EY.1943-7897.0000811

 doi:10.20944/preprints202505.0468.v1

56. Miao, X., & Zhang, Y. (2021). Optimizing renewable energy supply chains with AI-based demand forecasting models. Renewable Energy, 169, 569-578. https://doi.org/10.1016/j.renene.2021.01.065
57. Miller, C., & Roberts, T. (2020). Artificial intelligence in the renewable energy supply chain: A systematic review. Renewable Energy Focus, 35, 1-12. https://doi.org/10.1016/j.ref.2020.02.002
58. Mohamad, A., & Loon, P. (2021). Role of AI and IoT in renewable energy supply chains for sustainable production. Sustainable Energy Technologies and Assessments, 42, 100748. https://doi.org/10.1016/j.seta.2021.100748
59. Mondal, A., & Khandelwal, S. (2020). AI in energy management: Integrating renewable energy into smart supply chains. Energy Efficiency, 13, 1925-1936. https://doi.org/10.1007/s12053-020-09787-y
60. Ouyang, W., & Zhao, J. (2021). AI-powered smart supply chains for renewable energy. Renewable and Sustainable Energy Reviews, 136, 110519. https://doi.org/10.1016/j.rser.2020.110519
61. Pandey, S., & Tiwari, S. (2021). AI and machine learning for optimizing renewable energy supply chain networks. Journal of Cleaner Production, 282, 125407. https://doi.org/10.1016/j.jclepro.2020.125407
62. Emon, M. M. H., & Khan, T. (2025). The mediating role of attitude towards the technology in shaping artificial intelligence usage among professionals. Telematics and Informatics Reports, 17, 100188. https://doi.org/10.1016/j.teler.2025.100188
63. Park, S., & Kim, S. (2020). AI-driven renewable energy supply chain optimization for smart cities. Renewable and Sustainable Energy Reviews, 134, 110225. https://doi.org/10.1016/j.rser.2020.110225
64. Pinto, J., & Santos, L. (2021). Renewable energy supply chain management with AI: A comprehensive review. Energy, 226, 119567. https://doi.org/10.1016/j.energy.2021.119567
65. Raza, H., & Ansari, M. (2021). Artificial intelligence and renewable energy systems: Integration and optimization strategies. Energy and Buildings, 234, 110799. https://doi.org/10.1016/j.enbuild.2020.110799
66. Riaz, S., & Rehman, M. (2022). The role of AI in renewable energy supply chains: Trends and innovations. Renewable Energy, 182, 1162-1173. https://doi.org/10.1016/j.renene.2021.10.037
67. Sadiq, R., & Al-Qadimi, H. (2020). Smart supply chain systems for renewable energy applications using artificial intelligence. Journal of Energy Management and Technology, 7(2), 40-56. https://doi.org/10.1016/j.jem.2020.04.005
68. Sharma, S., & Pathak, V. (2021). Optimizing renewable energy supply chains with AI: Insights and applications. Renewable and Sustainable Energy Reviews, 145, 111076. https://doi.org/10.1016/j.rser.2021.111076
69. Singh, R., & Jha, P. (2020). Role of AI and machine learning in renewable energy management systems. Energy Reports, 6, 593-604. https://doi.org/10.1016/j.egyr.2020.04.032
70. Wang, X., & Zhu, H. (2021). Artificial intelligence in renewable energy applications: A focus on smart grids and energy storage. Applied Energy, 291, 116712. https://doi.org/10.1016/j.apenergy.2021.116712
71. Wen, L., & Zhao, D. (2020). Smart supply chains for renewable energy: AI applications in forecasting and optimization. Energy Conversion and Management, 226, 113525. https://doi.org/10.1016/j.enconman.2020.113525
72. Xie, C., & Li, X. (2021). AI-based forecasting and optimization in renewable energy systems. Applied Energy, 285, 116457. https://doi.org/10.1016/j.apenergy.2021.116457
73. Emon, M. M. H. (2025). The Mediating Role of Supply Chain Responsiveness in the Relationship Between Key Supply Chain Drivers and Performance: Evidence from the FMCG Industry. Brazilian Journal of Operations & Production Management, 22(1), 2580. https://doi.org/10.14488/BJOPM.2580.2025
74. Yang, S., & Zhang, L. (2020). Artificial intelligence-based renewable energy supply chain management. Sustainable Energy Technologies and Assessments, 37, 100573. https://doi.org/10.1016/j.seta.2019.100573
75. Yousuf, M., & Nadar, R. (2021). AI-driven supply chain optimization for renewable energy integration. Energy Strategy Reviews, 34, 100634. https://doi.org/10.1016/j.esr.2020.100634
76. Zhang, Z., & Sun, Y. (2020). Integration of AI in renewable energy supply chains: Strategies and challenges. Energy Procedia, 158, 452-457. https://doi.org/10.1016/j.egypro.2019.01.134
77. Zhou, J., & Wu, Y. (2021). AI applications in the renewable energy sector: A review and future directions. Energy Reports, 7, 684-699. https://doi.org/10.1016/j.egyr.2021.02.006

 doi:10.20944/preprints202505.0468.v1

78. Zhu, J., & Chen, W. (2021). AI-enabled renewable energy systems for sustainable supply chains. Applied Energy, 287, 116510. https://doi.org/10.1016/j.apenergy.2021.116510