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(Review Article)

The safety and environmental impacts of battery storage systems in renewable energy

Peter Simpa [1], Nko Okina Solomon [2,*], Olubunmi Adeolu Adenekan [3] and Scholar Chinenye Obasi [4]

[1] *Faculty of Science and Engineering, University of Hull, United Kingdom.*
[2] *Environmental Health and safety, Marshall University Huntington West Virginia. USA.*
[3] *Independent Telecommunications Engineer and Data Analyst, United Kingdom.*
[4] *University of South Wales, United Kingdom.*

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Abstract

The integration of battery storage systems in renewable energy infrastructure has garnered significant attention due to its potential to enhance energy reliability, efficiency, and sustainability. However, alongside these benefits, concerns persist regarding the safety and environmental impacts associated with the deployment and operation of such systems. This review explores the multifaceted aspects of safety and environmental considerations in battery storage systems within the context of renewable energy. Firstly, safety concerns encompass a range of factors, including thermal runaway, fire hazards, and chemical leakage, which pose risks to both human life and property. Mitigation strategies such as advanced battery management systems and fire suppression technologies are critical for addressing these risks effectively. Secondly, environmental impacts arise throughout the lifecycle of battery storage systems, from raw material extraction to end-of-life disposal. Key issues include resource depletion, greenhouse gas emissions, and pollution from mining activities. Sustainable practices such as responsible sourcing of materials, recycling initiatives, and the development of second-life applications are essential for minimizing environmental footprints. Furthermore, the interaction between battery storage systems and renewable energy sources introduces complexities in assessing environmental impacts. While battery storage facilitates the integration of intermittent renewables like solar and wind by providing grid stabilization and energy storage capabilities, its environmental benefits may be compromised by factors such as energy-intensive manufacturing processes and reliance on non-renewable resources. The safety and environmental impacts of battery storage systems in renewable energy demand comprehensive evaluation and management strategies to maximize benefits while minimizing risks. Collaboration among stakeholders, technological innovation, and regulatory frameworks are crucial for promoting the sustainable deployment and operation of these systems in the transition towards a cleaner and more resilient energy future.

Keyword: Safety; Environmental; Battery; Storage; Renewable Energy; Review

1. Introduction

The rapid growth of renewable energy sources, such as solar and wind power, has led to an increased need for effective energy storage solutions to address intermittency and grid stability challenges (Basit et al., 2020). Battery storage systems have emerged as a promising technology to store excess energy generated from renewables and release it when needed, thereby facilitating a more reliable and resilient energy infrastructure (Abaku, & Odimarha, 2024, Fawole, et. al., 2023, Fetuga, et. al. 2023, Wiggins, et. al., 2023). These systems play a crucial role in enabling the widespread adoption of renewable energy and reducing dependence on fossil fuels, contributing to global efforts to mitigate climate change and transition towards a sustainable energy future (Suman, 2021).

* Corresponding author: Nko Okina Solomon

While the integration of battery storage systems offers numerous benefits for the renewable energy sector, it also brings forth significant safety and environmental concerns (Abaku, & Odimarha, 2024, Familoni, Abaku & Odimarha, 2024, Fetuga, et. al. 2023). The operation, maintenance, and end-of-life disposal of batteries pose risks to human health, property, and the natural environment. Safety hazards such as thermal runaway, fire incidents, and chemical leakage can have catastrophic consequences, necessitating stringent safety measures and protocols (Abaku, Edunjobi & Odimarha, 2024, Familoni, Abaku & Odimarha, 2024, Igbinenikaro & Adewusi, 2024). Additionally, the environmental impacts associated with battery manufacturing, resource extraction, and disposal raise concerns about sustainability and long-term viability (Fan et al.,2020).

The primary objective of this paper is to comprehensively examine the safety and environmental impacts of battery storage systems within the context of renewable energy. It aims to explore the various safety hazards inherent in battery technologies, analyze the environmental footprint throughout their lifecycle, and identify sustainable practices and solutions to mitigate adverse effects. Furthermore, the paper will discuss the interactions between battery storage systems and renewable energy sources, highlighting both challenges and opportunities for enhancing sustainability (Behabtu et al.,2020). By addressing these critical issues, this paper seeks to inform policymakers, industry stakeholders, and researchers about the importance of prioritizing safety and environmental considerations in the deployment and management of battery storage systems for renewable energy applications (Abolarin, et. al., 2023, Eyo-Udo, Odimarha & Kolade, 2024, Igbinenikaro & Adewusi, 2024).

1.1. Safety Concerns in Battery Storage Systems

The integration of battery storage systems in renewable energy infrastructure has revolutionized the energy landscape, providing vital support for the transition towards a cleaner and more sustainable future (Zohuri, 2023). However, alongside their numerous benefits, battery storage systems also present significant safety concerns that must be carefully addressed to ensure the protection of human life, property, and the environment (Abolarin, et. al., 2023, Eyo-Udo, Odimarha & Ejairu, 2024, Igbinenikaro & Adewusi, 2024). This review delves into the primary safety concerns associated with battery storage systems, including thermal runaway and fire hazards, chemical leakage, and explores mitigation strategies to manage these risks effectively (Xu et al.,2021).

Thermal runaway refers to a chain reaction within a battery cell, typically lithium-ion batteries, characterized by uncontrollable heat generation, which can lead to catastrophic consequences such as fire or explosion (Wang and Shu, 2022). Several factors contribute to thermal runaway, including overcharging, manufacturing defects, physical damage, and exposure to high temperatures. Once initiated, thermal runaway can propagate rapidly, causing severe damage to equipment and infrastructure, as well as posing a significant risk to personnel and nearby communities (Adama & Okeke, 2024, Emeka-Okoli, et. al., 2024, Igbinenikaro & Adewusi, 2024).

Case studies illustrate the potentially devastating effects of thermal runaway incidents (Zhang et al.,2021). For instance, the 2019 blaze at a lithium-ion battery facility in Arizona resulted in the release of toxic fumes, extensive property damage, and forced evacuations in the surrounding area. Similarly, the 2016 Samsung Galaxy Note 7 recall was prompted by reports of battery explosions, highlighting the importance of rigorous safety measures in battery design and manufacturing processes to prevent such incidents (Diaz et al.,2020; Njemanze et al., 2008).

Certain types of batteries, particularly lead-acid batteries, are prone to chemical leakage, which can occur due to damage, corrosion, or improper handling (Schismenos ,2021). Chemical leakage poses significant risks to both human health and the environment, as it can lead to the release of toxic substances such as sulfuric acid and heavy metals into the surrounding soil, water, and air (Adama & Okeke, 2024, Emeka-Okoli, et. al., 2024, Igbinenikaro & Adewusi, 2024). Exposure to these hazardous materials can cause respiratory problems, skin irritation, and long-term health issues in humans, while also contributing to environmental pollution and ecosystem degradation (Ukaogo ,2020; Akagha et al., 2023).

To address safety concerns in battery storage systems, various mitigation strategies have been developed to minimize the risks associated with thermal runaway, fire hazards, and chemical leakage; BMS utilizes sophisticated algorithms and sensors to monitor and control battery performance in real-time, detecting abnormalities such as overcharging, over-discharging, and temperature fluctuations (Adama & Okeke, 2024, Emeka-Okoli, et. al., 2024, Igbinenikaro, Adekoya & Etukudoh, 2024). By actively managing battery parameters, BMS can prevent thermal runaway events and optimize battery performance while ensuring safe operation (Chavan et al.,2023; Uzougbo et al., 2023).

Fire suppression technologies, including fire extinguishing agents, thermal barriers, and enclosure designs, are essential for containing and extinguishing fires in battery storage systems (Zhang et al.,2022; Adebukola et al., 2022). These technologies are designed to suppress flames, cool battery cells, and prevent the spread of fire to adjacent equipment and structures, thereby minimizing damage and protecting personnel.

Regulatory agencies and industry organizations establish stringent standards and guidelines for the design, installation, and operation of battery storage systems to ensure compliance with safety requirements (Adama, et. al., 2024, Emeka-Okoli, et. al., 2024. Igbinenikaro, Adekoya & Etukudoh, 2024). These standards address various aspects of battery safety, including electrical, mechanical, and chemical hazards, and prescribe measures for risk mitigation, emergency response planning, and personnel training (Bin and Lim, 2023; Chidolue et al., 2023).

In conclusion, safety concerns in battery storage systems represent significant challenges that must be addressed through proactive risk management strategies and regulatory oversight. By understanding the causes and consequences of thermal runaway, fire hazards, and chemical leakage, and implementing appropriate mitigation measures such as advanced battery management systems, fire suppression technologies, and regulatory standards, the industry can ensure the safe and responsible deployment of battery storage systems in renewable energy applications (Adama, et. al., 2024, Emeka-Okoli, et. al., 2024, Igbinenikaro, Adekoya & Etukudoh, 2024). Through collaborative efforts between policymakers, industry stakeholders, and researchers, we can mitigate safety risks and foster the continued growth and sustainability of battery storage technologies in the global energy transition (Kalair al.,2021).

1.2. Environmental Impacts throughout the Lifecycle

The environmental footprint of battery storage systems extends across their entire lifecycle, from raw material extraction to end-of-life disposal (Pellow et al.,2020). This review examines the environmental impacts associated with each stage, including raw material extraction, manufacturing processes, the operation phase, and end-of-life disposal, and explores challenges and potential solutions to mitigate these impacts (Ali et al.,2023).

The extraction of raw materials such as lithium, cobalt, nickel, and rare earth metals for battery production can lead to resource depletion, as these materials are finite and non-renewable (Adama, et. al., 2024, Ekemezie & Digitemie, 2024, Igbinenikaro, Adekoya & Etukudoh, 2024, Usiagu, et. al., 2023). The increasing demand for batteries exacerbates pressure on natural resources, raising concerns about long-term sustainability and equitable access to essential minerals (Dou et al.,2023). Mining operations for battery materials often result in environmental degradation, including deforestation, soil erosion, habitat destruction, and water pollution. Extractive activities such as open-pit mining and chemical leaching can contaminate water sources with heavy metals and toxic chemicals, posing risks to local ecosystems and communities (Punia and Singh, 2021). Battery manufacturing processes are energy-intensive, requiring significant amounts of electricity for material processing, fabrication, and assembly (Liu et al.,2021). The reliance on fossil fuels for electricity generation in many regions contributes to greenhouse gas emissions, exacerbating climate change and air pollution. Battery production facilities generate various types of pollution, including air emissions, wastewater discharges, and solid waste disposal (Adama, et. al., 2024, Ekemezie & Digitemie, 2024, Igbinenikaro, Adekoya & Etukudoh, 2024, Usiagu, et. al., 2023). Chemicals used in manufacturing processes, such as solvents, acids, and heavy metals, can contaminate air, soil, and water, posing risks to human health and the environment (Ahmad et al.,2021).

While battery storage systems offer energy storage capabilities to support renewable energy integration, they also consume energy during charging and discharging cycles. Inefficient energy conversion processes and losses in transmission and distribution contribute to energy consumption and emissions during usage, impacting overall system efficiency and environmental performance (Schwarz et al.,2021). The operation of battery storage systems may have indirect impacts on surrounding ecosystems, particularly in sensitive habitats or protected areas. Infrastructure development, land use changes, and disturbance of natural landscapes can disrupt ecosystems, fragment habitats, and threaten biodiversity (Ntshanga ,2021).

End-of-life disposal presents significant challenges due to the complex composition of batteries and limited recycling infrastructure (Duarte ,2022). The recycling of battery materials requires specialized processes to recover valuable metals and minimize waste generation, but these technologies are not widely available or cost-effective. Improper disposal of batteries can lead to the release of hazardous materials into the environment, posing risks to soil, water, and wildlife (Adefemi, et. al., 2024, Ekemezie & Digitemie, 2024, Izuka, et. al., 2023, Uduafemhe, Ewim & Karfe, 2023). Leaching of heavy metals, electrolytes, In conclusion, addressing the environmental impacts of battery storage systems requires holistic approaches that consider the entire lifecycle of batteries, from raw material extraction to end-of-life disposal (Cristóbal et al.,2022). Sustainable practices such as responsible sourcing of materials, energy-efficient manufacturing processes, ecosystem-friendly operation, and effective recycling and waste management are essential for minimizing environmental footprints and promoting the long-term viability of battery storage technologies in renewable energy applications (Rahman, 2022, Ukoba et al., 2017). Collaboration among stakeholders, technological innovation, and regulatory frameworks are crucial for achieving environmental sustainability goals and ensuring a transition towards cleaner and more resilient energy systems (Ajayi & Udeh, 2024, Ekemezie & Digitemie, 2024, Lochab, Ewim & Prakash, 2023, Thompson, et. al., 2022).

1.3. Sustainable Practices and Solutions

As the demand for battery storage systems continues to rise, it becomes imperative to implement sustainable practices and solutions to mitigate their environmental impact and ensure long-term viability (Yang et al.,2021). This review explores key strategies for promoting sustainability in battery storage systems, including responsible sourcing of materials, recycling initiatives, and second-life applications.

Certification programs, such as the Responsible Cobalt Initiative and the Responsible Minerals Initiative, aim to ensure that battery manufacturers source materials ethically and sustainably (Deberdt and Le Billon, 2021). These programs establish standards for responsible mining practices, labor rights, and environmental protection, providing assurance to consumers and stakeholders that batteries are produced in an ethical manner (Ajayi & Udeh, 2024, Ekechi, et. al., 2024, Ewim, et. al. 2023, Kikanme, et. al., Suku, et. al., 2023). Additionally, companies are increasingly adopting ethical supply chain practices, engaging with suppliers to trace the origin of materials and address social and environmental risks throughout the supply chain (Chaudhuri et al.,2021).

Transparency and traceability are crucial for promoting responsible sourcing of materials in battery production (Mancini et al.,2020). By providing detailed information about the origin, extraction methods, and supply chain processes of materials, manufacturers can enhance accountability and identify opportunities for improvement. Technologies such as blockchain and digital tracking systems enable transparent supply chains, allowing stakeholders to verify the authenticity and sustainability of materials used in batteries (Júnior et al.,2022).

Advances in battery recycling technologies have the potential to recover valuable materials from spent batteries, reducing the need for raw material extraction and minimizing waste generation (Spooren et al.,2020; Babawurun et al., 2023). Recycling processes, such as hydrometallurgical and pyrometallurgical methods, enable the recovery of metals like lithium, cobalt, and nickel from battery cells (Ajayi & Udeh, 2024, Ekechi, et. al., 2024, Etukudoh, et. al., 2024, Isadare, et. al., Popoola, et. al., 2024). Additionally, innovations in recycling techniques, such as mechanical shredding and separation, improve the efficiency and scalability of battery recycling operations, making them economically viable (Fan et al.,2020).

Embracing a circular economy approach to battery management involves maximizing resource recovery and minimizing waste throughout the lifecycle of batteries (Harper et al.,2023). By designing batteries for recyclability and incorporating recycled materials into new battery production, manufacturers can reduce environmental impact and conserve natural resources (Blose, et. al., 2023, Daniyan, et. al., 2024, Onwuka & Adu, 2024). Furthermore, establishing closed-loop systems for battery collection, recycling, and remanufacturing promotes circularity and fosters a sustainable supply chain for battery materials (Silva ,2023).

Retired batteries from electric vehicles and stationary storage systems can be repurposed for secondary applications, extending their useful life and maximizing resource utilization (Akinsanya, Ekechi & Okeke, 2024, Esho, et. al., 2024, Lottu, et. al., 2023, Popoola, et. al., 2024). While these batteries may no longer meet the performance requirements for primary use, they still retain significant energy storage capacity and can be utilized for applications such as energy storage for off-grid communities, grid stabilization, or backup power systems (Spataru and Bouffaron, 2022).

Second-life batteries offer opportunities for grid support and energy storage, enabling the integration of renewable energy sources and enhancing grid stability (Gu et al.,2024). By deploying retired batteries in energy storage systems, utilities can optimize energy supply and demand, store excess renewable energy for later use, and improve the reliability and resilience of the electrical grid (Akinsanya, Ekechi & Okeke, 2024, Esho, et. al., 2024, Muteba, et. al., 2023, Popoola, et. al., 2024). Additionally, repurposing batteries for grid support applications reduces the environmental impact of battery disposal and contributes to the transition towards a more sustainable energy system (Faessler, 2021).

In conclusion, implementing sustainable practices and solutions is essential for mitigating the environmental impact of battery storage systems and fostering a more sustainable energy future (Akinsanya, Ekechi & Okeke, 2024, Esho, et. al., 2024, Ndiwe, et. al., 2024, Popoola, et. al., 2024). Responsible sourcing of materials, recycling initiatives, and second-life applications offer promising avenues for promoting sustainability and maximizing the value of battery storage technologies. Collaboration among stakeholders, technological innovation, and policy support are critical for advancing these initiatives and achieving environmental and social objectives in the battery industry (Cao et al.,2021).

1.4. Interactions with Renewable Energy Sources

The integration of battery storage systems with renewable energy sources presents both challenges and opportunities in terms of energy reliability, grid stability, and environmental sustainability (Akinsanya, Ekechi & Okeke, 2024, Ehimare, Orikpete & Ewim, 2023, Ntuli, et. al., 2024, Popoola, et. al., 2024). This section explores the dynamics of this relationship, focusing on integration challenges and opportunities, as well as technological advancements and future trends.

Battery storage plays a critical role in supporting the integration of intermittent renewable energy sources such as solar and wind power into the grid (Datta ,2020). By storing excess energy generated during periods of high renewable generation and releasing it during periods of low generation or high demand, battery storage helps to balance supply and demand, thereby improving grid stability and reliability (Akinsanya, Ekechi & Okeke, 2024, Digitemie & Ekemezie, 2024, Nwokediegwu, et. al., 2024, Popoola, et. al., 2024). Additionally, battery storage systems can provide ancillary services such as frequency regulation and voltage control, further enhancing the flexibility and resilience of the grid. While battery storage systems offer environmental benefits by enabling the transition to renewable energy, they also pose environmental challenges due to their manufacturing processes, resource extraction, and end-of-life disposal (Akintuyi, 2024, Digitemie & Ekemezie, 2024, Nwokediegwu, et. al., 2024, Popoola, et. al., 2024). Synergies between renewable energy and battery storage can help to mitigate these impacts by reducing reliance on fossil fuels and minimizing greenhouse gas emissions (Mulvaney et al.,2021). However, trade-offs may arise in terms of the environmental footprint of battery production and the potential for habitat disruption from large-scale renewable energy installations. Balancing these trade-offs requires careful consideration of factors such as energy efficiency, resource use, and ecosystem impacts throughout the lifecycle of renewable energy and battery storage systems (Banso, et. al., 2024, Daraojimba, et. al., 2024, Oluwatusin, et. al., 2022).

Technological advancements in battery chemistry and design hold promise for improving the performance, efficiency, and sustainability of battery storage systems (Fan et al.,2020). Innovations such as solid-state batteries, lithium-sulfur batteries, and flow batteries offer higher energy density, longer cycle life, and reduced environmental impact compared to conventional lithium-ion batteries (Akintuyi, 2024, Digitemie & Ekemezie, 2024, Odimarha, Ayodeji & Abaku, 2024, Popoola, et. al., 2024). Additionally, advances in materials science, manufacturing techniques, and battery management systems are driving improvements in safety, reliability, and cost-effectiveness, making battery storage a more viable option for renewable energy integration. Future trends in battery storage technology aim to reduce environmental footprints by optimizing resource use, increasing energy efficiency, and enhancing recyclability. Strategies such as closed-loop recycling, where materials are recovered and reused in new battery production, can minimize waste and reduce the need for raw material extraction. Furthermore, efforts to develop sustainable supply chains, improve manufacturing processes, and adopt eco-friendly materials contribute to reducing the overall environmental impact of battery storage systems (Akintuyi, 2024, Digitemie & Ekemezie, 2024, Odimarha, Ayodeji & Abaku, 2024, Orikpete, Leton & Ewim, 2020). As these technologies mature and scale up, they have the potential to accelerate the transition to a low-carbon energy system and mitigate the environmental impacts of renewable energy integration.

In conclusion, the interactions between battery storage and renewable energy sources are complex and multifaceted, with both challenges and opportunities for enhancing energy sustainability and mitigating environmental impacts (Akintuyi, 2024, Daudu, et. al., 2024, Odimarha, Ayodeji & Abaku, 2024, Orikpete & Ewim, 2023). By addressing integration challenges, leveraging synergies between renewable energy and battery storage, and advancing technological innovations, we can maximize the benefits of renewable energy integration while minimizing environmental harm. Collaboration among policymakers, industry stakeholders, and researchers is essential for driving forward these efforts and realizing the full potential of battery storage in the transition towards a clean and sustainable energy future (Aremo, et. al., 2024, Daudu, et. al., 2024, Odimarha, Ayodeji & Abaku, 2024, Onyiriuka, Ewim, & Abolarin, 2023).

1.5. Future Outlook

As the global transition towards renewable energy accelerates, the role of battery storage systems continues to grow in importance (Kalair et al.,2021). However, ensuring the safety and minimizing the environmental impacts of these systems remains a critical challenge. Looking ahead, several trends and developments are shaping the future outlook for the safety and environmental aspects of battery storage systems in renewable energy (Saldarini et al.,2023; Lukong et al., 2022).

Future advancements in battery management systems (BMS) and safety technologies are expected to enhance the safety performance of battery storage systems (Dai et al.,2021). Improved sensors, algorithms, and predictive analytics will enable better monitoring and control of battery operations, reducing the risk of thermal runaway and other safety hazards (Aturamu, Thompson & Banke, 2021, Daraojimba, et. al., 2023, Odimarha, Ayodeji & Abaku, 2024, Onwuka & Adu, 2024). Furthermore, the development of novel materials and designs that are inherently safer and more resistant to failure will contribute to enhanced safety standards in battery storage systems.

Artificial intelligence (AI) and machine learning (ML) technologies offer opportunities to optimize the operation and maintenance of battery storage systems, thereby improving safety and reliability (Kumar, 2023; Imoisili et al., 2012). AI algorithms can analyze vast amounts of data in real-time to identify potential risks, predict system failures, and optimize battery performance. By leveraging AI and ML capabilities, operators can proactively address safety concerns and minimize downtime, enhancing overall system safety and efficiency.

The adoption of circular economy principles will become increasingly important in mitigating the environmental impacts of battery storage systems. Manufacturers will focus on designing batteries for recyclability and incorporating recycled materials into new battery production (Ayodeji, et. al., 2023, Daraojimba, et. al., 2023, Ojo, et. al., 2023, Onwuka & Adu, 2024). Closed-loop recycling systems will be developed to recover and reuse valuable materials from spent batteries, reducing the demand for raw materials and minimizing waste generation. Additionally, advancements in recycling technologies and processes will enable more efficient and cost-effective recovery of battery materials, further promoting environmental sustainability.

Governments and regulatory bodies will play a crucial role in shaping the future of battery storage systems by implementing policies and regulations that prioritize safety and environmental sustainability. Strengthened safety standards, stringent emissions regulations, and incentives for adopting sustainable practices will drive industry-wide improvements in safety and environmental performance (Ayorinde, et. al., 2024, Daraojimba, et. al., 2023, Okoli, et. al., 2024, Onwuka & Adu, 2024). Moreover, policies promoting research and development, innovation, and investment in clean energy technologies will accelerate the development and deployment of safer and more environmentally friendly battery storage systems.

Increasing public awareness and stakeholder engagement will be essential in fostering a culture of safety and environmental responsibility in the battery storage industry. Education campaigns, outreach programs, and stakeholder dialogues will raise awareness about the importance of safety and environmental sustainability in battery storage systems (Ayorinde, et. al., 2024, Daraojimba, et. al., 2023, Oke, et. al., 2023, Onwuka & Adu, 2024). Collaboration among industry stakeholders, governments, academia, and civil society will facilitate knowledge sharing, best practices exchange, and collective action towards achieving common goals of safety and environmental protection.

In conclusion, the future outlook for the safety and environmental impacts of battery storage systems in renewable energy is characterized by technological advancements, policy support, and stakeholder engagement. By leveraging innovative technologies, adopting circular economy approaches, and implementing robust policies and regulations, the industry can address safety concerns and minimize environmental impacts while maximizing the benefits of renewable energy integration (Ayorinde, et. al., 2024, Daraojimba, et. al., 2023, Okogwu, et. al., 2023, Onwuka & Adu, 2024). Collaboration and collective action will be key to realizing a safer, cleaner, and more sustainable energy future powered by battery storage systems.

2. Recommendation

Throughout this exploration of the safety and environmental impacts of battery storage systems in renewable energy, several key findings have emerged. These systems offer vital support for integrating intermittent renewable energy sources into the grid, but they also present significant safety challenges such as thermal runaway and environmental concerns like resource depletion and pollution. Mitigation strategies, technological advancements, and policy measures are crucial for addressing these challenges and maximizing the benefits of battery storage systems.

The findings underscore the need for comprehensive policy frameworks that prioritize safety and environmental sustainability in battery storage systems. Policymakers should strengthen safety standards, implement regulations to minimize environmental impacts, and provide incentives for adopting sustainable practices. In the industry, companies should invest in research and development to improve battery safety, enhance recycling technologies, and optimize resource utilization. Moreover, collaboration among stakeholders, including governments, industry players, researchers, and civil society, is essential for driving innovation, sharing best practices, and advancing collective goals of safety and sustainability.

Governments should establish robust regulatory frameworks that mandate safety standards, environmental protections, and responsible practices throughout the lifecycle of battery storage systems. Industry stakeholders should allocate resources to research and development initiatives aimed at advancing battery safety, environmental sustainability, and recycling technologies. Stakeholders should foster collaboration and knowledge sharing through partnerships, industry associations, and research networks to accelerate innovation and address common challenges. Manufacturers should design batteries for recyclability, adopt closed-loop recycling systems, and prioritize the use of recycled materials to minimize waste and resource depletion. Efforts to raise public awareness about the importance of battery safety and environmental sustainability, as well as the benefits of renewable energy, are crucial for driving consumer demand and shaping policy decisions.

3. Conclusion

In conclusion, the safety and environmental impacts of battery storage systems in renewable energy present complex challenges that require coordinated action from policymakers, industry stakeholders, and researchers. By implementing robust regulations, investing in research and development, promoting collaboration, embracing circular economy principles, and raising public awareness, we can promote safety and sustainability in battery storage systems and accelerate the transition to a cleaner, more resilient energy future.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Reference

[1] Abaku, E.A. and Odimarha, A.C. (2024) 'Sustainable supply chain management in the medical industry: a theoretical and practical examination,' International Medical Science Research Journal, 4(3), pp. 319–340. https://doi.org/10.51594/imsrj.v4i3.931.

[2] Abaku, E.A. and Odimarha, A.C. (2024) 'Sustainable supply chain management in the medical industry: a theoretical and practical examination,' International Medical Science Research Journal, 4(3), pp. 319–340. https://doi.org/10.51594/imsrj.v4i3.931.

[3] Abaku, E.A., Edunjobi, T.E. and Odimarha, A.C. (2024) 'Theoretical approaches to AI in supply chain optimization: Pathways to efficiency and resilience,' International Journal of Science and Technology Research Archive, 6(1), pp. 092–107. https://doi.org/10.53771/ijstra.2024.6.1.0033.

[4] Abolarin, S. M., Everts, M., Ewim, D. R. E., Adelaja, A. O., Olakoyejo, O. T., and Meyer, J. P. (2023). Study on the heat transfer and pressure drop power curves for entropy generation rate in the laminar, transitional, and turbulent flow regimes. ASTFE Digital Library, 1103-1112.

[5] Abolarin, S. M., Everts, M., Ewim, D. R. E., Olakoyejo, O. T., Adelaja, A. O., and Meyer, J. P. (2023). Evaluation of the irreversibility distribution ratio and pumping power using heat transfer and pressure drop power curves of a smooth circular tube with laminar, transitional … International Heat Transfer Conference Digital Library.

[6] Adama, H. E., & Okeke, C. D. (2024). Comparative analysis and implementation of a transformative business and supply chain model for the FMCG sector in Africa and the USA. Magna Scientia Advanced Research and Reviews, 10(02), 265–271. DOI: https://doi.org/10.30574/msarr.2024.10.2.0067

[7] Adama, H. E., & Okeke, C. D. (2024). Digital transformation as a catalyst for business model innovation: A critical review of impact and implementation strategies. Magna Scientia Advanced Research and Reviews, 10(02), 256–264. DOI: https://doi.org/10.30574/msarr.2024.10.2.0066

[8] Adama, H. E., & Okeke, C. D. (2024). Harnessing business analytics for gaining competitive advantage in emerging markets: A systematic review of approaches and outcomes. International Journal of Science and Research Archive, 11(02), 1848–1854. DOI: https://doi.org/10.30574/ijsra.2024.11.2.0683

[9] Adama, H. E., Popoola, O. A., Okeke, C. D., & Akinoso, A. E. (2024). Theoretical frameworks supporting IT and business strategy alignment for sustained competitive advantage. International Journal of Management & Entrepreneurship Research, 6(4), 1273-1287. DOI: 10.51594/ijmer.v6i4.1058. Fair East Publishers. Retrieved from http://www.fepbl.com/index.php/ijmer

[10] Adama, H. E., Popoola, O. A., Okeke, C. D., & Akinoso, A. E. (2024). Economic theory and practical impacts of digital transformation in supply chain optimization. International Journal of Advanced Economics, 6(4), 95-107. DOI: 10.51594/ijae.v6i4.1072. Fair East Publishers. Retrieved from http://www.fepbl.com/index.php/ijae

[11] Adama, H. E., Popoola, O. A., Okeke, C. D., & Akinoso, A. E. (2024). THEORETICAL FRAMEWORKS SUPPORTING IT AND BUSINESS STRATEGY ALIGNMENT FOR SUSTAINED COMPETITIVE ADVANTAGE. *International Journal of Management & Entrepreneurship Research*, *6*(4), 1273-1287.

[12] Adama, H. E., Popoola, O. A., Okeke, C. D., & Akinoso, A. E. (2024). ECONOMIC THEORY AND PRACTICAL IMPACTS OF DIGITAL TRANSFORMATION IN SUPPLY CHAIN OPTIMIZATION. *International Journal of Advanced Economics*, *6*(4), 95-107.

[13] Adebukola, A. A., Navya, A. N., Jordan, F. J., Jenifer, N. J., & Begley, R. D. (2022). Cyber Security as a Threat to Health Care. Journal of Technology and Systems, 4(1), 32-64.

[14] Adefemi, A., Daudu, C. D., Okoli, C. E., Ayorinde, O. B., Adekoya, O. O., and Ibeh, C. V. (2024). Reviewing the development of floating LNG facilities and their global impact. Engineering Science & Technology Journal, 5(2), 367-384.

[15] Ahmad, W., Alharthy, R.D., Zubair, M., Ahmed, M., Hameed, A. and Rafique, S., 2021. Toxic and heavy metals contamination assessment in soil and water to evaluate human health risk. *Scientific Reports*, *11*(1), p.17006.

[16] Ajayi, F.A., Udeh, C.A. (2024) 'A comprehensive review of talent management strategies for seafarers: Challenges and opportunities', International Journal of Science and Research Archive, 11(02), pp. 1116–1131. https://doi.org/10.30574/ijsra.2024.11.2.056

[17] Ajayi, F.A., Udeh, C.A. (2024) 'Innovative recruitment strategies in the IT sector: A review of successes and failures', Magna Scientia Advanced Research and Reviews, 10(02), pp.150–164. https://doi.org/10.30574/msarr.2024.10.2.0057

[18] Ajayi, F.A., Udeh, C.A. (2024) 'Review of crew resilience and mental health practices in the marine industry: Pathways to improvement', Magna Scientia Advanced Biology and Pharmacy, 11(02), pp. 033–049. https://doi.org/10.30574/msabp.2024.11.2.0021

[19] Akagha, O. and Epie, C., 2022. Responsible People Management and Fairness During COVID-19 (Law and Ethics–The Case of Pan-Atlantic University). In Responsible Management of Shifts in Work Modes–Values for a Post Pandemic Future, Volume 1 (pp. 95-111). Emerald Publishing Limited.

[20] Akagha, O.V., Coker, J.O., Uzougbo, N.S. and Bakare, S.S., 2023. Company Secretarial and Administrative Services In Modern Irish Corporations: A Review Of The Strategies And Best Practices Adopted In Company Secretarial And Administrative Services. International Journal of Management & Entrepreneurship Research, 5(10), pp.793-813.

[21] Akinsanya, M. O., Ekechi, C. C., & Okeke, C. D. (2024). Data sovereignty and security in network engineering: A conceptual framework for compliance. *International Journal of Science and Research Archive*, *11*(2), 1832-1847.

[22] Akinsanya, M. O., Ekechi, C. C., & Okeke, C. D. (2024). SECURITY PARADIGMS FOR IOT IN TELECOM NETWORKS: CONCEPTUAL CHALLENGES AND SOLUTION PATHWAYS. *Engineering Science & Technology Journal*, *5*(4), 1431-1451.

[23] Akinsanya, M. O., Ekechi, C. C., & Okeke, C. D. (2024). THE EVOLUTION OF CYBER RESILIENCE FRAMEWORKS IN NETWORK SECURITY: A CONCEPTUAL ANALYSIS. *Computer Science & IT Research Journal*, *5*(4), 926-949.

[24] Akinsanya, M. O., Ekechi, C. C., & Okeke, C. D. (2024). THEORETICAL UNDERPINNINGS AND PRACTICAL IMPLICATIONS OF SD-WAN TECHNOLOGIES IN TELECOMMUNICATIONS. *Computer Science & IT Research Journal*, *5*(4), 950-971.

[25] Akinsanya, M. O., Ekechi, C. C., & Okeke, C. D. (2024). VIRTUAL PRIVATE NETWORKS (VPN): A CONCEPTUAL REVIEW OF SECURITY PROTOCOLS AND THEIR APPLICATION IN MODERN NETWORKS. *Engineering Science & Technology Journal*, *5*(4), 1452-1472.

[26] Akintuyi, O. B. (2024). Adaptive AI in Precision Agriculture: A Review: Investigating the use of self-learning algorithms in optimizing farm operations based on real-time data. Research Journal of Multidisciplinary Studies, 7(02), 016-030.

[27] Akintuyi, O. B. (2024). AI in agriculture: A comparative review of developments in the USA and Africa. Research Journal of Science and Engineering, 10(02), 060–070.

[28] Akintuyi, O. B. (2024). The Role of Artificial Intelligence in U.S. Agriculture: A Review: Assessing advancements, challenges, and the potential impact on food production and sustainability. Open Access Research Journal of Engineering and Technology, 6(02), 023–032.

[29] Akintuyi, O. B. (2024). Vertical Farming in Urban environments: A Review of Architectural Integration and Food Security. Journal of Biology and Pharmacy, 10(02), 114-126.

[30] Ali, A., Malik, S.A., Shafiullah, M., Malik, M.Z. and Zahir, M.H., 2023. Policies and regulations for solar photovoltaic end-of-life waste management: insights from China and the USA. *Chemosphere*, *340*, p.139840.

[31] Aremo, B., Isadare, D. A., Akinduro, O. E., Bello, O. E., Adeoye, M. O., Ayodeji, S. A., ... & Oluwasegun, K. M. (2024). Production of glass ceramic from rice husk and periwinkle shells. *Discover Materials*, *4*(1), 8.

[32] Aturamu, O. A., Thompson, O. A., & Banke, A. O. (2021). Forecasting the effect of climate variability on yam yield in rainforest and Guinea Savannah agro-ecological zone of Nigeria. Journal of Global Agriculture and Ecology, 11(4), 1-12.

[33] Ayodeji, S. A., Ohenhen, P.E., Olurin, J. O., Tula, O. A., Gidiagba, J. O. & Ofonagoro, K. A., 2023: Leading Drilling Innovations for Sustainable Oil Production: Trends and Transformation. Journal Acta Mechanica Malaysia (AMM). Volume 6 Issue 1 Pages 62-71

[34] Ayorinde, O. B., Daudu, C. D., Etukudoh, E. A., Adefemi, A., Adekoya, O. O., et al. (2024). Climate risk assessment in petroleum operations: A review of CSR practices for sustainable resilience in the United States and Africa. Engineering Science & Technology Journal, 5(2), 385-401.

[35] Ayorinde, O. B., Daudu, C. D., Okoli, C. E., Adefemi, A., Adekoya, O. O., and Ibeh, C. V. (2024). Reviewing the impact of LNG technology advancements on global energy markets. Engineering Science & Technology Journal, 5(2), 402-411.

[36] Ayorinde, O. B., Etukudoh, E. A., Nwokediegwu, Z. Q. S., Ibekwe, K. I., Umoh, A. A., et al. (2024). Renewable energy projects in Africa: A review of climate finance strategies. International Journal of Science and Research Archive, 11(1), 923-932.

[37] Babawurun, T., Ewim, D.R.E., Scott, T.O. and Neye-Akogo, C., 2023. A Comprehensive Review of Wind Turbine Modeling for Addressing Energy Challenges in Nigeria and South Africa in the 4IR Context. The Journal of Engineering and Exact Sciences, 9(2), pp.15479-01e.

[38] Banso, A. A., Gidiagba, J. O., Leonard, J. Olurin, J. O., Ehiaguina, V. E Ndiwe, T. C. & Ayodeji S. A. 2024: Protecting Energy Workers: A Review of Human Factors in Maintenance Accidents and Implications for Safety Improvement. Advances in Industrial Engineering and Management (AIEM). 13, issue 1, pages 33-38

[39] Basit, M.A., Dilshad, S., Badar, R. and Sami ur Rehman, S.M., 2020. Limitations, challenges, and solution approaches in grid-connected renewable energy systems. *International Journal of Energy Research*, *44*(6), pp.4132-4162.

[40] Behabtu, H.A., Messagie, M., Coosemans, T., Berecibar, M., Anlay Fante, K., Kebede, A.A. and Mierlo, J.V., 2020. A review of energy storage technologies' application potentials in renewable energy sources grid integration. *Sustainability*, *12*(24), p.10511.

[41] Bin Yep Abu, M.R. and Lim, K.H., 2023. Application of process safety management principles to laboratory safety management. *Process Safety Progress*, *42*(4), pp.694-700.

[42] Blose, S. C., Ewim, D. R. E., Eloka-Eboka, A. C., and Adelaja, A. O. (2023). Improved correlation for predicting heat transfer coefficients during condensation inside smooth horizontal tubes. International Journal of Low-Carbon Technologies, 18, 750-763.

[43] Cao, J., Chen, X., Qiu, R. and Hou, S., 2021. Electric vehicle industry sustainable development with a stakeholder engagement system. *Technology in Society*, *67*, p.101771.

[44] Chaudhuri, A., Bhatia, M.S., Kayikci, Y., Fernandes, K.J. and Fosso-Wamba, S., 2021. Improving social sustainability and reducing supply chain risks through blockchain implementation: Role of outcome and behavioural mechanisms. *Annals of operations research*, pp.1-33.

[45] Chavan, S., Venkateswarlu, B., Prabakaran, R., Salman, M., Joo, S.W., Choi, G.S. and Kim, S.C., 2023. Thermal runaway and mitigation strategies for electric vehicle lithium-ion batteries using battery cooling approach: A review of the current status and challenges. *Journal of Energy Storage*, *72*, p.108569.

[46] Chidolue, O. and Iqbal, T., 2023, March. System Monitoring and Data logging using PLX-DAQ for Solar-Powered Oil Well Pumping. In 2023 IEEE 13th Annual Computing and Communication Workshop and Conference (CCWC) (pp. 0690-0694). IEEE.

[47] Cristóbal, J., Jubayed, M., Wulff, N. and Schebek, L., 2020. Life cycle losses of critical raw materials from solar and wind energy technologies and their role in the future material availability. *Resources, Conservation and Recycling*, *161*, p.104916.\

[48] da Silva, E.R., Lohmer, J., Rohla, M. and Angelis, J., 2023. Unleashing the circular economy in the electric vehicle battery supply chain: A case study on data sharing and blockchain potential. *Resources, Conservation and Recycling*, *193*, p.106969.

[49] Dai, H., Jiang, B., Hu, X., Lin, X., Wei, X. and Pecht, M., 2021. Advanced battery management strategies for a sustainable energy future: Multilayer design concepts and research trends. *Renewable and Sustainable Energy Reviews*, *138*, p.110480

[50] Daniyan, A. A., Okonkwo, P. C., Ogundare, O. J., Oluwasegun, K. M., Umoru, L. E., Ayodeji, S., ... & Ige, O. O. (2024). Microstructural Characterization and Corrosion Behaviour of Heat Treated Standard Stainless Steels in Tar Sand. *Hybrid Advances*, 100195.

[51] Daraojimba, C,. Okogwu, C., Agho, M. O., Adeyinka, M. A. & Ayodeji, S. A. 2023: Environmental Contaminants Review. Volume 6 Issue 2 Pages 116-125

[52] Daraojimba, A., Okogwu, Agho, Ikwue, Ayodeji., S. A., 2024 : Value Engineering and Value Analysis: Unexplored Potentials in Procurement and Supply Chain Management. Advances in Industrial Engineering and Management (AIEM). 13, issue 1, pages 01-10

[53] Daraojimba, C. Ofonagoro, K. A., Gidiagba, J. O., Banso, A. A., Egbokhaebho, BA Tula, O. A., Ayodeji, S. A. & Ninduwezuor-Ehiobu, N., 2023: Towards a Sustainable Future: Making the Case for Advanced Decommissioning Practices in the US Oil and Gas Industry. Journal Acta Mechanica Malaysia (AMM). Volume 6 Issue 1 Pages 49-58

[54] Daraojimba, C., Agho, M. O., Adeyinka, M. A., Okogwu, C., Ikwe, U., Ufoaro, O. A. & Ayodeji, S. A., 2023: Big Data in the Oil Sector: A Review of How Analytics is Revolutionizing Supply Chain Operations. Journal Economic Growth & Environment Sustainability Journal (EGNES) Volume 2 Issue 2 Pages 85-93

[55] Daraojimba, C., Banso, A. A., Ofonagoro, K. A., Olurin, J. O., Ayodeji, S. A., Ehiaguina, V. E. & Ndiwe, T. C., 2023; Major Corporations and Environmental Advocacy: Efforts in Reducing Environmental Impact in Oil Exploration. Journal Engineering Heritage Journal Volume 4 Issue 1 Pages 49-59

[56] Daraojimba, C., Ofonagoro, K. A., Gidiagba, J. O., Banso, A. A., Egbokhaebho, B. A., Tula, O. A. & Ayodeji, S. A., 2023: The Evolution of Oilfield Testing: Integrating Sustainability into Operations Management. Journal Engineering Heritage Journal Volume 4 Issue 2 Pages 81-91

[57] Datta, U., Kalam, A. and Shi, J., 2021. A review of key functionalities of battery energy storage system in renewable energy integrated power systems. *Energy Storage*, *3*(5), p.e224.

[58] Daudu, C. D., Adefemi, A., Adekoya, O. O., Okoli, C. E., Ayorinde, O. B., et al. (2024). LNG and climate change: Evaluating its carbon footprint in comparison to other fossil fuels. Engineering Science & Technology Journal, 5(2), 412-426.

[59] Daudu, C. D., Okoli, C. E., Adefemi, A., Ayorinde, O. B., Adekoya, O. O., et al. (2024). Reviewing the economic viability of LNG projects in African nations. World Journal of Advanced Research and Reviews, 21(2), 109-118.

[60] Deberdt, R. and Le Billon, P., 2021. Conflict minerals and battery materials supply chains: A mapping review of responsible sourcing initiatives. *The Extractive Industries and Society*, *8*(4), p.100935.

[61] Diaz, L.B., He, X., Hu, Z., Restuccia, F., Marinescu, M., Barreras, J.V., Patel, Y., Offer, G. and Rein, G., 2020. Meta-review of fire safety of lithium-ion batteries: Industry challenges and research contributions. *Journal of The Electrochemical Society*, *167*(9), p.090559.

[62] Digitemie, W. N., & Ekemezie, I. O., (2024). "Assessing The Role of Climate Finance in Supporting Developing Nations: A Comprehensive Review". Finance & Accounting Research Journal, Volume 6, Issue 3, P.No. 408-420.

[63] Digitemie, W. N., & Ekemezie, I. O., (2024). "Assessing the role of LNG in global carbon neutrality efforts: A project management review". GSC Advanced Research and Reviews, 2024, 18(03), 091–100.

[64] Digitemie, W. N., & Ekemezie, I. O., (2024). "Assessing the role of carbon pricing in global climate change mitigation strategies". Magna Scientia Advanced Research and Reviews, 2024, 10(02), 022–031.

[65] Digitemie, W. N., & Ekemezie, I. O., (2024). "Enhancing Carbon Capture and Storage Efficiency in The Oil and Gas Sector: An Integrated Data Science and Geological Approach". Engineering Science & Technology Journal, Volume 5, Issue 3, P.No. 924-934, March 2024.

[66] Dou, S., Xu, D., Zhu, Y. and Keenan, R., 2023. Critical mineral sustainable supply: Challenges and governance. *Futures*, *146*, p.103101.

[67] Duarte Castro, F., Vaccari, M. and Cutaia, L., 2022. Valorization of resources from end-of-life lithium-ion batteries: A review. *Critical Reviews in Environmental Science and Technology*, *52*(12), pp.2060-2103.

[68] Ehimare, E., Orikpete, O., and Ewim, D. R. E. (2023). The perennial logistical challenges during Nigerian elections: The unmanned aircraft system (UAS) solution.

[69] Ekechi, C. C., Chukwurah, E. G., Oyeniyi, L. D., & Okeke, C. D. (2024). AI-INFUSED CHATBOTS FOR CUSTOMER SUPPORT: A CROSS-COUNTRY EVALUATION OF USER SATISFACTION IN THE USA AND THE UK. *International Journal of Management & Entrepreneurship Research*, *6*(4), 1259-1272.

[70] Ekechi, C. C., Chukwurah, E. G., Oyeniyi, L. D., & Okeke, C. D. (2024). A REVIEW OF SMALL BUSINESS GROWTH STRATEGIES IN AFRICAN ECONOMIES. *International Journal of Advanced Economics*, *6*(4), 76-94.

[71] Ekemezie, I. O., & Digitemie, W. N. (2024). " Climate Change Mitigation Strategies in The Oil & Gas Sector: A Review of Practices and Impact ". Engineering Science & Technology Journal, Volume 5, Issue 3, P.No. 935-948, March 2024.

[72] Ekemezie, I. O., & Digitemie, W. N. (2024). "A review of sustainable project management practices in modern LNG industry initiatives". World Journal of Advanced Engineering Technology and Sciences, 2024, 11(02), 009–018.

[73] Ekemezie, I. O., & Digitemie, W. N. (2024). "Best Practices in Strategic Project Management Across Multinational Corporations: A Global Perspective on Success Factors and Challenges". International Journal of Management & Entrepreneurship Research, Volume 6, Issue 3, P.No.795-805.

[74] Ekemezie, I. O., & Digitemie, W. N. (2024). "Carbon Capture and Utilization (CCU): A Review of Emerging Applications And Challenges". Engineering Science & Technology Journal, Volume 5, Issue 3, P.No. 949-961, March 2024.

[75] Ekemezie, I. O., & Digitemie, W. N. (2024)." A comprehensive review of Building Energy Management Systems (BEMS) for Improved Efficiency". World Journal of Advanced Research and Reviews, 2024, 21(03), 829–841.

[76] Emeka-Okoli, S., Nwankwo, T. C., Otonnah, C. A., and Nwankwo, E. (2024). Environmental stewardship and corporate social responsibility: A review of case studies from the oil and gas sector. World Journal of Advanced Research and Reviews, 21(3), 069-077.

[77] Emeka-Okoli, S., Nwankwo, T. C., Otonnah, C. A., and Nwankwo, E. (2024). Communication strategies for effective CSR and stakeholder engagement in the oil & gas industry: A conceptual analysis. World Journal of Advanced Research and Reviews, 21(3), 091-099.

[78] Emeka-Okoli, S., Nwankwo, T. C., Otonnah, C. A., and Nwankwo, E. (2024). The evolution of CSR reporting in the oil and gas industry and its future direction: A conceptual review. World Journal of Advanced Research and Reviews, 21(3), 100-108.

[79] Emeka-Okoli, S., Nwankwo, T. C., Otonnah, C. A., and Nwankwo, E. (2024). Corporate governance and CSR for sustainability in Oil and Gas: Trends, challenges, and best practices: A review. World Journal of Advanced Research and Reviews, 21(3), 078-090.

[80] Emeka-Okoli, S., Otonnah, C. A., Nwankwo, T. C., and Nwankwo, E. (2024). Internal and external communication in oil & gas for enhancing CSR implementation: A review. World Journal of Advanced Research and Reviews, 21(3), 109-118.

[81] Esho, A. O. O., Iluyomade, T. D., Olatunde, T. M., Igbinenikaro, O. P. (2024). Electrical Propulsion Systems For Satellites: A Review Of Current Technologies And Future Prospects. *International Journal of Frontiers in Engineering and Technology Research*. 06,(02), 035–044. https://doi.org/10.53294/ijfetr.2024.6.2.0034.

[82] Esho, A. O. O., Iluyomade, T. D., Olatunde, T. M., Igbinenikaro, O. P. (2024). Next-Generation Materials For Space Electronics: A Conceptual Review. *Open Access Research Journal of Engineering and Technology,* 06,(02), 051–062. https://doi.org/10.53022/oarjet.2024.6.2.0020.

[83] Esho, A. O. O., Iluyomade, T. D., Olatunde, T. M., Igbinenikaro, O. P. (2024). A Comprehensive Review Of Energy-Efficient Design In Satellite Communication Systems. *International Journal of Engineering Research Updates.* 06,(02), 013–025. https://doi.org/10.53430/ijeru.2024.6.2.0024

[84] Etukudoh, E. A., Ilojianya, V. I., Ayorinde, O. B., Daudu, C. D., Adefemi, A., et al. (2024). Review of climate change impact on water availability in the USA and Africa. International Journal of Science and Research Archive, 11(1), 942-951.

[85] Ewim, D. R. E., Nundlal, Y., Govender, K., Nzuke, N. L., Mbatha, M. V., Gwexa, N., et al. (2023). Knowledge, awareness, and perception of senior high school learners towards nuclear energy: A South African case study. African Journal of Science, Technology, Innovation and Development, 15(7).

[86] Eyo-Udo, N.L., Odimarha, A.C. and Ejairu, E. (2024) 'Sustainable and ethical supply chain management: The role of HR in current practices and future directions,' Magna Scientia Advanced Research and Reviews, 10(2), pp. 181–196. https://doi.org/10.30574/msarr.2024.10.2.0058.

[87] Eyo-Udo, N.L., Odimarha, A.C. and Kolade, O.O. (2024) 'Ethical supply chain management: balancing profit, social responsibility, and environmental stewardship,' International Journal of Management & Entrepreneurship Research, 6(4), pp. 1069–1077. https://doi.org/10.51594/ijmer.v6i4.985.

[88] Faessler, B., 2021. Stationary, second use battery energy storage systems and their applications: A research review. *Energies*, *14*(8), p.2335.

[89] Familoni, B.T., Abaku, E.A. and Odimarha, A.C. (2024) 'Blockchain for enhancing small business security: A theoretical and practical exploration,' Open Access Research Journal of Multidisciplinary Studies, 7(1), pp. 149–162. https://doi.org/10.53022/oarjms.2024.7.1.0020.

[90] Familoni, B.T., Abaku, E.A. and Odimarha, A.C. (2024) 'Blockchain for enhancing small business security: A theoretical and practical exploration,' Open Access Research Journal of Multidisciplinary Studies, 7(1), pp. 149–162. https://doi.org/10.53022/oarjms.2024.7.1.0020.

[91] Fan, E., Li, L., Wang, Z., Lin, J., Huang, Y., Yao, Y., Chen, R. and Wu, F., 2020. Sustainable recycling technology for Li-ion batteries and beyond: challenges and future prospects. *Chemical reviews*, *120*(14), pp.7020-7063.

[92] Fan, E., Li, L., Wang, Z., Lin, J., Huang, Y., Yao, Y., Chen, R. and Wu, F., 2020. Sustainable recycling technology for Li-ion batteries and beyond: challenges and future prospects. *Chemical reviews*, *120*(14), pp.7020-7063.

[93] Fawole, A. A., Orikpete, O. F., Ehiobu, N. N., and Ewim, D. R. E. (2023). Climate change implications of electronic waste: Strategies for sustainable management. Bulletin of the National Research Centre, 47(1), 147.

[94] Fetuga, I. A., Olakoyejo, O. T., Abolarin, S. M., Adelaja, A. O., and Ewim, D. R. E. (2023). Numerical investigation of ternary nanofluid flow with combined stent, torus-ring and grooved twisted tape inserts under a non-uniform temperature wall profile. International Heat Transfer Conference Digital Library.

[95] Fetuga, I. A., Olakoyejo, O. T., Oluwatusin, O., Adelaja, A. O., Ewim, D. R. E., et al. (2023). Computational fluid dynamics investigation of effects of anastomosis angle on hemodynamic indicators in end-to-side brachioaxillary arteriovenous graft. Series on Biomechanics.

[96] Gu, X., Bai, H., Cui, X., Zhu, J., Zhuang, W., Li, Z., Hu, X. and Song, Z., 2024. Challenges and opportunities for second-life batteries: Key technologies and economy. *Renewable and Sustainable Energy Reviews*, *192*, p.114191.

[97] Harper, G.D., Kendrick, E., Anderson, P.A., Mrozik, W., Christensen, P., Lambert, S., Greenwood, D., Das, P.K., Ahmeid, M., Milojevic, Z. and Du, W., 2023. Roadmap for a sustainable circular economy in lithium-ion and future battery technologies. *Journal of Physics: Energy*, *5*(2), p.021501.\

[98] Hirsh, H.S., Li, Y., Tan, D.H., Zhang, M., Zhao, E. and Meng, Y.S., 2020. Sodium-ion batteries paving the way for grid energy storage. *Advanced Energy Materials*, *10*(32), p.2001274.

[99] Igbinenikaro, E., & Adewusi, O. A. (2024). Developing International Policy Guidelines for Managing Cross-Border Insolvencies in the Digital Economy. *International Journal of Management & Entrepreneurship Research.* Vol. 6 No. 4 (2024). https://doi.org/10.51594/ijmer.v6i4.983

[100] Igbinenikaro, E., & Adewusi, O. A. (2024). Financial Law: Policy Frameworks for Regulating Fintech Innovations: Ensuring Consumer Protection while Fostering Innovation. *Finance &Accounting Research Journal,* Vol. 6 No. 4 (2024). https://doi.org/10.51594/farj.v6i4.991.

[101] Igbinenikaro, E., & Adewusi, O. A. (2024). Navigating the Legal Complexities of Artificial Intelligence in Global Trade Agreements. *International Journal of Applied Research in Social Sciences,* Vol. 6 No. 4 (2024). https://doi.org/10.51594/ijarss.v6i4.987.

[102] Igbinenikaro, E., & Adewusi, O. A. (2024). Policy Recommendations for Integrating Artificial Intelligence into Global Trade Agreements. *International Journal of Engineering Research Updates,* 06(01), 001-010. https://doi.org/10.53430/ijeru.2024.6.1.0022.

[103] Igbinenikaro, E., & Adewusi, O. A. (2024). Tax Havens Reexamined: The Impact of Global Digital Tax Reforms on International Taxation. *World Journal of Advanced Science and Technology*, 05(02), 001- 012. https://doi.org/10.53346/wjast.2024.5.2.0031.

[104] Igbinenikaro, O. P., Adekoya, O. O., & Etukudoh, E. A. (2024). A Comparative Review Of Subsea Navigation Technologies In Offshore Engineering Projects. *International Journal of Frontiers in Engineering and Technology Research.* 06,(02), 019–034. https://doi.org/10.53294/ijfetr.2024.6.2.0031.

[105] Igbinenikaro, O. P., Adekoya, O. O., & Etukudoh, E. A. (2024). Conceptualizing Sustainable Offshore Operations: Integration Of Renewable Energy Systems. *International Journal of Frontiers in Science and Technology Research. 06(02), 031–043.* https://doi.org/10.53294/ijfstr.2024.6.2.0034.

[106] Igbinenikaro, O. P., Adekoya, O. O., & Etukudoh, E. A. (2024). Emerging Underwater Survey Technologies: A Review And Future Outlook. *Open Access Research Journal of Science and Technology.* 10,(02), 071–084. https://doi.org/10.53022/oarjst.2024.10.2.0052.

[107] Igbinenikaro, O. P., Adekoya, O. O., & Etukudoh, E. A. (2024). Fostering Cross-Disciplinary Collaboration In Offshore Projects: Strategies And Best Practices. *International Journal of Management & Entrepreneurship Research.* 6,(4), 1176-1189. https://doi.org/10.51594/ijmer.v6i4.1006.

[108] Igbinenikaro, O. P., Adekoya, O. O., & Etukudoh, E. A. (2024). Review Of Modern Bathymetric Survey Techniques And Their Impact On Offshore Energy Development. *Engineering Science & Technology Journal.* 5,(4), 1281-1302. https://doi.org/10.51594/estj.v5i4.1018.

[109] Imoisili, P.E., Ukoba, K.O., Ibegbulam, C.M., Adgidzi, D. and Olusunle, S.O.O., 2012. Effect of Filler Volume Fraction on the Tensile Properties of Cocoa-Pod Epoxy Resin Composite. *International Journal of Science and Technology*, *2*(7), pp.432-434.

[110] Isadare Dayo, A., Ayodeji Sodrudeen, A., Abiodun Bukunmi, J., & Odun, A. The Re-Imagination of Electrochemical Power: A Global Awak-ening and Thoughts from Obafemi Awolowo University, Ile-Ife.

[111] Izuka, U., Ojo, G. G., Ayodeji, S. A., Ndiwe, T. C., & Ehiaguina, V. E. (2023). Powering Rural Healthcare With Sustainable Energy: A Global Review Of Solar Solutions. *Engineering Science & Technology Journal*, *4*(4), 190-208.

[112] Júnior, C.A.R., Sanseverino, E.R., Gallo, P., Koch, D., Schweiger, H.G. and Zanin, H., 2022. Blockchain review for battery supply chain monitoring and battery trading. *Renewable and Sustainable Energy Reviews*, *157*, p.112078.

[113] Kalair, A., Abas, N., Saleem, M.S., Kalair, A.R. and Khan, N., 2021. Role of energy storage systems in energy transition from fossil fuels to renewables. *Energy Storage*, *3*(1), p.e135.

[114] Karduri, R.K.R. and Ananth, C., 2023. Hydrogen Economy: Opportunities and Challenges for a Sustainable Future. *This paper has been published in International Journal of Advanced Research In Basic Engineering Sciences and Technology (IJARBEST) DOI*, *10*.

[115] Kikanme, K., Dennis, N. M., Orikpete, O. F., and Ewim, D. R. E. PFAS in Nigeria: Identifying data gaps that hinder assessments of ecotoxicological and human health impacts. Available at SSRN 4714590.

[116] Kumar, N., 2023. Artificial intelligence and machine learning applications in energy storage system: technology overview and perspectives. *Emerging Trends in Energy Storage Systems and Industrial Applications*, pp.1-26.

[117] Liu, Y., Zhang, R., Wang, J. and Wang, Y., 2021. Current and future lithium-ion battery manufacturing. *IScience*, *24*(4).

[118] Lochab, V., Ewim, E. D., and Prakash, S. (2023). Continuous flow microfluidics for colloidal particle assembly on porous substrates. Soft Matter, 19(14), 2564-2569.

[119] Lottu, O. A., Ehiaguina, V. E., Ayodeji, S. A., Ndiwe, T. C., & Izuka, U. (2023). GLOBAL REVIEW OF SOLAR POWER IN EDUCATION: INITIATIVES, CHALLENGES, AND BENEFITS. *Engineering Science & Technology Journal*, *4*(4), 209-221.

[120] Lukong, V.T., Ukoba, K., Yoro, K.O. and Jen, T.C., 2022. Annealing temperature variation and its influence on the self-cleaning properties of TiO2 thin films. *Heliyon*, *8*(5).

[121] Mancini, L., Eslava, N.A., Traverso, M. and Mathieux, F., 2020. Responsible and sustainable sourcing of battery raw materials. *Publications Office of the European Union: Luxembourg*.

[122] Mulvaney, D., Richards, R.M., Bazilian, M.D., Hensley, E., Clough, G. and Sridhar, S., 2021. Progress towards a circular economy in materials to decarbonize electricity and mobility. *Renewable and Sustainable Energy Reviews*, *137*, p.110604.

[123] Muteba, G. K., Ewim, D. R. E., Dirker, J., and Meyer, J. P. (2023). Heat transfer and pressure drop investigation for prescribed heat fluxes on both the inner and outer wall of an annular duct. Experimental Thermal and Fluid Science, 145, 110907.

[124] Ndiwe, T.C., Olurin, J. O., Lotu, O. A., Izuka, U., Agho, M. O. & Ayodeji., S. A., 2024; Urban Solar Integration: A Global Review and Potential in Urban Planning. Economic Growth & Environment Sustainability Journal (EGNES)

[125] Njemanze, P.C., Njemanze, J., Skelton, A., Akudo, A., Akagha, O., Chukwu, A.A., Peters, C. and Maduka, O., 2008. High-frequency ultrasound imaging of the duodenum and colon in patients with symptomatic giardiasis in comparison to amebiasis and healthy subjects. Journal of Gastroenterology and Hepatology, 23(7pt2), pp.e34-e42.

[126] Ntshanga, N.K., Procheş, S. and Slingsby, J.A., 2021. Assessing the threat of landscape transformation and habitat fragmentation in a global biodiversity hotspot. *Austral Ecology*, *46*(7), pp.1052-1069.

[127] Ntuli, M. N., Eloka-Eboka, A. C., Mwangi, F. M., Ewim, D. R. E., and Dioha, M. O. (2024). Energy sustainability and carbon dioxide emissions mitigation options for South Africa's road transport sector. Bulletin of the National Research Centre, 48(1), 37.

[128] Nwokediegwu, Z. Q. S., Adefemi, A., Ayorinde, O. B., Ilojianya, V. I., and Etukudoh, E. A. (2024). Review of water policy and management: Comparing the USA and Africa. Engineering Science & Technology Journal, 5(2), 385-401.

[129] Nwokediegwu, Z. Q. S., Ibekwe, K. I., Ilojianya, V. I., Etukudoh, E. A., and Ayorinde, O. B. (2024). Renewable energy technologies in engineering: A review of current developments and future prospects. Engineering Science & Technology Journal, 5(2), 367-384.

[130] Odimarha, A. C., Ayodeji, S. A., & Abaku, E. A. (2024). MACHINE LEARNING'S INFLUENCE ON SUPPLY CHAIN AND LOGISTICS OPTIMIZATION IN THE OIL AND GAS SECTOR: A COMPREHENSIVE ANALYSIS. *Computer Science & IT Research Journal*, *5*(3), 725-740.

[131] Odimarha, A. C., Ayodeji, S. A., & Abaku, E. A. (2024). The role of technology in supply chain risk management: Innovations and challenges in logistics. *Magna Scientia Advanced Research and Reviews*, *10*(2), 138-145.

[132] Odimarha, A.C., Ayodeji, S.A. and Abaku, E.A. (2024a) 'Machine learning's influence on supply chain and logistics optimization in the oil and gas sector: a comprehensive analysis,' Computer Science & IT Research Journal, 5(3), pp. 725–740. https://doi.org/10.51594/csitrj.v5i3.976.

[133] Odimarha, A.C., Ayodeji, S.A. and Abaku, E.A. (2024b) 'Securing the digital supply chain: Cybersecurity best practices for logistics and shipping companies,' World Journal of Advanced Science and Technology, 5(1), pp. 026–030. https://doi.org/10.53346/wjast.2024.5.1.0030.

[134] Odimarha, A.C., Ayodeji, S.A. and Abaku, E.A. (2024c) 'The role of technology in supply chain risk management: Innovations and challenges in logistics,' Magna Scientia Advanced Research and Reviews, 10(2), pp. 138–145. https://doi.org/10.30574/msarr.2024.10.2.0052.

[135] Ojo, G. G., Olurin, J. O., Gidiagba, J. O., Ehiaguina, V. E., Ndiwe, T. C., Ayodeji, S. A., Banso, A. A. & Tula, O. A., 2023: The Engineering Innovations and Sustainable Entrepreneurship: A Comprehensive Literature Review. Materials & Corrosion Engineering Manageme. Volume 4, Issue 2, Pages 62-71

[136] Oke, I. A., Aremo, B., Isadare, D. A., Olorunniwo, O. E., Ayodeji, S. A., Abass, G. F., & Daniyan, A. A. (2023). Microstructures of Developed Composite Graphite-Resin Electrodes. *Materials Sciences and Applications*, *14*(12), 526-534.

[137] Okogwu, C., Agho, M. O., Adeyinka, M. A., Odulaja, B. A., Ufoaro, O. A., Ayodeji, S. A., & Daraojimba, C. (2023). Adapting To Oil Price Volatility: A Strategic Review Of Supply Chain Responses Over Two Decades. *International Journal of Research and Scientific Innovation*, *10*(10), 68-87.

[138] Okoli, C. E., Adekoya, O. O., Ilojianya, V. I., Ayorinde, O. B., Etukudoh, E. A., et al. (2024). Sustainable energy transition strategies: A comparative review of CSR and corporate advising in the petroleum industry in the United States and Africa. International Journal of Science and Research Archive, 11(1), 933-941.

[139] Oluwatusin, O., Adelaja, A. O., Aderemi, K. S., Fetuga, I. A., Olakoyejo, O. T., and Ewim, D. R. E. (2022). Numerical prediction of flow recirculation length zone in an artery with multiple stenoses at low and high Reynolds number. Series on Biomechanics, 36(2).

[140] Onwuka, O. U., and Adu, A. (2024). Carbon capture integration in seismic interpretation: Advancing subsurface models for sustainable exploration. International Journal of Scholarly Research in Science and Technology, 2024, 04(01), 032–041

[141] Onwuka, O. U., and Adu, A. (2024). Eco-efficient well planning: Engineering solutions for reduced environmental impact in hydrocarbon extraction. International Journal of Scholarly Research in Multidisciplinary Studies, 2024, 04(01), 033–043

[142] Onwuka, O. U., and Adu, A. (2024). Subsurface carbon sequestration potential in offshore environments: A geoscientific perspective. Engineering Science & Technology Journal, 5(4), 1173-1183.

[143] Onwuka, O. U., and Adu, A. (2024). Sustainable strategies in onshore gas exploration: Incorporating carbon capture for environmental compliance. Engineering Science & Technology Journal, 5(4), 1184-1202.

[144] Onwuka, O. U., and Adu, A. (2024). Technological synergies for sustainable resource discovery: Enhancing energy exploration with carbon management. Engineering Science & Technology Journal, 5(4), 1203-1213.

[145] Onyiriuka, E. J., Ewim, D. R. E., and Abolarin, S. M. (2023). An optimization technique to identify simulation assumptions for various nanofluids using machine learning. International Heat Transfer Conference Digital Library.

[146] Orikpete, O. F., and Ewim, D. R. E. (2023). A review of noise management practice in Nigeria. Environmental Science & Sustainable Development, 8(1), 31-44.

[147] Orikpete, O. F., Leton, T. G., and Ewim, D. R. E. (2020). Mathematical modeling of environmental noise generated by rotorcraft overflight. Journal of Critical Reviews, 7(19), 10097-10110.

[148] Pellow, M.A., Ambrose, H., Mulvaney, D., Betita, R. and Shaw, S., 2020. Research gaps in environmental life cycle assessments of lithium ion batteries for grid-scale stationary energy storage systems: End-of-life options and other issues. *Sustainable Materials and Technologies*, *23*, p.e00120.

[149] Popoola, O. A., Adama, H. E., Okeke, C. D., & Akinoso, A. E. (2024). The strategic value of business analysts in enhancing organizational efficiency and operations. International Journal of Management & Entrepreneurship Research, 6(4), 1288-1303. DOI: 10.51594/ijmer.v6i4.1059. Fair East Publishers. Retrieved from http://www.fepbl.com/index.php/ijmer

[150] Popoola, O. A., Adama, H. E., Okeke, C. D., & Akinoso, A. E. (2024). Cross-industry frameworks for business process reengineering: Conceptual models and practical executions. World Journal of Advanced Research and Reviews, 22(01), 1198–1208. DOI: 10.30574/wjarr.2024.22.1.1201. https://doi.org/10.30574/wjarr.2024.22.1.1201

[151] Popoola, O. A., Adama, H. E., Okeke, C. D., & Akinoso, A. E. (2024). Conceptualizing agile development in digital transformations: Theoretical foundations and practical applications. Engineering Science & Technology Journal, 5(4), 1524-1541. DOI: 10.51594/estj/v5i4.1080. Fair East Publishers. Retrieved from http://www.fepbl.com/index.php/estj

[152] Popoola, O. A., Adama, H. E., Okeke, C. D., & Akinoso, A. E. (2024). Advancements and innovations in requirements elicitation: Developing a comprehensive conceptual model. World Journal of Advanced Research and Reviews, 22(01), 1209–1220. DOI: https://doi.org/10.30574/wjarr.2024.22.1.1202

[153] Popoola, O. A., Adama, H. E., Okeke, C. D., & Akinoso, A. E. (2024). Advancements and innovations in requirements elicitation: Developing a comprehensive conceptual model. *World Journal of Advanced Research and Reviews*, *22*(1), 1209-1220.

[154] Popoola, O. A., Adama, H. E., Okeke, C. D., & Akinoso, A. E. (2024). THE STRATEGIC VALUE OF BUSINESS ANALYSTS IN ENHANCING ORGANIZATIONAL EFFICIENCY AND OPERATIONS. *International Journal of Management & Entrepreneurship Research*, *6*(4), 1288-1303.

[155] Popoola, O. A., Adama, H. E., Okeke, C. D., & Akinoso, A. E. (2024). CONCEPTUALIZING AGILE DEVELOPMENT IN DIGITAL TRANSFORMATIONS: THEORETICAL FOUNDATIONS AND PRACTICAL APPLICATIONS. *Engineering Science & Technology Journal*, *5*(4), 1524-1541.

[156] Popoola, O. A., Adama, H. E., Okeke, C. D., & Emmanuel, A. (2024). Cross-industry frameworks for business process reengineering: Conceptual models and practical executions.

[157] Punia, A. and Singh, S.K., 2021. Contamination of water resources in the mining region. In *Contamination of water* (pp. 3-17). Academic Press.

[158] Rahman, A., Farrok, O. and Haque, M.M., 2022. Environmental impact of renewable energy source based electrical power plants: Solar, wind, hydroelectric, biomass, geothermal, tidal, ocean, and osmotic. *Renewable and Sustainable Energy Reviews*, *161*, p.112279.

[159] Saldarini, A., Longo, M., Brenna, M. and Zaninelli, D., 2023. Battery Electric Storage Systems: Advances, Challenges, and Market Trends. *Energies*, *16*(22), p.7566.

[160] Schismenos, S., Chalaris, M. and Stevens, G., 2021. Battery hazards and safety: A scoping review for lead acid and silver-zinc batteries. *Safety science*, *140*, p.105290.

[161] Schwarz, A.E., Ligthart, T.N., Bizarro, D.G., De Wild, P., Vreugdenhil, B. and Van Harmelen, T., 2021. Plastic recycling in a circular economy; determining environmental performance through an LCA matrix model approach. *Waste Management*, *121*, pp.331-342.

[162] Spataru, C. and Bouffaron, P., 2022. Off-grid energy storage. In *Storing Energy* (pp. 731-752). Elsevier.

[163] Spooren, J., Binnemans, K., Björkmalm, J., Breemersch, K., Dams, Y., Folens, K., González-Moya, M., Horckmans, L., Komnitsas, K., Kurylak, W. and Lopez, M., 2020. Near-zero-waste processing of low-grade, complex primary ores and secondary raw materials in Europe: technology development trends. *Resources, Conservation and Recycling*, *160*, p.104919.

[164] Suku, P. G., Ugwoha, E., Orikpete, O. F., and Ewim, D. R. E. (2023). Assessment of respiratory and reproductive impacts of artisanal refinery activities on male Albino Wistar rats: Implications for environmental health. Bulletin of the National Research Centre, 47(1), 149.

[165] Suman, A., 2021. Role of renewable energy technologies in climate change adaptation and mitigation: A brief review from Nepal. *Renewable and Sustainable Energy Reviews*, *151*, p.111524.

[166] Thompson, O. A., Akintuyi, O. B., Omoniyi, L. O., & Fatoki, O. A. (2022). Analysis of Land Use and Land Cover Change in Oil Palm Producing Agro-Ecological Zones of Nigeria. Journal of Agroforestry and Environment, 15(1), 30-41.

[167] Uduafemhe, M. E., Ewim, D. R. E., and Karfe, R. Y. (2023). Adapting to the new normal: Equipping career and technical education graduates with essential digital skills for remote employment. ATBU Journal of Science, Technology and Education, 11(4), 51-62.

[168] Ukaogo, P.O., Ewuzie, U. and Onwuka, C.V., 2020. Environmental pollution: causes, effects, and the remedies. In *Microorganisms for sustainable environment and health* (pp. 419-429). Elsevier.

[169] Ukoba, K.O., Eloka-Eboka, A.C. and Inambao, F.L., 2017. Review of solar energy inclusion in Africa: a case study of Nigeria.

[170] Usiagu, G. S., Adekoya, O. O., Okoli, C. E., Daudu, C. D., Ekemezie, I. O., et al. (2024). LNG as a bridge fuel in the transition to renewable energy: A global perspective. World Journal of Advanced Research and Reviews, 21(2), 742-749.

[171] Usiagu, G. S., Ayorinde, O. B., Okoli, C. E., Daudu, C. D., Adekoya, O. O., et al. (2024). Environmental implications of LNG usage: A comparative review of policies in the USA and Africa. World Journal of Advanced Research and Reviews, 21(2), 742-749.

[172] Uzougbo, N.S., Akagha, O.V., Coker, J.O., Bakare, S.S. and Ijiga, A.C., 2023. Effective strategies for resolving labour disputes in the corporate sector: Lessons from Nigeria and the United States.

[173] Wang, Y.W. and Shu, C.M., 2022. Energy generation mechanisms for a Li-ion cell in case of thermal explosion: A review. *Journal of Energy Storage*, *55*, p.105501.

[174] Wiggins, J., Cox, M. F., Howard, A., Leveni, M., Cuellar-Gaviria, T. Z., Hisey, C. L., et al. (2023). Doing academia differently: The creation of a cohort-based postdoctoral scholars program for emerging engineering faculty. 2023 ASEE Annual Conference & Exposition.

[175] Xu, B., Lee, J., Kwon, D., Kong, L. and Pecht, M., 2021. Mitigation strategies for Li-ion battery thermal runaway: A review. *Renewable and Sustainable Energy Reviews*, *150*, p.111437.

[176] Yang, Y., Okonkwo, E.G., Huang, G., Xu, S., Sun, W. and He, Y., 2021. On the sustainability of lithium ion battery industry–A review and perspective. *Energy Storage Materials*, *36*, pp.186-212.

[177] Zhang, H., Bai, M., Wang, X., Gai, J., Shu, C.M., Roy, N. and Liu, Y., 2021. Thermal runaway incidents-a serious cause of concern: An analysis of runaway incidents in China. *Process Safety and Environmental Protection*, *155*, pp.277-286.

[178] Zohuri, B., 2023. Navigating the Global Energy Landscape Balancing Growth, Demand, and Sustainability. *J. Mat. Sci. Apl. Eng*, *2*(7).