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Sustainable Procurement and Supply Chain Management in Geothermal Energy and Environmental Projects

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ABSTRACT: Sustainable procurement and supply chain management are crucial for advancing geothermal energy and environmental projects, given their role in mitigating climate change and promoting resource efficiency. This review explores the integration of sustainability practices into the procurement and supply chain processes specific to geothermal energy projects and environmental initiatives. Geothermal energy, recognized for its low carbon footprint and renewable nature, requires a sustainable approach to procurement to maximize its environmental benefits. Key strategies include selecting suppliers with strong sustainability credentials and implementing green procurement policies that prioritize eco-friendly materials and technologies. Moreover, lifecycle assessment plays a critical role in evaluating the environmental impacts of equipment and materials used in geothermal projects, ensuring that all components contribute to the overall sustainability goals. In the context of environmental projects, sustainable supply chain management involves reducing waste, optimizing resource use, and enhancing the overall efficiency of project execution. Technologies such as blockchain and artificial intelligence (AI) are increasingly utilized to enhance transparency and traceability in supply chains, allowing for real-time monitoring of environmental impacts and ensuring compliance with sustainability standards. These technologies facilitate the management of complex supply chains by providing accurate data on supplier practices and environmental performance. Challenges in implementing sustainable procurement and supply chain practices include balancing cost with sustainability objectives and managing the complexities of global supply chains. However, companies that successfully integrate these practices benefit from enhanced corporate reputation, improved stakeholder relations, and long-term operational resilience. Sustainable procurement and supply chain management not only support the achievement of environmental goals but also contribute to the economic viability of geothermal energy and environmental projects. The paper concludes that adopting sustainable practices in these sectors is essential for advancing global sustainability objectives and ensuring the long-term success of energy and environmental initiatives.

KEYWORDS: sustainable procurement, supply chain management, geothermal energy, environmental projects, green procurement, lifecycle assessment, blockchain, artificial intelligence, transparency, resource efficiency, carbon footprint.

1.0. INTRODUCTION

Sustainable procurement and supply chain management (SCM) are essential frameworks that promote the responsible sourcing, acquisition, and distribution of goods and services while prioritizing environmental, social, and economic sustainability. Sustainable procurement refers to the process of selecting products, services, and suppliers based on criteria that ensure minimal environmental impact, social equity, and economic efficiency (Bello, Idemudia & Iyelolu, 2024, Ige, Kupa & Ilori, 2024, Olanrewaju, Oduro & Babayeju, 2024). In contrast, SCM encompasses the planning, execution, and oversight of the entire supply chain, ensuring that sustainability is maintained at every stage, from material sourcing to product delivery.

In the context of geothermal energy and environmental projects, sustainability is particularly crucial due to the need to balance technological advancements with environmental protection. Geothermal energy, as a renewable energy source, plays a vital role in reducing greenhouse gas emissions and supporting global efforts to mitigate climate change (Chukwurah, et al., 2024, Olatunji, et al., 2024, Oyewole, et al., 2024, Uzougbo, Ikegwu & Adewusi, 2024). However, the processes involved in developing geothermal infrastructure can have significant environmental impacts, including land disturbance, water usage, and emissions. Environmental

projects, aimed at conservation and resource management, similarly depend on sustainable procurement to source eco-friendly materials and implement technologies that mitigate ecological harm.

Integrating sustainability into procurement and SCM offers multiple benefits for geothermal energy and environmental projects. First, it reduces the environmental footprint of these projects by promoting the use of eco-friendly materials and processes. By choosing suppliers who adhere to sustainable practices, organizations can lower their carbon emissions and waste production (Ekechukwu & Simpa, 2024, Oluokun, Idemudia & Iyelolu, 2024, Porlles, et al., 2023). Additionally, sustainable procurement enhances operational efficiency, as eco-friendly technologies and materials often offer long-term cost savings through reduced energy consumption and maintenance costs. Furthermore, these practices strengthen corporate social responsibility (CSR) by ensuring that project activities align with ethical standards, promoting social equity and local community engagement. Overall, embedding sustainability in procurement and SCM is vital for ensuring the long-term success and environmental integrity of geothermal energy and environmental projects, aligning operational practices with broader goals of ecological stewardship and social responsibility.

2.1. SUSTAINABLE PROCUREMENT IN GEOTHERMAL ENERGY PROJECTS

Sustainable procurement in geothermal energy projects is a critical component in ensuring that these initiatives contribute positively to environmental and social goals while maximizing economic benefits. This approach involves selecting materials and suppliers based on their environmental impact and their alignment with sustainability principles, ultimately enhancing the overall sustainability of the project. Material selection plays a central role in sustainable procurement (Abdul-Azeez, Ihechere & Idemudia, 2024, Ikevuje, Anaba & Iheanyichukwu, 2024, Uzougbo, Ikegwu & Adewusi, 2024). In geothermal energy projects, it is essential to choose materials that minimize environmental impacts and contribute to the efficient and effective operation of geothermal systems. The criteria for selecting eco-friendly materials typically include their environmental impact throughout their lifecycle, from extraction and processing to disposal. Key factors include the material's durability, its energy efficiency during use, and the extent of its recyclability or biodegradability.

For instance, in geothermal energy projects, using high-performance, energy-efficient materials can significantly reduce the system's overall environmental impact. Examples of sustainable materials include advanced, low-emission drilling fluids that minimize environmental contamination during geothermal well drilling. These fluids are designed to be less harmful to the environment compared to traditional options, often utilizing biodegradable or less toxic components (Ikevuje, Anaba & Iheanyichukwu, 2024, Oluokun, Ige & Ameyaw, 2024, Segun-Falade, et al., 2024). Another example is the use of high-efficiency turbines and pumps made from advanced composite materials that offer improved performance while reducing energy consumption. Additionally, materials with a low carbon footprint, such as recycled metals or eco-friendly concrete, contribute to reducing the overall emissions associated with geothermal projects.

Supplier evaluation is another crucial aspect of sustainable procurement. Selecting suppliers who align with sustainability criteria helps ensure that the materials and services provided adhere to environmental and social standards. Sustainability criteria for evaluating suppliers often include their commitment to environmental management practices, their use of renewable resources, and their adherence to ethical labor practices (Ikevuje, Anaba & Iheanyichukwu, 2024, Onita & Ochulor, 2024, Oyewole, et al., 2024). It is essential to assess whether suppliers have certifications or standards that indicate their sustainability performance, such as ISO 14001 for environmental management or Fair Trade certifications for ethical labor practices.

Methods for assessing supplier sustainability practices include conducting thorough supplier audits and requiring detailed sustainability reports. Audits can evaluate a supplier's adherence to environmental regulations, waste management practices, and energy usage. Sustainability reports, on the other hand, provide insights into a supplier's environmental and social performance, including their carbon footprint, waste generation, and efforts to reduce their impact (Akinsulire, et al., 2024, Ikevuje, Anaba & Iheanyichukwu, 2024, Onwuka & Adu, 2024). Implementing a robust supplier evaluation process helps ensure that procurement decisions support the overarching sustainability goals of geothermal energy projects. Reducing the environmental impact of procurement activities involves adopting techniques that minimize waste and optimize resource use. Techniques for reducing environmental footprints include implementing just-in-time inventory systems to reduce excess materials and associated waste, as well as optimizing transportation logistics to lower emissions. Additionally, promoting the use of sustainable packaging materials and encouraging suppliers to adopt eco-friendly practices contribute to reducing the overall environmental impact of procurement activities (Adeoye, et al., 2024, Bello, Ige & Ameyaw, 2024, Ogbu, et al., 2024, Segun-Falade, et al., 2024).

Lifecycle assessment (LCA) is a critical tool in sustainable procurement, offering a comprehensive evaluation of a product's environmental impact from cradle to grave. LCA helps in identifying the stages in a product's lifecycle that have the most significant environmental impact, such as raw material extraction, manufacturing, transportation, use, and disposal (Bello, Idemudia & Iyelolu, 2024, Iyelolu & Paul, 2024, Osimobi, et al., 2023). By understanding these impacts, organizations can make more informed decisions about

material selection and procurement practices. For geothermal energy projects, LCA can reveal the environmental benefits of using materials with lower carbon footprints or those that offer better energy efficiency, thus supporting more sustainable project outcomes. Incorporating LCA into procurement processes allows project managers to evaluate and compare the environmental impacts of different materials and suppliers, leading to more sustainable choices. For example, comparing the lifecycle emissions of different drilling fluids or evaluating the long-term energy savings of various turbine materials can guide procurement decisions toward more environmentally friendly options.

In conclusion, sustainable procurement in geothermal energy projects is fundamental for achieving environmental and social sustainability goals. By focusing on eco-friendly material selection, rigorous supplier evaluation, and effective techniques for reducing environmental impacts, geothermal projects can significantly enhance their overall sustainability (Eziamaka, Odonkor & Akinsulire, 2024, Onita & Ochulor, 2024, Osundare & Ige, 2024). Integrating lifecycle assessments into procurement processes further ensures that materials and practices contribute to long-term environmental benefits. This comprehensive approach not only supports the efficient and responsible development of geothermal energy projects but also aligns with broader objectives of ecological stewardship and social responsibility.

2.2. SUPPLY CHAIN MANAGEMENT IN GEOTHERMAL ENERGY PROJECTS

Supply chain management (SCM) in geothermal energy projects is pivotal in ensuring that sustainability principles are integrated throughout the lifecycle of the project, from procurement to delivery and operation. Effective SCM practices not only streamline operations but also contribute to the environmental and social goals of the project (Adesina, Iyelolu & Paul, 2024, Iyelolu, et al., 2024, Ozowe, et al., 2024). By focusing on sustainability, geothermal projects can enhance their efficiency, reduce their environmental footprint, and foster greater transparency and collaboration among stakeholders.

Sustainable SCM practices are essential for managing the supply chain in a way that aligns with the broader goals of sustainability. Key practices include adopting green logistics, optimizing resource use, and implementing circular economy principles. Green logistics involves minimizing the environmental impact of transportation and distribution activities, which can be achieved through strategies such as optimizing delivery routes to reduce fuel consumption, using energy-efficient transportation modes, and consolidating shipments to decrease the number of trips (Ekechukwu, 2021, Iyelolu, et al., 2024, Olanrewaju, Daramola & Babayeju, 2024). By focusing on these practices, geothermal projects can lower their carbon footprint and improve overall efficiency.

Another important aspect of sustainable SCM is the integration of sustainability criteria into procurement and supply chain processes. This involves setting clear sustainability goals and performance metrics for suppliers and ensuring that these criteria are incorporated into contract terms and supplier evaluations (Abdul-Azeez, Ihechere & Idemudia, 2024, Jambol, et al., 2024, Ozowe, 2018, Uzougbo, Ikegwu & Adewusi, 2024). For instance, contracts can stipulate requirements for environmental certifications, energy efficiency, and waste reduction. Integrating sustainability criteria also means actively engaging with suppliers to promote their adoption of sustainable practices and technologies, ensuring that all components of the supply chain contribute to the project's sustainability objectives.

Risk management is a critical component of SCM, particularly in the context of geothermal energy projects where environmental and social risks can be significant. Identifying and managing these risks involves assessing potential impacts at various stages of the supply chain, from raw material extraction to construction and operation. Environmental risks might include pollution from materials, habitat disruption, or resource depletion (Addy, et al., 2024, Ezeh, et al., 2024, Ige, Kupa & Ilori, 2024, Onwuka & Adu, 2024). Social risks could involve labor practices, community impacts, or stakeholder conflicts.

Effective strategies for mitigating these risks include implementing comprehensive risk assessment frameworks, conducting regular audits, and establishing contingency plans. Risk assessments can help identify potential issues and develop strategies to address them proactively. For example, if a supplier is found to have inadequate environmental controls, the project team can work with the supplier to improve practices or seek alternative sources (Agu, et al., 2024, Jambol, et al., 2024, Olanrewaju, Ekechukwu & Simpa, 2024). Contingency plans ensure that there are predefined responses to potential disruptions or negative impacts, reducing the likelihood of project delays or increased costs.

Collaboration and transparency are vital for fostering sustainable SCM in geothermal energy projects. Engaging with stakeholders, including suppliers, local communities, and regulatory bodies, helps ensure that all parties are aligned with the project's sustainability goals and can contribute to achieving them (Ekechukwu & Simpa, 2024, Ogbu, et al., 2023, Ogbu, Ozowe & Ikevuje, 2024). Effective stakeholder collaboration involves regular communication, joint problem-solving, and shared decision-making. For instance, involving local communities in planning and decision-making processes can address concerns and improve the project's social acceptance.

Enhancing supply chain transparency and accountability is also crucial. Transparency involves providing clear and accessible information about supply chain practices, environmental impacts, and social performance (Bello, Idemudia & Iyelolu, 2024, Jambol, et al., 2024, Uzougbo, Ikegwu & Adewusi, 2024). This can be achieved through

measures such as publishing sustainability reports, tracking and reporting on key performance indicators, and disclosing supply chain information to stakeholders. Accountability ensures that all parties in the supply chain are held responsible for their actions and adherence to sustainability standards. This can be supported through regular performance reviews, compliance checks, and the establishment of clear consequences for non-compliance.

In conclusion, effective SCM in geothermal energy projects is essential for integrating sustainability throughout the supply chain, managing risks, and fostering collaboration and transparency. By adopting sustainable practices, assessing and mitigating risks, and engaging with stakeholders, geothermal projects can enhance their environmental and social performance while achieving operational efficiency (Babayeju, et al., 2024, Kedi, et al., 2024, Ozowe, 2021, Ozowe, Daramola & Ekemezie, 2023). These efforts not only contribute to the overall success of the project but also support broader goals of sustainability and responsible resource management.

2.3. SUSTAINABLE PROCUREMENT IN ENVIRONMENTAL PROJECTS

Sustainable procurement in environmental projects is essential for achieving ecological and social goals while ensuring the efficient use of resources. This approach involves selecting eco-friendly materials and technologies, as well as adhering to ethical practices throughout the procurement process. By prioritizing sustainability, environmental projects can minimize their impact on the environment, support social equity, and enhance overall project success (Gyimah, et al., 2023, Kedi, et al., 2024, Osundare & Ige, 2024, Oyewole, et al., 2024).

The procurement of eco-friendly materials is a fundamental aspect of sustainable procurement. When selecting construction materials and technologies for environmental projects, several criteria must be considered to ensure that they align with sustainability goals. First, the environmental impact of the materials throughout their lifecycle must be assessed (Idemudia, et al., 2024, Oriekhoe, et al., 2024, Raji, Ijomah & Eyieyien, 2024). This includes evaluating the materials' resource consumption during production, their energy efficiency during use, and their disposal or recycling options at the end of their life. Materials that have a lower carbon footprint, use fewer non-renewable resources, and are recyclable or biodegradable are preferred.

Durability is another critical factor in selecting sustainable materials. Durable materials reduce the need for frequent replacements and maintenance, which can contribute to lower environmental impacts over time. For example, materials that withstand harsh weather conditions or resist wear and tear can extend the lifespan of a project and reduce the frequency of repairs or replacements (Addy, et al., 2024, Eyieyien, et al., 2024, Kedi, et al., 2024, Ozowe, Daramola & Ekemezie, 2024). Examples of sustainable materials used in environmental projects include recycled content products, such as recycled steel, glass, or plastic, which help reduce the demand for virgin materials and minimize waste. Another example is the use of low-impact building materials like bamboo, which is rapidly renewable and has a lower environmental footprint compared to traditional hardwoods. Additionally, advanced technologies such as green roofs and permeable pavements contribute to environmental sustainability by improving stormwater management and reducing the urban heat island effect.

Ethical sourcing is equally important in sustainable procurement, as it ensures that goods and services are obtained in a manner that respects human rights and supports fair labor practices. Ethical sourcing involves verifying that suppliers adhere to social and environmental standards and that their practices do not contribute to exploitation or harm (Kwakye, Ekechukwu & Ogundipe, 2024, Obeng, et al., 2924, Udo, et al., 2024). This can be achieved by requiring suppliers to provide evidence of their compliance with ethical labor practices, such as fair wages, safe working conditions, and non-discriminatory practices. Addressing social responsibility issues in procurement includes engaging with suppliers to promote ethical practices and supporting initiatives that enhance the well-being of communities. This might involve sourcing products from companies that support local economies or those that invest in community development projects. Additionally, it includes ensuring that procurement practices do not contribute to negative social impacts, such as forced labor or child labor.

To ensure ethical practices, organizations can implement supplier codes of conduct and conduct regular audits to verify compliance. These codes outline the expectations for ethical behavior and provide a framework for assessing supplier practices. Audits, both internal and third-party, help to identify and address any issues related to labor practices, environmental impact, or ethical conduct. Incorporating sustainability into procurement processes also involves fostering transparency and accountability (Bello, Idemudia & Iyelolu, 2024, Oyewole, et al., 2024, Sofoluwe, et al., 2024, Uzougbo, Ikegwu & Adewusi, 2024). Organizations should require suppliers to provide detailed information about their environmental and social practices, including any certifications or standards they adhere to. This transparency helps in making informed decisions and ensuring that procurement activities align with sustainability objectives.

Moreover, organizations can support sustainable procurement by collaborating with industry groups and stakeholders to develop and promote best practices. Engaging in industry initiatives, such as certification programs for sustainable materials or ethical sourcing standards, helps to drive broader adoption of sustainable practices and contributes to the overall advancement of sustainability in environmental projects (Abdul-Azeez, Ihechere & Idemudia, 2024, Okoye, et al., 2024, Ukato, et al.,2024). In conclusion, sustainable procurement in environmental projects is a critical element in

achieving environmental and social sustainability goals. By focusing on the procurement of eco-friendly materials and adhering to ethical sourcing practices, organizations can significantly reduce the environmental impact of their projects and support social responsibility. Implementing criteria for selecting sustainable materials, addressing ethical issues in procurement, and fostering transparency and accountability contribute to the overall success of environmental projects and promote a more sustainable future.

2.4. SUPPLY CHAIN MANAGEMENT IN ENVIRONMENTAL PROJECTS

Supply chain management (SCM) in environmental projects plays a pivotal role in ensuring that sustainability principles are applied throughout the project lifecycle. Effective SCM involves not only the efficient handling and distribution of resources but also the proactive management and mitigation of environmental impacts (Esiri, Sofoluwe & Ukato, 2024, Ige, Kupa & Ilori, 2024, Tula, Babayeju & Aigbedion, 2023). By employing rigorous environmental impact monitoring and establishing robust performance metrics and reporting systems, organizations can enhance the sustainability of their projects and support broader ecological goals. Environmental impact monitoring is a fundamental aspect of sustainable SCM. It involves the systematic tracking and assessment of environmental impacts associated with various stages of the supply chain, from raw material extraction to final delivery and use. Tools and methods for monitoring these impacts include environmental impact assessments (EIAs), real-time monitoring technologies, and lifecycle assessments (LCAs).

Environmental impact assessments are used to evaluate the potential effects of project activities on the environment before they commence. They provide a comprehensive analysis of various environmental factors, such as air and water quality, noise levels, and habitat disruption, and help in identifying potential risks and mitigation strategies (Eziamaka, Odonkor & Akinsulire, 2024, Ogunleye, 2024, Urefe, et al., 2024). By conducting EIAs, organizations can make informed decisions about sourcing materials and managing processes to minimize negative environmental impacts. Real-time monitoring technologies, such as remote sensing and geographic information systems (GIS), offer valuable insights into the environmental performance of supply chain activities. Remote sensing tools can track changes in land use, monitor air and water quality, and detect environmental degradation. GIS can be used to visualize and analyze spatial data related to environmental impacts, enabling more effective management and mitigation strategies.

Lifecycle assessments provide a comprehensive evaluation of a product's environmental impacts from cradle to grave. This includes assessing resource extraction, manufacturing, transportation, use, and disposal. LCAs help in identifying stages with significant environmental impacts and guide the selection of more sustainable alternatives (Obeng, et al., 2924, Okeke & Olurin, 2019, Oyewole, et al., 2024, Uzougbo, et al., 2023). For instance, LCAs can reveal the benefits of using materials with lower carbon footprints or those that offer better energy efficiency. Best practices for minimizing adverse environmental effects in SCM include adopting green logistics, optimizing resource use, and implementing waste reduction strategies. Green logistics involves reducing the environmental footprint of transportation and distribution activities, such as optimizing delivery routes, using energy-efficient transportation modes, and consolidating shipments to decrease fuel consumption and emissions (Akagha, et al., 2023, Latilo, et al., 2024, Oduro, Uzougbo & Ugwu, 2024). Optimizing resource use involves practices such as reducing material waste, improving resource efficiency, and promoting the use of renewable resources. Waste reduction strategies include recycling, reusing materials, and minimizing packaging to reduce the overall environmental impact of supply chain activities.

Performance metrics and reporting are crucial for assessing and communicating the sustainability of SCM practices. Key performance indicators (KPIs) for SCM sustainability typically include metrics related to environmental performance, such as carbon emissions, energy consumption, and waste generation (Abah, et al., 2024, Ofodile, et al., 2024, Ekechukwu, Daramola & Kehinde, 2024). For instance, organizations may track the carbon footprint of their supply chain operations, measure energy usage per unit of output, or monitor the percentage of waste recycled or diverted from landfills. Reporting frameworks and standards provide a structured approach to communicating environmental performance and sustainability efforts. Common reporting frameworks include the Global Reporting Initiative (GRI) Standards, which offer guidelines for reporting on a range of environmental, social, and governance (ESG) issues. The GRI Standards help organizations disclose their sustainability performance in a transparent and consistent manner, allowing stakeholders to evaluate their environmental impact and sustainability efforts (Abdul-Azeez, Ihechere & Idemudia, 2024, Ogbu, et al., 2024, Olanrewaju, Daramola & Babayeju, 2024).

Another important standard is the Carbon Disclosure Project (CDP), which focuses on reporting and managing carbon emissions and climate-related risks. The CDP provides a platform for organizations to disclose their greenhouse gas emissions, climate strategies, and risk management practices, helping to drive accountability and improvements in environmental performance (Adeoye, et al., 2024, Ameyaw, Idemudia & Iyelolu, 2024, Ofodile, et al., 2024). The Sustainability Accounting Standards Board (SASB) provides industry-specific standards for reporting on sustainability issues that are material to financial performance. SASB standards help organizations disclose relevant environmental and social impacts in a way that is useful for investors and other stakeholders. By implementing these performance

metrics and reporting frameworks, organizations can effectively track and communicate their sustainability performance, identify areas for improvement, and demonstrate their commitment to environmental stewardship. Transparent reporting also fosters trust with stakeholders and supports informed decision-making (Aziza, Uzougbo & Ugwu, 2023, Latilo, et al., 2024, Oduro, Uzougbo & Ugwu, 2024).

In conclusion, effective SCM in environmental projects involves rigorous environmental impact monitoring and the establishment of robust performance metrics and reporting systems. By employing tools and methods for monitoring environmental impacts, organizations can proactively manage and mitigate adverse effects, enhancing the overall sustainability of their projects. Additionally, by utilizing key performance indicators and reporting frameworks, organizations can track and communicate their environmental performance, demonstrating their commitment to sustainability and supporting broader ecological goals (Akinsulire, et al., 2024, Odeyemi, et al., 2024, Raji, Ijomah & Eyieyien, 2024). Through these practices, SCM can significantly contribute to the success and sustainability of environmental projects, driving positive environmental and social outcomes.

2.5. CASE STUDIES

Sustainable procurement and supply chain management (SCM) have become critical components in the successful execution of geothermal energy and environmental projects. By examining case studies from various projects, we can glean valuable insights into effective practices and strategies that have led to successful outcomes in these fields (Bello, Idemudia & Iyelolu, 2024, Odeyemi, et al., 2024, Udo, et al., 2023). These examples illustrate how integrating sustainability into procurement and SCM can drive positive environmental impacts, enhance operational efficiency, and support long-term project goals.

One notable example of sustainable procurement in geothermal energy projects is the Hellisheidi Geothermal Power Plant in Iceland. This project exemplifies the integration of sustainable practices throughout its procurement and supply chain processes. The Hellisheidi plant, operated by Reykjavik Energy, focuses on harnessing geothermal energy to generate electricity and provide district heating (Abdul-Azeez, Ihechere & Idemudia, 2024, Obeng, et al., 2024). The project stands out for its commitment to minimizing environmental impact through careful selection of materials and suppliers.

The procurement strategy for the Hellisheidi project emphasized the use of high-performance, eco-friendly materials. For instance, the construction of the power plant incorporated low-impact drilling fluids, which are less harmful to the environment compared to traditional options. These fluids, derived from biodegradable substances, help reduce the risk of contamination during drilling operations (Aziza, Uzougbo & Ugwu, 2023, Latilo, et al., 2024, Oguejiofor, et al., 2023). Additionally, the project utilized advanced composite materials for turbine and pump components, which offer improved efficiency and durability while reducing overall energy consumption.

Supplier evaluation was another critical aspect of the Hellisheidi project's success. Reykjavik Energy established strict sustainability criteria for selecting suppliers, including requirements for environmental management practices and ethical labor standards. Suppliers were required to demonstrate their commitment to reducing their carbon footprint and adhering to responsible labor practices (Adesina, Iyelolu & Paul, 2024, Obeng, et al., 2024). This rigorous evaluation process ensured that all components of the supply chain aligned with the project's sustainability goals.

Another successful case study in geothermal energy is the Salton Sea Geothermal Project in California. This project, managed by CalEnergy Operating Corporation, highlights effective SCM practices in managing environmental impacts. The Salton Sea project focuses on harnessing geothermal energy from the Salton Sea Geothermal Field to generate electricity (Akinsulire, et al., 2024, Obeng, et al., 2024, Sofoluwe, et al., 2024). The procurement process for the Salton Sea project emphasized the use of materials and technologies that minimize environmental impact. For example, the project incorporated advanced reinjection wells, which help manage and mitigate potential environmental effects of geothermal fluid extraction. These wells reinject spent geothermal fluids back into the reservoir, reducing the risk of surface contamination and supporting the long-term sustainability of the geothermal resource.

Additionally, the Salton Sea project employed real-time monitoring technologies to track environmental impacts associated with the supply chain. These technologies include remote sensing and geographic information systems (GIS) that provide valuable data on air and water quality, land use changes, and other environmental factors. By leveraging these tools, the project team was able to identify potential issues and implement corrective measures proactively (Idemudia, et al., 2024, Obeng, et al., 2924, Osundare & Ige, 2024, Segun-Falade, et al., 2024). In the realm of environmental projects, the City of Toronto's Green Roof Bylaw offers a compelling case study in sustainable procurement and SCM. The bylaw mandates the installation of green roofs on new and existing buildings, promoting environmental benefits such as improved stormwater management, reduced urban heat island effect, and enhanced biodiversity.

The procurement strategy for green roof installations in Toronto focuses on using sustainable materials and technologies. For example, the project encourages the use of locally sourced, eco-friendly materials such as recycled content and low-impact growing mediums. Additionally, suppliers are required to adhere to sustainability criteria,

including the use of energy-efficient installation practices and the implementation of waste reduction measures (Eyieyien, et al., 2024, Ochulor, et al., 2024, Raji, Ijomah & Eyieyien, 2024). One key lesson from Toronto's green roof initiative is the importance of stakeholder collaboration and transparency. The city engages with various stakeholders, including building owners, contractors, and environmental organizations, to ensure that all parties are aligned with the project's sustainability goals. This collaborative approach helps address challenges, share best practices, and foster a collective commitment to environmental stewardship.

Another example of best practices in environmental projects is the World Wildlife Fund's (WWF) Earth Hour campaign. This global initiative encourages individuals, businesses, and governments to turn off non-essential lights for one hour each year to raise awareness about climate change and promote energy conservation (Bello, Ige & Ameyaw, 2024, Ochulor, et al., 2024, Udo, et al., 2024). The Earth Hour campaign employs sustainable procurement and SCM practices to support its objectives. For instance, the campaign prioritizes the use of eco-friendly materials and services for event planning and promotion. This includes sourcing recyclable or biodegradable materials for promotional materials, reducing waste through digital communications, and selecting vendors who adhere to sustainability principles. One notable lesson from the Earth Hour campaign is the impact of effective performance metrics and reporting. The campaign tracks key performance indicators such as the amount of energy saved during the event and the level of participant engagement (Moones, et al., 2023, Ogbu, et al., 2024, Okoye, et al., 2024, Segun-Falade, et al., 2024). By reporting these metrics transparently, the campaign demonstrates its commitment to sustainability and provides valuable insights for future initiatives.

In conclusion, case studies from geothermal energy and environmental projects highlight the importance of sustainable procurement and SCM practices. The Hellisheidi Geothermal Power Plant and Salton Sea Geothermal Project illustrate effective strategies for selecting eco-friendly materials, evaluating suppliers, and managing environmental impacts. Similarly, Toronto's Green Roof Bylaw and the WWF's Earth Hour campaign showcase best practices in material selection, stakeholder collaboration, and performance reporting (Abdul-Azeez, Ihechere & Idemudia, 2024, Olanrewaju, Daramola & Ekechukwu, 2024). These examples offer valuable lessons for integrating sustainability into procurement and supply chain management, ultimately driving positive environmental outcomes and supporting long-term project success.

2.6. CHALLENGES AND OPPORTUNITIES

Sustainable procurement and supply chain management (SCM) in geothermal energy and environmental projects present a complex interplay of challenges and opportunities. These areas are crucial as they significantly impact the overall sustainability and efficiency of energy and environmental initiatives (Adeoye, et al., 2024, Ezeh, et al., 2024, Ochulor, et al., 2024, Ozowe, Ogbu & Ikevuje, 2024). As the world shifts towards more sustainable practices, addressing these challenges and seizing the opportunities becomes imperative for achieving long-term success and reducing environmental impact. Implementing sustainable procurement and SCM in geothermal energy and environmental projects is fraught with several challenges. One significant barrier is the lack of standardization in sustainability metrics and criteria. Different organizations and regions may have varying standards for what constitutes sustainable practices, making it difficult to align procurement and supply chain strategies with these diverse standards. This lack of uniformity can lead to inconsistencies in evaluating suppliers, assessing environmental impacts, and ensuring compliance with sustainability goals.

Another challenge is the limited availability of sustainable materials and technologies. Geothermal energy projects often require specialized equipment and materials that are not always available in sustainable or environmentally friendly versions. This scarcity can lead to a reliance on less sustainable options, undermining the overall goals of the project (Raji & Olodo, 2024, Odonkor, Eziamaka & Akinsulire, 2024). Furthermore, the high cost associated with sustainable materials and technologies can be a significant barrier. While these options may offer long-term benefits, their initial costs can be prohibitive, especially for projects with tight budgets.

Supply chain complexity also poses a challenge. Geothermal energy projects and environmental initiatives often involve multiple stakeholders, including suppliers, contractors, and regulatory bodies. Coordinating these various entities to ensure adherence to sustainable practices can be challenging, particularly when stakeholders are spread across different geographic regions with differing regulations and expectations (Ogunleye, 2024, Raji & Olodo, 2024, Ogbu, Ozowe & Ikevuje, 2024, Segun-Falade, et al., 2024). This complexity can result in delays, increased costs, and difficulties in maintaining consistent sustainability standards throughout the supply chain.

Additionally, there is often a lack of transparency and traceability in the supply chain. Ensuring that suppliers and contractors adhere to sustainable practices requires clear visibility into their operations and practices. However, achieving this level of transparency can be difficult, particularly in complex supply chains with numerous intermediaries (Ezeh, et al., 2024, Odonkor, et al., 2024, Ozowe, Daramola & Ekemezie, 2024). Without adequate traceability, it becomes challenging to verify the sustainability claims of suppliers and to address any issues that arise promptly. Despite these challenges, there are several opportunities for improvement in sustainable procurement and SCM within geothermal energy and environmental projects. Emerging trends and innovations offer promising

avenues for addressing the barriers and enhancing the effectiveness of sustainable practices.

One significant opportunity lies in the development and adoption of standardized sustainability metrics and certification frameworks. By establishing clear and consistent standards for sustainability, organizations can more effectively evaluate suppliers and assess the environmental impact of their procurement and supply chain activities. Standardization can also facilitate better communication and collaboration between stakeholders, helping to align their efforts towards common sustainability goals (Aziza, Uzougbo & Ugwu, 2023, Banso, et al., 2023, Latilo, et al., 2024, Coker, et al., 2023).

Advancements in technology offer another opportunity for improving sustainable procurement and SCM. Digital tools such as blockchain and supply chain management software can enhance transparency and traceability throughout the supply chain (Abdul-Azeez, Ihechere & Idemudia, 2024, Ogbu, Latilo, et al., 2024, Ozowe & Ikevuje, 2024, Ukato, et al.,2024). Blockchain technology, in particular, can provide a secure and immutable record of transactions, enabling better verification of sustainability claims and more efficient tracking of materials and products. Supply chain management software can also streamline procurement processes, improve data analysis, and facilitate better decision-making, contributing to more sustainable practices.

The growing emphasis on circular economy principles presents an opportunity to enhance sustainability in procurement and SCM. Circular economy approaches focus on minimizing waste and maximizing resource efficiency by promoting recycling, reuse, and remanufacturing. Integrating circular economy principles into procurement and supply chain strategies can help reduce environmental impact, lower costs, and create new business opportunities (Ekechukwu & Simpa, 2024, Odonkor, et al., 2024, Raji, Ijomah & Eyieyien, 2024). For example, using recycled materials in geothermal energy projects or implementing take-back schemes for equipment can contribute to a more sustainable supply chain.

Collaboration and partnerships are also crucial for advancing sustainable procurement and SCM. Engaging with suppliers, contractors, and other stakeholders to jointly develop and implement sustainability practices can lead to more effective and innovative solutions. Collaborative efforts can also help address challenges such as the availability of sustainable materials and technologies (Ogunleye, 2024, Raji & Olodo, 2024, Ogbu, Ozowe & Ikevuje, 2024, Segun-Falade, et al., 2024). By working together, organizations can share knowledge, resources, and best practices, fostering a more sustainable and resilient supply chain.

Furthermore, the increasing consumer and regulatory pressure for sustainability provides an opportunity for organizations to enhance their procurement and supply chain practices. As stakeholders become more conscious of environmental and social issues, there is a growing demand for transparent and sustainable practices (Akinsulire, et al., 2024, Oduro, Simpa & Ekechukwu, 2024, Paul & Iyelolu, 2024). Organizations that proactively address these expectations can gain a competitive advantage, improve their reputation, and build stronger relationships with stakeholders.

In conclusion, sustainable procurement and supply chain management in geothermal energy and environmental projects face several challenges, including the lack of standardization, limited availability of sustainable materials, supply chain complexity, and issues with transparency. However, these challenges also present opportunities for improvement (Bello, Idemudia & Iyelolu, 2024, Ogbu, et al., 2024, Oyewole, et al., 2024). By embracing standardized metrics, leveraging technological advancements, adopting circular economy principles, fostering collaboration, and responding to growing sustainability pressures, organizations can enhance their procurement and supply chain practices. Addressing these challenges and seizing these opportunities will be crucial for achieving the goals of sustainability and environmental stewardship in geothermal energy and environmental projects.

2.7. CONCLUSION

In summary, sustainable procurement and supply chain management (SCM) in geothermal energy and environmental projects present a nuanced landscape of challenges and opportunities. The key challenges include the lack of standardization in sustainability metrics, the limited availability and high cost of sustainable materials and technologies, supply chain complexity, and issues with transparency and traceability. These barriers can hinder the effective implementation of sustainable practices and impact the overall success of projects aimed at advancing environmental stewardship and energy efficiency.

However, the evolving field of sustainable procurement and SCM also offers significant opportunities for improvement. The development of standardized sustainability metrics and certification frameworks can provide clarity and consistency, facilitating more effective evaluation and implementation of sustainable practices. Technological advancements such as blockchain and supply chain management software promise to enhance transparency and traceability, addressing some of the challenges related to monitoring and verifying sustainability claims. The principles of the circular economy offer innovative approaches to reducing waste and improving resource efficiency, while increased collaboration and partnerships among stakeholders can lead to more effective and integrated solutions. Additionally, growing consumer and regulatory pressures for sustainability create incentives for organizations to adopt and strengthen their sustainable practices.

Looking ahead, the future of sustainable procurement and SCM in geothermal energy and environmental projects appears promising. As technology continues to advance and sustainability becomes a more central focus for stakeholders, there will likely be increased adoption of best practices and

innovative solutions. Organizations that embrace these trends and address the existing challenges will be better positioned to achieve their sustainability goals and contribute to broader environmental and societal benefits. Integrating sustainability into procurement and SCM practices is crucial for advancing the goals of geothermal energy and environmental projects. It not only helps in minimizing environmental impact but also enhances the overall resilience and efficiency of supply chains. By prioritizing sustainability, organizations can drive positive change, improve their competitive position, and build stronger relationships with stakeholders. Ultimately, a commitment to sustainable procurement and SCM is essential for fostering a more sustainable and equitable future.

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