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# Geological survey techniques and carbon storage: Optimizing renewable energy site selection and carbon sequestration

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## Abstract

Geological survey techniques play a crucial role in optimizing site selection for renewable energy projects and identifying suitable locations for carbon storage to mitigate climate change. This abstract provides an overview of how geological survey techniques can be used to achieve these objectives. Renewable energy development, particularly solar and wind power, requires careful site selection to maximize energy generation efficiency and minimize environmental impacts. Geological surveys are instrumental in assessing factors such as subsurface geology, topography, soil composition, and hydrological conditions. These surveys help identify suitable locations with optimal wind or solar resources and geologic conditions for infrastructure development. Additionally, geological surveys are essential for identifying suitable sites for carbon storage, a critical component of carbon capture and storage (CCS) technologies aimed at reducing greenhouse gas emissions. Geological formations, such as deep saline aquifers, depleted oil and gas reservoirs, and unmineable coal seams, can serve as storage reservoirs for captured carbon dioxide ($CO_2$). Geological surveys help characterize these formations to assess their suitability for long-term $CO_2$ storage, considering factors such as porosity, permeability, and sealing integrity. Optimizing site selection for renewable energy projects and carbon storage requires a comprehensive understanding of subsurface geology and environmental conditions. Advanced geological survey techniques, such as seismic imaging, remote sensing, and geophysical surveys, are essential for acquiring detailed subsurface data. These techniques enable scientists and engineers to assess site suitability, evaluate risks, and design effective mitigation measures. In conclusion, geological survey techniques are invaluable tools for optimizing site selection for renewable energy projects and identifying suitable locations for carbon storage. By leveraging these techniques, stakeholders can make informed decisions that promote sustainable energy development and mitigate the impacts of climate change.

**Keywords:** Geological Survey Techniques; Carbon Storage; Carbon Sequestration; Optimizing; Renewable Energy Site Selection

## 1. Introduction

Geological survey techniques play a crucial role in the sustainable development of renewable energy sources by aiding in site selection and assessment (Oyewole, et. al., 2024, Oyebode, Olowe & Makanjuola, 2023). These techniques provide valuable insights into the geological and environmental factors that influence the feasibility and effectiveness of renewable energy projects. Moreover, as the world seeks to mitigate the impacts of climate change, carbon storage technologies have emerged as a critical tool for reducing greenhouse gas emissions. Carbon storage, also known as carbon sequestration, involves capturing $CO_2$emissions from industrial processes and storing them underground to prevent their release into the atmosphere (Addy, et. al., 2024, Penerbit, 2020).

This paper explores the pivotal role of geological survey techniques in optimizing both renewable energy site selection and carbon sequestration efforts. By evaluating the geological characteristics of potential sites, these techniques help

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identify suitable locations for renewable energy projects such as wind and solar farms. Additionally, they play a crucial role in assessing the viability of geological formations for storing captured $CO_2$, contributing to efforts to combat climate change.

The thesis of this paper is that geological survey techniques are essential for optimizing renewable energy site selection and ensuring the effective implementation of carbon storage strategies. By understanding the geological properties of a site, stakeholders can make informed decisions regarding its suitability for renewable energy projects and carbon storage initiatives. This paper will examine the various geological survey techniques used in these contexts, highlighting their importance and impact on sustainable energy development and climate change mitigation.

Geological survey techniques are instrumental in advancing renewable energy development and mitigating climate change by optimizing site selection and facilitating carbon sequestration (Adelani, et. al., 2024, Oyegoke, et. al., 2020). As the world transitions towards sustainable energy sources, the need for efficient site selection for renewable energy projects becomes increasingly critical. Geological survey techniques provide a comprehensive understanding of subsurface conditions, enabling informed decisions regarding site suitability, resource assessment, and environmental impact assessment.

Furthermore, carbon storage technologies offer a promising solution for reducing greenhouse gas emissions by capturing and storing $CO_2$ from industrial processes and power generation (Gür, s2022, Udegbe, et. al., 2024). These technologies rely on geological formations, such as saline aquifers and depleted oil and gas reservoirs, for secure and permanent storage of $CO_2$. Geological survey techniques play a pivotal role in identifying suitable storage sites, assessing their capacity, and ensuring long-term containment of captured $CO_2$.

This paper explores the multifaceted role of geological survey techniques in optimizing renewable energy site selection and facilitating carbon sequestration. It examines the principles, methods, and applications of these techniques in the context of sustainable energy development and climate change mitigation. Additionally, it discusses the challenges and opportunities associated with integrating geological survey data into renewable energy and carbon capture projects, highlighting best practices and emerging trends in the field.

The thesis of this paper is that geological survey techniques are indispensable tools for advancing renewable energy site selection and carbon sequestration efforts. By leveraging these techniques, stakeholders can identify optimal locations for renewable energy projects and ensure the effective implementation of carbon storage strategies (Danish & Senjyu, 2023, Udegbe, et. al., 2024, Usman, et. al., 2024). This paper aims to provide a comprehensive overview of the role of geological survey techniques in sustainable energy development, emphasizing their importance in shaping a more sustainable and resilient future.

## 2. Geological Survey Techniques for Renewable Energy Site Selection

Geological survey techniques play a crucial role in identifying suitable sites for renewable energy projects, such as wind and solar farms (Adelani, et. al., 2024, Oyebode, eti. Al., 2020). These techniques involve the systematic study and analysis of geological, topographical, and environmental factors to determine the feasibility and potential of a site for renewable energy development. This section provides an overview of geological survey methods and discusses the factors considered in site selection, focusing on their role in identifying optimal locations for wind and solar energy projects.

Geological survey methods encompass a range of techniques used to study the Earth's subsurface and surface features. These methods include remote sensing, geophysical surveys, borehole drilling, and geological mapping (Sofia, 2020, Udegbe, et. al., 2024). Remote sensing techniques, such as satellite imagery and LiDAR (Light Detection and Ranging), provide valuable information about the terrain, vegetation cover, and land use, helping to identify potential sites for renewable energy projects. Geophysical surveys involve the use of various instruments to measure and map subsurface geological structures, such as rock formations and groundwater reservoirs (Ekwok, et. al., 2020, Wagner & Uhlemann, 2021). These surveys help to determine the geological suitability of a site for renewable energy development. Borehole drilling is another important technique that allows for the collection of core samples from the subsurface, providing valuable information about the geological composition and structure of a site.

Several factors are considered in site selection for renewable energy projects, including geology, topography, soil composition, and hydrology. Geology plays a critical role in determining the stability of the land and the presence of geological formations suitable for energy extraction, such as geothermal reservoirs or wind corridors (Mirabadi, et. al., 2024, Udegbe, et. al., 2024). Topography influences the layout and orientation of solar panels and wind turbines, affecting energy production efficiency. Soil composition is important for determining the suitability of a site for construction and the anchoring of renewable energy infrastructure. Hydrology refers to the study of water resources, including surface water and groundwater, which can impact the design and operation of renewable energy projects.

Geological surveys play a key role in identifying optimal locations for wind and solar energy projects by providing detailed information about the subsurface geology, terrain, and environmental conditions of a site (Oyebode, et. al., 2015, Olowe, 2018). For wind energy projects, geological surveys help identify areas with consistent and strong wind patterns, known as wind corridors, which are ideal for the placement of wind turbines. For solar energy projects, geological surveys help identify sites with optimal solar exposure, taking into account factors such as slope, orientation, and shading. By considering these factors, geological surveys enable developers to make informed decisions about site selection, ensuring the efficient and effective deployment of renewable energy infrastructure.

Geological survey techniques are essential tools for identifying optimal locations for renewable energy projects (Aremu, Olodo & Olaitan, 2020, Chen, et. al., 2022). By providing detailed information about the geological, topographical, and environmental characteristics of a site, these techniques help developers minimize risks and maximize the efficiency of renewable energy development. Geological survey techniques are multifaceted, encompassing a variety of methods that aid in the comprehensive assessment of potential sites for renewable energy projects (Bohra & Anvari-Moghaddam, 2022, Udegbe, et. al., 2024, Zinovieva, et. al., 2023). These techniques provide crucial insights into the subsurface geology, topography, soil composition, and hydrological conditions of a site, which are essential factors in determining its suitability for renewable energy development.

Remote sensing techniques, such as satellite imagery and LiDAR, are invaluable in gathering data on surface features, vegetation cover, and land use, providing an initial assessment of potential sites (Neyns & Canters, 2022, Wang, et. al., 2022). Geophysical surveys, including seismic surveys and electromagnetic surveys, help to map subsurface geological structures and identify geothermal reservoirs, which are critical for geothermal energy projects. These surveys also assist in identifying wind corridors for wind energy projects and evaluating the potential for solar energy generation based on sun exposure and shading.

Borehole drilling is another important technique used in geological surveys for renewable energy site selection (Adelani, et. al., 2024, Elbarbary, et. al., 2022). By extracting core samples from the subsurface, geologists can analyze the geological composition and structure of a site, providing valuable information for assessing its suitability for renewable energy development. Soil composition is a key consideration, as it affects the stability of the land and the feasibility of constructing renewable energy infrastructure. Hydrological surveys are also essential, as they assess the availability and quality of water resources, which are crucial for geothermal and hydropower projects.

Geological surveys for renewable energy site selection involve a combination of fieldwork, laboratory analysis, and data interpretation (Ajala & Balogun, 2024, Oyebode, Adebayo & Olowe, 2015). The data collected from these surveys enable developers to make informed decisions about site selection, ensuring that renewable energy projects are located in areas that maximize energy production while minimizing environmental impacts. In summary, geological survey techniques play a critical role in renewable energy site selection by providing detailed information about the geological, topographical, and environmental characteristics of a site. These techniques help developers identify optimal locations for renewable energy projects, ensuring the efficient and sustainable development of renewable energy resources.

## 3. Geological Survey Techniques for Carbon Storage

Geological survey techniques play a crucial role in identifying and characterizing geological formations suitable for carbon storage, a key component of carbon sequestration strategies (Adelani, et. al., 2024, Olowe, 2018, Rasool, Ahmad & Ayoub, 2023). Carbon storage, also known as carbon capture and storage (CCS), involves capturing carbon dioxide ($CO_2$) emissions from industrial processes and storing them underground to prevent their release into the atmosphere. Geological formations such as deep saline aquifers, depleted oil and gas reservoirs, and unmineable coal seams are considered suitable for carbon storage due to their porosity, permeability, and sealing integrity.

Deep saline aquifers are vast underground reservoirs of saline water found deep below the earth's surface (Adeoye, et. al., 2024, Owoola, Adebayo & Olowe, 2019). These formations are often located beneath impermeable rock layers, making them ideal for storing large volumes of $CO_2$. Depleted oil and gas reservoirs, once productive oil and gas fields that have been depleted of their hydrocarbon resources, are also suitable for carbon storage due to their porosity and permeability. Injecting $CO_2$into these reservoirs can help enhance oil recovery while safely storing $CO_2$underground. Unmineable coal seams, coal deposits that are too deep or too thin to be economically mined, can also serve as potential carbon storage sites. $CO_2$ can be injected into these seams, where it adsorbs onto the coal surfaces, effectively trapping the $CO_2$ underground.

Characterizing geological formations for $CO_2$ storage involves assessing their porosity, permeability, and sealing integrity (Ajala, 2024, Oyebode, et. al., 2022). Porosity refers to the amount of pore space within a rock formation, which determines its capacity to store $CO_2$. Permeability is the ability of a rock to allow fluids to flow through it, which is important for ensuring that $CO_2$ remains trapped underground. Sealing integrity refers to the presence of impermeable rock layers above the storage formation, which prevents $CO_2$f rom leaking back to the surface.

Geological surveys play a crucial role in identifying suitable sites for carbon storage by providing detailed information about the geological characteristics of potential storage formations. These surveys often involve seismic imaging, well logging, and core sampling to assess the subsurface geology and identify suitable storage formations (Ajayi, Gomes & Bera, 2019, Kelemen, et. al., 2019). Seismic imaging uses sound waves to create detailed images of underground rock formations, allowing geologists to map the structure of potential storage formations. Well logging involves lowering instruments into boreholes to measure properties such as porosity and permeability, providing valuable data for assessing the suitability of a site for carbon storage. Core sampling involves extracting core samples from underground formations to analyze their composition and porosity, providing further insights into their suitability for carbon storage.

In conclusion, geological survey techniques are essential for identifying and characterizing geological formations suitable for carbon storage. These techniques provide valuable data that enable scientists and engineers to assess the feasibility of carbon storage projects and ensure the safe and effective storage of $CO_2$ underground (Albertz, Stewart & Goteti, 2023, Ali, et. al., 2022). Geological survey techniques for carbon storage involve a comprehensive approach to evaluating potential storage sites, ensuring the safe and effective containment of $CO_2$ underground. These techniques are critical for understanding the subsurface geology, identifying suitable storage formations, and assessing the long-term integrity of storage sites.

One key aspect of geological survey techniques for carbon storage is the characterization of geological formations (Ajala, et. al., 2024, Ali, et. al., 2022). This involves assessing the porosity, permeability, and sealing integrity of potential storage formations to determine their capacity to safely contain $CO_2$. Porosity refers to the volume of pore space in a rock formation, which affects its ability to store $CO_2$. Permeability is the ability of a rock to transmit fluids, influencing the movement of $CO_2$ within the formation. Sealing integrity refers to the presence of impermeable cap rocks or seals that prevent $CO_2$ from migrating out of the storage formation.

Various methods are used to characterize geological formations for carbon storage. Seismic surveys, for example, use sound waves to create detailed images of subsurface rock layers, providing information about the structure and composition of potential storage formations (Ochuba, et. al., 2024, Ofodile, et. al., 2024). Well logging is another technique that involves lowering instruments into boreholes to measure properties such as porosity, permeability, and rock composition. Core sampling, which involves extracting core samples from underground formations, provides direct evidence of the rock's properties and allows for laboratory analysis to further understand its suitability for $CO_2$ storage.

In addition to characterizing geological formations, geological survey techniques also play a crucial role in site selection and risk assessment (Odejide & Edunjobi, 2024, Odeyemi, et. al., 2024). Geologists and engineers evaluate factors such as proximity to emission sources, geological stability, and environmental impact to identify suitable storage sites. They also assess the potential risks associated with $CO_2$ leakage, such as groundwater contamination and seismic activity, to ensure the long-term safety and effectiveness of carbon storage projects.

Overall, geological survey techniques are essential for evaluating potential carbon storage sites, assessing their suitability, and ensuring the safe and effective containment of $CO_2$ underground. These techniques provide valuable insights into the subsurface geology, helping to mitigate risks and optimize the storage of $CO_2$ for long-term climate change mitigation.

## 4. Advanced Geological Survey Techniques

Advanced geological survey techniques are essential for obtaining detailed and accurate subsurface information for various applications, including renewable energy site selection and carbon storage (Krevor, et. al., 2023, Olowe & Adebayo, 2015). These techniques utilize advanced technologies and methodologies to characterize geological formations, evaluate potential sites, and assess the feasibility of projects.

Seismic imaging is a powerful technique used to create detailed images of subsurface rock layers (Ajala, et. al., 2024, Ochuba, et. al., 2024). It involves generating and recording seismic waves that travel through the ground and bounce back to the surface, providing information about the structure and composition of the subsurface. Seismic imaging is particularly useful for identifying potential storage formations for carbon sequestration and assessing the geological characteristics of renewable energy sites. By analyzing the speed and direction of seismic waves, geologists can create 3D models of the subsurface, helping to identify suitable locations for carbon storage or renewable energy projects.

Remote sensing is another advanced technique used for site evaluation. It involves the use of aerial or satellite-based sensors to collect data about the Earth's surface without direct physical contact (Chuvieco, 2020, Ogundipe, Odejide & Edunjobi, 2024). Remote sensing can provide valuable information about terrain, vegetation, and land use, which are crucial for assessing the suitability of sites for renewable energy projects or carbon storage. For example, remote sensing can help identify areas with high solar or wind potential for renewable energy development.

Geophysical surveys are also important for obtaining detailed subsurface data. These surveys use various techniques, such as electrical resistivity, magnetometry, and ground-penetrating radar, to measure physical properties of the subsurface, such as rock density, composition, and moisture content (Garré, et. al., 2022, Ochuba, et. al., 2024). Geophysical surveys can provide valuable insights into the subsurface geology, helping to identify potential storage formations or assess the feasibility of renewable energy projects.

Overall, advanced geological survey techniques play a crucial role in optimizing renewable energy site selection and carbon storage projects. These techniques provide detailed and accurate subsurface information, helping to identify suitable locations, assess risks, and ensure the long-term success of projects (Alcalde, et. al., 2021, Okafor, et. al. 2024). By utilizing advanced technologies and methodologies, geologists and engineers can make informed decisions that contribute to sustainable energy development and climate change mitigation efforts. Advanced geological survey techniques play a pivotal role in modern environmental and energy management, particularly in the context of optimizing renewable energy site selection and carbon storage. These techniques leverage cutting-edge technologies and methodologies to provide detailed insights into subsurface conditions, helping to identify suitable locations for renewable energy projects and assess the feasibility of carbon storage initiatives.

One of the key advanced techniques is seismic imaging, which involves generating and analyzing seismic waves to create detailed subsurface images (Giustiniani, Tinivella & Nicolich, 2022, Okoro, et. al., 2023). This method helps geologists and engineers understand the geological structures and properties of potential sites, aiding in the selection of optimal locations for renewable energy projects such as wind farms and solar installations. Seismic imaging also plays a crucial role in carbon storage projects by identifying suitable geological formations for $CO_2$ sequestration.

Remote sensing is another advanced technique that has revolutionized geological surveys. By utilizing satellite or aerial-based sensors, remote sensing allows for the collection of data on the Earth's surface without direct contact (Abdulraheem, et. al., 2023, Gui, et. al., 2024). This technology provides valuable information on terrain, vegetation, and land use, which is essential for assessing the suitability of sites for renewable energy projects and carbon storage facilities. Remote sensing data can be integrated with other geological data to create comprehensive site evaluation models.

Geophysical surveys are also critical for obtaining detailed subsurface information. These surveys use various techniques, such as electrical resistivity, magnetometry, and ground-penetrating radar, to measure physical properties of the subsurface. Geophysical surveys help identify potential storage formations for carbon sequestration and assess the geological characteristics of renewable energy sites, ensuring that projects are located in geologically suitable areas.

In conclusion, advanced geological survey techniques are indispensable tools for optimizing renewable energy site selection and carbon storage projects (Ochuba, et. al., 2024, Okoye, et. al., 2024). These techniques provide valuable insights into subsurface conditions, helping to identify suitable locations, assess risks, and ensure the success of sustainable energy initiatives. By leveraging advanced technologies and methodologies, geologists and engineers can make informed decisions that contribute to a more sustainable and environmentally friendly future.

## 5. Case Studies

In the realm of renewable energy, geological survey techniques are instrumental in identifying optimal locations for projects. One such case is the Alta Wind Energy Center (AWEC) in California, which utilized advanced geological surveys to optimize its site selection and layout (Ajala, et. al., 2024, Ochuba, et. al., 2024). AWEC is one of the largest wind farms in the United States, comprising several wind power projects. Geological surveys were crucial in determining the wind patterns, terrain suitability, and foundation requirements, leading to the successful development of this renewable energy site (Ololade, 2024, Olodo, et. al., 2020). On the other hand, carbon storage projects heavily rely on geological surveys to identify suitable storage formations. An excellent example is the Sleipner project in the North Sea, where $CO_2$ captured from natural gas processing is injected into a deep saline aquifer. Geological surveys were pivotal in assessing the aquifer's capacity, porosity, and permeability, ensuring the safe and effective storage of $CO_2$.

The Alta Wind Energy Center (AWEC) in California serves as an exemplary case of how geological surveys can optimize renewable energy site selection (Olowe & Kumarasamy, 2017, Olatunde, Adelani & Sikhakhane, 2024). AWEC comprises several wind power projects and is one of the largest wind farms in the United States. The site's selection and layout were optimized through advanced geological surveys, which helped determine wind patterns, terrain suitability, and foundation requirements. These surveys played a crucial role in the successful development of AWEC, demonstrating the importance of geological surveys in renewable energy projects.

Similarly, the Sleipner project in the North Sea is a notable example of successful carbon storage enabled by geological surveys (Ochuba, et. al., 2024, Ralanarko, et. al., 2024). In this project, $CO_2$ captured from natural gas processing is injected into a deep saline aquifer for storage. Geological surveys were instrumental in assessing the aquifer's capacity, porosity, and permeability, ensuring the safe and effective storage of $CO_2$. The Sleipner project showcases how geological surveys are essential for identifying suitable storage formations and mitigating the environmental impact of $CO_2$ emissions (Ololade, 2024, Olodo, et. al., 2017). These case studies highlight the critical role of geological survey techniques in optimizing renewable energy site selection and enabling carbon storage projects. By leveraging advanced geological surveys, developers can identify optimal locations, assess risks, and ensure the success of sustainable energy initiatives.

Another compelling case study demonstrating the impact of geological survey techniques on renewable energy site selection is the Tengger Desert Solar Park in China. This solar park, one of the largest in the world, was strategically located in the Tengger Desert to capitalize on its high solar irradiance levels and vast, flat terrain (Ajala, et. al., 2024, Ochuba, et. al., 2024). Geological surveys played a crucial role in assessing the desert's geological stability, soil composition, and sun exposure, ensuring optimal placement of solar panels and infrastructure. The meticulous site selection process, guided by geological surveys, contributed to the park's efficiency and success in generating clean, renewable energy.

In the realm of carbon storage, the In Salah Gas Project in Algeria serves as a prominent example of effective carbon capture and storage (CCS) facilitated by geological surveys (Nageri, et. al., 2013, Raji, et. al., 2024). The project involves capturing $CO_2$ from natural gas processing and injecting it into a deep saline aquifer for storage . Prior to injection, extensive geological surveys were conducted to evaluate the aquifer's capacity, porosity, and permeability. Additionally, seismic monitoring techniques were employed to ensure the injected $CO_2$ remained securely stored underground (Ochuba, et. al., 2024, Olorunsogo, Jacks & Ajala, 2024). The In Salah Gas Project demonstrates the importance of geological surveys in identifying suitable storage sites and implementing CCS projects with minimal environmental impact.

These case studies underscore the pivotal role of geological survey techniques in optimizing renewable energy site selection and enabling carbon storage initiatives. By leveraging advanced geological surveys, developers and energy companies can make informed decisions that maximize the efficiency, sustainability, and environmental compatibility of their projects (Jacks, et. al., 2024, Lottu, et. al., 2024).

## 6. Challenges and Future Directions

Geological survey techniques play a critical role in optimizing renewable energy site selection and carbon sequestration, but they are not without challenges. One major challenge is the complexity of geological formations, which can vary significantly in composition and structure (Aremu, Aremu, & Olodo, 2015, Raji, et. al., 2024). This variability can make it difficult to accurately assess the suitability of a site for renewable energy projects or carbon storage. Additionally, accessing remote or underground sites for surveys can be logistically challenging and costly, further complicating the process.

Another challenge is the limited availability of data for certain regions. In some areas, geological data may be scarce or outdated, making it difficult to conduct thorough surveys. This lack of data can hinder the identification of suitable sites for renewable energy projects or carbon storage initiatives (Edunjobi, 2024, Olowe & Kumarasamy, 2021). Furthermore, there are challenges related to the interpretation of geological data. Interpreting geological data requires specialized knowledge and expertise, and misinterpretations can lead to inaccurate assessments of site suitability.

Additionally, the integration of geological data with other types of data, such as environmental or socio-economic data, can be complex and require advanced analytical techniques.

Despite these challenges, there are several promising future directions for geological survey techniques in the context of renewable energy site selection and carbon sequestration (Babatunde, et. al., 2024, Raji, et. al., 2024). One such direction is the use of advanced technologies, such as machine learning and artificial intelligence, to analyze geological data more efficiently and accurately. These technologies have the potential to streamline the survey process and improve the accuracy of site assessments. Another future direction is the development of new survey techniques that can access and characterize underground formations more effectively. For example, the use of advanced drilling technologies, such as horizontal drilling, can enable more precise and targeted surveys of underground formations.

Additionally, there is a growing trend towards the use of geophysical surveys, which involve the use of seismic, electromagnetic, and other geophysical methods to characterize subsurface formations (Ayanda, et. al., 2018, Olowe, Oyebode & Dada, 2015). These surveys can provide valuable information about the structure and composition of underground formations, helping to identify suitable sites for renewable energy projects or carbon storage.

To enhance the effectiveness of geological surveys, it is important to invest in research and development of new technologies and techniques (Farayola, et. al., 2023, Raji, et. al., 2024). This includes developing new methods for data collection and analysis, as well as improving the integration of geological data with other types of data. Additionally, collaboration between researchers, industry, and government agencies can help to address data gaps and improve the availability of geological data for site assessments.

In conclusion, while there are challenges associated with geological survey techniques for renewable energy site selection and carbon sequestration, there are also exciting opportunities for future advancements (Hassan, et. al., 2024, Igah, et. al., 2023). By addressing these challenges and embracing new technologies and techniques, we can optimize the use of geological surveys to support the transition to a more sustainable energy future.

Another significant challenge is the potential environmental impact of geological survey techniques. Some techniques, such as seismic imaging, can have a disruptive effect on local ecosystems and wildlife. Mitigating these impacts requires careful planning and implementation of survey activities, as well as adherence to strict environmental regulations (Oladeinde, et. al., 2023, Olowe, Wasiu & Adebayo, 2019). In addition to environmental concerns, there are also social and cultural challenges associated with geological survey techniques. Some communities may resist survey activities due to concerns about land use, property rights, or the perceived risks of renewable energy projects or carbon storage initiatives. Building trust and engaging with local communities are essential for addressing these challenges and ensuring the acceptance of survey activities.

Looking ahead, the future of geological survey techniques for renewable energy site selection and carbon sequestration is promising (Ikumapayi, et. al., 2022, Olatunde, Adelani & Sikhakhane, 2024). One key future direction is the continued development of advanced technologies for data collection and analysis. For example, the use of drones and satellites for remote sensing can provide valuable data for site assessments without the need for ground-based surveys (Arinze, et. al., 2024, Shoetan, et. al., 2024). Another future direction is the integration of geological surveys with other types of data, such as climate data and energy demand forecasts (Jacks, et. al., 2024, Raji, et. al., 2024). By combining these data sources, decision-makers can make more informed choices about the optimal locations for renewable energy projects and carbon storage facilities.

Furthermore, there is a growing recognition of the importance of community engagement and stakeholder consultation in the survey process. Involving local communities in decision-making can help to address concerns and build support for survey activities, leading to more successful outcomes (Aremu, et. al., 2015, Oladeinde, et. al., 2023). Overall, while there are challenges to overcome, the future of geological survey techniques for renewable energy site selection and carbon sequestration is bright. By addressing these challenges and embracing new technologies and approaches, we can enhance the effectiveness of geological surveys and support the transition to a more sustainable energy future.

## 7. Conclusion

In conclusion, geological survey techniques play a pivotal role in optimizing renewable energy site selection and carbon sequestration, offering valuable insights into subsurface conditions and aiding in the identification of suitable locations for energy projects. Throughout this exploration, several key points have emerged.

Firstly, geological survey techniques encompass a diverse range of methods, from traditional field surveys to advanced technologies like seismic imaging and remote sensing. These techniques allow us to assess geological formations, identify potential renewable energy sites, and evaluate options for carbon storage with precision and accuracy.

Secondly, the importance of geological survey techniques cannot be overstated in the context of renewable energy and carbon storage. These techniques provide the foundation upon which sustainable energy projects are built, ensuring that they are located in areas conducive to efficient energy production while minimizing environmental impact. Moreover, they enable us to assess the viability of carbon capture and storage initiatives, contributing to global efforts to mitigate climate change.

In light of these insights, there is a clear call to action for leveraging geological survey techniques for sustainable energy development and climate change mitigation. It is imperative that we continue to invest in research and development to advance these techniques, making them more effective, efficient, and environmentally friendly. Additionally, there is a need for greater collaboration between stakeholders, including government agencies, industry players, and local communities, to ensure that geological survey activities are conducted responsibly and with due consideration for environmental and social concerns.

By harnessing the power of geological survey techniques, we can unlock the full potential of renewable energy resources and accelerate the transition to a low-carbon future. This requires a concerted effort from all stakeholders to prioritize sustainability, innovation, and responsible stewardship of our planet's resources. With strategic investments and collective action, we can realize the promise of geological survey techniques in driving sustainable energy development and combating climate change.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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