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STRATEGIES FOR CARBON EMISSION REDUCTION: A CASE STUDY OF KGHM POLSKA MIEDŹ S.A.

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ABSTRACT: This article explores the role of energy in reducing global carbon emissions, which is crucial in the worldwide fight against climate change. Using the case study of KGHM, a leading industry player that has successfully integrated energy solutions, this study highlights the impact and key results of such efforts. By searching into the state of energy consumption this research addresses the widespread dependence on fossil fuels and the potential impact of renewable sources like solar, wind, hydroelectric power and biomass in reshaping our energy landscape. The study provides insights into technologies, the challenges they face during implementation and the economic and policy structures that influence their adoption. The study outlines technologies, their challenges in implementation and the economic and policy frameworks that impact their adoption. In this research, some recommendations have been provided for companies aiming to reduce their impact and encourage eco initiatives. The findings highlighted the growing of the transition to renewable energy in order to meet the targets set forth in agreements such as the Paris Agreement, which seeks to limit temperature rise to than 2 degrees Celsius. Finally, it was concluded a call to action for widespread policy reforms and increased corporate accountability in fostering a sustainable future for energy.

KEYWORDS: Renewable Energy, Carbon Reduction, CCS/CCU, Improving energy efficiency

Introduction

The transition to the use of renewable energy sources is widely recognised as an approach in the global fight against climate change. As the world faces the increasing impacts of climate change, countries worldwide are placing emphasis on reducing carbon emissions. The energy sector, known for contributing to greenhouse gas emissions using fuels, is at the forefront of this transition. Renewable energy sources such as electricity, wind power, hydropower and biomass have the potential to generate energy with environmental impact. Numerous studies show that accelerated deployment of these energy technologies is essential to achieve the goals set out in agreements such as the Paris Agreement, which aims to limit warming to below 2 degrees Celsius compared to industrial levels (IPCC, 2018). This research examines how practical deployment of energy solutions can help reduce carbon emissions in the energy sector. A detailed case study of KGHM company is used to demonstrate how targeted and strategic technology integration can reduce carbon emissions. KGHM company, a leader in the copper industry, has successfully implemented energy initiatives that have reduced its carbon footprint while improving its overall efficiency and sustainability practices.

As temperatures on Earth continue to rise, the effects of climate change are getting worse. Transitioning to renewable energy sources is one step to promote progress and achieve sustainable development. In the past, fuels have dramatically damaged the environment, and there is a need for changes now. This article explores how renewable energy technologies can bring about change, drawing on insights from a detailed case study of the company KGHM, a leading player in energy integration. By examining sources such as electricity and bioenergy, this article will demonstrate how strategic adoption and technological advances can help significantly reduce carbon emissions. It also examines the energy landscape, identifies barriers to renewable energy adoption, and highlights approaches that will move us towards a greener future. Recently, there are companies that are trying to implement sustainable strategies. Neon is one of these companies, a leading renewable energy developer, which secured $ 1.4 billion to fund 10 GW of new projects in Australia. The company will invest in large-scale batteries and solar farms to support generating 82% of its power from renewable sources by 2030 (Parkinson, 2024). Also, Canada is finalising a new clean electricity regulation that targets is a net-zero electricity grid to 2050 (Thurton, 2024). As numerous companies are focusing on sustainability and renewable energy, but few provide an in-depth analysis within the mining sector. This study is focused on a case study, KGHM Polska Miedż S.A., as this company is industry leadership and innovative efforts in renewable energy. The timeline of 2021-2022 has been selected to ensure that the used data are aligned with the company's climate policy updates. Only Scope 1 and 2 emissions were considered due to data availability and their impact on the carbon footprint of the company. The aim here is to address a unique approach to carbon reduction and to emphasise actionable strategies that align with global sustainability goals. However, future studies can be expanded in multiple companies and also longer timelines in this company of this study.

The Global Energy Landscape

Current data shows that fossil fuels such as coal, oil and gas remain the main sources of energy worldwide, up to 84% of total energy consumption. Regardless of alternative energy options, dependency on fuels is continuing due to their role in transportation, power generation and various industrial processes. Oil remains a primary resource used in the transportation and industrial sectors. Although coal consumption has declined in some regions, it remains important for electricity generation in areas such as Asia. On the other hand, natural gas is becoming increasingly popular due to its carbon dioxide emissions compared to coal or oil when burned. Although natural gas is called a "bridge fuel", it contributes to greenhouse gas emissions (Ritchie et al., 2024; Holechek et al., 2022).

Energy use and greenhouse gas emissions are increasing all over the world. This growing demand for energy is causing more carbon emissions, even though there are ongoing efforts to be more energy-efficient and use cleaner sources. After a drop during the COVID-19 pandemic, greenhouse gas emissions shot up again in 2021, with carbon dioxide levels from energy consumption nearing record highs (Cozzi, 2021; IPCC, 2019).

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The increased attention on this issue shows how hard it is to balance our energy needs with environmental concerns. There is a noticeable move towards renewable energy sources like wind and solar, which are spreading globally. Speeding up this transition is crucial to meet the goals of the Paris Agreement, which focuses on cutting down fossil fuel use and promoting sustainable technologies and practices (IRENA, 2020; Goodson, 2021).

Fundamentals of Renewable Energy

Renewable energy is derived from sources that renew themselves quickly. In contrast to fuels that require millions of years to develop and get depleted upon consumption, renewable sources are viewed as limitless within the span of a lifetime. Some categories of energy sources and methods are utilised to transform these natural assets into practical energy. Solar power, a type of energy, is derived from the sun using methods. It is widely recognised as a source of energy. The primary technology employed to harness this energy is photovoltaic (PV) cells, which directly transform sunlight into power. These cells are typically made from materials such as silicon, which can generate a charge when exposed to sunlight. Another method involves using systems with mirrors or lenses to concentrate energy, heat a fluid and create steam to drive a turbine that produces electricity (Abed & Badescu, 2015; Sahoo, 2019). Another type of energy is Wind energy, and it originates from the motion of air in the sky driven by heat. Windmills transform the energy of wind into force. This force can be utilised directly, such as in wind-driven mills, or converted into electricity through a generator. Contemporary wind turbines come in sizes from ones for personal residences to extensive offshore installations that supply power to numerous households (Global Wind Energy Council, 2020; Global Wind Energy Council, 2013). Another alternative form of energy is Hydropower, which is generated by capturing the energy from moving water utilising methods such as damming rivers to create reservoirs. The flowing water spins turbines to produce electricity. Additionally, river systems rely on natural river flow and pumped storage plants that store water in reservoirs for electricity generation during demand periods (Hall, 2006; Bushnell, 1998). Another distinct form of energy is Geothermal energy, derived from the Earth's internal heat which can be found from shallow ground to several miles below the surface or even farther in the form of magma. Geothermal power plants harness this energy to produce electricity in three ways: dry steam plants use steam directly from the ground, flash steam plants pull deep, high-pressure hot water into cooler, low-pressure water, and binary cycle plants transfer the heat from geothermal hot water to another liquid that boils at a lower temperature than water (Hamm et al., 2021; Akar & Young, 2015). A different category of energy is Biomass energy, which uses materials like wood, crops, or leftover items that can be burned directly for heat or electricity or processed into gases or fuels. Methods such as burning to produce a gas mixture through gasification and breaking down without oxygen to create biogas via digestion are used to convert biomass into energy. Ethanol and biodiesel biofuels are produced by fermenting or processing biomass materials (Lueken, 2023; Ejemeyovwi et al., 2022).

Impacts of Renewable Energy on Carbon Reduction

As mentioned, the use of energy sources plays a role in the global effort to reduce greenhouse gas emissions, which is crucial to face climate change and challenges. Various studies show that increasing the share of energy in the energy mix leads to a significant reduction in carbon emissions. For example, according to the International Renewable Energy Agency (IRENA), doubling the share of energy by 2030 could lead to a 70% reduction in carbon emissions. In addition, IRENA data suggests that achieving this goal would effectively contribute to meeting the goals of the Paris Agreement, which aims to limit global temperature rise to below 2 degrees Celsius (IEA, 2021). Further evidence from the National Renewable Energy Laboratory (NREL) in the United States shows that solar and wind energy installations offset about 200 million tons of carbon dioxide in 2019 alone. These examples highlight the critical role that renewable energy plays in carbon reduction strategies in different regions (NREL, 2021). Renewable energy sources are gaining an advantage over fuels primarily due to their competitive cost. The cost of electricity from renewables such as solar photovoltaics and

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onshore wind is continuously reducing, making it economically attractive in various markets compared to traditional coal and gas.

This lower cost makes renewables a preferred option, encouraging investment and deployment while reducing reliance on carbon sources (Amin, 2015). Government rules and regulations are vital in helping to transition from fuels to renewable energy sources. Some policies, like feed-in tariffs, portfolio standards (RPS), and carbon pricing, require a decrease in the use of carbon-heavy resources. Take the European Union's Emission Trading Scheme (EU ETS), for instance, which limits emissions and permits the trading of emission allowances. This system encourages investments in energy by increasing the cost of carbon production (The Guardian, 2024; Topping, 2021). With the progress of energy technologies and enhancements in energy storage and grid management systems, integrating sources into the grid has become more dependable and efficient. This technological advancement enhances the appeal and capacity of renewables to fulfil a portion of energy needs, progressively phasing out fossil fuels and utilising grids and energy storage solutions like batteries. Pumped hydro storage aids in managing the fluctuations in sources such as wind and solar, thus improving their viability as primary energy sources (Vaghela et al., 2023; Bhattacharjee & Nandi, 2021).

Barriers and Solutions to Renewable Energy Adoption

Transitioning to the use of energy encounters numerous obstacles. One major challenge is the aspect. Despite the declining expenses over time, the upfront investment needed for energy technologies, like panels and wind turbines, is still substantial. This initial cost can be counted as a potential barrier (Morris et al., 2014). Renewable energy options often find it tough to rival the established fossil fuel sector, which has advantages from its infrastructure and government support (Maradin, 2021). In developing countries with less mature financial markets, access to financing is a critical barrier (IRENA, 2019).

Considering the technological barriers, the intermittent nature of sources like solar and wind can lead to reliability issues for the energy grid (Denholm et al., 2010; Denholm et al., 2021). On the other hand, adequate energy storage solutions are essential to compensate for renewables' variability but are currently costly and underdeveloped (World Bank Group, 2023). Many existing energy infrastructures are not equipped to handle the integration of decentralised and varied renewable energy sources (Brijs, 2021). Additionally, there are some policy barriers. In many companies, lack of clear long-term strategies can deter investment in renewable energy projects (Royston et al., 2023). Continued subsidies for fossil fuels prevent the shift to renewable energy by artificially lowering the cost of fossil fuel energy (IEA, 2023b). Overlapping regulations and bureaucratic procedures can slow down the development and deployment of renewable energy technologies (Dzwigol et al., 2023).

Solutions to Overcome Barriers

Offering support tax breaks and reduced tariffs for renewable technologies can assist in managing the initial expenses and promoting their use. Upgrading grid infrastructure to accommodate the fluctuating and decentralised nature of energy sources can help address issues related to their intermittent. Implementing storage solutions such as batteries and thermal storage systems can further tackle concerns about intermittency and reliability (Gracie Brown et al., 2022). It is essential to establish policy frameworks that support investments in energy. Educating stakeholders about the advantages of energy and the practical aspect of its implementation is crucial for overcoming resistance and driving change (UNCTAD, 2023). Collaborative international initiatives play a role in overcoming technological obstacles by combining resources, standardising regulations, and sharing successful strategies (IEA, 2022).

Success Rates and Impacting Factors

The Carbon Disclosure Project shares information from numerous companies annually regarding effects, such as global carbon emissions. As per CDP 2020 Global Climate Change Assessment findings, some companies have indicated a decline in emissions due to sustainability efforts. Specifically

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highlighted in the 2020 report is the progress made by companies overseeing more than one-third of investment in aligning with the targets set out in the Paris Agreement through a reduction of emissions by up to 25% compared to the baseline period of 2015 – 2020 (CDP, 2020). The International Energy Agency regularly releases data and forecasts related to energy consumption and carbon emissions. Their industry outlooks often point to a growing number of energy sector companies, including major oil and gas players, achieving emission reductions through the integration of renewable energy sources, energy efficiency improvements, and carbon capture technologies. The IEA's report titled "CO2 Emissions in 2023" offers a detailed overview of energy-related emissions for that year, highlighting how clean energy growth has limited the rise in global emissions, which saw an increase of 1.1%. Additionally, the IEA's "CO2 Emissions in 2022" report provides insights into energy-related greenhouse gas emissions in 2022, noting that the global growth in emissions was not as high as some had anticipated despite the disruptions caused by the global energy crisis (IEA, 2023a).

Several key factors have been identified that influence how businesses can lower their carbon footprint. For example, stringent environmental regulations and policies such as carbon pricing, emissions trading systems, and high ecological standards serve as incentives for companies to reduce their carbon emissions. The integration and utilisation of technologies in energy, energy efficiency and carbon capture and storage (CCS) are crucial in this endeavour. Financial backing through subsidies, tax breaks and support programs for initiatives enable both companies and small-to-sized businesses (SMEs) to invest in technologies that curb carbon emissions. Companies that demonstrate a commitment to sustainability by incorporating objectives into their governance structures are better equipped to implement strategies for decreasing carbon emissions. There is a growing call from investors, consumers and society at large for transparency and action on climate change concerns, prompting businesses to adopt practices (Wang et al., 2023; Mendiluce, 2021).

Despite attempts worldwide to adopt environmentally friendly practices, numerous businesses face difficulties in efficiently lowering their carbon emissions. Amidst this challenging scenario, the inspiring tale of Company KGHM in Poland shines brightly as a source of optimism. This article highlights how this company successfully tackled obstacles and established a standard for reducing carbon emissions by implementing approaches and staying dedicated to renewable energy. Their accomplishments provide insights and motivation for businesses to harmonise their activities with environmental sustainability objectives.

Case Study

This study examines the renewable energy strategies for the Polish company KGHM Polska Miedź S.A. as a case study that shows greenhouse gas emissions reduction efforts. This company is one of the world's largest producers of copper and silver and, therefore, has been selected.

In 2022, the company produced 733 thousand tons of copper and 1,327 tons of silver (KGHM, 2022). The company tries to operate in accordance with the principles of sustainable development and responsible business and actively reduces its greenhouse gas emissions to limit its responsibility for climate change.

Although the Group's products support the ecological transformation of the global economy, KGHM is also constantly modifying its own business profile to achieve climate neutrality by 2050 and reduce total emissions in scopes 1 and 2 by 30% by 2030 compared to 2020 (from 3.03 million teCO2). The pursuit of sustainable development through the development of its own low-emission generation capacity (construction and acquisition of photovoltaic and wind projects as well as, in the long term, the use of small modular reactors). one of the main pillars of the Group's Strategy.

Emissions at KGHM can be divided into two scopes:

Scope 1 – are direct emissions related primarily to the Company's production activities, i.e. in particular, emissions from metallurgical processes, emissions related to the operation of fuel engines by vehicles and mining machines in mines, and emissions related to energy production from own sources and the use of natural gas.

Scope 2 – they are related to indirect emissions from the use of electricity and heat purchased on the market. Their level depends primarily on the energy mix in Poland's power supply system.

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Detailed internal reports (Table 1) indicate KGHM Company's emissions.

Table 1. Greenhouse gas emissions in KGHM Polska Miedź S.A. in 2020 – 2022 [t eCO2]

	Year 2022	Year 2021	Year 2020 (base year)	Change [%]
Scope 1	1288052	1457899	1413129	- 8,9%
Scope 2	1912062	1651717	1617217	+ 18,2%
Total emissions (Scope 1 + 2)	**3200114**	**3109616**	**3030346**	**+ 5.6%**

Source: authors' work based on KGHM (2022).

In recent years, the company has carried out a detailed analysis and assessment of its activities in terms of greenhouse gas emissions. The emissions of the entire KGHM group and the emissions of its individual divisions of the Group were carefully analysed. KGHM is a large mining and metallurgical company. The company's total emissions include:

- deep underground copper ore mines – three main mines,
- copper smelter – three smelters in different locations,
- other divisions.

KGHM Polska Miedź S.A. emits approximately 3 million tonnes of CO2 equivalent annually. Approximately 47% of which consist of Scope 1 emissions, and 53% are Scope 2 emissions according to the GHG Protocol (Greenhouse Gas Protocol)(KGHM, 2022).

Emissions of individual KGHM divisions, it is as follows (Table 2.)

Table 2. Total greenhouse gas emissions (scope 1 +2) in KGHM Polska Miedź S. A. Group (location based) in 2021-2022 [t eCO2]

	Year 2022		Year 2021	
Location	**Scope 1**	**Scope 2**	**Scope 1**	**Scope 2**
Copper Mine Rudna	78 391	335 365	68 506	300 019
Copper Mine Lubin	26 973	111 549	26 303	111 536
Copper Mine Polkowice Sieroszowice	58 443	362 494	55 212	258 854
Central	371	Not calculated	333	Not calculated
Copper Ore Upgrading Plant	33 262	396 345	33 428	363 356
Hydrotechnical Plant	2099	65 157	1951	60 291
Copper Smelter Legnica	35 707	79 675	36 129	72 551
Copper Smelter Głogów	**929 467**	**541 548**	**1 008 261**	**464 996**
Copper Smelter Cedynia	16 727	15 721	18 370	15 775
Gas and Steam Power Plants	106 611	4 208	209 406	4 339

Source: authors' work based on KGHM (2022).

As it is shown, the most emission (scope 1 + 2) relates to Copper Smelter Głogów.

Ambitious plans for the reduction of greenhouse gas emissions by KGHM Polska Miedź S.A. have two-time horizons (two objectives). The main objective of the Company's Climate Policy is to achieve climate neutrality by 2050 Year with respect to Scope 1 and Scope 2 greenhouse gas emissions, with the maximum possible reduction of the emissions. The intermediate objective of KGHM Polska Miedź S.A. is to reduce total Scope 1, and Scope 2 emissions levels by 30% by 2030 Year relative to the emission levels in 2020 (KGHM, 2021).

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The primary methods of reducing the Company's carbon footprint in terms of scope 1 direct emissions will include:

1) Using hydrogen technologies in production processes.
2) The development of electromobility (gradual replacement of lightweight surface vehicles and mining machines with electric ones).
3) Implementation of advanced technologies on the production line.
4) Use of CCS/CCU (Carbon Capture, Storage and Utilization Technologies – technologies for capturing, storing and utilising carbon dioxide) technologies to manage the remaining CO2 emissions from metallurgical processes.

The primary directions for reducing indirect emissions scope 2 will include:

1) Development of own emission-free and low-carbon sources (solar farm wind farm and module nuclear reactors).
2) Improving energy efficiency in production branches and streamlining technological processes.
3) Purchase energy via PPA (Power Purchase Agreement – an agreement for the supply of electricity between two parties) contracts.

These activities also relate to the implementation of the UN Sustainable Development Goals. The Climate Policy of KGHM Polska Miedź S. A. will directly support the achievement of the United Nations Sustainable Development Goals (SDG)(Carboni et al., 2018). The company has chosen three goals to achieve (KGHM, 2021):

- Goal 7 – Ensure access to affordable, reliable, sustainable and modern energy for all.
- Goal 12 – Ensure sustainable consumption and production patterns.
- Goal 13 – Take urgent action to combat climate change and its impacts.

Conclusion and Recommendation

As already mentioned, KGHM has set two-time horizons for achieving its greenhouse gas emission reduction goals. The company's current activities focus on achieving the goals related to the first time horizon – 2030 (emission reduction by 30%). To meet emission reduction goals, the company is strongly involved in the project of building a CO2 capture installation at the Głogów Copper Smelter. Table 2 clearly shows that this division is responsible for the largest individual CO2 emissions (about 1,5 million tons of CO_2 in 2022 year) in the KGHM Group. This project should be completed in 2030 and it is highly probable that this deadline will be maintained. The company is also developing the construction of wind farms and photovoltaic farms. However, the key issue is investment in modular nuclear reactors. The launch of these reactors will enable KGHM to become fully independent in the supply of electricity and reduce Scope 2 emissions. This is a cardinal condition for achieving climate neutrality by KGHM Poska Miedź S.A. in 2050 Year. For companies operating within the same sector, specific advanced technical recommendations are provided to address unique industry challenges and capitalise on opportunities for innovation in carbon management. These tailored strategies focus on integrating cutting-edge technologies and best practices that are most applicable and beneficial for businesses with similar operational frameworks and environmental impacts:

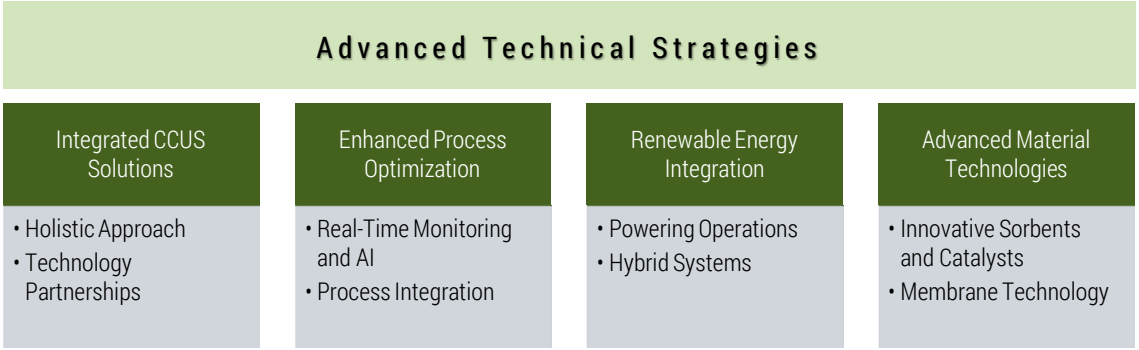

Figure 1. Advanced Technical Strategies

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Companies need to implement an integrated approach that combines CCS with CCU to optimise the benefits of carbon capture. For instance, the captured carbon dioxide can be utilised for creating fuels, chemicals and construction materials thereby lessening the dependence on resources. On the other hand, forming partnerships with tech firms and research organisations is crucial in advancing CCUS technologies to enhance effectiveness and cut expenses. Additionally leveraging intelligence and machine learning algorithms for monitoring and optimising CCS/CCU processes in time is essential. Design processes are important to ensure that carbon capture is an integral part of the production process rather than an add-on. This can lead to efficiencies in both the capture process and the overall operations. They should use renewable energy sources to power carbon capture systems, reducing the overall carbon footprint of the capture and storage operations, and they have to develop hybrid systems where renewable energy intermittency is managed through integration with energy storage systems, ensuring a consistent energy supply for carbon capture processes. It will also be essential to invest in the development of advanced materials, such as novel sorbents and catalysts that can increase the efficiency and selectivity of CO2 capture and to explore the use of membrane technologies for CO2 separation, which can offer lower energy consumption and higher purity compared to traditional methods.

The contribution of the authors

Conceptualisation, A.Ś. and Y.Z.; literature review, A.Ś. and Y.Z.; methodology, A.Ś.; formal analysis, A.Ś. and Y.Z.; writing, A.Ś. and Y.Z.; conclusions and discussion, A.Ś. and Y.Z.

The authors have read and agreed to the published version of the manuscript.

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STRATEGIE REDUKCJI EMISJI DWUTLENKU WĘGLA: STUDIUM PRZYPADKU KGHM POLSKA MIEDŹ S.A.

STRESZCZENIE: Artykuł ten analizuje rolę energii w redukcji globalnych emisji dwutlenku węgla, co jest kluczowe w światowej walce ze zmianami klimatycznymi. Na przykładzie KGHM, czołowego gracza w branży, który z powodzeniem zintegrował rozwiązania energetyczne, badanie to podkreśla wpływ i kluczowe wyniki takich działań. Analizując stan zużycia energii, badanie zwraca uwagę na powszechną zależność od paliw kopalnych oraz potencjalny wpływ odnawialnych źródeł, takich jak energia słoneczna, wiatrowa, hydroelektryczna i biomasa, na przekształcanie naszego krajobrazu energetycznego. Badanie dostarcza wglądu w technologie, wyzwania związane z ich wdrażaniem oraz struktury ekonomiczne i polityczne wpływające na ich adopcję. W badaniu przedstawiono zalecenia dla firm dążących do zmniejszenia swojego wpływu i promowania inicjatyw ekologicznych. Wyniki podkreślają rosnące znaczenie przejścia na odnawialne źródła energii w celu osiągnięcia celów określonych w porozumieniach, takich jak Porozumienie Paryskie, które dąży do ograniczenia wzrostu temperatury do mniej niż 2 stopni Celsjusza. Na koniec sformułowano apel o powszechne reformy polityczne i zwiększoną odpowiedzialność korporacyjną w promowaniu zrównoważonej przyszłości energetycznej.

SŁOWA KLUCZOWE: odnawialna energia, redukcja emisji dwutlenku węgla, CCS/CCU (sekwestracja i wykorzystanie dwutlenku węgla), poprawa efektywności energetycznej

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