

SUSTAINABLE DEVELOPMENT IN THE COAL MINING OPERATION: CHALLENGES, OPPORTUNITIES, AND STRATEGIES

Wahyu SARDJONO¹, MARYANI¹, Jajat SUDRAJAT², Erma LUSIA³

¹*Information Systems Management, Binus Graduate Program, Bina Nusantara University Jl. Kebon Jeruk Raya No. 27, Kebon Jeruk, Jakarta Barat 11530 - INDONESIA* ^b*Information Systems Department, School of Information Systems, Bina Nusantara University Jl. Kebon Jeruk Raya No. 27, Kebon Jeruk, Jakarta Barat 11530 – INDONESIA*

²*BINUS Entrepreneurship Center, Management Department, BINUS Business School Undergraduate Program Bina Nusantara University,*

Jl. Kebon Jeruk Raya No. 27, Kebon Jeruk, Jakarta Barat 11530 – INDONESIA

³*Tourism Department, Faculty of Economics & Communication, Bina Nusantara University, Jakarta, Indonesia 11480*

**wahyu.s@binus.ac.id*

ABSTRACT

This paper delves into the critical pursuit of sustainable development within the coal mining industry, addressing challenges, opportunities, and strategies. Sustainable development is imperative for the survival of our planet and the growth of our economies. With the coal mining sector being a significant contributor to global energy needs, it is essential to reconcile its operations with sustainable principles. The concept of sustainable development entails economic, social, and environmental considerations, and its relevance has been underscored by the United Nations' Sustainable Development Goals (SDGs). The paper explores various challenges, including economic dependence, environmental degradation, technological constraints, and regulatory hurdles, while also identifying opportunities such as local procurement, energy efficiency, renewable energy integration, and social responsibility. Strategies for sustainable development encompass fostering a diverse and inclusive workplace, investing in education, supporting emerging industries, implementing environmentally responsible practices, and adopting cleaner technologies. Ultimately, this paper seeks to engage stakeholders in a comprehensive dialogue to advance sustainable development in the coal mining sector, promoting a harmonious coexistence of mining activities with our planet and society.

Keywords: sustainable development, coal mining, SDGs, ESG framework, environmental responsibility

1. INTRODUCTION

To ensure the further existence of life on earth and the better development of the economy, a sustainable development strategy should be emphasized and adopted. This strategy is not a temporary undertaking but rather an ongoing process. One industry that requires particular attention in terms of sustainable development is the coal mining industry. The global mining industry has already reached a consensus on the need for sustainable development in the sector.

As we embark on this journey, it is impossible to overlook the profound words of Le Quéré *et al.* (2020), who underscored the urgent need for transformative action to combat climate change: the future of humanity depends on our ability to rise to the challenge.

The coal mining industry, as an integral part of the global energy landscape, it is incumbent upon us to heed this call to action and navigate the path toward sustainable development. In the context of coal mining, within the concept of sustainable development, it is expected that a region can sustain its existence and continue to grow because alternative economic sectors have evolved to replace the mining industry. This is achieved by fostering the region's capabilities and ensuring that the local community possesses the skills to utilize them. Consequently, the community that once relied on the coal mining sector as the backbone of its economy can now live independently without depending on mining companies.

In this paper, our aim is to actively engage in a comprehensive conversation involving policymakers, industry leaders, environmental champions, and the public. We will discuss the strategies, challenges, and opportunities that exist in developing and implementing sustainable development concept in the coal mining industry and its operation (Que *et al.*, 2018). Through an analysis of various sources, including the importance of sustainable development and the

specific improvements that can be made in the coal mining industries, we will shed light on the critical aspects of this ongoing endeavor.

Sustainable Development Concept

Sustainable development is a concept that has gained significant attention in recent years. It is a comprehensive and widely embraced concept that aims to balance economic, social, and environmental factors (often referred to as “the triple bottom line” – can be seen in Figure 1) in decision-making processes to ensure the well-being and prosperity of present and future generations. It represents a holistic approach to development that seeks to address a range of interconnected challenges and goals, with a focus on long-term viability and harmony with the planet. There are some key aspects and principles of sustainable development, include the environmental sustainability, economic sustainability, social equity, inter-generational equity, community and stakeholder engagement, global cooperation, adaptive and resilient approaches, and innovation and technology (United Nations Environment Programme, 2020).

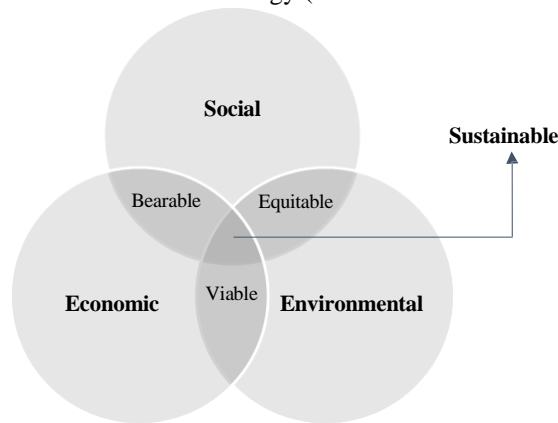


Figure 1. The Triple Bottom Line of Sustainability (Arif, 2021)

In 2015, the world collectively agreed that sustainable development should serve as a global guide for all countries through the Sustainable Development Goals (SDGs), which were enforced from January 1st, 2016 until December 31st, 2030. The 17 SDGs (Figure 2) are interconnected, acknowledging that efforts in one domain will influence results in others and that development should harmonize the triple bottom line of sustainability.

Consequently, companies, including those in the mining sector, play a pivotal role in advancing SDGs. The core activities of these companies, their social investments, and policy advocacy efforts are expected to consistently contribute to the achievement of SDGs, whether at the local, national, or global level.

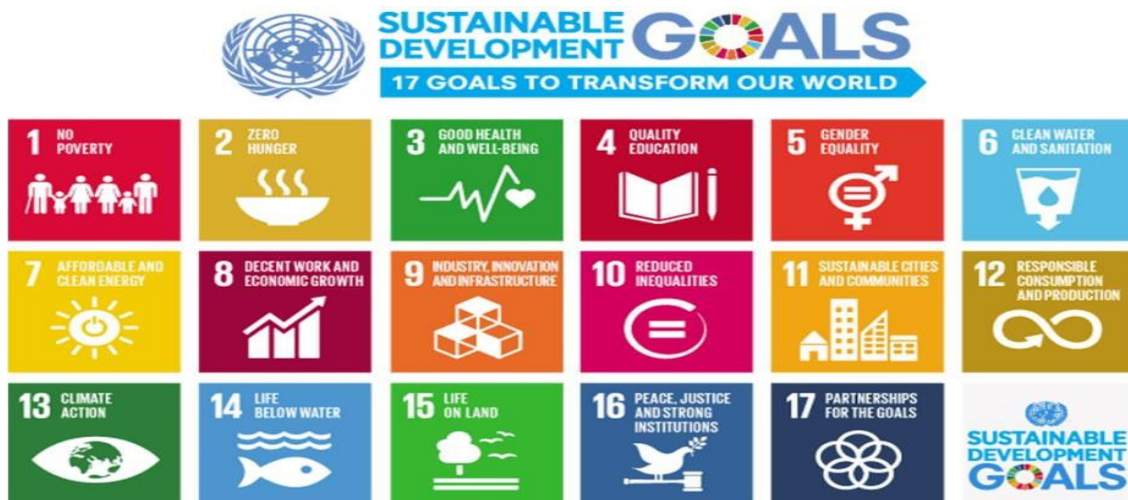


Figure 2. The 17 SDGs (Sachs, 2023)

Production of Coal Mining in the World

The coal mining industry plays a critical role in the global energy landscape, providing a substantial portion of the world's energy needs. Coal is one of the energy sources that is still used in the world because until now coal is a relatively cheap energy source. The International Energy Agency (IEA) predicts that the demand for coal will continue to rise in the coming decades, particularly in developing countries like India and China (Sivageerthi *et al.*, 2022). As a result of this growing demand, there is a need for the coal mining industry to operate more sustainably to minimize its negative impacts on the environment and communities.

Mining activities are unique in that they involve deposits beneath the earth's surface that are geologically diverse in terms of type, quantity, grade or quality, as well as other characteristics. In general, open-pit coal mining consists of several stages, including exploration, geological modeling, feasibility studies, land clearing and topsoil removal, overburden removal, coal getting, coal hauling, coal crushing and washing, marketing, and coal environmental management (Arif, 2022) (Figure 3).

According to the IEA, in 2022, the largest coal-producing country in the world was China. The IEA estimated that throughout 2022, China produced 4.2 billion tons of coal, consisting of 3.6 billion tons of thermal coal, along with 676 million tons of metallurgical coal. Thermal coal is typically used as a source of energy for electricity generation, while metallurgical coal is used as a raw material in steel production. Overall, the IEA projected that global coal production in 2022 reached 8.3 billion tons, marking a 5.4% increase compared to 2021 (International Energy Agency, 2023).

According to the Statistical Review of World Energy published by the Energy Institute, the ten countries with the largest production amounts in 2022 can be seen in Figure 4. The coal mining industry in Indonesia is of particular interest as it is one of the world's largest coal producers and exporters. Indonesia is the third-largest coal-producing country in the world, behind only India and China, with total production in 2022 reached 684.7 million tons. Despite its significant contributions to the global economy, the coal mining industry is faced with numerous sustainability challenges.

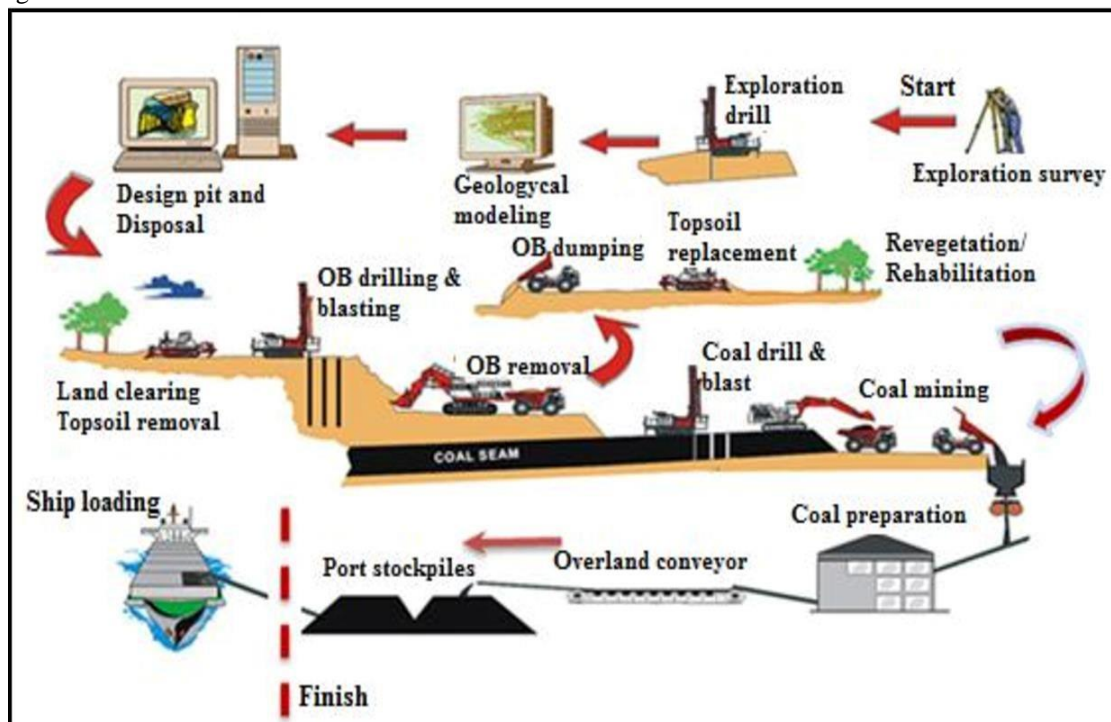


Figure 3. Open pit mines cycle processes (Permana and Drebenstedt, 2014)

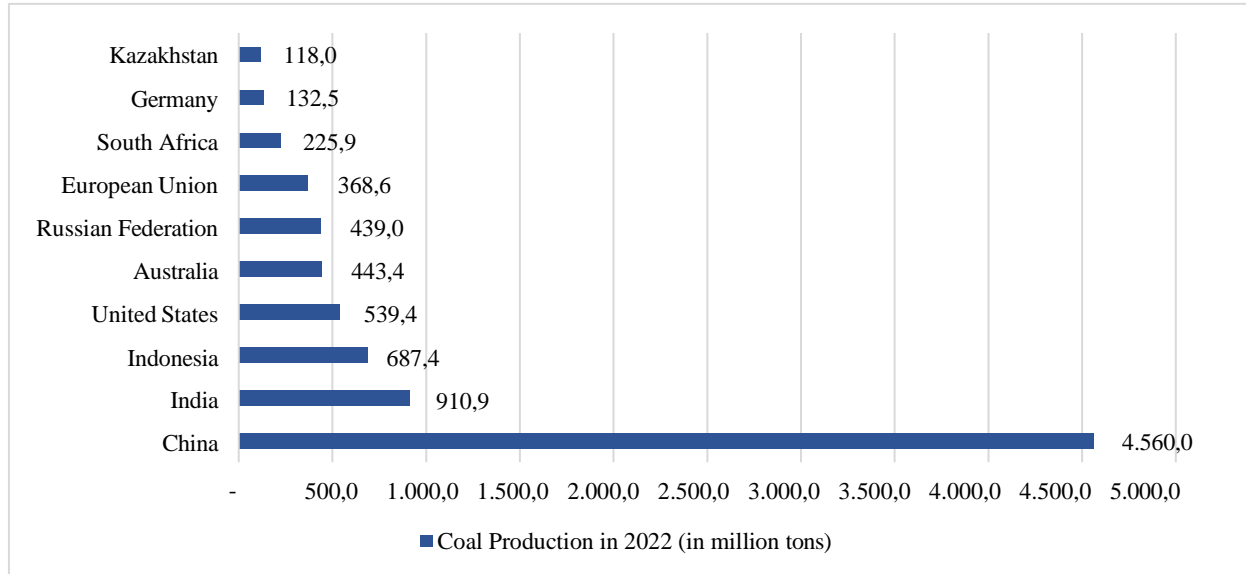


Figure 4. Top ten countries with the largest coal production in 2022 (Energy Institute, 2023)

The Importance of Sustainable Development in the Coal Mining Industry

The mining industry, including coal mining, plays a crucial role in the global economy. Natural resources and the environment are primary factors that influence sustainable development (Masood *et al.*, 2020). For decades, academic and public policy institutes worldwide have conducted significant research on mining and sustainable development, recognizing the need to strike a balance between economic growth and environmental conservation. It is widely acknowledged that coal is a strategic resource in terms of development and energy security due to its affordability as a fuel source. In order to ensure the sustainable development of the coal mining industry, it is imperative to consider the triple bottom line factors that contribute to overall sustainability. This includes addressing challenges such as energy utilization, water usage, and social and environmental impacts, as well as finding better ways to clean raw materials and reduce emissions impact.

As development partners for many countries, mining operations have both opportunities and responsibilities to demonstrate how they conduct business in alignment with the SDGs. Companies can showcase their social responsibility through systematic actions aimed at avoiding and mitigating their negative impacts on people, profit, and the planet. They can also leverage their potential transformative influence to catalyze sustainable development.

By actively engaging various stakeholders and promoting a comprehensive conversation, we can work towards the goal of achieving sustainable development in the coal mining industry. By adopting sustainable practices in the coal mining industry, we can mitigate the negative environmental impact that is associated with mining operations.

2. METHOD

An extensive review of the books, literature, and internet resources relevant to the topic under discussion was conducted as part of the research process. This literature review's main goals were to gather relevant data and evaluate how closely the data correlated with one another and if they supported or refuted one another.

1. Gather information from a variety of sources, including books, websites, previously published papers, personal experiences, and other materials that are pertinent to the topic.
2. Analyze the gathered sources thoroughly.
3. Assess the information's applicability to forthcoming conversations.
4. Recap the main ideas from all the relevant sources.
5. To include into the paper, organize and clearly state the key topics you have learned.

3. RESULT AND DISCUSSION

Standard of Sustainable Development in the Mining Industry: Environmental, Social and Governance (ESG)

The Environmental, Social, and Governance (ESG) framework is widely accepted as the standard for assessing sustainable development in the mining industry. This framework encompasses three key dimensions: environmental, social, and governance factors. These dimensions provide a comprehensive understanding of the impact of coal mining activities on the environment, local communities, and corporate governance practices. The use of indicators is crucial in monitoring the mining industry's adherence to sustainable development guidelines (Raborar and Recio, 2020). Indicators play a vital role in assessing the level of sustainability and compliance within the mining industry.

The ESG term has also gained attraction among investors, encouraging coal mining companies to adopt good mining practice (GMP). GMP refers to mining operations that align with specified criteria and standards for responsible mining, adhere to applicable regulations, and facilitate the realization of sustainable development objectives. For investors, ESG is a factor considered in investment decisions and risk management processes. ESG-based investments imply that companies, in their business operations, take into account environmental, social, and governance factors.

In an era marked by growing environmental consciousness and increased scrutiny of corporate practices, the mining industry finds itself at the intersection of a critical juncture: reconciling its long-standing role as a vital global resource provider with the imperative to adhere to sustainable development principles.

As the world grapples with pressing environmental challenges and heightened social expectations, the mining sector faces a compelling mandate to redefine its practices, ensuring that they align with the principles of sustainability and responsible resource extraction. In this exploration, we illuminate the multifaceted dimensions of ESG within the mining domain, highlighting the industry's evolving landscape and its profound implications for our planet and society.

The mining industry, including coal mining, faces significant challenges in achieving sustainable development. One area in which the industry can develop sustainability is by improving its overall sustainable model. By incorporating eco-efficiency and sustainable development assessment methods into decision-making processes and strategic planning for coal mines, decision-makers can assess the industry's development strategy and identify areas for improvement.

By utilizing the frameworks for developing indicators, decision-makers can gain a comprehensive understanding of the current state of sustainability in the coal mining industry. They can identify strengths, weaknesses, opportunities, and threats related to environmental, social, and governance factors. These analyses can contribute to the development of strategies that address key sustainability issues such as reducing greenhouse gas emissions and improving overall resource efficiency. Moreover, the coal and mining industries can focus on optimizing energy utilization to minimize their environmental impact.

Developing and Implementing Sustainable Development in the Coal Mining Industry

Amidst the global push for a cleaner and more sustainable energy future, the coal mining industry stands at a critical crossroads. Recognized for its historical significance as a major energy source, coal mining faces the formidable challenge of aligning its practices with the imperatives of sustainability. As societies worldwide transition towards greener energy alternatives and heightened environmental consciousness, the coal sector finds itself under increasing scrutiny, necessitating a profound reevaluation of its operations and their impact on the planet. In this exploration, we navigate the complex terrain of sustainable development within the coal mining domain, shedding light on the industry's evolving strategies and their implications for both energy security and environmental responsibility.

The clear linkage between coal mining and sustainable development was explicitly outlined in 2016 in the publication titled "Mapping Mining to the Sustainable Development Goals: An Atlas" (Figure 5). This Atlas illustrates how mining can positively impact the achievement of SDGs by promoting broad-based economic development and supplying crucial minerals for technology, infrastructure, energy, and agriculture. It simultaneously underscores the ways in which mining contributes to various challenges that the SDGs aim to address, such as human rights violations, social inequality, environmental degradation, and corruption (UNDP, 2016).



Figure 5. Mining and the 17 SDGs (UNDP, 2016)

Developing and implementing sustainable development in the coal mining industry is a multifaceted and crucial endeavor aimed at addressing the environmental, social, and economic challenges associated with coal extraction and utilization. Sustainable development in coal mining involves reducing the environmental impact of mining operations. This includes implementing technologies and practices that minimize air and water pollution, soil erosion, and habitat destruction. It also encompasses efforts to mitigate the greenhouse gas emissions associated with coal mining, such as through carbon capture and storage (CCS) technologies.

Challenges to Sustainable Development in the Mining Industry

The coal mining industry, while holding potential for sustainable development, confronts a series of formidable challenges that demand comprehensive solutions. These include but are not limited to economic dependence, environmental concerns, technological hurdles, and regulatory and political challenges (Responsible Mining Foundation, 2021).

The coal mining sector plays a pivotal role in many regions, serving as the cornerstone of local economies, offering livelihoods, and contributing to overall economic stability. Nevertheless, the process of shifting away from coal as a primary energy source poses substantial economic challenges for these areas. The specter of job losses and the urgent need to create alternative economic prospects cast a substantial shadow over these communities. Confronting this multifaceted challenge demands a comprehensive and nuanced strategy that goes beyond a one-size-fits-all approach.

Coal mining activities frequently impose a significant environmental toll, resulting in extensive habitat destruction, contamination of water sources, and erosion of soil quality. Mitigating these environmental impacts is a complex endeavor that demands substantial resources and commitment. This includes the implementation of stringent environmental regulations, investment in state-of-the-art mitigation technologies, and a commitment to ecosystem restoration.

The transition towards cleaner technologies represents crucial steps in making the coal mining industry more sustainable. However, these technologies and innovations are not only expensive but also technologically challenging to implement. Coal mining companies must grapple with the financial constraints of adopting advanced technologies and surmount the technical complexities involved in their integration.

The coal sector functions in an environment characterized by stringent regulations and constantly shifting political circumstances. Adapting to evolving policies, which may involve the introduction of carbon pricing methods and more

stringent emissions regulations, presents a significant obstacle. Successfully maneuvering through these changes requires a proactive strategy, involving active participation in policy dialogues, the diversification of energy sources, and the formulation of sustainable business models that align with emerging environmental and regulatory criteria.

Opportunities for Sustainable Development in the Mining Industry

Amidst the formidable challenges confronting the coal mining industry, there exists a spectrum of promising opportunities for its sustainable development, which, when harnessed effectively, can pave the way for a more responsible and eco-friendly future, including drive economic growth with local procurement, improve energy efficiency and reduce emissions, and incorporate renewable energy (Malinowski, 2021).

Local procurement refers to the process of acquiring goods and services from close-by vendors and establishments located close to coal mining operations. By collaborating with local chambers of commerce, financial institutions, and non-governmental organizations (NGOs), coal mining companies can establish business incubators and work closely with local suppliers to enhance their capabilities and elevate product quality. This approach presents numerous advantages for fostering sustainable coal mining, including stimulating economic growth, diminishing the environmental footprint, and fostering community involvement.

In order to mine coal sustainably, it is essential to increase energy efficiency and reduce emissions. These opportunities can be pursued in a variety of ways, including by collaborating with rural electrification initiatives, pursuing co-financing arrangements, taking part in research and development projects focused on the environment, testing out emission trading systems or cutting-edge technology, and publicly endorsing carbon pricing mechanisms.

An innovative step in the direction of sustainability is the integration of renewable energy sources into the coal mining process. This possibility might be realized by the installation of off-grid wind, solar, or geothermal power systems, the diversification of energy sources to lessen power outages, and the phase-out of diesel generators. Hybrid energy systems can also be produced by combining renewable energy sources with traditional power producing techniques. These integrated technologies improve energy efficiency, reduce costs, and mitigate environmental effects, ushering in a more responsible and ecologically sensitive era for coal mining.

Strategies for Sustainable Development in the Mining Industry

In line with the concept of sustainable development and the implementation of GMP, several strategies that can be pursued to establish sustainable coal mining in the future include embracing social responsibility, practicing environmental stewardship, transitioning to cleaner technologies, and expanding the range of energy sources.

Promoting social responsibility is another key strategy for coal mining companies. One critical facet of social responsibility lies in job creation. Beyond providing employment opportunities, these companies can actively contribute to the socio-economic landscape by fostering a diverse and inclusive workplace. By doing so, they empower individuals with gainful employment while simultaneously promoting diversity and equity within their workforce.

Education is another indispensable pillar of social responsibility. Coal mining companies can make substantial investments in educational initiatives, ranging from scholarships to vocational training programs. Collaborations with local educational institutions can help bridge educational disparities, particularly in underserved communities where mining operations are often situated. By enhancing the skill set and knowledge base of both current and potential employees, these initiatives nurture a more capable and employable workforce, thereby fostering long-term economic stability and societal progress.

It is essential to foster investment in emerging industries that can provide employment and economic growth in these regions. This might include renewable energy projects, technology innovation hubs, or other sectors poised for growth. By strategically directing investments towards these industries, regions can diversify their economic bases and reduce their dependency on coal mining.

The importance of implementing environmentally responsible practices in mining operations cannot be overstated. It requires a comprehensive approach that covers various critical aspects. Foremost among these is the rigorous reclamation of land. This involves actively restoring and revitalizing areas that have been mined to their original natural condition, ensuring their ability to support ecosystems and communities in the long run. Equally crucial is effective water management, which entails measures to prevent water source contamination. This includes the implementation of advanced filtration and treatment systems to maintain water quality at acceptable levels.

Additionally, biodiversity conservation is of paramount importance, given that mining often impacts local plant and animal life.

Companies must take proactive measures to safeguard and, when necessary, restore the affected natural habitats. This might entail initiatives such as creating wildlife corridors, establishing protected zones, and engaging in habitat restoration efforts. Prioritizing these practices not only reduces the environmental impact of mining but also demonstrates a commitment to sustainable and responsible resource extraction. This, in turn, benefits the environment and fosters positive relationships with local communities and regulatory bodies, ultimately contributing to a more sustainable and harmonious coexistence between mining activities and the natural world.

One of the key strategies for the coal mining industry is the adoption of cleaner and more efficient technologies. This includes the implementation of clean coal technology (CCT). CCT is a technology developed to facilitate cleaner coal combustion. CCT encompasses technologies such as Integrated Gasification Combined Cycle (IGCC), oxyfuel combustion, and Underground Coal Gasification (UCG), all of which are utilized to generate heat from coal with low emissions.

Furthermore, one of the CCT technologies that is well known and is starting to be implemented in several countries, namely carbon capture and storage (CCS), to reduce greenhouse gas emissions, as well as implementing advanced mining techniques that minimize environmental impacts. CCS or Carbon Capture, Utilization, and Storage (CCUS) refers to the concept of capturing and securely storing CO₂ produced from combustion, effectively reducing CO₂ emissions in the atmosphere (Figure 6). The CCS/CCUS technology can be applied to both newly constructed power plants and those that have been in operation previously (Mirgaux et al., 2021).

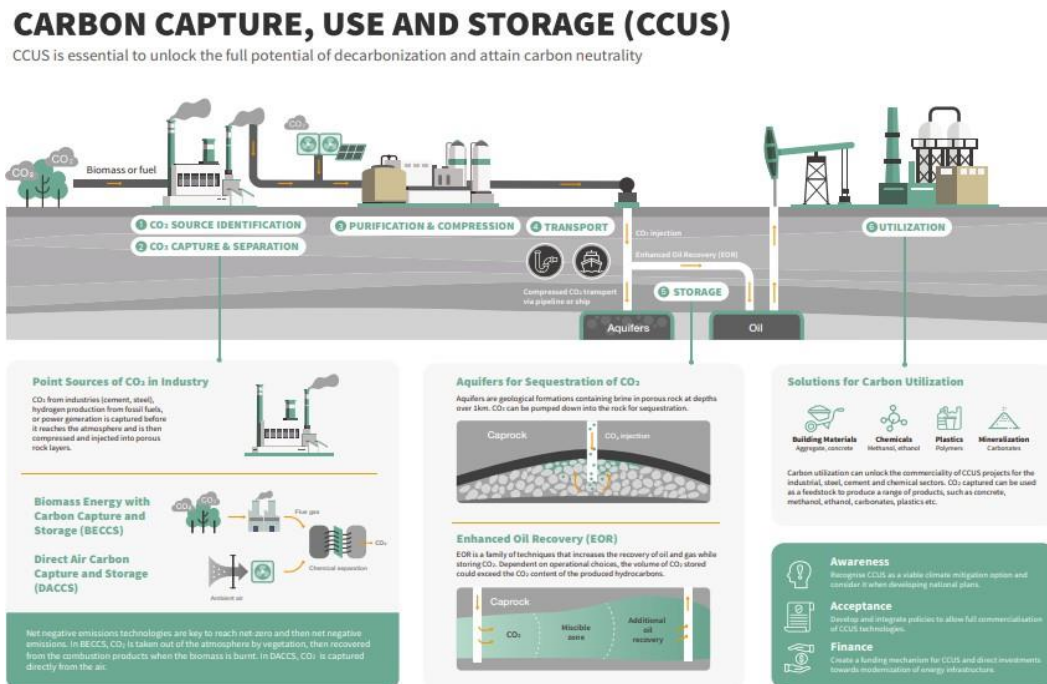


Figure 6. CCS/CCUS technology scheme (UNECE, 2021)

Diversifying energy sources plays a pivotal role in fostering sustainable development by promoting environmental responsibility and resilience in the energy sector. Coal mining companies, traditionally associated with high carbon emissions, have an opportunity to actively engage in sustainable practices. One impactful strategy is also to allocate resources and invest in renewable energy projects, such as wind and solar (Pai et al., 2020). By doing so, these companies not only reduce their own carbon footprint but also contribute positively to the broader energy landscape. This shift towards renewables not only aligns with global efforts to combat climate change but also positions these companies as part of the solution, ensuring a more balanced and sustainable energy mix. It signifies a transition from reliance on fossil fuels to harnessing cleaner and more sustainable sources of energy, ultimately benefiting both the environment and society as a whole.

4. CONCLUSION

In conclusion, this paper underscores the critical imperative of embracing sustainable development within the coal mining industry. The global consensus on the necessity of sustainable practices in mining, guided by the principles of the triple bottom line and the United Nations' Sustainable Development Goals (SDGs), forms the backdrop for this discourse. The coal mining sector, as an integral component of the global energy landscape, faces both challenges and opportunities in its journey toward sustainability.

Challenges include economic dependence on coal, environmental degradation, technological complexities, and navigating evolving regulations. Addressing these hurdles demands tailored, region-specific approaches. However, amid these challenges, there are compelling opportunities for sustainable development. These include stimulating economic growth through local procurement, enhancing energy efficiency, reducing emissions, and integrating renewable energy sources.

To actualize these opportunities, coal mining companies must commit to social responsibility, environmental stewardship, cleaner technologies, and diversification of energy sources. By adopting a comprehensive approach that encompasses these strategies, the coal mining industry can evolve into a more sustainable, responsible, and eco-friendly contributor to the global energy matrix, thereby aligning with the overarching goal of a sustainable future for all.

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