ENHANCING THE QUALITY OF LIVING ENVIRONMENT - THE UTILIZATION OF CARBON DIOXIDE AS A GREEN INDUSTRY INNOVATION

Meningkatkan Kualitas Lingkungan - Pemanfaatan Karbondioksida sebagai Inovasi dalam Industri Hijau

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Abstract

The rapid growth in the productivity of the world's chemical industry has had adverse environmental impacts. One of the efforts to protect the environment is by reprocessing carbon dioxide. This research is an initiative to link the use of CO2 with the formation of green industrial innovation in the long term. A qualitative-descriptive approach is implemented to achieve this goal, aided by a literature review. The research results show that CO2 is not only produced from non-fossil energy residues but also from other fossil energy sources. The importance of campaigning for developing a carbon capture and storage technology that is actively supported by all parties is the key to the success of tackling the future climate change problem.

Keywords: utilization; carbon dioxide (CO_2); green industry; sustainable development

Abstrak

Pesatnya pertumbuhan produktivitas industri kimia dunia telah menimbulkan dampak lingkungan yang merugikan. Salah satu upaya menjaga keberlanjutan lingkungan adalah melalui pengolahan kembali karbondioksida. Penelitian ini diharapkan dapat menjadi salah satu cara untuk menghubungkan penggunaan CO2 sebagai inovasi industri hijau untuk jangka panjang. Dalam mencapai tujuan ini, diterapkan pendekatan deskriptif kualitatif yang didukung oleh kajian kepustakaan. Hasil penelitian menunjukkan bahwa CO2 tidak hanya diproduksi dari sisa energi non-fosil tetapi juga dari sumber energi fosil lainnya. Pentingnya kampanye terkait teknologi penangkapan dan penyimpanan karbon yang didukung peran aktif dari semua pihak menjadi kunci keberhasilan dalam penanganan masalah perubahan iklim di masa depan.

Kata kunci: pemanfaatan; karbondioksida (Co_2); industri hijau; pembangunan berkelanjutan

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Introduction

The increase in industrial chemical production processes throughout the world produces various impacts; on the one hand, an increase in the economy and on the other hand, it has a negative impact on the environment, especially with the amount of waste produced that cannot be adequately decomposed. For this reason, the strategy used to manage chemical waste has become the main point in overcoming waste problems to date (Anastas & Zimmerman, 2013), as well as efforts in managing carbon dioxide as an environmentally friendly medium that can be useful for other energy sources.

Estes (2009) added that environmental issues over time would become one of the issues that attract attention because of the increasing awareness of humans about the surrounding environment accompanied by the development of knowledge and technology. Business people now do not only focus on profit alone but also on environmental and social impacts.

There is a strong connection between sustainable development, the engineering that science represents, and the mission of creating true knowledge. However, engineering is about changing the world. As a result, sustainability is an engineering responsibility. The Manufacturing Industry remains essential not only for the success of a country in the world market but also for all other countries in the world. Economic, social and environmental sustainability has been recognised as a top priority in manufacturing research, but sustainability is considered a complex and unstructured issue.

Thus, Sustainability is and will be an essential issue for present and future generations. Continuous manufacturing is considered one of the most critical issues in pursuing large SD images. This means that SD manufacturing companies are characterised by interactions in a sustainable dimension related to economic, social and environmental issues. The idea of SD also lies in progress in economic development, environmental protection, and social cohesion (Garbie, 2016).

Although CO_2 has a negative impact on the environment, especially in climate change on earth, if it is understood as a whole, it can actually be an energy solution for the future (Billig et al., 2019). Chappin et al. (2020) stated that environmental innovation should be emphasised as an obligation in the industry to regulate the eco-innovation process to find solutions to increasingly complex environmental problems. Heek et al. (2017) also added that one of the actions is an effort to capture and store carbon as an energy source to mitigate climate change. In this process, carbon dioxide emissions can be controlled simultaneously with the carbon emission process so that it becomes the raw material for production.

There are three important areas in the application of green industrial innovation, namely first; technology (technical innovation tools), second; management (innovation in planning and implementation), and third; staff (innovation of internal and external motive power represented by competent people in their field) (Lenort et al., 2017).

Based on these various views, the authors are interested in raising the topic of carbon capture and storage as evidence that the development of carbon capture technology will support sustainable development. In particular, the benefits are for the economic prosperity of developing countries, most of which still use fossil energy, so they always produce large amounts of carbon. As a result, industries that successfully utilise carbon dioxide will promote harmony between economic, social and environmental factors for a better future.

Literature Review

Goel and Sudhakar (2017) stated that it is well known that the atmospheric carbon dioxide cycle has a vital role in maintaining Earth's dynamic systems, the components of which act on different timescales varying from less than one second to hundreds of years. More and more CO_2 is being added to the atmosphere from increased energy use and generation from burning fossil fuels. This affects the natural carbon cycle, resulting in the threat of global warming and climate change.

Thus, the motivation for carbon dioxide capture and storage comes from developing ways to remove excess carbon dioxide from the atmosphere for climate control. The geoengineering approach to climate change mitigation consists of 'removing' carbon dioxide from the atmosphere as well as 'managing solar radiation' to control global warming. Mechanisms for reflecting part of the radiation back into space, thereby preventing it from entering the Earth's atmosphere, are being worked out for solar radiation management.

Sequestration of carbon dioxide by capture and storage or utilisation into value-added products and energy fuels remains one of the most researched options for removing excess carbon dioxide accumulated in the atmosphere. CO_2 absorption and utilisation have become a global research agenda. National governments invest heavily in Carbon Capture and Utilization (CCU), and there are significant ongoing research programs worldwide. The economics of CO_2 utilisation will be successful in the future depending on the purity and process used.

Carbon Dioxide Utilization (CDU), also understood as Carbon Capture and Utilization (CCU), refers to the reuse of carbon dioxide emitted from electricity or industrial plants into value-added products. This involves CO_2 captured from its point source and its utilisation through chemical and biological means as well as an underground injection for fuel synergies such as Enhanced Oil Recovery (EOR) and Enhanced Coal Seam Methane Recovery (ECBM).

Wawrzynczak et al. (2022) argued that the issue of climate change and activities aimed at reducing anthropogenic CO_2 emissions have contributed to the development of CCS and CCU technologies (Carbon Capture and Storage and Carbon Capture and Utilization). Interest in this technology resulted from the need to reduce the large amount of CO_2 waste streams that mainly come from power plants and other energy-intensive industries. The high potential of CCS/CCU technology in energy-intensive industrial branches results not only from the sizeable CO_2 emissions but also from the fact that many industrial processes produce exhaust gas with high CO2 concentrations, significantly reducing the cost of CCS/ CCU technology. The initial process, both in CCS and CCU technology, is the CO_2 capture process.

CO_2 capture technology is divided into pre- or post-combustion combustion systems and oxy-combustion. Pre-combustion is a process in which carbon dioxide is removed before the combustion process. This process is carried out in the case of coal gasification and gas and oil fuel reforming processes that convert carbon compounds into fuel, the main components of which are CO and H_2. These components are obtained as a result of the reaction of fuel with a lack of water or with water vapour. Carbon monoxide reacts with water vapour in the catalytic reactor, where CO_2 and hydrogen are formed. Carbon dioxide can be removed while maintaining hydrogen-rich fuel. Post-combustion is the process by which CO_2 is captured from the combustion gases. The course of the capture process does not affect the fuel combustion process. Oxy combustion is an oxygen-fuel combustion process that burns pure oxygen instead of air (or highly enriched air with prior nitrogen removal).

Compared to air combustion, a much smaller gas stream volume is obtained in oxy-combustion, mainly consisting of high concentrations of CO_2, water vapour, N_2 (a waste from the air separation process), and O_2 (derived from an excess of oxidants). The pre-combustion, post-combustion, and oxy-combustion systems aim to increase the concentration of CO_2 in the gas to be separated. The leading technologies of flue gas CO_2 separation include absorption, adsorption, membranes, and cryogenics (Figure 1.).

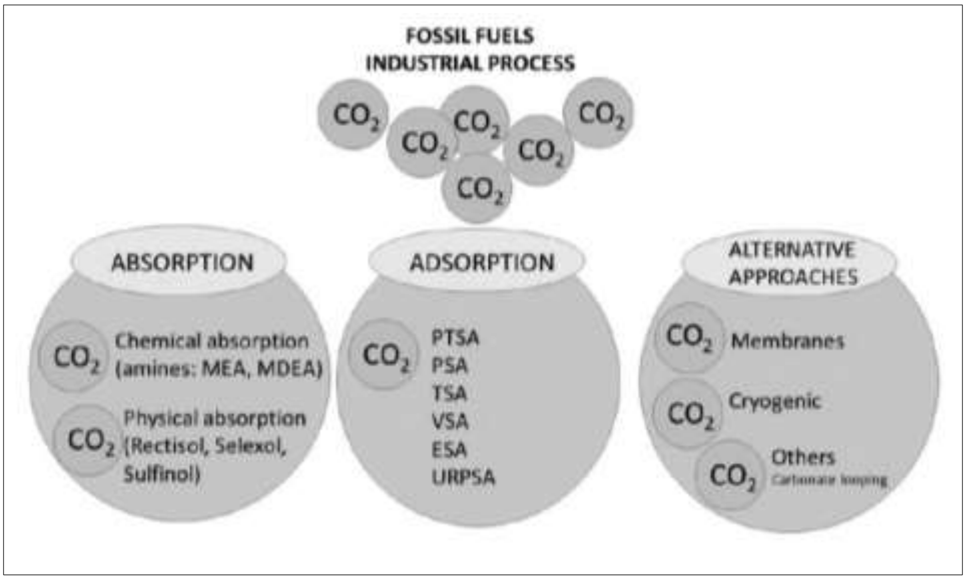

Figure 1. Schematic Diagram of CO_2 Capture Technologies
Sources: Wawrzynczak et al.,(2022)

The CO2 separation method is influenced by the concentration and pressure of CO2 in the combustion gas. So that the most suitable separation technology is chemical adsorption technology with amine solutions. The advantage of absorbing this chemical is that it reduces CO2 by 75-96% while carrying out industrial processes with high CO2 concentrations. With the intensive development of absorption techniques for CO_2 capture from combustion gases, which have been observed for many years, adsorption CO2 capture techniques relying on solid adsorbents are generating increasing interest.

Then, Wang et al. (2023) stated that Low-carbon pilot policies are an important way to achieve the goal of "peak carbon neutrality" and are very important for international commitments to promote urban innovation and the development of advanced urban industrial structures. Nielsen, Stavrianakis & Morrison (2022) also add that it is important to pay attention to considerations of community acceptance and social impacts of site-specific Carbon Capture Utilization and Storage (CCUS) projects to inform the design and implementation of CCUS projects that seek to engage with communities during this process, as well as similar climate mitigation and adaptation initiatives will thus encourage planned collaboration.

Oncel (2023) adds that the global challenge to sustainability without limiting development and progress is a key factor for the future of the Anthropocene. Even if sustainable development forever goes against the laws of nature where the struggle between energy, exergy and entropy rules the balance, humanity is still trying to find a moderate way to survive without sacrificing too many advantages in the modern era. Every day we hear pessimistic news about poverty, pandemics, energy crises, wars or pollution that can develop defensive behaviour. However, this will not be enough to sharply change reality unless channelled into a powerful consciousness that will compel policymakers as well as the public to lead change.

Thus, a Green Vision that is built on the main pillars of modern society, such as economy, energy, health, and urbanisation, is an important issue to achieve what ultimately becomes the target of sustainable development of human well-being while respecting the planet. This is an interrelated and layered challenge that highlights the social, economic, and environmental problems facing the world today to build a green society that must be fair, equitable, and inclusive, especially in creating a sustainable green industry for the future by utilising CO_2 as a new energy that supports the balance of life systems on Earth.

Method

This article used a qualitative descriptive method with a review paper technique focusing on the study of CO_2 use and green industry innovation. Rahmayanti et al. (2019) stated that six procedures were carried out; 1) understand the focus of the research to be studied. 2) redefining the research sub-focus in accordance with the research study. 3) choose the relevant articles according to the study. 4) combine all the findings of the article according to the study. 5) evaluate the findings of the article. 6) then synthesise and conclude the findings in the form of information and theory based on the study to obtain new contributions in solving the research problem.

Result and Discussion

From the several articles obtained, the search for relevant articles began from 2015-2021, and the results can be found in Table 1. as follows;

Table 1. Relevant Research

Author	Year	Result
Wei	2015	The promotion of green innovation is the key to the successful use of CO_2
Wang	2017	The application of efficient green technology supports the green transformation.
Dacosta	2018	Carbon sequestration is a business opportunity for the fossil industry
Hitce	2019	Application of sustainable chemistry to industry
Zou	2019	Integration of environmental analysis framework in CO_2 waste management
Gulzar	2020	Utilization of CO_2 through biomass products from algae cultivation
Chen and Lee	2020	The high use of green technology in determining the difference in emission levels between developed and developing countries
Zhang and Vigne	2020	Green productivity improvement based on pollution is carried out by companies in support of SDGs goals
Zeng	2021	Collaborative strategy for industry and service producers in the use of CO_2
Wang and Yu	2021	Management of environmental tax rates in support of green innovation

Sources: Researcher (2022)

In general, the findings in the table above show that the development of green industry innovation has become the forerunner in efforts to utilize carbon dioxide to become green innovation inventions for the future. As a result, this strategy is increasingly being promoted, so it is hoped that it will integrate into every line of industrial management processes that are integrated with a green environment.

The capture and utilization of carbon are also not limited, not only obtained from residual fossil energy sources but also other non-fossil energy sources so that it is more flexible in minimizing the carbon emissions produced because it can be obtained from all existing energy elements. For this reason, the active support of all components will be more positive and will be the key to success in reducing the existing environmental impact. This carbon dioxide capture technology must be able to be integrated with other scientific disciplines in order to increasingly create new discoveries for long-term solutions in supporting the realization of the SDGs.

Especially if it can be applied to every developing country, it will become a promising green economic potential. Indonesia, which is one of the most developing countries in the world, also plays a role in supporting efforts to utilize this carbon. This environmental commitment is evidenced by the issuance of Regulation of the Minister of Energy and Mineral Resources of Indonesia Number 2 of 2023 concerning procedures for carbon capture and storage, as well as carbon capture, utilization, and storage in upstream oil and gas business activities which was ratified on March 2, 2023. The scope of the This Minister of Energy and Mineral Resources regulation covers two focuses, namely the first implementation of CCS and the second implementation of CCUS along with the capture of carbon emissions.

Article 6 of this regulation also explains that carbon emissions are utilized not only by upstream oil and gas business activities but also by other industries. In other articles, namely articles 56 and 57, various types of administrative sanctions are also explained for industries that do not follow these regulations. The formulation of this regulation is proof that the Indonesian government has a lofty target in helping to deal with the problem of climate change in the world towards low emission and climate resilient development in 2050.

Efforts to reduce carbon emissions in Indonesia have actually been carried out so far since the publication of institutional rules that apply to the national greenhouse gas inventory in the regulation of the Minister of Environment and Forestry of Indonesia Number 73 of 2017 concerning guidelines for conducting and reporting greenhouse gas inventories. However, implementation in the field still faces various kinds of obstacles because the development of the greenhouse gas inventory is still concentrated on the provincial scale, so for small scales such as districts and cities, it is not implemented optimally.

Indonesia itself, even though it is known that transportation is one of the largest carbon contributors, the use of electric vehicles has still not been successful in becoming a solution for reducing emissions because not all people are interested in using electric vehicles. Then also increasing the activity of the business industry, especially fossils such as oil, natural gas, and coal, is also the cause of increasing carbon in Indonesia itself.

In line with the opinion of Suartika (2021), also added that business people also play a significant role in creating climate change and global warming. These findings are in accordance with an important meeting in 2021, namely the Global Climate Talks-COP 26, which will be held in the City of Glasgow, United Kingdom. This meeting highlighted the decline in the quality of the world's environment, which was attended by all aspects of society individually and in groups, be it state leaders, the public, environmentalists, industry players, and the mass media. For this reason, the existence of this meeting agenda makes it essential for us to immediately act directly in order to build environmental quality in a green manner and to be able to overcome various environmental problems that have occurred to date.

Takalo et al. (2021) said that environmental protection awareness had become a significant momentum for a number of organizations and communities in the world. Tight competition in the business world resulted in every industry must have an advantage that can compete with its competitors. For this reason, green innovation is the key to success in supporting the company's characteristics in creating a competitive advantage.

Three crucial components in the green industry innovation strategy that must be kept in mind are; 1) environmental impact, 2) resource management, and 3) the use of recycling. Compliance behaviour must be carried out directly by the industry indiscriminately with strict and binding environmental rules (Ishak et al., 2017).

Managerial action in encouraging green practices is a determinant in the management of green innovation, then coupled with government regulatory support is also a positive factor (Qi et al., 2010).

Mobley et al. (2017) also added information that carbon dioxide management processes could also be carried out as the conversion process of ethylene to ethylene oxide in the greenhouse gas life cycle, which has been shown that the utilization of CO_2 to the O_2 pathway is similar to the conversion of ethylene and the yield of ethylene oxide.

Bomtempo and Alves (2014) found that the active role of local government and the private sector in promoting green innovation can be a competitive advantage differentiating it from other regions. The government is not only a supervisor but also an important actor who plays a direct role. Efforts are made with evidence of strategic environmental policies that require every industry in the region to use green technology (Bakar & Basri, 2017).

Hakim, Endangsih, and Iskandaria (2022) who found that increasing CO_2 emissions to date have also added to the long list of problems with increasing energy operational costs; for this reason, the importance of sustainable development is an essential step in supporting better environmental quality because minimising energy use will be a significant value in environmental sustainability for the future.

Yanwu et al. (2020) said that industrial and campus collaboration is the dominant factor in achieving green innovation. Combining applicable research and campaigning for green industry transformation will further strengthen the country in achieving the 17 SDGs goals.

Anderton (2017) added that using ideas and brainstorming from the process of institutional communication, socio-political governance, and cross-disciplinary will create the development of green innovation. Exploring the complex role of multi-level and multi-actor governance by exploring the interactions between various stakeholders will create some of the results of tensions between multi-level policy mixes. This is an institutional challenge that must be fully faced and resolved, especially in campaigning for the reuse of CO_2 as a solution to reduce air pollution in preserving the environment.

The expertise of policymakers in carrying out exact calculations to calculate the potential price range achieved in carbon mitigation must be adequately studied so that the expected results become a positive contribution to the State (Oh et al., 2020). The results of the evaluation in low-carbon mitigation are useful for the process of improving city performance for a certain period. The critical role of the government as a co-facilitator who carries out the process of measuring the carbon index score (Chen et al., 2020). Then, political action in disseminating green innovation practices is also a determinant of the efficacy of low-carbon city development (Miranda et al., 2021).

Liu et al. (2017) found the obligation to tackle carbon emission mitigation efforts crucial in the new city governance planning stage. The management of low-carbon governance that occurs in developed and developing countries has a huge difference. The urbanization process that is increasingly booming continues to put pressure on the environment, which impacts increasing carbon emissions every year. Carbon emission mitigation measures must be a top priority for sustainable urban development.

For example, the urbanization that has occurred, especially in Indonesia, has caused excessive industrial activities in rural locations to cause environmental damage and cultural changes in local communities (Usop & Iskandar, 2020).

For this reason, the role of the government and other related institutions in managing the urbanization process must be thorough, and the law of cause and effect that occurs must be taken into account. The point is how to continue to use industrial energy without negative effects on the environment, economy, and social. Thus, a green industry innovation development strategy is needed, which can be the best key solution in utilizing wasted energy sources so that they do not become a danger to all of these aspects. This is in line with the 9th SDG's goal, which is to create a solid infrastructure in the process of sustainable industrialization and green innovation. The use of carbon dioxide as a green innovation is a determinant of the success of sustainable development which is focused on developed countries and developing countries so that it becomes an opportunity for progress for environmental management for a better future for the earth.

Conclusion

The use of carbon dioxide as green energy must be campaigned by the general public so that this becomes a green culture that primarily focuses on being a solution to reducing carbon buildup from all of these industrial processes. Minimizing this carbon potential will be a solution that is in line with the goals of the 9th SDGs so that the role of active collaboration from local governments, practitioners, academics, and the private sector, which is increasingly in positive synergy will form a life cycle that is interrelated and dependent on one another. We cannot just blame one party; here, the importance of cooperation between each party in supporting opportunities for carbon utilization is the ultimate goal. The use of carbon capture technology, which can then be stored, can also be reused, which has proven to be a new, more efficient energy source. This process itself has been implemented in several developed countries. However, it has not been appropriately implemented in developing countries due to the lack of environmental knowledge based on renewable technology and funding allocations. For this reason, the development of carbon utilization technology should not be underestimated because it will be the primary key to reducing the adverse effects of increasing carbon. After all, with the development of increasingly sophisticated science and collaboration with other disciplines, it will be the best solution for now and in the future.

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