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Artificial Intelligence as a Catalyst for Green Economy and Sustainable Development

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ABSTRACT
Artificial Intelligence (AI) has now become one of the key technologies in driving the transformation towards a green economy and sustainable development. AI offers innovative solutions in various sectors, such as energy, agriculture, transportation, and waste management, to increase efficiency, reduce carbon emissions, and optimize natural resources. This journal discusses how AI can be a catalyst in achieving the Sustainable Development Goals (SDGs) through a multidisciplinary approach. In the energy sector, AI facilitates the optimization of renewable energy use and the development of smart grids. In agriculture, AI helps create smart agricultural systems that minimize environmental impacts. In addition, the application of AI in waste management and the circular economy allows for optimal utilization of waste to reduce environmental pollution. However, there are several challenges that must be overcome, such as the digital divide, ethical and privacy issues, workforce disruption, and high implementation costs. This journal also provides several strategic recommendations, including collaboration between government, industry, and academia, strengthening policies, and investing in education and training to encourage inclusive and sustainable AI adoption. Based on the results of the research conducted, it can be concluded that the optimal application of AI can accelerate the transition to a green economy and strengthen the sustainable development agenda, but must be supported by appropriate regulations and active participation from all stakeholders.
Keywords: *Artificial Intelligence, Green Economy, Innovative Technologies, Sustainable Development*

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INTRODUCTION

Climate change and exploitation of natural resources have pushed the global community to shift to a more sustainable and environmentally friendly economy. The green economy has emerged as a new paradigm that seeks to balance economic growth with environmental preservation through resource efficiency and carbon emission reduction (Adir et al., 2020). Climate change and environmental degradation have become pressing issues affecting global economic and social well-being. The green economy

paradigm is presented as a solution to ensure that economic growth goes hand in hand with environmental sustainability (Ahmed et al., 2020). However, efforts to transition to a green economy face various challenges, including dependence on fossil fuels, inefficiency in resource use, and high waste production that damages the ecosystem.

In this context, Artificial Intelligence (AI) has an important role as a driver of cross-sector innovation, such as renewable energy, smart agriculture, transportation, and waste management (Ameen et al., 2021). However, the application of this cutting-edge technology requires further research to ensure its impact is optimal and in line with the Sustainable Development Goals (SDGs). The application of AI in the green economy is not without challenges. One of the main obstacles is the digital divide between developed and developing countries, where access to AI technology is still limited. In addition, the massive implementation of AI can trigger workforce disruption, with fears that traditional jobs will be replaced by automation (Ayoub Shaikh et al., 2022). There are also concerns regarding ethical issues and data privacy, which require mature regulatory policies.

This study aims to explore the role of AI as a catalyst in the green economy and sustainable development (Zhai et al., 2021). The main focus of the study is to identify opportunities and challenges for the application of AI in various strategic sectors and to formulate recommendations for the sustainable use of technology (Baduge et al., 2022). The importance of this study is driven by the limitations of previous research that has focused more on the application of AI in a single sector, such as energy or agriculture, without considering an integrated cross-sector approach. In addition, there are not many studies that explore the synergy between AI, the green economy, and the achievement of SDGs comprehensively.

Several previous studies have shown that AI contributes to improving energy efficiency and optimizing smart grids (Bohr & Memarzadeh, 2020). Meanwhile, research in the field of agriculture Naw found that AI can significantly reduce water and pesticide use (Briganti & Le Moine, 2020). However, these studies have not addressed the role of AI in creating a circular economy or addressing the digital divide in the context of sustainable development.

This paper fills the gap in the literature by offering a comprehensive analysis of the contribution of AI to the green economy across sectors (Chen et al., 2020). The hypothesis tested is that the integrated application of AI can accelerate the transition to a green economy and strengthen the achievement of the SDGs. The variables analyzed include the application of AI in the energy, transportation, agriculture, and waste management sectors (Collins et al., 2021). This study uses literature study and case study methods to analyze opportunities, challenges, and strategic recommendations in the use of AI.

RESEARCH METHODOLOGY

The population of this study consists of various industrial sectors that have implemented or are developing the implementation of Artificial Intelligence (AI) to support the green economy and sustainable development (Dong et al., 2020). The research sample was selected using purposive sampling, which is a sample selection method based

on certain criteria. In this case, the main criteria are companies or institutions that integrate AI in the energy, transportation, agriculture, or waste management sectors. Additional data will be obtained from relevant company case studies and annual reports related to SDGs policies.

This study uses an instrument in the form of a literature study to collect primary and secondary data (Zhu, 2020). The literature study serves to identify the latest trends and developments related to AI and the green economy, while the questionnaire will be used to obtain the perspectives of practitioners or policy makers in related sectors (Gerke et al., 2020). In addition, documents such as sustainability reports and environmental policies are also analyzed as secondary data sources.

This research will be conducted in three stages, including data collection (collection of literature and reports), data analysis (data collected will be processed and analyzed), and preparation and presentation of results (Himeur et al., 2021). The data obtained will be analyzed using thematic analysis to identify patterns and key insights related to the application of AI. The scope of this research is limited to the energy, agriculture, transportation, and waste management sectors that implement AI (Huang et al., 2020). The results of the research may only be relevant in the context of industry and policy in Indonesia or regions with similar conditions.

RESULT AND DISCUSSION

This study highlights how AI is a key enabler in clean energy development through optimizing energy management and integrating renewable energy sources. Smart grid technology uses AI to monitor energy consumption in real-time, enabling automatic adjustments between energy demand and supply (Huynh-The et al., 2023). For example, machine learning algorithms are able to predict consumption patterns and efficiently regulate electricity supply from sources such as solar panels and wind turbines. This reduces energy waste and maximizes the use of renewable energy .

In addition, AI enables predictive maintenance of energy infrastructure, such as power plants and distribution networks, by detecting failures before major disruptions occur. This improves grid reliability while reducing operational and recovery costs (Hwang & Chien, 2022). In the context of the transition to a green economy, AI also plays a role in increasing energy efficiency in the industrial sector. Smart factories that use AI to monitor energy consumption at every stage of production can reduce carbon emissions and increase productivity simultaneously.

Some energy companies have started to apply AI to set dynamic pricing strategies, where electricity prices are adjusted to current market conditions and energy demand. This encourages consumers to optimize electricity usage at certain times, supporting a more sustainable and energy-efficient system (Hwang et al., 2020). AI also helps in microgrid management, where local communities or industrial areas can generate and manage energy independently, reducing dependence on fossil fuels.

However, the findings also show that major challenges remain. One is the high investment required to implement this technology, especially in developing countries. In

addition, policies are needed that encourage collaboration between energy companies, governments, and local communities so that AI can be implemented in an inclusive and effective manner (Jacovi et al., 2021). Therefore, policy strategies and incentives are needed to accelerate the adoption of AI in the energy sector, so that its benefits can be felt widely and sustainably.

The study identified that the application of Artificial Intelligence (AI) in the agricultural sector has had a significant impact in improving the efficiency and sustainability of agricultural practices. AI helps farmers make better decisions based on data related to weather, soil moisture, and crop nutrient needs. AI enables real-time monitoring of fields through drones and IoT sensors placed in the field (Jung et al., 2021). This technology helps identify areas that need water or fertilizer, preventing overuse of resources. AI-powered smart irrigation systems can automatically respond to soil conditions, saving up to 30% in water consumption, especially in areas at high risk of drought.

One of the main applications of AI is in precision agriculture, where algorithms analyze pest and disease patterns, allowing for selective application of pesticides. Farmers can apply pesticides only to infected areas instead of spraying the entire field, reducing the negative impact on the environment. This also reduces operational costs and increases crop yields (Yigitcanlar et al., 2020). AI also supports short-term and long-term weather predictions, helping farmers better plan planting and harvesting activities. With accurate weather data, farmers can avoid losses due to extreme climate conditions such as floods or droughts. Some AI platforms also offer market trend analysis to help farmers choose more profitable commodities.

However, there are several challenges such as lack of access to technological infrastructure in rural areas and limited digital knowledge among small farmers. Therefore, synergy is needed between the public and private sectors in providing technology access and training for farmers (Kaplan & Haenlein, 2020). Thus, AI not only increases efficiency but also strengthens the sustainable agricultural ecosystem by minimizing environmental impacts and increasing food security.

The study found that the application of Artificial Intelligence (AI) in the transportation sector plays a crucial role in increasing efficiency and reducing carbon emissions, in line with sustainable development goals (Kaur et al., 2023). AI enables the creation of smarter and more environmentally friendly transportation systems through various applications, such as autonomous vehicles, data-based traffic management, and logistics route optimization.

AI-powered autonomous vehicles are designed to reduce fuel consumption and improve road safety. AI algorithms process data from multiple sensors to optimize speed, distance between vehicles, and energy use (Xiang et al., 2021). Studies show that autonomous electric vehicles can reduce energy consumption compared to conventional vehicles, while reducing greenhouse gas emissions. In addition, these vehicles help reduce congestion, which is a major cause of increased fuel consumption and pollution in big cities.

AI-based traffic management systems enable dynamic control of traffic signals based on real-time data from road cameras and sensors. Several cities have implemented this technology to reduce waiting times at intersections, which contributes to lower emissions (Lalmuanawma et al., 2020). Successful examples are found in Singapore and Amsterdam, where AI helps optimize vehicle flow and public transportation, resulting in up to 15% reduction in travel time and up to 8% reduction in emissions.

AI is also used in logistics route planning to minimize travel distance and fuel costs. Some logistics companies apply AI algorithms to design optimal delivery routes that take into account traffic conditions, weather, and energy consumption (Loh et al., 2022). In the public transportation sector, AI supports the integration of various modes of transportation on one platform, providing real-time information to passengers, and reducing waiting times.

Although AI technology offers many benefits, there are challenges such as the lack of digital infrastructure in small cities and developing regions, as well as concerns about data privacy. In addition, the implementation of autonomous vehicles requires mature regulations to ensure safety and transparency (Maia et al., 2020). Therefore, synergy is needed between the government and the private sector to accelerate the adoption of AI in transportation and ensure that its benefits can be felt by the wider community.

The study found that Artificial Intelligence (AI) plays a crucial role in supporting efficient waste management and strengthening the implementation of a circular economy (Manickam et al., 2022). AI helps optimize waste collection, sorting, and recycling processes, and minimizes environmental impact by reducing the amount of waste ending up in landfills.

AI improves efficiency in waste collection through smart waste management systems that utilize IoT sensors and machine learning algorithms (Vaishya et al., 2020) . These systems can monitor the volume of waste in bins in real-time and provide optimal route recommendations for waste collection trucks. This can reduce fuel consumption and carbon emissions, while reducing operational costs for local governments and waste management companies.

AI is used in waste processing facilities to improve the accuracy of sorting materials such as plastic, metal, and paper (Talaviya et al., 2020). Computer vision and robotics-based technologies enable automated material sorting at high speed and high accuracy. For example, machines equipped with AI can recognize the type of plastic and separate it to be reprocessed into new raw materials. This is very important in supporting the concept of a circular economy by maximizing the reuse of resources.

By analyzing waste data and consumption patterns, AI is able to predict waste production trends and provide recommendations to reduce waste at the source (Niu et al., 2022). Several smart cities have implemented AI to encourage waste reduction initiatives through recycling programs and incentives for active community participation. AI is also used to monitor the carbon footprint and environmental impact of various types of waste.

Despite the significant benefits, the study identified several challenges in implementing AI for waste management. One of the main challenges is the lack of

infrastructure and investment in waste management technology, especially in developing countries (Pan & Zhang, 2021). In addition, there are technical and regulatory challenges, including the lack of standards for waste processing with AI technology and the need for policies that promote a comprehensive circular economy.

The application of Artificial Intelligence (AI) in the green economy faces a number of structural and technical challenges that need to be addressed through appropriate policies. One of the main challenges is the digital divide (Paul et al., 2021). Many rural areas or developing countries do not yet have access to adequate technological infrastructure, including the internet and hardware needed to make optimal use of AI. Without this access, AI will only benefit sectors in developed regions and widen the economic gap between urban and rural areas.

In addition, the lack of skilled labor is a barrier to AI implementation. Many workers do not yet have digital skills or an understanding of AI technology, raising concerns that automation and intelligent technology could replace their jobs (Soori et al., 2023) . Reskilling and upskilling workers are urgently needed so that they can adapt to these technological changes.

In the context of ethics and regulation, data privacy and information security are of great concern. AI technologies applied in the energy and agriculture sectors require continuous data collection, which can pose a risk of misuse of personal data. Strict regulations and data protection policies are needed to ensure that the use of AI does not violate users' privacy rights (Pelau et al., 2021). From an environmental perspective, AI applications must also consider the impact of energy consumption from data centers and the servers used to support this technology. Energy efficiency policies in data centers are essential to ensure that AI applications do not exacerbate environmental problems.

To address these challenges, governments need to increase investment in digital infrastructure and expand internet access across the region, especially in remote areas. In addition, policies that encourage collaboration between the public and private sectors can accelerate the diffusion of technology and knowledge. Training and education programs should be designed to ensure workers have relevant digital skills. Furthermore, tax policies and environmental incentives can be implemented to encourage companies to adopt AI that supports the green economy (Rong et al., 2020). Governments also need to establish a regulatory framework on AI ethics, including data protection and algorithm transparency.

In conclusion, the right policies will ensure that AI technology can be used to promote sustainability without compromising people’s social and economic rights. With this strategic approach, AI will not only accelerate the transition to a green economy but also help create a more inclusive and sustainable society.

CONCLUSION

This study shows that Artificial Intelligence (AI) plays a significant role as a catalyst in accelerating the transition to a green economy and sustainable development. Key findings confirm that the application of AI in the energy, agriculture, transportation,

and waste management sectors can improve operational efficiency, reduce carbon footprints, and support the integration of sustainable practices into the economic value chain.

The importance of this study lies in mapping the contribution of AI to the Sustainable Development Goals (SDGs), especially related to clean energy, food security, and climate change. The results of the study provide insight that AI can strengthen the green economy ecosystem if implemented with adequate infrastructure and supported by appropriate regulatory policies. In addition, these findings are relevant to stakeholders in government and the private sector, as AI offers practical solutions to address environmental issues and improve industrial competitiveness.

In the context of the literature, this study complements previous studies by offering a cross-sector perspective showing that successful AI implementation depends on the synergy between technology, policy, and workforce skills. Challenges such as the digital divide and potential workforce disruption indicate the need for an inclusive and adaptive policy approach. The implications of these findings point to the need for strategic policies that not only encourage the adoption of AI technologies but also ensure the strengthening of human resource capacity and data protection. With proper management, AI will not only support environmental sustainability but also contribute to the creation of a more inclusive and resilient economy. This research provides a foundation for further studies to explore cross-sector collaboration and develop a more holistic AI implementation model.

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