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Enhancing Environmental Sustainability of Airports in Indonesia through Green Technology: Strategies for Pollution Reduction and Climate Change Adaptation

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Abstract - **Climate change and pollution generated by the transportation sector, particularly airports, present major challenges in achieving environmental sustainability. This article discusses the application of green technology at Indonesian airports as a strategy to reduce pollution and adapt to climate change. The main focus of this study is to identify various environmentally friendly technologies that can be implemented at airports, such as the use of renewable energy, efficient waste management, and energy-efficient building design. Additionally, this article explores the policies and challenges faced in the implementation of green technology at Indonesian airports. The findings show that implementing green technology can significantly reduce airport carbon footprints, improve operational efficiency, and reduce negative environmental impacts. Therefore, the development and application of green technology at Indonesian airports is a crucial step in supporting climate change mitigation and achieving environmental sustainability in the air transportation sector.**

Keywords *– Environmental Sustainability, Indonesian Airports, Green Technology, Pollution Reduction, Climate Change Adaptation, Renewable Energy, Waste Management, Energy Efficiency.*

INTRODUCTION

Global climate change has become a major issue affecting various sectors, including air transportation. Airports, as vital elements in the air transportation system, contribute significantly to environmental pollution [1]. The continued growth in the number of passengers has led to an increase in the environmental impacts caused by airport activities [2]. The main issues that urgently need to be addressed are high carbon emissions [3], air pollution [4], and inefficient energy use, which potentially threaten environmental sustainability around airports [5].

A relevant solution to mitigate these adverse impacts is the adoption of green technology in airports. Green technology encompasses a range of innovations aimed at reducing dependence on fossil fuels, improving waste management efficiency, and maximizing the sustainable use of natural resources [6]. Innovations such as the utilization of renewable energy (solar and wind power), efficient water and waste management, and energy-efficient building designs [7] can reduce airport carbon footprints [8], enhance operational efficiency [9], and lessen generated pollution [10].

This article aims to examine the application of green technology in airport infrastructure in Indonesia and its role in reducing pollution and adapting to climate change. This study will identify the most effective green technologies to be implemented at Indonesian airports, the challenges faced in their implementation, and policies that can support broader adoption of these technologies. Thus, this article is expected to provide a positive

contribution to improving environmental sustainability in Indonesia's air transportation sector and help airports adapt to global climate change.

DISCUSSION

Review of Concepts/Mitigation Methods

1. Specific Problems Related to Climate

Change at Indonesian Airports

Climate change poses a major global challenge, and the air transportation sector particularly airports contributes significantly to greenhouse gas emissions [11]. Airports are activity centers that involve extremely high energy consumption, with emissions from aircraft and vehicles operating within them exceeding 70%, according to the International Civil Aviation Organization (ICAO) between 2013 and 2019 [12]. In Indonesia, the increasing number of passengers and the widespread distribution of airports have amplified the environmental impact. Rising carbon emissions, air pollution, and poor waste management are key issues that must be addressed to support climate change mitigation efforts in the air transportation sector [13].

Moreover, climate change increases vulnerability to natural disasters, such as flooding and sea level rise [14], which can affect airport infrastructure. Therefore, mitigation measures must not only reduce pollution but also enhance the resilience of airport infrastructure to the impacts of climate change [15].

2. Mitigation/Management through Green Technology

To address these challenges, the implementation of green technology at Indonesian airports is essential. Green technology refers to innovations that reduce negative environmental impacts and promote sustainability [16]. Several green technologies that can be applied at airports to mitigate climate change and reduce pollution include:

Renewable Energy: Solar Power Systems
Using solar and wind energy to meet most of an airport's electricity needs [16] can reduce reliance on fossil fuels, which are major contributors to carbon emissions [17]. This is supported by a study at Doncaster Sheffield Airport in the UK, where a 12 MWp solar power plant reduced CO_2 emissions by 10,562,270 kg annually [18]. Such implementation is highly feasible in Indonesian airports, considering the country's abundant sunlight.

According to Climate Change Control Regulation No. P5/PPI/SET/KUM I/12/2017 on "Guidelines for Calculating Greenhouse Gas Emissions for Climate Change Mitigation Measures," solar power plants (PLTS) utilize solar energy and do not produce greenhouse gas (GHG) emissions [19]. Implementing such systems effectively supports the development of eco-airports as a form of sustainable energy application in the Society 5.0 era [20].

Green Building Design and Energy Efficiency
Energy-efficient building designs using environmentally friendly materials and green building technologies can reduce energy consumption at airports. This includes energy-saving lighting technologies and natural ventilation systems to minimize heating and cooling demands [20]. Lighting optimization in airport terminals is influenced by roof designs using skylight types and passive ventilation such as clerestories. Skylight roofs are designed by considering sunrise and sunset directions and made transparent with glass materials to maximize natural sunlight from morning until evening [21].

Environmentally Friendly Transportation at Airports
Using electric vehicles for passenger and operational transport within the airport will reduce exhaust emissions and air pollution. Developing electric vehicle charging infrastructure also supports the use of environmentally friendly transportation. Electric vehicles have the potential to make airport transport more efficient and eco-friendly [22].

A U.S. study found that autonomous electric vehicles can reduce greenhouse gas emissions by up to 34% of total transport emissions by 2050. The study revealed that reducing transportation-related impacts requires paradigm shifts in field practices across all sectors [23], including aviation.

3. Opinions on Mitigation Studies at Indonesian Airports

To achieve environmental sustainability at airports, it is essential to involve various stakeholders in the development and implementation of green technologies. The government must play a central role by providing fiscal incentives or subsidies for the adoption of green technology at airports, as well as formulating policies that encourage the adoption of environmentally friendly technologies [24]. Additionally, airport operators need to collaborate with the private sector and the public to ensure effective implementation.

Green technology not only reduces the carbon footprint but can also serve as a differentiating factor for airports to attract investment and enhance their environmentally friendly image. Thus, sustainability strategies can provide long-term economic benefits while supporting climate change mitigation efforts [25].

4. Challenges in Developing Green Technology at Indonesian Airports

Although the potential for implementing green technology is significant, several challenges can hinder its development at Indonesian airports:

High Implementation Costs
One of the main challenges is the high initial cost required to adopt green technologies [26], such as installing solar panels, building waste management systems, and replacing fossil-fuel vehicles with electric vehicles. Despite the long-term benefits, the high upfront cost can be a barrier for airport operators, especially those with limited budgets.

Limited Infrastructure
Many airports in Indonesia still lack the infrastructure needed to support green technologies, such as electricity grids capable of integrating renewable energy or charging stations for electric vehicles [27]. This requires significant investment in upgrading existing airport infrastructure.

Lack of Supportive Policies
Government policies regarding green technology in Indonesian airports are still limited. There is a need for stronger policies that provide incentives to airport operators for implementing environmentally friendly technologies and accelerating the transition toward renewable energy [28].

Limited Technical Knowledge and Capacity
The lack of knowledge about green technology and limited technical capacity [29] among airport operators and contractors can also hinder effective implementation. Adequate training and education in this field are crucial to ensure successful adoption [30].

CONCLUSION

Global climate change presents significant challenges for the air transportation sector, especially airports, which contribute greatly to pollution and greenhouse gas emissions. The use of green technology in Indonesian airports—such as renewable energy, energy-efficient building designs, and environmentally friendly vehicles—can help reduce environmental impacts and support climate change mitigation.

However, several obstacles hinder the implementation of green technology, including high implementation costs, limited infrastructure, lack of supportive policies, and limited technical knowledge. Therefore, cooperation between the government, airport operators, and the private sector is crucial to overcome these challenges and achieve environmental sustainability at airports.

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