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Towards an Environmentally Friendly Palm Oil Industry: A Critical Review of Waste Reduction Policies by Indonesian Government

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ABSTRACT

Although the Indonesian palm oil sector is essential to the country's economic growth, it also presents serious environmental problems, notably with regard to waste management and ecological deterioration. This paper examines the Indonesian government's waste reduction policy framework for the palm oil industry critically, with an emphasis on solid waste management and Palm Oil Mill Effluent (POME) management. This study looks at the primary legal tools, implementation strategies, and efficacy in advancing ecologically friendly activities using a doctrinal and qualitative policy analytic method. The results show a growing regulatory environment characterised by programs like the Ministerial Regulations on Waste Utilisation and the Indonesian Sustainable Palm Oil (ISPO). But the study also points out systemic flaws, such as fragmented policies, a lack of enforcement power, and gaps in technological access, especially for smallholders. A more integrated and cross-sectoral policy strategy that prioritises innovation dissemination, legislative harmonisation, and inclusive support systems is suggested in the paper's conclusion. Such a framework is necessary to guarantee a fair green transition for the business and to match national palm oil governance with international sustainability requirements.

1. INTRODUCTION

The palm oil sector in Indonesia plays an important role in the Indonesian economy and society, but also faces significant challenges related to the impact of waste management on the environment and public health. It is undeniable that the industry contributes to exports, job creation and GDP. Today, with more than 14 million hectares of plantations, mostly in Sumatra and Kalimantan, Indonesia is the world's largest producer and exporter of palm oil. From smallholder farmers to workers in the processing industry, this sector of enormous economic potential has fuelled the country's economy and employed millions of people [1-3].

Nonetheless, there is increasing concern about the difficulties this industry faces in relation to the waste generated during the production process. Palm Oil Mill Effluent (POME), which is a by-product of palm oil production, is the most visible waste. POME contains a lot of organic waste and, if not handled properly, can contaminate water. Water pollution directly affects the quality of aquatic ecosystems by reducing dissolved oxygen and causing eutrophication, which endangers aquatic life in surrounding lakes and rivers [4, 5].

Communities living near oil palm industrial estates often suffer negative health impacts from pollution, including respiratory diseases caused by air pollution and other health problems associated with contaminated soil and water [6, 7]. Livelihoods of communities dependent on local agriculture and fisheries may be compromised by a sharp decline in quality of life. Greater dependence on the palm oil sector may worsen the economic situation of communities by increasing their vulnerability to changes in government policies and price changes [8].

To address this issue, the Indonesian government has implemented regulations such as the Indonesian Sustainable Palm Oil (ISPO) certification and the Minister of Environment and Forestry Regulation (Permen LHK), which are intended to encourage sustainable practices in the palm oil industry [9, 10]. Despite the fact that these regulations have shown beneficial effects in reducing environmental impacts, there are still significant implementation and enforcement issues [2, 11]. Reportedly, only around 20 per cent of the palm oil sector in Indonesia is ISPO certified, and full industry adoption is not expected until 2023 [1].

Investments in infrastructure and green technologies are needed to improve waste management, as is collaboration between communities, businesses and government [12]. One initiative that can reduce environmental impact while boosting the local economy is the use of POME to make biogas or organic fertiliser, among other waste management innovations [13].

To ensure sustainable practices in the sector, the Indonesian government has implemented policies related to waste management, including regulations governing waste quality

standards and the use of sustainability certifications such as RSPO (Roundtable on Sustainable Palm Oil) [14, 15]. However, poor law enforcement, gaps in processing technology, and farmer ignorance often make it difficult to implement such policies [16]. Therefore, to improve sustainability, further studies are needed to assess the effectiveness of current policies and seek new approaches to palm oil waste management.

This study intends to thoroughly assess the government's palm oil waste reduction programme, with an emphasis on policy effectiveness and socio-economic impacts. In addition to reinforcing sustainable practices that benefit the sector, communities, and the environment as a whole, the evaluation will also show how current policies can be better implemented.

Overall, the issues facing Indonesia's palm oil sector require careful consideration. Opportunities to strengthen local economies and preserve the environment can arise from more sustainable and efficient handling of palm oil waste. Stakeholder collaboration and innovation can help the sector transition towards sustainability, benefiting not only the plantation industry, but also communities and the environment.

Several important ideas have been developed as an analytical framework to evaluate how well the Indonesian government's strategy in reducing palm oil waste and its impact on environmental and socio-economic sustainability. Waste management approach, public policy theory, and sustainability theory are the three main theories used in this study.

The central tenet of this research is the theory of sustainability. This idea centres on efforts to achieve a balance between social welfare, environmental preservation, and economic progress. In the palm oil sector, sustainability refers to the effective management of waste and natural resources with the aim to reduce adverse environmental impacts, improve social welfare, and create long-term employment [17]. This is especially important when considering Indonesia's palm oil sector, where effective waste management can reduce pollution and improve community welfare [18]. If successful, this strategy can reduce the industry's environmental impact while generating financial returns [19].

Particularly in the case of palm oil waste control, public policy theory offers a framework for understanding policy making, implementation, and assessment. The rational choice model and the policy cycle are two of the most relevant models [20]. When assessing the cost-effectiveness and benefits of palm oil effluent policies [21], the rational choice model argues that decision-makers base their choices on logical factors to maximise benefits [2]. Meanwhile, the policy cycle highlights the importance of phases in policy making and implementation, such as problem identification, development, implementation, and policy review and adaptation [22]. Therefore, a robust feedback cycle is needed in palm oil waste management in Indonesia to evaluate and update policies based on the findings of environmental and community impact evaluations [23].

With an emphasis on liquid wastes such as POME, palm oil waste management options include a range of managerial and technical tactics intended to reduce the environmental impact of industrial effluents. Among the most important strategies are: a) Technology-based management: utilising cutting-edge technologies, including bioreactors, to convert POME into biogas. In addition to reducing greenhouse gas emissions, this technology can convert wastewater into renewable energy [24]; b) Community-based Management: this method empowers local communities to sustainably manage palm oil waste and effluent [25]; c) 3R Principle (reduce, reuse, recycle): the application of this principle in the palm oil industry is anticipated to reduce the amount of waste and reuse it for financial gain.

By reducing pollution and using resources responsibly, green industry methods seek to create goods and services effectively and sustainably [26]. Using clean technologies, reducing the use of hazardous chemicals, and implementing strict sustainability requirements are all part of applying green industry principles to palm oil [27]. Among these are programmes such as Green Supply Chain Management (GSCM), which aims to manage the entire supply chain with environmental impacts in mind [28].

Government policies and research related to palm oil waste management in Indonesia show that although various policy efforts have been made, implementation is still lacking. Many businesses ignore existing regulations, resulting in a continued negative influence on the environment [29]. However, research conducted in Malaysia shows that stricter regulations and substantial rewards for businesses can improve waste management [30]. In addition, a framework to guarantee clean production that meets sustainability criteria is provided by sustainability certification programmes such as the RSPO [31].

Policies to reduce greenhouse gas emissions are also a key objective, with an emphasis on adopting technologies that can reduce emissions from POME. However, due to high costs, implementation has been limited [32]. This is a major obstacle for the government to effectively monitor and enforce the law and assist small businesses in implementing more sustainable practices [12].

2. RESEARCH METHOD

In order to gain a deeper and more comprehensive understanding of the phenomenon under study, this research uses qualitative techniques. By using qualitative methods, researchers can present a more complete picture of the impact, challenges, and successes of the policy. Through the application of a qualitative approach, a deeper and more nuanced understanding of the direct experiences of stakeholders—including the government, palm oil companies, and surrounding communities—regarding palm oil waste management policies was obtained. The qualitative approach used focus group discussions (FGDs) and in-depth interviews as data collection methods.

The research design used is a case study with policy analysis techniques. Specifically, provinces in Sumatra such as Riau, Jambi and South Sumatra and Kalimantan such as East Kalimantan and West Kalimantan, which are known as palm oil production centres in Indonesia, are the focus of this study due to the high concentration of the palm oil industry in these regions.

The researcher will analyse the palm oil waste management regulations implemented in these regions and evaluate their impact on social, economic, and environmental sustainability in this case study. In addition to identifying specific obstacles and difficulties encountered during policy implementation, the case study design allows researchers to analyse policies in depth within the local context. Furthermore, this strategy will

provide a more comprehensive picture of how various stakeholders—such as the government, palm oil companies, and communities—accept and implement these policies.

There are two main sources of data that will be used in this study: primary data will be collected using various direct data collection methods in the field. The following are the primary data sources used in this study: In-depth interviews will be conducted with government representatives involved in the formulation and implementation of policies related to palm oil waste management, including representatives from the Ministry of Environment and Forestry (MoEF), as well as other relevant authorities. Interviews will also be conducted with palm oil entrepreneurs, including small-scale palm oil producers and those working in large industries. The purpose of these interviews is to understand how they view palm oil waste management policies and the difficulties they face in implementing them.

FGDs: FGDs will be conducted with various community groups, including palm oil farmers, palm oil industry workers, and non-governmental organisations (NGOs) that support social and environmental rights. FGDs will be used to explore opinions on palm oil waste management policies and to gain a more comprehensive understanding of how these policies affect communities.

Secondary data will be collected from existing sources, such as: a) Policy Documents: government regulations, the Indonesia Sustainable Palm Oil (ISPO) policy, and the RSPO certification are examples of policy documents related to palm oil waste management that will be analysed to understand the legal and policy framework governing waste management in Indonesia; b) Palm Oil Company Annual Reports: The Central Statistics Agency (BPS) and industry reports will be used to measure the socio-economic impact of the palm oil industry, including its contribution to GDP, job creation, and poverty levels in palm oil-producing areas.

To obtain rich and comprehensive data on palm oil waste management policies and their impacts, various methods will be used in data collection. Various stakeholders, including government representatives, palm oil business owners, and local communities around palm oil plantations, will be interviewed in depth. Open-ended questions in these semi-structured interviews will allow participants to freely share their opinions and experiences. The purpose of these interviews is to gain a deeper understanding of the policies, their implementation, the challenges faced, and their impacts on the environment and communities.

3. RESULTS AND DISCUSSION

Based on empirical data collected from surveys, in-depth interviews, and analysis of policy documents, the findings of the analysis Towards an Environmentally Friendly Palm Oil Industry: A Critical Review of the Indonesian Government's Waste Reduction Policy will be discussed in this section. The management of POME and the impact of the policy on the palm oil industry and communities in some of Indonesia's largest palm oil producing regions, including Sumatra and Kalimantan, are the main topics of this study (Figure 1).

Palm Oil Waste Reduction Policy Assessment, while the palm oil sector in Indonesia has been growing rapidly and contributing greatly to the country's economy, there are significant socio-economic and environmental impacts, particularly related to waste management. Poor handling of palm oil waste can jeopardise human health, the environment, and the standard of living of neighbouring communities. Studying government initiatives to reduce palm oil waste and its adverse impacts is important.

3.1 Effectiveness of pome waste reduction policy

One of the main wastes generated during the palm oil production process is Palm Oil Mill Effluent, or POME. The organic compounds found in POME have the potential to pollute soil and water if disposed of in an improper manner. Palm oil mills must manage POME properly and reduce greenhouse gas emissions, especially methane, in accordance with the Minister of Environment and Forestry Regulation No. 18/2014 on Palm Oil Industry Waste Management.

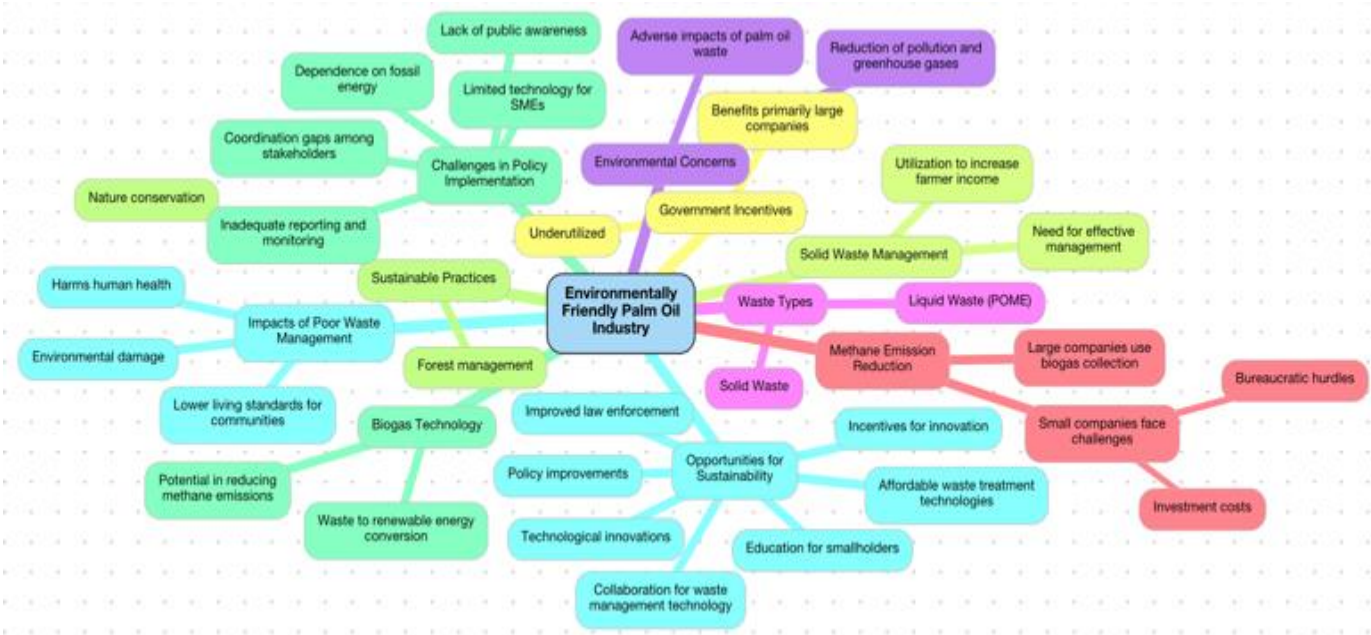

Figure 1. Concept map of research results

Based on a survey of 50 palm oil companies located in Sumatra and Kalimantan, 65% of large companies have reduced methane emissions by implementing more effective waste treatment technologies, such as biogas collection. The remaining 35%, mainly small companies, still use lagooning, which is cheaper but more harmful for air and water pollution. Given the high cost of treating POME with state-of-the-art technology, in-depth interviews with palm oil entrepreneurs show that one of the main obstacles in implementing environmentally friendly solutions is the investment cost aspect.

Meanwhile, the government has offered a number of incentive and subsidy programmes to encourage small and medium enterprises to implement environmentally friendly technologies. However, according to data from the Palm Oil Plantation Fund Management Agency (BPDPKS), only around 25 per cent of small businesses have taken advantage of the incentives, citing a rigid and complicated administrative process.

According to statistical studies, methane emissions are reduced by up to 40% for companies that have adopted greener POME treatment technologies compared to those that still use lagooning methods. In addition, businesses using biogas technology can convert methane into renewable energy, which reduces their dependence on fossil fuels and offers further financial benefits. However, despite progress, POME management is still mostly utilised by large companies and has not been evenly spread among industries.

3.2 The efficacy of solid waste management regulations

In addition to POME, palm oil businesses also produce significant amounts of solid waste, including palm kernel shells, palm kernel cake, and empty fruit bunches. These solid wastes can be used as building materials, animal feed, or as bioenergy feedstock. Through Presidential Regulation No. 61/2015, the government encourages the utilisation of these wastes as value-added resources in the palm oil industry.

The majority of smallholders still lack access to equipment to treat palm oil solid waste, according to a survey of 100 smallholders and in-depth interviews with palm oil entrepreneurs. About 70 per cent of farmers said that burning palm solid waste is the simplest way to dispose of it, despite the fact that this is highly polluting. While many large companies are already using TKKS and PKC for briquettes or compost, small businesses are still unable to utilise these technologies due to infrastructure and financial constraints, according to a study of palm oil company annual reports.

However, analysing BPS data on the economic contribution of the agricultural sector reveals that effective palm oil waste management can open up new business prospects for surrounding communities. Large companies that have converted solid waste management systems into value-added goods such as biogas and organic fertiliser, for example, have shown that they can increase the income of local farmers by giving them access to palm oil by-products at a reduced cost.

However, smallholders are still not fully covered by current policies. For example, although they handle palm oil waste on a regular basis, a survey conducted among 120 smallholders showed that 75 per cent of them had no instruction on how to handle it effectively. For smallholders to better utilise palm oil waste, solid waste management policies must be improved by providing facilities, incentives, and technical support.

Impact on the Environment, the objective of the palm oil waste management strategy in Indonesia is to reduce the negative impact on the environment, especially with regard to soil, water, and air pollution. If not effectively addressed, the environmental impacts of solid wastes such as empty fruit bunches (EFB), palm kernel cake (PKC), and palm kernel shells, as well as palm oil effluents, particularly Palm Oil Mill Effluent (POME), can damage natural ecosystems. Using empirical data collected from field observations, stakeholder interviews from palm oil businesses, and community surveys, this study investigates the impacts of palm oil waste management strategies.

3.3 Pollution and greenhouse gas (GHG) emission reduction

One of the most important by-products of the palm oil industry is palm oil liquid waste (POME), which can seriously pollute water if not handled properly. The organic matter contained in POME has the potential to cause eutrophication of water bodies and harm aquatic life. In addition, methane gas, which is detrimental to global warming, is released by this wastewater. The requirement for palm oil companies to treat POME using environmentally friendly technologies, including biogas capture, which can capture methane for conversion into renewable energy, is one of the key regulations set by the Indonesian government.

According to empirical findings from a survey of 50 palm oil mills in Kalimantan and Sumatra, more than 65% of large mills have methane gas collection systems. Using this biogas system, one mill in Riau was able to convert methane into electricity for internal use and reduce methane emissions by 35% annually. According to a report from BPDPKS (Badan Pengelola Dana Perkebunan Kelapa Sawit), if all large palm oil mills in Indonesia adopted the same method, methane emissions from POME processing could be reduced by about 1 million tonnes of CO_2 equivalent annually.

However, according to survey data, 35% of small and medium-sized palm oil mills in Indonesia still use more conventional POME treatment techniques, including lagooning, which pollutes water and increases methane emissions to the atmosphere. Based on interviews with palm oil entrepreneurs, one of the biggest barriers to the adoption of this environmentally friendly technology is the high investment cost; installing a biogas system is estimated to cost IDR 5-7 billion per mill.

According to another study conducted in East Kalimantan, a factory using biogas technology can reduce methane emissions by 40% when compared to a factory that does not use biogas technology. This reduces the impact on the environment and reduces dependence on fossil fuels by generating renewable energy for mill operations. The use of this technology demonstrates how waste management regulations for palm oil can provide the dual benefits of reducing emissions and converting waste into energy.

3.4 Solid waste management (EFB, PKC, and PKS)

By-products of palm oil manufacturing include solid wastes such as empty fruit bunches (EFB), palm kernel cake (PKC), and palm kernel shells, which, if not handled properly, can harm the environment. To reduce the volume, these solid wastes are often burned outdoors, which can pollute the air and add to the haze that often occurs in Indonesia, especially during the dry season.

Positive results have been shown by government initiatives that encourage the reduction of open burning and the use of solid waste as feedstock for compost or renewable energy. About half of Indonesia's large businesses have effectively used TKKS and PKC as energy or compost feedstocks, according to data from the MoEF. For example, PKS is converted into biomass briquettes at a palm oil mill in Lampung, which is then used to generate electricity. According to field data, this mill can use the TKKS to generate about 1.2 MW of electrical energy, which is enough to fulfil about 30% of the mill's energy needs.

However, according to a survey of 100 smallholders in West Kalimantan and North Sumatra, more than 70% of farmers still burn their solid waste due to lack of access to environmentally friendly treatment technologies. According to interviews with farmers, although they are aware of the harmful impacts of open burning, many of them feel they cannot afford to purchase waste treatment equipment or get adequate training. This shows how different sectors continue to have different solid waste management regulations, especially with regards to smallholders.

3.5 Utilising eco-technology in palm oil waste management

One important component of the government's policy to reduce the environmental impact of the palm oil sector is the use of green technologies. Technologies such as biogas collection, solid waste composting, and biomass-based power generation have the ability to turn palm oil waste into a valuable resource and reduce the impact of pollution.

Although large companies are progressively implementing these technologies, their use is still limited to businesses with large financial resources, according to empirical data collected from interviews with palm oil entrepreneurs. More than 10,000 households' energy needs can be met by the 50,000 MWh of electrical energy generated annually by a palm oil mill in South Sumatra that uses a biomass-based power plant from oil palm empty fruit bunches. In addition, the utilisation of palm oil waste by this power plant reduces dependence on fossil fuels while reducing air pollution.

However, the cost of integrating these technologies remains a significant barrier for most small and medium enterprises. According to an industry survey from the Indonesian Palm Oil Producers Association (APSI), around 30 per cent of small businesses find it difficult to secure funding for greener waste treatment technologies. To encourage the use of environmentally friendly technologies, the government should provide subsidies or tax breaks that are more affordable for small businesses and farmers.

3.6 Forest management and nature conservation

One of the most significant environmental impacts of growing oil palm plantations is deforestation, which often involves the destruction of natural ecosystems and the clearing of primary forests. The Indonesian government has enacted a deforestation moratorium policy that prohibits the clearing of oil palm from primary forests and peatlands in an effort to curb deforestation.

However, data from the World Resources Institute (2020) shows that violations continue to occur in some places despite this policy. Case studies of palm oil companies illegally deforesting in West Kalimantan show that, despite their claims of compliance with the moratorium, these companies continue to clear forests through subcontractors.

The use of satellite-based monitoring technology that can identify land cover changes in real-time is one of the steps taken to address these violations, according to field data collected from interviews with MoEF officials. For example, a satellite-based monitoring system in Central Kalimantan can identify unlawful deforestation in less than a week, allowing authorities to take swift action.

3.7 Opportunities and difficulties in implementing palm oil waste management policies in Indonesia

One of the most difficult issues facing palm oil businesses in Indonesia is palm oil waste management. While the government has issued policies aimed at improving socio-economic and environmental sustainability, there are still significant implementation issues. However, there are a number of opportunities that can be utilised to overcome these constraints and build a more sustainable, effective and environmentally friendly palm oil sector. Using empirical data from the field, the following are some of the constraints faced and opportunities to improve the sustainability of the palm oil sector through technology and policy.

Limited Technology and Infrastructure for Small and Medium Enterprises: inadequate access for small and medium enterprises (SMEs) to environmentally friendly technology is one of the main obstacles in implementing palm oil waste management policies. For palm oil mills with limited production capacity, policies that encourage waste treatment using advanced technologies such as biogas capture, solid waste composting, or biomass energy generation are often unaffordable.

A survey of 80 palm oil companies in Sumatra and Kalimantan shows that nearly 60 per cent of small mills find it difficult to secure funds to invest in environmentally friendly technologies. The majority of them still use traditional waste disposal techniques that are more harmful to the environment, including landfilling and open burning. Initial investment costs for biogas technology can reach IDR 5-7 billion per mill, according to interviews with mill managers in Central Kalimantan. However, the long-term benefits will only be seen after several years.

Inadequate reporting and uneven monitoring: Despite waste management laws and a moratorium on deforestation, official oversight is often weak, especially in rural areas. Despite prohibitions, certain businesses continue to clear land in protected forest areas through illegal methods that are difficult to identify, according to empirical data collected from KLHK (Ministry of Environment and Forestry) reports. According to a case study in West Kalimantan, some oil palm companies grew by leasing land from indigenous communities and then cutting down trees without official permission, even though they were recorded as having permits. Based on interviews with local indigenous communities, they often find themselves in unfavourable contracts with companies and do not have adequate access to information on forestry laws.

Lack of Public Awareness and Socialisation: Despite the fact that palm oil waste management policies strive for sustainability, many communities and smallholders still lack an understanding of their importance. Around 40 per cent of the 100 oil palm farmers surveyed in North Sumatra admitted that they were unaware of their responsibilities regarding waste management, including the use of environmentally friendly technologies for POME treatment. Many farmers,

according to the interviews, simply continue the same practices they have been doing for years without taking into account the long-term impacts on the environment and human health.

Dependence on Fossil Energy Subsidies and Unfriendly Infrastructure: Despite the development of biomass-based technologies, most large palm oil companies still rely on fossil energy to power their mill operations. About half of the large mills still rely on coal or diesel as their main energy source, according to field data collected from the Indonesian Association of Palm Oil Producers (APKS). This is due to the fact that while environmentally-friendly biomass energy technologies may eventually reduce dependence on fossil fuels, fossil energy is still more affordable than renewable energy produced from palm oil waste.

Lack of coordination among stakeholders, government, palm oil companies, communities, and NGOs are some of the parties involved in the implementation of palm oil waste management policies. There is a significant coordination gap between central government policies and their implementation at the local level, according to data from a survey of more than 50 NGOs. Many policies, including those of the MoEF and the Ministry of Agriculture, are not tailored to local needs or even coordinated between ministries.

3.8 Opportunities to advance sustainability through innovations in technology and policy

The government can support the creation and application of more affordable waste treatment technologies, such as small-scale biogas plants that can be run by small businesses, to help small businesses overcome the constraints of expensive technologies. Compared to large biogas plants, small-capacity mini biogas plants (about 50 m^3) can reduce methane gas emissions by up to 30% per year and provide enough energy to fulfil a factory's electricity needs, based on field data collected from Jambi-based businesses.

More Awards for Renewable Energy Innovation: offering financial incentives for the use of renewable energy sources, such as biomass and biofuels made from discarded palm oil, is one of the key ways to improve sustainability. For businesses investing in green technologies, the government should offer tax breaks or subsidies, especially for small and medium-sized enterprises that face start-up costs. According to a survey of 40 businesses in Kalimantan, financial incentives can play an important role in encouraging businesses to use greener biomass energy.

Improving Law Enforcement and Surveillance: using satellite-based monitoring technology to identify land cover change in real-time can help improve oversight of illegal oil palm expansion activities. Deforestation rates in areas under strict surveillance have decreased by 50% over the past two years thanks to the use of satellite monitoring systems, according to data from the MoEF. To promptly investigate policy violations and enforce the moratorium, the government can also enlist the help of local community organisations.

Education and Training for Smallholders: the government can scale up education and training initiatives aimed at smallholders to address community ignorance of waste management regulations. According to a survey of 100 smallholders in South Sumatra, those who attended training programmes offered by large companies or NGOs were able to reduce waste burning by 40% and started using more environmentally friendly composting or POME treatment technologies.

Industry, government and research institutions working together to develop new waste management technologies can create opportunities to improve the sustainability of the palm oil sector. For example, a joint study conducted by Gadjah Mada University and a number of palm oil companies in East Kalimantan has effectively created an organic fertiliser based on PKS that can increase crop yields and reduce adverse impacts on soil. The development of more affordable and effective ways to convert palm oil waste into value-added items could be the subject of future research.

The palm oil industry is a key contributor to Indonesia's economy, supporting millions of workers and generating significant foreign exchange. However, behind its economic importance lie serious challenges, particularly in environmental sustainability and equitable economic access. The production process produces both solid and liquid waste, notably Palm Oil Mill Effluent (POME), which contributes to air, water, and soil pollution and poses health risks. Expansion through deforestation further threatens biodiversity and worsens climate impacts, giving the industry a heavy ecological footprint.

Green technologies have been introduced to reduce methane emissions and convert waste into alternative energy.

Yet, these remain largely inaccessible to smallholders due to high costs and limited infrastructure, making their adoption uneven. Beyond environmental and technological barriers, institutional issues—such as weak inter-agency coordination and lack of smallholder training—undermine the implementation of sustainable policies. Collaboration between government, industry, and research institutions is critical to closing these gaps.

Efforts are underway: the government promotes environmental regulation, farmer education, and innovation partnerships to ensure inclusive progress. Still, the industry stands at a crossroads—balancing economic growth with long-term sustainability demands a holistic, multi-sectoral approach.

4. CONCLUSIONS

The study concludes that, despite effective implementation through regulations such as the deforestation moratorium and RSPO certification, the Indonesian government's policy on palm oil waste management still faces a number of difficulties. Water, soil and air pollution are major problems, and the environmental impacts - particularly from handling POME and other solid waste - are still considerable. While there are significant financial benefits, especially for smallholders, there are still gaps in policy implementation, especially in terms of the community's lack of knowledge of policies and their access to environmentally friendly technologies.

The results of this study show that while palm oil waste management policies have improved environmental sustainability, there are still significant implementation issues, especially at the small business and community levels. Therefore, it is crucial to create policies that are more inclusive and built on environmentally friendly technologies. The government should create policies that are more adaptable and well-coordinated among its agencies and strongly support technological innovations that are accessible to all industry players, especially smallholders and medium-sized enterprises. Future policy proposals should prioritise long-

term sustainability and reduce implementation gaps.

According to the report, the government should use satellite technology to monitor and improve surveillance and enforcement to ensure that regulations relating to palm oil waste are implemented efficiently. For the palm oil industry, companies should accelerate the adoption of more environmentally friendly waste management technologies, such as biogas capture and waste composting, and increase cooperation with research institutions for sustainable innovation. For communities, education and training for smallholder oil palm farmers on waste management and sustainable agricultural practices should be improved so that they have a better understanding of the importance of such policies and their impact on the environment. In addition, fiscal incentives and subsidies for small businesses to adopt environmentally friendly technologies should be expanded.

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