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GREEN TECHNOPRENEURSHIP FOR PALM OIL WASTE VALORIZATION AND SUSTAINABLE BUSINESS DEVELOPMENT

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Abstract

The palm oil industry plays a vital role in the economy but also generates substantial waste that can cause environmental problems when not managed properly. However, palm oil waste contains economic value that can be enhanced through technological innovation and sustainable entrepreneurial approaches. This study aims to analyze the application of green technopreneurship in palm oil waste utilization and its contribution to sustainable business development. A literature review approach was employed by examining relevant studies on green technology, palm oil waste utilization, circular economy, entrepreneurial innovation, and business sustainability. The findings indicate that green technology can increase the economic value of palm oil waste through products such as compost, alternative fuels, bioenergy, bioproducts, and other value-added materials. Integrating technology with green entrepreneurship can create new business opportunities, improve resource efficiency, reduce environmental impacts, and strengthen business competitiveness. The development of green technopreneurship requires technological innovation, competent human resources, access to financing, collaboration among government, industry, academia, and communities, and supportive circular economy policies. Therefore, across the palm oil value chain, palm oil waste valorization can function not only as an environmental management strategy but also as a foundation for innovative, productive, and sustainable business models.

Keywords: Green Technopreneurship, Palm Oil Waste, Waste Valorization, Sustainable Business, Circular Economy.

INTRODUCTION

The palm oil industry contributes significantly to economic growth, employment, trade, and regional development, but its expansion also generates substantial solid and liquid waste (Jalani & Zainal, 2024). Empty fruit bunches, fibers, shells, fronds, and POME require effective management to prevent environmental impacts and avoid losing economic potential (Idris et al., 2026a). Waste valorization offers a sustainable solution by converting these by-products into fertilizers, energy, fuels, biomaterials, and other value-added products, consistent with circular economy principles (Amin et al., 2022). Technological innovation can improve this process, but commercialization also requires entrepreneurial capabilities, market knowledge, risk management, and business networks. Green technopreneurship integrates these elements by combining technology, entrepreneurial innovation, and environmental responsibility to create waste-based businesses that generate economic, social, and ecological value (Adebiyi et al., 2020).

Opportunities for developing green technopreneurship are expanding due to the growing focus on environmental issues and sustainability within the business world. Consumers, investors, governments, and various stakeholders are increasingly factoring environmental considerations into their product choices and investment decisions. This landscape offers business players the chance to develop products that deliver both economic value and environmental benefits. Products derived from the valorization of palm oil waste can enter the green economy market, provided they are supported by high product quality, appropriate processing technology, cost efficiency, reliable raw material supplies, and effective marketing strategies (Awa et al., n.d.). Through this approach, sustainability becomes not merely an environmental goal but also a source of competitive advantage for companies and entrepreneurs.

The implementation of palm oil waste valorization faces several challenges, including limited access to suitable technologies, high investment requirements, inadequate human resources, financing constraints, market uncertainty, and uneven innovation capacity. Weak integration between palm oil companies and waste-processing enterprises can further limit the development of sustainable business models. Therefore, successful valorization

requires an integrated approach that connects technological, entrepreneurial, environmental, institutional, and market dimensions. Stakeholder collaboration is essential for building an effective innovation ecosystem. Palm oil companies can provide raw materials and technical knowledge, entrepreneurs can develop products and business models, universities can support research and technology development, and governments can provide regulations, incentives, infrastructure, and financing mechanisms (Idris et al., 2026b). Local communities can also participate through employment and waste-based business opportunities.

From a circular economy perspective, green technopreneurship can reintegrate palm oil waste into productive economic activities, reduce dependence on virgin resources, improve resource efficiency, and minimize environmental impacts. At the same time, waste valorization can generate additional revenue and strengthen business sustainability. Therefore, this research examines how green technology, waste valorization, and entrepreneurship can support sustainable business development and identifies factors that enable the creation of economically viable and environmentally responsible palm oil waste-based ventures.

LITERATURE REVIEW

Palm Oil Waste as a Resource for Sustainable Value Creation

The palm oil industry generates substantial amounts of solid and liquid by-products, including empty fruit bunches (EFB), fibers, shells, fronds, and palm oil mill effluent (POME). These materials should not be viewed solely as production residues because they contain organic matter, biomass, and energy potential that can be recovered through appropriate technologies. The transition from conventional waste management toward waste valorization creates opportunities to improve resource efficiency and generate additional economic value within the palm oil value chain (Yusoff, 2006; Cheah et al., 2023).

The circular economy provides an important conceptual basis for this transformation. Unlike the conventional linear model, which separates production from waste disposal, a circular economy seeks to retain the value of materials through reuse, recovery, recycling, and conversion into new products. In the palm oil industry, this approach allows biomass residues to re-enter economic activities as raw materials, energy sources, fertilizers, and other value-added products (Goh & Potter, 2022; Usapein et al., 2022). Recent research also emphasizes that circular economy implementation in the palm oil sector requires integration between technological innovation, industrial practices, institutional support, and economic incentives (Cheah et al., 2023; Firdaus & Alifiyah, 2025).

Empty fruit bunches provide a relevant example of agricultural waste valorization. EFB can be processed into compost and organic fertilizer because of its organic matter content. Its application can support nutrient recycling within oil palm plantations and reduce the need to dispose of large quantities of biomass. Empirical evidence from Hasibuan et al. (2023) showed that EFB application affected nutrient concentrations in oil palm tissues, particularly Ca, Mg, and B in rachis, although the treatment did not significantly increase fresh fruit bunch production. This finding indicates that the value of EFB utilization should not be evaluated only through short-term yield increases. Nutrient recycling, waste reduction, input substitution, and resource efficiency also represent important components of its agricultural and economic value.

Palm biomass also has considerable potential for energy production. Fibers and shells can be used as biomass fuels, while other palm-derived residues can support renewable energy systems. Yusoff (2006) identified palm oil waste as an important source of renewable energy and highlighted the potential for improving waste utilization through technological innovation. Ng et al. (2012) further demonstrated the waste-to-wealth potential of palm biomass in Malaysia, particularly through energy recovery and other value-added applications. POME represents another important resource. Anaerobic digestion can convert its organic content into biogas, providing an opportunity to recover energy while reducing the environmental burden associated with untreated effluent (Amin et al., 2022).

The development of advanced processing technologies expands the potential applications of palm oil biomass beyond conventional composting and energy recovery. Biomass can be processed into bioproducts, intermediate materials, and other value-added products. Jalani and Zainal (2024) emphasized the importance of biorefinery concepts in converting oil palm biomass into higher-value products within a circular economy framework. Cheah et al. (2023) similarly highlighted the potential of a circular bioeconomy to integrate biomass utilization, resource recovery, and technological innovation in the palm oil industry.

Green Technology and Technopreneurship

Technology alone does not automatically create sustainable economic value. The commercialization of palm oil waste requires entrepreneurs who can identify technological opportunities, understand market requirements, manage resources, and develop viable business models. This relationship places green technopreneurship at the

intersection of technological innovation, entrepreneurship, and environmental sustainability. Technopreneurship emphasizes the use of technology to develop innovative products, services, and business models. In a sustainability context, green technopreneurship extends this concept by incorporating environmental objectives into entrepreneurial activities. Rathnayake and Roca (2022) describe technopreneurship as an important mechanism for technology-enabled economic development, while Julitha et al. (2025) associate technopreneurship with sustainable innovation and the development of new economic opportunities. Therefore, green technopreneurship in the palm oil sector can be understood as an entrepreneurial approach that uses environmentally oriented technologies to transform palm oil waste into economically valuable products and services.

This concept is particularly relevant for EFB, fibers, shells, fronds, and POME because these materials are continuously generated along the palm oil production chain. Entrepreneurs can develop businesses not only in waste processing but also in collection, transportation, equipment provision, compost production, biomass energy, biogas systems, product development, quality testing, packaging, and marketing. Such activities can create new linkages among plantation companies, palm oil mills, technology providers, small and medium enterprises, research institutions, and local communities.

The transition from waste to value therefore requires a combination of technological capability and entrepreneurial capability. Green technopreneurs need to select technologies according to feedstock characteristics, investment capacity, processing scale, product quality, and market demand. A technically sophisticated technology may not be appropriate if its capital requirements and operating costs exceed the capacity of small and medium enterprises. Consequently, technology selection should consider both technical performance and economic feasibility.

Circular Economy and Sustainable Business Development

The circular economy provides a strategic framework for linking waste valorization with sustainable business development. Palm oil waste can become an input for another production process, allowing economic value to circulate within the industrial system. This model can generate multiple revenue streams while reducing the demand for virgin resources and minimizing waste generation (Goh & Potter, 2022; Cheah et al., 2023). Firdaus and Alifiyah (2025) identified substantial opportunities for implementing circular economy principles in the Indonesian palm oil industry. These opportunities include the development of green economy activities based on biomass utilization and resource recovery. Usapein et al. (2022) also demonstrated the relevance of a bio-circular-green economy framework for transforming palm oil production toward more sustainable resource utilization.

Green entrepreneurship strengthens this process by converting circular economy opportunities into commercially viable activities. Munir and Fausiah (2025) emphasized the relationship between circular economy principles, green entrepreneurship, and sustainable business models. From this perspective, palm oil waste can become a strategic resource for creating businesses that simultaneously pursue economic, environmental, and social outcomes. Business performance also depends on access to appropriate financing. Green technology frequently requires investment in equipment, processing facilities, testing, certification, and market development. Adebiyi et al. (2020) showed that green technology financing can influence the business performance of renewable energy producers. This finding is relevant to palm oil waste-based enterprises because financing mechanisms can reduce the investment barriers associated with adopting environmentally oriented technologies.

In addition to finance, green technopreneurship requires technological competence, human resources, market access, and institutional support. Green entrepreneurs must understand both the technical characteristics of waste and the commercial requirements of the products developed from it. Product quality, cost competitiveness, reliable feedstock supply, certification, and consumer acceptance determine whether a waste-based innovation can move beyond the research stage toward commercial implementation.

Research Gap and Conceptual Position

Existing studies have demonstrated the potential of palm oil waste for agricultural inputs, renewable energy, biogas production, and higher-value bioproducts (Yusoff, 2006; Ng et al., 2012; Amin et al., 2022; Hasibuan et al., 2023; Cheah et al., 2023; Goh & Potter, 2022; Jalani & Zainal, 2024). However, these research areas are frequently examined independently, creating a gap between technological innovation and entrepreneurial application. Technological potential alone does not guarantee commercial value without appropriate business models, market strategies, and institutional support. This study addresses this gap by integrating green technology, waste valorization, circular economy principles, and green technopreneurship. Green technology provides the technical mechanism for converting palm oil waste into useful products and energy, while green technopreneurship facilitates

commercialization and business development. Meanwhile, the circular economy provides a systemic framework for connecting waste generation, resource recovery, value creation, and sustainable production. This integrated perspective positions palm oil waste as both an environmental management challenge and a strategic resource for innovative, economically viable, and sustainable business development.

METHOD

This study employs a qualitative approach using a literature review method to analyze the application of green technopreneurship in the valorization of palm oil waste and the development of sustainable businesses. Research data were gathered from various relevant scholarly sources including national and international journal articles, academic books, research reports, and supporting documents covering topics such as green technology, palm oil waste utilization, the circular economy, green entrepreneurship, technological innovation, and business sustainability. The review process involved identifying, selecting, categorizing, and analyzing information based on its relevance to the research focus. The collected literature underwent a descriptive-critical analysis, comparing findings across sources to identify patterns of waste utilization, opportunities for technological innovation, potential for economic value creation, and the factors facilitating or hindering the development of palm oil waste-based enterprises. Finally, the analysis results were synthesized to gain a comprehensive understanding of the role of green technopreneurship in driving palm oil waste valorization while simultaneously establishing business models that are more innovative, efficient, environmentally friendly, and sustainable.

RESULTS AND DISCUSSION

The Role of Green Technopreneurship in Driving Palm Oil Waste Valorization

Green technopreneurship provides a strategic approach for transforming palm oil waste into resources with economic, social, and environmental value. The concept integrates green technology, entrepreneurial innovation, and sustainability to address waste management challenges while creating new business opportunities (Idris et al., 2026c). This approach is highly relevant to the palm oil industry, which generates empty fruit bunches (EFB), fibers, shells, fronds, and palm oil mill effluent (POME). Through appropriate technologies, these materials can be converted into compost, bioenergy, biogas, biochar, biomaterials, and other value-added products. Waste valorization therefore becomes a practical mechanism for improving resource efficiency and reducing environmental burdens (Cheah et al., 2023).

Green technology supports efficient, safe, and economically feasible waste processing. Technology selection should consider waste characteristics, investment capacity, technical skills, processing requirements, product specifications, and market demand (Putra et al., n.d.). Meanwhile, entrepreneurship connects technological opportunities with commercial applications. Green technopreneurs can develop businesses in waste collection, processing, technology services, product manufacturing, and distribution. However, technological feasibility alone does not ensure market success. Entrepreneurs must understand consumer needs, product quality, pricing, competition, and market access. Thus, green technopreneurship can facilitate the transition of palm oil waste from a management cost into a productive resource and a foundation for sustainable business development (Hadiyanto, 2016).

From a business perspective, palm oil waste valorization can create additional revenue streams while improving resource and production efficiency. Palm oil mills can utilize their own by-products to reduce dependence on external fuels and agricultural inputs. EFB can be processed into compost to return organic matter and nutrients to plantation soils, while fibers and shells can support internal energy generation. These activities can create interconnected value chains involving plantation companies, mills, technology providers, waste processors, local communities, distributors, and consumers. Such integration supports circular economic practices in which waste from one process becomes an input for another.

Green technopreneurship also provides environmental and social benefits. Converting solid residues into useful products or energy can reduce waste accumulation and pressure on virgin resources, while POME treatment can reduce pollution risks and recover biogas energy (Tan et al., 2025). Local communities can participate in collection, processing, logistics, production, and marketing, creating employment and additional income opportunities. However, implementation faces constraints, including limited capital, technological capacity, skilled labor, infrastructure, market access, and quality assurance. Government, industry, academia, entrepreneurs, and communities therefore need to collaborate to strengthen financing, technology development, training, standards, and commercialization (Mohamad et al., 2015). This integrated approach can accelerate the development of a circular palm oil waste economy that generates economic, environmental, and social value.

Technological Innovation and Opportunities for Sustainable Business Development Based on Palm Oil Waste

Technological innovation provides significant opportunities to transform palm oil waste into valuable resources and support sustainable business development. The industry generates empty fruit bunches (EFB), fibers, shells, fronds, and palm oil mill effluent (POME), which contain organic matter, lignocellulosic components, and energy potential. Appropriate technologies can convert these residues into fertilizers, bioenergy, biomaterials, and other value-added products, shifting waste management from a disposal-oriented approach toward resource recovery and value creation (Firdaus & Alifiyah, 2025). In this context, technological innovation should not only focus on the technical conversion of waste but also consider production costs, process efficiency, greenhouse gas implications, and long-term economic feasibility. Hamdani et al. (2022) demonstrated that system dynamics can be used to optimize the cost structure of aerobic-based compost production from palm oil mill waste. Their findings showed that the economic performance of waste treatment depends on the interaction between processing technology, operating costs, investment requirements, and greenhouse gas-related costs.

EFB offers substantial potential for compost and organic fertilizer production. Through size reduction, controlled decomposition, moisture management, aeration, and maturation, EFB can become a stable organic amendment that returns nutrients and organic matter to plantation soils (Yusoff, 2006). Further processing can recover cellulose, hemicellulose, and lignin for bioproducts and biomaterials, although commercialization requires technological optimization, quality assurance, investment, and reliable markets (Usapein et al., 2022). The economic dimension is particularly important because composting technology requires an appropriate balance between processing efficiency and production cost. Hamdani et al. (2022) found that aerobic composting can provide an economically relevant alternative for palm oil mill waste treatment, although its initial development cost was relatively high. Their system dynamics analysis showed that cost optimization should consider changes in treatment costs over time rather than relying only on initial investment estimates.

Fibers and shells also provide important opportunities for biomass-based enterprises. Their energy content supports heat and power generation through boilers, combustion, gasification, and other conversion technologies (Ng et al., 2012). Their availability near processing facilities can reduce transportation costs and strengthen supply chain efficiency. Partnerships among palm oil companies, technology providers, biomass processors, and energy enterprises can further improve commercialization and resource utilization (Utilization of Oil Palm Waste as a Renewable Energy Source: A Current Literature Review, n.d.).

Oil palm fronds represent another underutilized biomass resource with potential for technological conversion. Depending on their composition and processing requirements, fronds can be used as organic material, biomass fuel, animal feed after appropriate treatment, or raw material for other derivative products. Processing technologies can improve their physical characteristics and facilitate their integration into agricultural or industrial applications. For green technopreneurs, frond utilization creates opportunities to diversify product portfolios and reduce dependence on a single agricultural output. The development of frond-based businesses can also increase the utilization rate of plantation biomass and provide additional economic opportunities within rural production systems (Ayompe et al., 2025).

POME requires a different technological approach because it is a liquid waste stream with a high organic load. One important utilization pathway involves anaerobic digestion to produce biogas. The process converts organic matter into methane-rich gas that can be used as an energy source. At the same time, appropriate treatment reduces the organic pollution load before further management or discharge according to applicable environmental requirements. Biogas recovery can therefore provide two complementary benefits: pollution control and energy generation. From a business perspective, this creates opportunities for biogas plant development, equipment supply, operation and maintenance services, and energy management. POME management can consequently shift from a cost-centered waste treatment activity toward a resource recovery model. However, the choice between aerobic and anaerobic treatment should consider both environmental and economic consequences. Hamdani et al. (2022) showed that anaerobic treatment can involve additional economic implications when greenhouse gas costs are incorporated, while aerobic treatment can provide an alternative pathway that avoids methane generation during the composting process.

Integrating different waste utilization pathways can strengthen the application of circular economy principles within the palm oil industry. A conventional linear model follows a sequence of resource extraction, production, consumption, and waste disposal. A circular model seeks to retain materials and energy within productive systems for as long as possible. Under this approach, EFB can become compost or bioproduct feedstock, fibers and shells can support energy generation, fronds can become biomass-based products, and POME can generate biogas. The integration of these pathways creates multiple value streams from a single production system and can improve

resource efficiency while creating additional sources of revenue (Goh & Potter, 2022). The case of aerobic composting further illustrates that circular waste utilization requires technological and economic optimization. Hamdani et al. (2022) used system dynamics to compare aerobic and anaerobic waste treatment scenarios and demonstrated that changes in treatment technology and greenhouse gas-related costs can influence the relative economic attractiveness of alternative waste management systems.

Business opportunities in palm oil waste utilization extend across the entire value chain, including collection, sorting, transportation, preprocessing, technology provision, processing, quality control, certification, distribution, and marketing. This ecosystem can involve palm oil companies, small enterprises, technology providers, universities, financial institutions, and local communities. Such collaboration can distribute economic benefits, encourage specialization, and strengthen innovation. However, successful development requires reliable feedstock supplies, appropriate technology costs, consistent product quality, skilled human resources, and stable market demand. Hamdani et al. (2022) highlighted the importance of cost optimization in determining the feasibility of waste-based processing systems. Their findings indicate that investment and operational costs should be assessed dynamically because the economic position of a technology can change over time.

Technological innovation also generates interconnected environmental, economic, and social benefits. It can reduce waste accumulation, recover energy, improve resource efficiency, and minimize pollution risks. At the same time, waste becomes an input for new products, services, and revenue streams, while waste-based enterprises can create employment and stimulate local economies. Nevertheless, commercialization faces challenges related to investment, technology readiness, feedstock variability, operational capacity, quality standards, and market uncertainty. Technical feasibility should therefore be combined with economic analysis, product testing, market assessment, and supply chain planning. The findings of Hamdani et al. (2022) reinforce this argument because their system dynamics model demonstrated that technological selection and cost structures should be evaluated simultaneously. Policy incentives, financing, research collaboration, and industry partnerships can further accelerate technology adoption and support a circular palm oil waste business ecosystem.

Strategies to Strengthen the Green Technopreneurship Ecosystem in Support of the Circular Economy

Strengthening the green technopreneurship ecosystem is essential for accelerating palm oil waste utilization within a circular economy framework (Munir & Fausiah, 2025). The circular economy treats waste as a resource that can retain economic value through reuse, recovery, processing, and conversion into new products. In the palm oil industry, however, achieving this transition requires more than waste processing technologies. It requires an integrated ecosystem that connects technological innovation with financing, human resources, markets, regulations, and institutional support. Without these components, promising innovations may remain at the research or pilot stage and fail to develop into sustainable businesses.

Appropriate technology represents a fundamental component of this ecosystem. Palm oil waste processing technologies should produce consistent quality, operate efficiently, and remain economically feasible for business operators. Highly complex systems and large capital requirements can limit adoption, particularly among small and medium-sized enterprises (Mondal et al., 2025). Technology development should therefore consider waste characteristics, production scale, energy availability, technical capacity, and local socio-economic conditions. Context-specific technologies can improve adoption and increase the probability of successful commercialization.

Financing also determines the capacity of entrepreneurs to adopt and scale green technologies. Investments are required for equipment, processing facilities, product testing, certification, and market development. Financial institutions may perceive waste-based businesses as relatively risky because market and technological uncertainties remain. Accessible financing mechanisms, including green loans, government incentives, industry partnerships, and innovation funding, can reduce these barriers. Financial support should also include business mentoring to improve investment effectiveness and enterprise performance (Julitha et al., 2025).

Human resource capacity represents another critical factor. Green technopreneurs require competencies in waste processing, business management, marketing, product development, and sustainability. Training, incubation, mentoring, and knowledge transfer involving universities and industry can strengthen these competencies (Khairusy et al., n.d.).

Market development is equally important. Waste-derived products must meet consumer expectations regarding quality, price, safety, and functional benefits. Certification, standardization, packaging, and quality assurance can strengthen market confidence (Nursari et al., 2026). Finally, supportive policies can provide regulatory certainty and encourage investment in circular business models. Governments can strengthen infrastructure, provide incentives, and develop green entrepreneurship programs while ensuring that regulations remain feasible for

businesses (Utaminingsih et al., 2026). Integrating technology, finance, human resources, markets, and policy can create a stronger ecosystem for commercializing palm oil waste innovations and advancing a circular, sustainable industry.

Collaboration among government, industry, academia, and the community is a vital strategy for addressing these challenges. The government holds a strategic position in formulating policies, providing supporting facilities, and creating a conducive investment climate. Industries can supply waste raw materials, technological requirements, production expertise, and market access. Higher education institutions play a role in conducting research, developing technology, performing testing, and enhancing human resource competencies. Meanwhile, the community can participate as business operators, a workforce, or part of the raw material supply chain. Integrated relationships among these actors can accelerate the innovation process from the development stage through to implementation and commercialization.

Such collaboration can be fostered through the establishment of innovation centers, green business incubators, research partnerships, and business-matching models between industries and business players. Through partnership arrangements, research findings with commercial potential can be more easily implemented in the field. Industries can gain solutions to their waste management challenges, while business players gain access to raw materials and technology. Collaborative models of this nature create mutually beneficial relationships while strengthening the value chain for palm oil waste utilization (Rathnayake & Roca, 2022). Consequently, innovation does not occur in isolation but becomes part of an ecosystem involving diverse stakeholders.

Strengthening the green technopreneurship ecosystem requires efficient supply chains that ensure the volume, quality, and continuity of palm oil waste as raw materials. Partnerships between palm oil companies and waste-based enterprises can improve material availability, reduce logistics costs, and strengthen by-product management (Rathnayake & Roca, 2022). In the long term, integrated business models should balance economic, environmental, and social benefits. Reusing waste reduces dependence on virgin resources, creates community-based economic opportunities, and supports circular economy principles by keeping material value within productive systems.

CONCLUSION

This study demonstrates that green technopreneurship plays a pivotal role in driving the utilization and economic value enhancement of palm oil waste through the integration of green technology, innovation, and entrepreneurship. Literature review findings indicate that waste materials such as empty fruit bunches, fibers, shells, fronds, and liquid effluents hold the potential to be developed into compost, bioenergy, biogas, alternative fuels, and various value-added bioproducts. Such utilization not only mitigates potential environmental impacts but also creates business opportunities, improves resource efficiency, and supports a shift in business models from linear patterns toward a more circular economy. Consequently, the valorization of palm oil waste can serve as a crucial element in building businesses that integrate economic benefits with environmental sustainability.

Developing palm oil waste-based green technopreneurship requires a supportive ecosystem, particularly regarding technology, financing, human resource competence, market access, and institutional frameworks. The study highlights that collaboration among government, industry, academia, and the community is essential for accelerating the adoption of innovations and the sustainable development of waste-based businesses. Policy support, appropriate technology, capacity building for business actors, and the strengthening of value chains and markets are necessary to fully realize the potential of this waste. Therefore, strengthening green technopreneurship serves not only as a waste management strategy but also as an approach to generating new economic value, enhancing the competitiveness of the palm oil industry, and supporting the implementation of a circular economy oriented toward long-term sustainability.

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