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Sustainable innovation: Economic valuation of wood waste for sustainable development at PT Wapoga Mutiara Industries

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ABSTRACT

Background: This study describes the economic valuation of wood waste at PT Wapoga Mutiara Industries using the Market Price Approach to calculate the Total Economic Value (TEV) derived from utilising production waste. This research uses qualitative methods to explore how processed wood waste contributes economically to the company and the local community. Wood waste in industrial processes is often an underutilised asset. However, at PT Wapoga Mutiara Industries, innovative practices have turned this by-product into a significant economic opportunity. **Method:** This research investigated the direct use value of wood waste - mainly wood chips and sawdust – converted into local charcoal products, a resource increasingly recognized for its environmental and economic benefits. The research assessed the monthly economic impact of these waste products, measuring their market value to quantify the total benefits accruing to the local economy. **Findings:** The findings from this study are considerable, showing that wood chips alone contribute IDR 42,300,000 to the economy each month. Sawdust was processed in the same way, adding IDR 72,860,000 per month. Combined, these waste materials contribute a total direct use value of IDR 166,160,000 per month to the local economy, which on average provides a potential income of IDR 1,350,700 per person per month, suggesting there is significant economic potential from sustainable wood waste management practices. **Conclusion:** In addition, the study provides insight into the broader implications of such valuation practices, demonstrating that with the right innovations, what is often considered industrial waste can be re-evaluated as a viable economic resource. This aligns with the global shift towards more sustainable industrial processes, where waste minimisation and reuse contribute to environmental sustainability, economic resilience, and community well-being. **Novelty/Originality of this study:** This study presents a comprehensive analysis of the economic valuation of wood waste in the processing industry, demonstrating the significant potential of innovative waste management practices. This research opens up new perspectives on how industrial 'waste' can be transformed into valuable economic resources, supporting environmental sustainability and the well-being of local communities.

KEYWORDS: economic value; total economic value; market approach.

1. Introduction

Innovation is a crucial element in sustainable development, especially in the context of business. Innovation is essential in improving business performance, enabling faster growth, better efficiency, and, ultimately, more significant profits. Innovation is necessary to meet consumer needs, compete, and produce new marketable products, processes, or services. in addition, open innovation, which involves external resources, is also recognised

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as an approach that can drive innovation performance in SMEs. In addition, innovation is also needed in the broader context of sustainable development. Sustainable development requires accelerated innovation and investment in sustainable development. In this context, innovation is not only seen as a way to improve business performance but also as a means to achieve sustainable economic growth and address environmental issues.

The population in this area is 17,242 people, among whom work as farmers or factory labourers, which is one of the sources of income. Yendidori District is one of the operating areas of PT Wapoga Mutiara Industries, with an area of 275.13 km^2, according to the Biak Numfor Regency Central Bureau of Statistics. The wood processing in the area carried out by the Company has resulted in a pile of wood waste that is left to accumulate or burned. Handling like this can increase the effectiveness of the Company in handling the wood waste generated. The volume of wood waste generated has affected environmental conditions. The type and volume of wood waste generated depends on environmental conditions and the processing methods used by PT Wapoga Mutiara Industries. Common types of wood waste include sawdust, bark, and wood chips. The more wood that is processed, the more wood waste is generated. This shows a direct relationship between production activities and waste output.

Understanding and addressing the challenges associated with wood waste is critical to improving environmental sustainability and operational efficiency. By re-evaluating waste management practices, PT Wapoga Mutiara Industries has the potential to turn a problematic by-product into a valuable resource. Sustainable innovation is essential in sustainable development, especially using wood waste to improve the local economy. Various studies highlight the strategy and implementation of sustainable development in various sectors. Research by Waluyo et al. (2021) highlights the development of wood plastic composite (WPC) by utilising plastic waste and wood sawdust, showing efforts to produce new products from wood waste. Wood waste management can also be a source of added economic value, as shown by the research of Sulistyono et al. (2022), who highlighted the increased value of wood waste through a community partnership program in Serenan Village. In this context, the development of operational techniques for waste management can provide benefits, as efforts to utilise wood waste can also have an impact on other sectors. Thus, innovation in utilising wood waste supports sustainable economic, social, and environmental development.

Wood waste is a resource that can be utilised in various ways. Several studies have been conducted to optimise the utilisation of wood waste. One is the production of crude cellulase from mahogany wood waste (Rulianah et al., 2019). In addition, wood waste can also be utilised as an alternative energy source, such as biomass (Mulyadi & Tezakumala, 2021). The use of wood waste is not only limited to energy but also in construction. Sawdust waste has been used as an acceptable aggregate substitute in concrete mixes, which has been shown to meet the required concrete characteristics (Palian et al., 2023). In addition, sawdust waste has also been utilized as an acceptable aggregate substitute in concrete, with results showing a specific decrease in compressive strength (Paranggai et al., 2022). In addition, wood waste can also be developed into composite products, such as wood plastic composite (WPC), by utilising plastic waste and wood sawdust (Waluyo et al., 2021). The manufacture of lightweight bricks can also be utilised for wood waste by using wood powder as a mixture (Ningrum et al., 2022). In an environmental context, wood waste can also be utilised for phytoremediation, where wood, water hyacinth, and water bamboo plants reduce BOD levels in tofu factory wastewater (Riyanto, 2023). Thus, the utilisation of wood waste can not only reduce waste but also provide added value in various fields.

Sustainable innovation, particularly in the context of wood waste management at PT Wapoga Mutiara Industries, can be assessed economically by integrating insights from various research findings. The economic feasibility of using wood waste to generate economic benefits while reducing environmental impacts is evidenced by studies showing the efficiency of waste treatment at the company. This approach contributes to thermal energy generation and goes hand in hand with recycling and the development of low-waste technologies, offering positive economic effects and improving companies' financial results

(Zaynullina, 2021). Within the broader scope of sustainable development, the importance of integrating economic growth, social integration and environmental protection is highlighted, with the timber industry no exception. The sustainable development of the forestry complex requires strategic management decisions that minimise the use of forest resources and harmful environmental impacts, thus ensuring the industry's sustainability. This approach aligns with the principles of the circular economy, where the reuse of materials, such as natural textile waste for environmental applications. Innovation plays a vital role in changing the economic reality of organisations and reducing the environmental impact caused by industrial activities.

According to Julio et al. (2020), the relationship between environmental management practices, human resources, and corporate social responsibility with sustainable product innovation is critical to achieving economic success. In addition, optimising raw wood for the wood construction industry through green business practices and sustainable development requirements further confirms the ecological and economic benefits of sustainable innovation Anastasiya et al. (2022). However, pursuing innovation is not without risk, especially in contexts with more significant uncertainty, such as in the case of innovative Russian companies. Risk assessment of innovative projects, including technical and marketing risks, is essential to form a management strategy that integrates risk management methods Tatyana et al. (2020). A comprehensive approach to sustainable innovation, combining economic feasibility, strategic management, and risk assessment, is critical to achieving sustainable development at PT Wapoga Mutiara Industries. In conducting an economic analysis of wood waste, PT Wapoga Mutiara Industries must also consider environmental and social aspects. Environmentally friendly wood waste management has provided social benefits to the community; therefore, it is necessary to ask whether sustainable innovation through economic assessment of wood waste can provide economic benefits.

2. Methods

Wapoga Village is one of the areas in Yendidori District and is where the PT Wapoga Mutiara Industries Company is. Geographically, Wapoga Village is located at 0^{o} 55' - 1^{o} 27' South latitude and 134^{o} 47' - 136^{o} East longitude with an area of 275.13 km^2 or 10.57%. This study used a qualitative approach to explore and identify efficient and environmentally friendly wood waste management practices at PT Wapoga Mutiara Industries. Data was collected through in-depth interviews with workers, farmers, and PT Wapoga Mutiara Industries management. Direct field observations were also conducted to see the wood waste processing process, from collection to burning or reutilization. Secondary data was collected from the company's annual report and Biak Numfor Regency Bureau of Statistics publications to understand the economic and demographic context of Yendidori District. The collected data were analysed to determine patterns in wood waste management. This analysis included an evaluation of the efficiency of the current process and its impact on the environment and local economy.

$$\mathrm{DUVi} = \sum_{i=1}^{n} \mathrm{MLi}$$

$$\mathrm{DUV} = \mathrm{DUV1} + \mathrm{DUV2} \qquad \text{(Eq. 1)}$$

The sampling method used in this research is nonprobability sampling with an accidental sampling technique. The research determines sampling by taking respondents based on research considerations such as the community and employees who utilise the results of processing wood production waste at PT Wapoga Mutiara Industries. The data obtained is processed using descriptive statistics using Maximum, Minimum, and Average. Maximum, Minimum, and Average determine the economic value of wood waste at PT

Wapoga Mutiara Industries per day. Data analysis is done using the use value approach by calculating the amount of direct benefits received by the community and employees. The direct use value (DUV) represents the economic benefit derived from utilizing wood waste and wood pulp waste, particularly by the surrounding community and employees of PT Wapoga Mutiara Industries. This value is primarily associated with the use of wood chip waste (DUV1) and wood pulp waste (DUV2), both measured in Indonesian Rupiah (IDR) per month. The direct benefit of waste (MLi), calculated based on a given sample size (n), reflects the tangible economic contributions these materials provide. Equation 1 formalizes the relationship between these variables to determine the overall DUV, highlighting the practical value of waste reuse in supporting local livelihoods and resource optimization.

$$MV = Sc + ADJc \quad \text{(Eq. 2)}$$

Analysis of the market price approach used to calculate the utilisation of wood waste and wood pulp waste by the surrounding community and PT Wapoga Mutiara Industries employees. To determine the market price approach in the utilization of wood waste and wood pulp waste, Equation 2 is applied, where MV represents the market value (IDR/month). This value is calculated based on the Sc (selling price of wood chips and wood pulp waste in IDR/month) and ADJe (additional value derived from waste utilization, such as wood charcoal production, in IDR/month). In order to avoid errors in the variables used in this study, operational definitions are provided to examine what is being investigated and to explain the terms used in the research. This is presented in Table 1 to provide clarity regarding the variables being studied and the terms used in the research.

Table 1. Variable Operational Definition

Variable	Definition	Indicator	Scale of Measurement
Direct Use Value (DUV)	benefits of the economic value of wood waste from production processing.	- Purchase price - Purchase amount - Total price	Ratio (rupiah)
Market Price Approach	The approach used to calculate the benefits of wood waste from direct production processing, namely wood chip waste, wood pulp and utilisation for making charcoal briquettes.	- Use value directly - Selling price	Ratio (rupiah)

3. Results and Discussion

3.1 Overview of the Research Area

PT WMT II has data on potential stands per ecosystem type from the results of IHMB and the results of the Inventory of Stands Before Logging (ITSP) for the last three years (URKT block 2015, 2016 and 2017), along with the completeness of the supporting map (Tree distribution map made at a scale of 1: 1000). Data on the potential of stands from the IHMB in 2012, showed that the number of pole-level budding stocks was 225 stems/ha. Field observations in the former logging area in 2018 showed an average number of pole-level budding stocks of 280 stems/ha and sapling-level budding of 1,020 stems/ha. The data shows a supply of pole-level budding as much as ≥ 100 pole stems / ha. PT WMT II, from 2013 to 2017, produced timber from the area and plots that were authorised with the types as planned. During this period, PT WMT II has realised harvesting/logging activities in 18,200 Ha or 78.76% of the planned area with a volume realisation of 218,197.46 m3 or 38.06%.

The financial health condition of PT WMT II from 2013 to 2016 is an average Liquidity of 26.85%, an average Solvency of 47.67% and a Rentability of 3.32% (positive). Based on the Independent Auditor's Report, the Financial Statements are fairly presented in all

material respects. The financial position of PT WMT II, as well as financial performance and cash flow for the year ended on that date, is by financial accounting standards in Indonesia.

According to the AMDAL document, PT WMT II's protected area spans 12,259 ha. Following a change in the work area in 2012, the RKUPHHK-HA document for PT WMT II, based on IHMB from 2012 to 2021, was issued, allocating a protected area of 9,790 ha. This area consists of 1,707 ha of HL buffer zone, 6,153 ha of river border, 600 ha of KPPN, 330 ha of lake buffer, and 1,000 ha of Insitu. Additionally, the protected area was confirmed through the Board of Directors Decree No. SK 21/SK-PKL/WMT/VI/2014, which defined the protected areas. Therefore, PT WMT II's protected area is outlined in the company's planning document, specifically the RKUPHHK-HA document for 2012-2021 based on IHMB. The designation of the protected area type is influenced by the site conditions, including, 1) the work area bordering the protected Mansiap Mountain Forest on the north side, 2) several rivers flowing through the area, ranging in width from 30 m to 70 m, such as the Tor, Biri, Wiru, and Toarim rivers, 3) the presence of two large caves, Lake Teun and Pianfon, and 4) the discovery of endemic and protected species of flora and fauna, including orchids, resin, kangaroos, cassowary birds, and others.

The results of the review of the PT WMT II Satellite Image Interpretation Map Composite of Landsat 8 OLI Band 653 Path 101 Row 62 Coverage Dated July 3, 2018, March 29, 2017 and August 30, 2016 Path 102 Row 62 Coverage Dated July 5, 2018, June 30, 2017 and September 22, 2016 show that the land cover of the PT WMT II work area is non-forest (old scrub and young scrub and bushes) covering an area of 1,424 ha, forested (virgin forest and LOA) 165,764 ha and covered by clouds covering 1,942 ha. From the results of the delineation of the map with the RKUPHHK-HA map of PT WMT II Based on IHMB Period 2012 - 2021, it was obtained that the data of protected areas that were forested reached 9,728 ha or equivalent to 99.37% of the total protected area.

3.2 Direct Use Value Analysis Results

Direct use value can be interpreted as the benefits of utilising wood waste's economic value from production processing. Then, using wood chip waste, wood pulp waste can be calculated as material for making/burning charcoal and reused and sold using containers with a use value. However, the results of field research show that the utilisation of wood chip waste and wood pulp waste in the study area is only in this commodity (Charcoal Making).

Table 2. Wood chip waste, wood pulp waste

Purchase Price of Waste (m^3)	Average (m^3)	Minimum (m^3)	Maximum (m^3)
Wood Scrap Waste	IDR 166.667	IDR 100.000	IDR 500.000
Wood Pulp Waste	IDR 140.455	IDR 50.000	IDR 500.000

This direct use value is obtained from 68 respondents with a dominant age range from 30 to 49 years, reaching 70%, while the education level is at the high school level, reaching 33.8%. The respondents' type of work is 32.35% as a wood charcoal business, 25% as a seller of wood chip waste, and the rest as employees. The selling price of wood chip waste ranges from IDR 70,000 to IDR 500,000 per m3, while the price of wood pulp waste ranges from IDR 50,000 to IDR 300,000 per m3, while the price of wood charcoal is around IDR 70,000 to 80,000 per m3. The purchase price is the cost incurred by the community to buy wood chip waste and wood pulp waste sold by PT Wapoga Mutiara Industries employees. Respondents based on the purchase price of wood chip waste and wood pulp can be seen in Table 2.

Table 2 explains the purchase price of wood chip waste and wood pulp by the community per month, with a range of purchase prices for wood chip waste with an average value (m^3) of IDR 166,667, - minimum value (m^3) IDR 100,000, - maximum value (m^3) IDR 500,000, the purchase price of wood pulp waste with an average value (m^3) IDR 140,455, -

minimum value (m^3) IDR 50,000, - maximum value (m^3) IDR 500,000. Total value is the addition or reduction of satisfaction due to adding or reducing one unit of a particular commodity seen using wood chips and pulp waste.

Table 3. Wood chip waste, wood pulp waste

Total Price (m^3)	Average (m^3)	Minimum (m^3)	Maximum (m^3)	Total (m^3)
Wood Scrap Waste	IDR 1.762.500	IDR 300.000	IDR 10.000.000	Rp 1.762.500
Wood Pulp Waste	IDR 1.665.909	IDR 150.000	IDR 8.400.000	Rp 1.665.909

Table 3 explains the total price of wood chip waste and wood pulp by the community per month, with a total price range of wood chip waste with an average value (m^3) of IDR 1,762,500, - minimum value (m^3) IDR 300,000, - maximum value (m^3) IDR 10,000,000, - the total price of wood pulp waste with an average value (m^3) IDR 1,665,909, minimum value (m^3) IDR 150,000, - maximum value (m^3) IDR 8,400,000. Purchase Cost is the cost incurred by the community to buy wood chip waste and wood pulp waste to be utilised.

Table 4. Cost of Purchasing Solid Waste

Total Price (m^3)	Average (m^3)	Minimum (m^3)	Maximum (m^3)	Total (m^3)
Wood Scrap Waste	IDR 143.750	IDR 50.000	IDR 300.000	IDR 3.450.000
Wood Pulp Waste	IDR 166.667	IDR 100.000	IDR 500.000	IDR 4.000.000

Table 4 explains the cost of purchasing wood chip waste, Average Value (m^3) IDR 143,750,000, - Minimum Value (m^3) IDR 50,000, - Maximum Value (m^3) IDR 300,000, - Total (m^3) IDR 3,450,000, - wood pulp waste, Average Value (m^3) IDR 166,667, - Minimum Value (m^3) IDR 100,000, - Maximum Value (m^3) IDR 500,000, - Total (m^3) IDR 4,000,000. The use value of natural resources can be estimated directly from consumption or production, where market mechanisms determine goods. Use value is the value obtained from the direct use of or related to the natural resources under study or the output (goods and services) contained in the resources that can be directly utilised. In this case, PT Wapoga Mutiara Industries can manage wood waste again to produce economic value.

Utilisation of wood waste into wood charcoal is the process of reprocessing wood waste is a process where reducing environmental pollution or the impact caused during the wood processing process that occurs at PT Wapoga Mutiara Industries; the wood waste reprocessing process is divided into two things, namely: Wood scraps from cutting that are still in good condition and not too small in size can be reprocessed into more extended pieces of wood. The remaining wood scraps can be sold back to the community, and The sawdust produced during the production process is collected and sold back to the community.

One of the utilisations made by the community to reprocess the waste to become an economic value for the community is buying waste wood pieces and wood pulp waste sold by PT Wapoga Industries employees, which are reprocessed by the community and utilised as wood charcoal. Wood waste is the remains of wood or wood parts that are considered to have no economic value in a particular process, at a certain time and in a specific place, which may still be helpful in a different process and time and wood waste is utilised by the community and employees so that it is not thrown away or burned so that it can overcome environmental pollution. The advantage obtained from PT Wapoga Mutiara Industries employees is to sell/reprocess solid waste for resale to the community. The advantage obtained from the community is to buy solid waste sold by employees to make the economic value of the solid waste to make/process it into wood charcoal briquettes and open new jobs for the community.

This research focuses on the value of direct use of wood waste for charcoal production, highlighting its economic benefits to the communities around PT Wapoga Mutiara Industries. In addition, research by Alpian et al. (2022) on converting wood waste into

activated charcoal showed that not all types of wood waste meet the quality standards for activated charcoal, suggesting limitations in the usefulness of specific wood waste for charcoal production. Similarly, Weng et al. (2018), who has researched converting sago waste into value-added products, present a model to maximise industrial waste's economic and environmental benefits, suggesting that a more diversified approach to wood waste utilisation may yield better results.

The economic value of wood waste from production processing, particularly in the context of PT Wapoga Mutiara Industries, highlights significant opportunities for pollution reduction and economic improvement through the direct use of wood scrap waste. This is echoed in research which underscores the potential of forest biomass resources, including wood processing plant residues, for bioenergy conversion, thereby contributing to Indonesia's energy mix and offering increased economic value (Dafi et al., 2023).

Similarly, the broader issue of waste management in Indonesia suggests that cultural practices and economic incentives can be essential in shaping environmental outcomes (Firdausi et al., 2022). The direct use value derived from utilising wood scrap waste for charcoal making, as observed among communities surrounding PT Wapoga Mutiara Industries, is in line with findings from Saputra, A. Z., & Fauzi, A. S. (2022), who explored waste management through incineration, producing charcoal and liquid smoke as by-products. This approach not only addresses waste reduction but also utilises the economic potential of waste as a resource. In addition, research on recycling waste in Indonesia shows a parallel in waste valorisation, where waste paper management significantly reduces waste volume while contributing to environmental sustainability (Kurnia et.al., 2022). Studies on wood processing in Indonesia further support this principle of turning waste into valuable products. Afrianisa (2022) suggested that sawdust waste can be converted into liquid smoke for fish preservatives, thus utilising waste for economic gain. The value of direct use of wood waste for manufacturing charcoal and other by-products presents a viable pathway for increasing economic value and reducing environmental pollution. This is consistent with broader research findings across Indonesia, which advocate innovative and sustainable use of waste materials to generate economic benefits while addressing critical environmental challenges (Anggraini et al., 2022; Fransisca et al., 2018; Bintang et al., 2019; Budi et al., 2018)

4. Conclusions

Based on the description and analysis in the previous chapter, the conclusion that can be drawn is that wood waste from production processing at PT Wapoga Mutiara Industries provides significant economic benefits to the surrounding community. Specifically, the total direct use value of wood chip waste is recorded at IDR 42,300,000 per month, while the direct use value of wood pulp waste is IDR 72,860,000 per month. Thus, the total direct use value of both types of wood waste reached IDR 116,160,000 per month, which provides a potential income of IDR 1,350,700 per person per month.

The significant average revenue per person from wood waste shows that the wood processing industry not only acts as a material processor but also as a driver of the local economy. Wood waste income helps improve the quality of life of surrounding communities and reduce poverty levels. The efficient utilisation of wood waste at PT Wapoga Mutiara Industries helps reduce negative environmental impacts, such as waste reduction and greenhouse gas emissions. This is in line with the principles of sustainable development that focus on economic benefits and environmental balance. Besides being used for charcoal making, wood waste can be processed into various other products, such as energy briquettes, building materials, and raw materials for the chemical industry. This product diversification can open up more jobs and sources of income for the community.

Investments in training and skill development of local communities in managing and utilising wood waste can improve production efficiency and product quality. This, in turn, will increase the competitiveness and added value of the products produced. PT Wapoga

Mutiara Industries can work with the government and research institutions to develop new technologies and best practices in wood waste processing. This cooperation will improve operational efficiency and strengthen the company's commitment to social and environmental responsibility. This development demonstrates that wood waste, which is often perceived as leftover material, actually has great economic potential that can be utilised to boost the local economy, support environmental sustainability, and strengthen community capacity.

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Author Contribution

Conceptualization, J.Y.W. and R.N.W.; Methodology, J.Y.W.; Software, A.G.A.; Validation, S.M.P.; Formal Analysis, J.Y.W. and R.N.W.; Investigation, A.G.A.; Resources, J.Y.W.; Data Curation, J.Y.W.. ; Writing - Initial Draft Preparation, J.Y.W. and R.N.W.; Writing - Review & Editing, A.G.A.; Visualization, S.M.P.; Supervision, R.N.W.; Project Administration, A.G.A.; and Funding Acquisition, J.Y.W.

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Informed Consent Statement

This research has received permission and recommendations from PT Wapoga Mutiara Industries and the surrounding community.

Data Availability Statement

Research data can be accessed at the Library of the Faculty of Economics and Business, University of Papua.

Conflicts of Interest

There is no conflict of interest in the research activities conducted in Paniai Regency because this research is purely to obtain recommendations for tourism development in Paniai Regency.

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