**Jurnal Ekonomi Teknologi & Bisnis (JETBIS)**
Volume 2, Number 6 June 2023
p-ISSN 2964-903X; e-ISSN 2962-9330

# BOOSTING CIRCULAR ECONOMICS ON MUNICIPAL WASTE MANAGEMENT: CASE STUDY IN, WEST JAVA

**Iman Chaerudin[1], Vita Sarasi[2]**
STIE UnisadhuGuna, Indonesia
iman.chaerudin@ubs-usg.ac.id, vita.sarasi@unpad.ac.id

**KEYWORDS :**
Circular Economic; Municipal Solid Waste; Sustainable Waste Management Business.

## ABSTRACT

The economic development and population rapid growth has led to the uncontrolled increase of Municipal Solid Waste (MSW) generations in West Java since around half of the world's waste production is MSW from the residential, commercial, and service sectors. Currently, the government implements some actions of MSW management, such as composting programs, recycling programs, and MSW banks. Although the programs run well they can only reduce 18% of MSW every day. Thus, the government is still facing MSW problems while landfill, as the most common waste disposal practice, is considered unsustainable. Now the government is trying to shift its mind that sound waste management should generate economic, social & environmental value while offering great opportunities to the private sector for revenue-making business instead of a cost center. The purpose of this study is to develop a circulating economic business model on the recycling and recovery system of MSW using green technology to create alternative sustainable products for social development business as a circulating economy. This is applied research that uses the qualitative analysis method to get a zero household waste management model based on secondary data (from the period of 2019-2022) from the pilot project at the Nambo site, Cirebon plant, and Cibiru site. The result of the study is beneficial for the government in supporting its policies to recycle & recover MSW. Moreover, the integrated business process of MSW will encourage the private sector to invest in sustainable waste management businesses.

## INTRODUCTION

Research findings indicate that household solid waste exhibits a direct correlation with population growth, but its growth rate is comparatively lower than that of household income. Additionally, the reduction in solid waste generation is not commensurate with the rise in waste collection service charges. In economic terms, this implies that the household demand for waste services exhibits unitary elasticity concerning population, while it demonstrates inelasticity concerning income and price factors (Johnstone & Labonne, 2004). MSW management in Indonesia is becoming more complex every day due to a variety of reasons. The amount of waste accumulated in National Final Disposal Sites (TPAS) nationwide reaches 66.39%, indicating that the current waste management practices in Indonesia are still ineffective in reducing waste volume. If the waste issue is not addressed promptly, by the year 2020, the volume of waste in Indonesia is projected to increase fivefold, amounting to 1 million tons of garbage per day (KLHK, 2016). Based on the aforementioned phenomenon, the West Java Regional Government is committed to improving the management and processing of household waste through the implementation of a new technology called Mass Biological Technology (MBT) (Chaerul et al., 2007). This technology aims to generate something that holds economic value for the community and businesses. It involves creating a process for managing household waste that can transform it into alternative materials while also reducing the use of large landfill areas (Fransisco Szekely, 1992).

As shown in Figure 1, Geographically, West Java province is located in the Southern Latitude 5o 50' – 70 50' and East Longitude 1040 48'- 1080 48' East with a total area is 35.377,76 km2. 2019, In 2019, the population of West Java Province reached 46,497,175 people, making it the most populous province in Indonesia. Due to economic growth and industrialization, two-thirds, or 66.5% of the population live in urban areas in West Java (Marques & Teixeira, 2022). While One-Third or 30, 8% of the population lives in areas of Bogor, Depok, and Bekasi which is the supporting area of the Capital City, Jakarta. Based on the population of Western Java today the province of West Java will generate 35,337 tons of Municipal Solid Waste (MSW) or 141,351 m3 per day or, every people (Indonesian) generates  0,76 kg/day of solid waste on average (Alexandra, 2012).

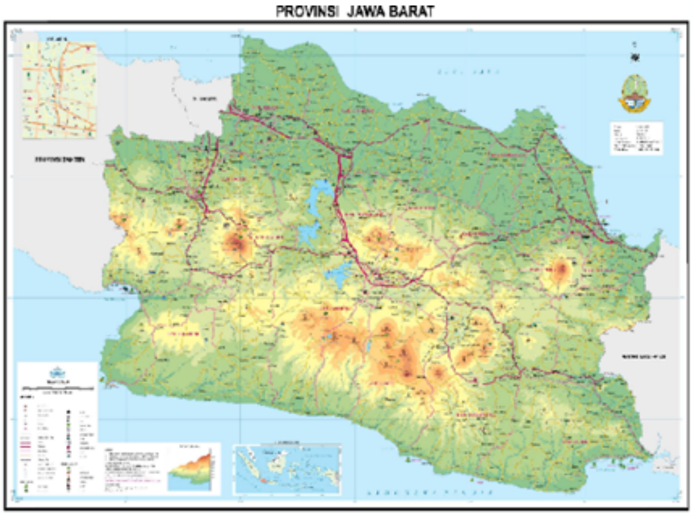


**Figure 1**
**West Java Map**

Indonesia, as a rapidly developing country, faces significant challenges in waste management, particularly in densely populated areas such as West Java (Adel Azar, and, 2011). The current waste management practices in the region are primarily focused on disposal, leading to environmental pollution, health hazards, and resource depletion. To address these issues and promote sustainable development, there is a growing need to boost circular economy principles in municipal waste management. At present, approximately 85% of the collected municipal solid waste (MSW) is disposed of in landfills, while only 15% undergoes recycling processes. The Government develops community-based solid waste management treatment located in the household or near the area of the source; it can reduce only 18% by weight of MSW. In the absence of interventions addressing waste management and treatment at the source, and considering the estimated annual growth rate of municipal solid waste (MSW) at approximately 2-4%, the MSW volume is projected to surpass 40,000 tons per day or 160,000 m3 per day by 2020. This would necessitate an additional 12,721 hectares of disposal land annually and nearly double that amount in the following decade. Certainly, the ineffective and inefficient condition of household waste management presents a challenge for the West Java Provincial Government to carry out sustainable household waste management practices. There is a pressing need to effectively manage municipal solid waste (MSW) in a manner that minimizes environmental degradation and reduces reliance on Final Disposal Sites.

This research aims to investigate and analyze the potential for boosting circular economics in municipal waste management, with a specific focus on the case study of West Java. The primary objectives are (Porter, 2002):

1. Assessing the existing waste management practices in West Java, including waste generation, collection, treatment, and disposal methods.
2. Identifying the key challenges and barriers to implementing circular economy principles in municipal waste management.
3. Analyzing the potential opportunities and benefits of adopting circular economy approaches in West Java's waste management system.
4. Proposing strategies, policy recommendations, and practical solutions to enhance circular economics in municipal waste management in West Java.

The research outcomes will provide valuable insights into the current status of municipal waste management in West Java and highlight the potential for integrating circular economy principles. The findings will contribute to the existing literature on circular economy and waste management, particularly in the context of developing regions. The proposed strategies and policy recommendations will serve as a roadmap for policymakers, waste management authorities, and other stakeholders to enhance circular economics in West Java's waste management system.

## RESEARCH METHODS

The method used in this study is an exploratory survey. The type of research used is qualitative research. The scope of observation in this study is a time series, meaning that the information or data obtained resulted from research conducted over some time from 2019 to 2022. This research will be conducted using the Analytical Hierarchy Process (AHP) approach. AHP will be used to analyze three alternative waste management techniques, namely MBT (Mechanical Biological Treatment), sanitary landfill, and open dumping, based on social, economic, environmental, and technological aspects. The unit of analysis in this study is the Regional Disposal Site and the Price Purchase Agreement (PPA) in West Java. The observation unit focuses on the Business Unit Recycle Processing Plant (Ackerman, 2013). The research methodology includes reviewing relevant documents and conducting field visits to key areas where municipal solid waste (MSW) is disposed of or managed. Additionally, key informant interviews (KIIs) will be conducted with Government Agents to gather valuable insights and information.

## RESULTS AND DISCUSSION

Based on the above phenomenon, If household waste management continues to be carried out in such a manner, it will lead to waste accumulation at the TPPAS, causing an overload in waste capacity, potential land erosion, pollution, and health issues. The conventional approach has traditionally involved systematically collecting, transporting, and disposing of waste in municipal landfills. In a typical Municipal Solid Waste (MSW) management system, waste is initially stored in various types of containers and collected regularly, ranging from daily to three times a week, as depicted in Figure 2 below. In this system, the waste is not directly taken from each source to final disposal, but it is first brought to temporary transfer stations. In the second stage, the waste is transported by open trucks, dump trucks, or compactor trucks. Meanwhile, in the direct transportation system, the waste is picked up by using the open truck, dump truck, or compact vehicle, and then transported to the final disposal.

This research focuses on the development of environmental economics in the context of municipal waste management. The emphasis on the concept of environmental economics as the main approach to optimizing the economic benefits of municipal waste and reducing environmental impact, can be a new contribution in this research domain.


**Figure 2**
**Current MSW System in West Java**

Additionally, the current waste management processes do not implement a circular business model that could provide benefits and added value to household waste, which has the potential to be utilized as renewable energy. The primary waste management techniques commonly used are landfilling and composting, as they offer cost-effective solutions. In the case of West Java, the government aimed to enhance the MSW hauling service level from 63.52% in 2013 to 73% in 2018 by increasing the available fleet. Additionally, the goal was to improve composting systems to treat up to 20% of the waste. These objectives were outlined in Table 1 of the Government Work Plan of West Java in 2015 (Kularatne, 2015).

**Table 1**
**MSW Trasported Service Level *)**
***) West Java in Figure Year 2015 – BPS Statistic West Java – page 191-192**

| Description | 2013 | 2014 | 2018 |
|---|---|---|---|
| Service | 63.52% | 57.42% | 73% |
| Waste generation | 46.393m3/d | 60.289m3/d | 50.799m3/d |
| Waste transported | 29.472m3/d | 34.619m3/d | 34.794m3/d |
| Fleet available | 975 unit | 1,126 unit | 1,450 unit |

As shown in Table 1, in 2013 Total daily waste generation is 46.393 m3/day, and the total daily waste transported to the landfill is 29.472 m3/day. The waste generation in 2018 is estimated to achieve 50.799 m3/day. The largest contribution of household waste comes from the cities and greater of Bekasi, Bandung, and Bogor, each generating 4,307 m3/day, 13,173 m3/day, and 4,083 m3/day, respectively. Therefore each waste generation has a correlation with each population in those two areas (Swink et al., 2014).

The average production of MSW in West Java was estimated between 0,4 kg and 1.1 kg per capita/ day. The total MSW generated by West Java people was about 11,598 tons/day (46,392 $m^3$ per day) in 2013 and 35,378 tons per day (141,351 $m^3$ per day) in 2015. It is predicted to increase double in the next 10 years

West Java Province initiated the Integrated Regional Waste Management in three areas in 2006 to address the issues and mitigate the environmental impact, as illustrated in Figure 4 below.

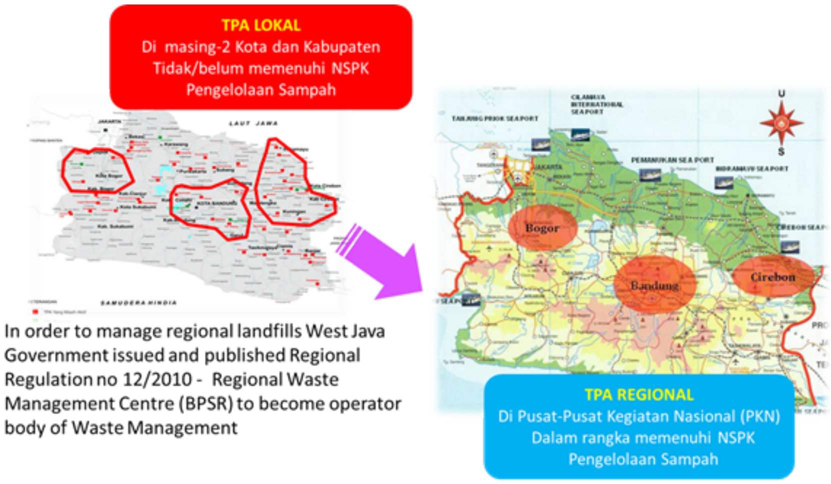


**Figure 3**
**Regional Waste Management Policy at West Java**
Source: Regional Waste Management Centre, 2020

Since one-third of 30,8% of the population live in areas such as Bogor, Depok, and Bekasi which is a supporting area of the Capital City, Jakarta. And also the overload condition of the final disposal site (TPA) of Galuga and Cipayung Bogor is shown in Table 2 below.

**Table 3**
**Condition of Waste Management 2021 ***

| No | Region | Waste production | Level of service | Final disposal site | condition |
|---|---|---|---|---|---|
| 1 | Bogor city | 457 ton/day | 77% | galuga | Overload |
| 2 | Depok city | 759 ton/day | 21% | Cipayung | Overload |
| 3 | Bogor region | 904 tons/day | 10% | Galuga | Overload |

The "command and control" approach involves government authorities enacting legislation regarding the use of waste management and ensuring its enforcement. To manage regional landfills West Java Government-issued and published Regional Regulation no 12/2010 regarding Regional Waste Management and Develop a special institution called **Regional Waste Management Centre** (**BPSR**) to become the operator body of Waste Management in West Java. The objectives of BPSR are as follows;

a. Regional waste policy in the Bandung Basin (Bandung City, Cimahi City, Bandung Regency), Bodebek (Bogor, Depok, Bekasi), and Ciayumajakuning (Cirebon, Indramayu, Majalengka dan Kuningan) includes respective Regional Final Disposal Sites (TPPAS)
b. Reducing household waste generation;
c. Development of waste process infrastructure, to effectively utilize land for a period of up to 25 years;
d. Creating environmentally friendly and functional green products with eco-friendly technology;
e. Establishing collaboration between the West Java government and private.

In response to the previous regulations from the minister and West Java governments, the West

Java Provincial Government issued Governor's Decree Number 660.1/Kep.577-Invest&BUMD/2015 on June 17, 2015, inviting stakeholders to collaborate in planning waste management at the Regional Final Disposal Site (TPPAS).

To promote the implementation of circular economics in waste management, the West Java Government, together with PT. Indocement researched household waste types and their moisture content. The research findings illustrate that the waste composition consists of 48.17% food waste (organic), 24.37% plastic, 7.91% paper materials, 1.78% metal, 5.05% wood, and 1.54% glass, with a high water content ranging from 45% to 65%. The high moisture content, temperature, and pressure within the waste piles that are deposited in landfills contribute to the generation of leachate. If the generated leachate is not controlled, it can affect the ground and surface water, thus posing a potential danger to human health. There is an economical, sustainable, and environmentally friendly technology for this condition known as Mechanical Biological Treatment (MBT). The MBT system is a waste processing facility that combines a sorting facility with a form of biological treatment, such as composting or anaerobic digestion. MBT plants are designed to process mixed household waste as well as commercial and industrial waste. MBT can be used as an alternative method to process waste and produce a high-calorific fuel known as Refuse Derived Fuel (RDF). RDF can be utilized in cement kilns or thermal combustion power plants and typically consists of plastics and biodegradable organic waste.

To select the best waste management concept from several alternative concepts that have been developed previously based on economic, social, environmental, and technical aspects, the Analytic Hierarchy Process (AHP) method will be used. To create a hierarchy of processes in this research, the initial step is to determine the objective of selecting the concept for Waste Management and Treatment Technology (WMTT). Then, identify and group the criteria related to WMTT, including social, economic, environmental, and technical aspects. Under each aspect, sub-criteria are established. The Social Aspect includes changes in community behavior and public health. The Economic Aspect encompasses investment size, operating costs, and economic value generated. The Environmental Aspect covers the reduction of water pollution, land use, and residue management. The Technical Aspect includes waste reduction, land utilization, and value-added outputs. Finally, determine the alternative waste management and treatment concepts, namely **Sanitary Landfill, Open Dumping**, and **MBT.**

**Table 3**
**Determination of waste management criteria and sub-criteria**

| Criteria | sub-criteria | Description | Indicator |
|---|---|---|---|
| Social | SK 1 | The welfare of the community, | Number of waste pickers |
| | SK 2 | Public health | Level of diseases caused by waste |
| Economics | SK 3 | Investment Size | Investment Cost (IDR) |
| | SK 4 | Operating Cost | Operating Expenses (IDR) |
| | SK 5 | Economic Value | IRR, NPV |

| | | | |
|---|---|---|---|
| Environmental | SK 6 | Reducing Water Pollution | Leachate Volume |
| | SK 7 | Land Use | Land Area (m2) |
| | SK 8 | Residue Reduction | Residue Quantity (%) |
| Technical | SK 9 | Reducing Waste Generation | Waste Volume (m3) |
| | SK 10 | Land Benefit | Life Time (Years) |
| | SK 11 | Technology of Waste | Reduction Quantity |
| | SK 12 | Value-Added Output | Benefits of Waste Utilization |

Source: Data Survey, Processed data, 2021

The next step is to calculate the weights given by respondents through the questionnaire for criteria, sub-criteria, and alternatives. The first calculation involves determining the combined assessment for the predetermined criteria: Social, Economic, Environmental, and Technical, as well as their respective sub-criteria. This combined assessment is obtained by calculating the geometric mean based on the criteria comparison from the questionnaire distributed to 12 waste management operators in West Java who already have waste processing and waste banks. Some of them are TPAS Nambo, TPAS Cempaka, TPAS Baros, TPAS Cicalengka, TPAS Cipayung, TPAS Galuga, TPAS Sari Mukti, TPAS Hegarmanah Sumedang, TPA Cipayung, TPA Pasir Gambung Cianjur, TPAS Cicabe Padalarang, TPAS Jelekong Bandung. The result of weighting must be equal to the total weighting of the hierarchy, such as follow.

**Table 4**
**The weighting of Criteria in Household Waste Management.**

| Criteria | sub-criteria | Indicator | Weighted |
|---|---|---|---|
| Social (0.480) | SK 1 | Number of waste pickers | 0.819 |
| | SK 2 | Level of diseases caused by waste | 0.181 |
| Economics (0.123) | SK 3 | Investment Cost (IDR) | 0.226 |
| | SK 4 | Operating Expenses (IDR) | 0.446 |
| | SK 5 | IRR, NPV | 0.328 |
| Environmental (0.182) | SK 6 | Leachate Volume | 0.434 |
| | SK 7 | Land Area (m2) | 0.160 |
| | SK 8 | Residue Quantity (%) | 0.406 |
| Technical (0.214) | SK 9 | Waste Volume (m3) | 0.517 |
| | SK 10 | Life Time (Years) | 0.930 |
| | SK 11 | Waste Reduction Quantity | 0.165 |
| | SK 12 | Benefits of Waste Utilization | 0.225 |

Source: Data Survey, Processed data, 2021

Based on above Table 4, the Social aspect has the highest weighting value of 0.480. The Technical aspect has the second-highest weighting value of 0.214. The lowest weights are assigned to the Environmental aspect (0.182) and the Economic aspect (0.123). The weighting of these aspects indicates that improving waste management and treatment processes should primarily focus on the social and technical aspects. This highlights the importance of community well-being in the sustainability of waste management business processes, while the technical aspect is crucial for supporting production processes in waste management and treatment.

The weighting of each sub-criterion within the waste management and treatment aspects is as follows: For the Social aspect, the highest weight is assigned to community well-being with a value of 0.819. This indicates that community well-being is an important consideration in improving the business model of waste management and treatment. Adopting sustainable waste management concepts can positively impact the productivity of the community, such as creating job opportunities for residents or waste pickers in the area.

The highest weight in the Economic aspect is assigned to operating costs, which is 0.446. From an economic perspective, the MBT waste management method requires significant expenditure compared to the current waste management system. This is due to the need for high initial capital investment in machinery and equipment for waste transportation and processing into fuel. However, if a forecast is made, it can result in substantial profits, allowing the recovery of the initial capital investment. In the Environmental aspect, the highest weight is assigned to reducing water pollution, which is 0.434. This aspect is closely related to the social aspect, as reducing water pollution requires public awareness and responsible waste disposal practices, such as avoiding dumping waste into rivers or direct discharge of industrial wastewater. The MBT method can contribute to reducing water pollution through its sustainable waste treatment concept. Lastly, in the technical aspect, the highest weight is assigned to waste reduction. With the MBT method, waste generation can be reduced as the output of the process is 35% RDF (Refuse Derived Fuel). This means that the remaining waste that cannot be turned into fuel is significantly reduced.

Since the Nambo Final Disposal Site is located near the cement industry and facilities, it offers the most cost-effective and sustainable business model, resulting in a 50% reduction in the requirement for landfill sites. The utilization of Refuse Derived Fuel (RDF) as an alternative energy source has emerged as one of the optimal solutions for waste management in addressing future challenges. By Law No. 18 of 2008 on Waste Management, the development of RDF as an alternative energy source can enhance the economic value of waste while simultaneously reducing reliance on fossil fuels, particularly coal. Consequently, this contributes to the reduction of greenhouse gas emissions (GHG). The Regional Waste Management Centre (BPSR) of West Java, in collaboration with "Indocement," has initiated an Integrated Solid Waste Management (ISWM) project for handling 80 tons per day of Municipal Solid Waste originating from Temporary Waste Storage sites in Bogor and Depok, as illustrated in Figure 5 below (Kardono, 2007).


**Figure 5**
**Pilot Project of Final Disposal Site Nambo**
Source : Indocement Tunggal Prakarsa, 2019

The purpose of this experiment is concerned with the current situation: source of waste generation, processes used to manage solid waste, the effectiveness of the process, and effect and impact on the public. Then suggested an integrated and sustainable business model for waste management, especially in West Java. The site is located in Nambo Village near "Indocement" with Mechanical Biological Technology (MBT) to produce Refused Derived Fuel (RDF) which will be sent and applied at Indocement Plant. The average production of MSW in the Bogor & Depok surrounding area is 1.000 -2.000 tons/day while the amount of waste received on the experiment site is about 80 tons/day from the Temporary Storage around Bogor & Depok Area. The waste transfer transport by 10 -12 trucks belongs to the government every day to produce 26 tons/day of RDF in 21 days with a heating value of 4.560 kJ/kg while Indocement will absorb 500 tons/day RDF to replace coal as Preheating Fuel. And the waste will be received 360 days per year. They are compacted to half-one volume using a landfill compactor to expand the project life of the landfill. In operation of The experimental project was using 1 loader and 1 operator, 8 workers, and 1 manager on 12 hours days.

Although Solid Waste Management is a public utility service nevertheless it is also important as an economic sector. Waste is not always an unwanted product. A waste product can be converted into a profitable operation. Refused Derived Fuel (RDF) is an economic product for the cement industry as an alternative fuel to coal with 4.560 Kj/Kg. In case the amount of received waste is 1000 tons/day Waste characteristics have been assumed based on the sampling and analysis data. While on the full operation is done by :

- 1 Manager,
- 40 Equipment Operators in 2 shifts,
- 2 QC Engineers in 2 shifts,
- 4 Mechanics in 2 shifts, and

• 10 Common Workers in 2 shift

The cost of capital amounted to USD. 30,855,712 and the waste should be received in 16 hrs (8:00–24:00) with worker number and work time considered for shift work are 474 workers. The Operation & Maintenace cost should be USD. 4,504,489/month.

In the discussion with the Regional Waste Management Centre (BPSR ) and PT. Indocement so far, there is the possibility of income recyclable plastics. The market price of the waste plastics trade depends on the type of plastic but ranges at approximately Rp 350.000/kg. To be conservative, an average trading price of Rp 800/kg is assumed to be possible. To be on the safe side of the potential for sale and pricing, approximately 4,600 USD/day of income source is anticipated.

123ton/day × 40% × Rp 800/kg = Rp 39,360,000/day *(approximately USD4,600/day)*

Incidentally, the income from service fees (tipping fee) is USD 10,000/day in the case that the tipping fee is USD 10/ton. The IRR of the ISWM is 14,2% and the payback period is 8 years. This is called the recycling economy since it assists to stop the pile of MSW of 25% and stop decreasing environment value by reducing 50% of the landfill site and also reduce coal usage by 50%, while on the other side, there is an opportunity to invite private investor as a new business with creating employment opportunities of 5 people/ ton of Waste.

## CONCLUSION

Based on the analysis and description of the research findings on the waste management system in 12 TPPAS in West Java, the following conclusions are obtained As the disposal of waste volume increases, the use of open dumping and sanitary landfill for waste management is not appropriate. This condition leads to the area becoming more congested and forming waste piles that can cause landslides, air pollution, and groundwater contamination. Consequently, it creates problems for the surrounding environment, particularly the health of the local community. After examining the primary environmental issues in Greater Bogor City, Depok, Bekasi, and Bandung, it is evident that waste minimization plays a significant role. Furthermore, new business opportunities have begun to emerge for industries actively involved in preventing and addressing environmental problems in these major cities. Household waste management using MBT has the highest weighting value because it has the technical aspect with the second-highest weighting value. This is due to its successful ability to process waste quickly, reducing waste generation and extending the lifespan of land up to 25 years using environmentally friendly recycling technology. Additionally, this technology can transform household waste into Refuse Derived Fuel (RDF), which embodies the Waste-to-Energy concept as a reflection of Circular Economics theory. There are success factors that can be drawn from the Nambo pilot project in applying integrated solid waste management solution approaches, such as:

a) Waste management is an opportunity, not a burden.
b) Waste is like a mirror that reflects various aspects of society. The state of a society is closely related to its economic, historical, cultural, environmental, and other aspects.
c) On a national average, there are 5 jobs, $9,250 million wages, and $ 450 tax revenues attributable, for every 1,000 (US) tons of recyclables collected and recycled.
d) Public-private partnerships are essential for successful waste management programs.

e) To improve the situation, there is an urgent need to act strategically on improving overall MSW management system that includes a variety of management aspects such as collection and transportation, intermediate treatment, final disposal, institutional and financial aspects, and public participant and environment education.

## BIBLIOGRAPHY


Ackerman, F. (2013). *Why do We Recycle?: markets, values, and public policy*. Island Press. Google Scholar

Adel Azar , and, K. B. (2011). Developing a model for "Business Process Orientation" using Interpretive Structural Modelling Approach. Department of Industrial Management, School of Management & Economics, Tarbiat Moderas University, Teheran, Iran, African. *Journal of Business Management*, *7*(26), 2558–2569. Google Scholar

Alexandra, L. C. (2012). Municipal Solid Waste: Turning a Problem Into Resourcewaste: The Challenges Facing Developing Countries, Urban Specialist. *World Bank*, 2–4. Google Scholar

Chaerul, M., Tanaka, M., & V Shekdar, A. (2007). Municipal solid waste management in Indonesia: status and the strategic actions. 岡山大学環境理工学部研究報告, *12*(1), 41–49. Google Scholar

Fransisco Szekely. (1992). Managing the Environment in Megacities, Business Potential of Industrial Waste. *European Management Journal*, *10*(3). Google Scholar

Johnstone, N., & Labonne, J. (2004). Generation of household solid waste in OECD countries: an empirical analysis using macroeconomic data. *Land Economics*, *80*(4), 529–538. Google Scholar

Kardono, K. (2007). Integrated solid waste management in Indonesia. *Proc. International Symposium on EcoTopia Science 2007*, 629–633. Google Scholar

Kularatne, R. K. A. (2015). Case study on municipal solid waste management in Vavuniya township: practices, issues and viable management options. *Journal of Material Cycles and Waste Management*, *17*, 51–62. Google Scholar

Marques, A. C., & Teixeira, N. M. (2022). Assessment of municipal waste in a circular economy: Do European Union countries share identical performance? *Cleaner Waste Systems*, *3*, 100034. https://doi.org/https://doi.org/10.1016/j.clwas.2022.100034. Google Scholar

Porter, R. C. (2002). The economics of waste. Resources for the Future, Washington, DC. *Resource Policy*, *30*(2), 141–142. Google Scholar

Swink, M., Melnyk, S. A., Cooper, M., & Hartley, J. (2014). *Managing operations* (Vol. 1260547639). New York: McGraw-Hill/Irwin. Google Scholar