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Research Article

Optimization of Waste Management at the Purwosari Material Recovery Facility (MRF) Mijen District, Semarang City

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Abstract

Semarang City is working on constructing a Material Recovery Facility (MRF) in various urban villages to reduce the waste that enters the Jatibarang Landfill. However, the construction of MRF is not optimal. MRF Purwosari still functions as a container without waste processing. By projecting waste generation for the next ten years, the results of optimization planning are processing waste into RDF, redesigning MRF covering an area of 1,571 m^2 with an investment cost of IDR 1,602,837,997 and an operational cost of IDR 307,741/ton/day. The NPV value was Rp.4,836,965, EIRR 12%, and BCR value of 1.81.

Keywords: optimization, waste management, MRF, Semarang

1. Introduction

Material Recovery Facility (MRF) which is in some places in Indonesia is called Integrated Waste Processing Site (IWPS) is a place where collecting, sorting, reusing, recycling, processing, and final processing waste are carried out (Law Number 18 of 2008). In line with the SDGs (Sustainable Development Goals) efforts that have been regulated in Presidential Regulation Number 59 of 2017 concerning the Implementation of the Achievement of Sustainable Development Goals, that one of the national targets is the realization of a green city that is climate and disaster-resilient through the development and application of green water, green waste (waste and waste management through reducing reuse-recycle), and green transportation. The waste management target set by the government is 70% in 2025, which is regulated in Presidential Regulation Number 97 of 2017 concerning National Policies and Strategies for the Management of Household Waste and Waste Like Household Waste. However, waste management on the downstream side cannot be used as a focus because the condition of the landfill in Indonesia is experiencing many problems, such as the age of the landfill, which has exceeded its design life, the condition is complete but still forced to accept new waste, there is no land for building a landfill, and still using the open dumping and controlled landfill system (Purnomo, 2020). In Semarang, waste management on the downstream side is the final waste processing at the Jatibarang Landfill. Reporting to Ayosemarang.com, in 2020, the amount of waste that enters the Jatibarang Landfill will average 900-1000 tons per day. With an area of around 46 hectares, the Jatibarang Landfill

will likely be complete within three years. To overcome the waste problem at the Jatibarang Landfill, Semarang implements a regional-scale waste management system through the material recovery facility program, which aims to reduce the volume of waste generated to be transported to the Jatibarang Landfill (Kustyardhi *et al*., 2008). One of the MRF built by the Semarang City Government is the Purwosari MRF located in Mijen District.

Purwosari MRF is located on Jalan Sodong, Purwosari Village, Mijen District, Semarang City. Purwosari MRF has only been running since 2019 by serving one RW in Purwosari Village. KSM activities are still focused on waste bank activities and have not processed organic waste. The waste counted into the Jatibarang Landfill from the Purwosari MRF is 6 tons/day consisting of 2.5 tons/day organic waste and 3.5 tons/day of inorganic waste. This study aims to analyze the existing conditions of the Purwosari MRF management, make a design for optimizing waste management in Purwosari MRF and calculate the economic feasibility of waste management in Purwosari MRF.

2. Method

The location of the MRF is in Purwosari Village, Mijen District, Semarang City, with the waste service area planned to cover the entire Mijen District. Planning is carried out for six months, from September 1, 2020, to March 31, 2021. There are several steps in the optimization planning of MRF Purwosari, which will be explained further.

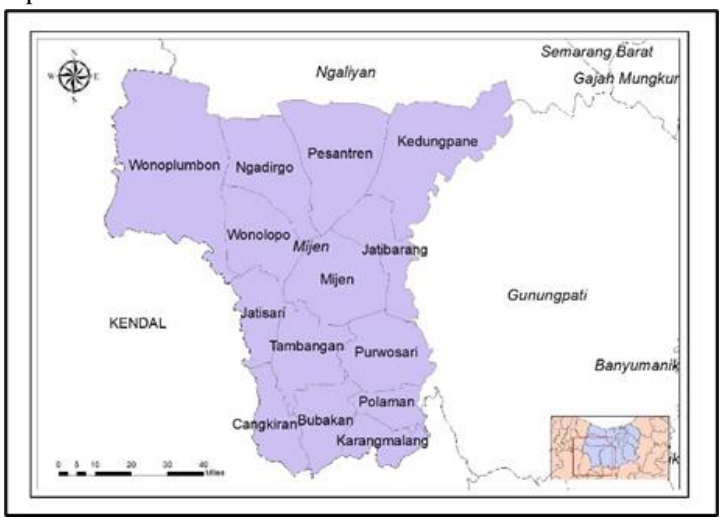

Figure 1. Planning Location

2.1 Assessment of Existing Condition of Purwosari MRF

The assessment of the existing condition of the Purwosari MRF includes five aspects of waste management, namely regulatory aspects, institutional aspects, technical-technological aspects, financing aspects, and community participation aspects. The data needed in this stage was obtained from interviews with KSM Sido Rahayu and field surveys.

2.2 Study of Population Data and Gross Regional Domestic Product (GRDP) of Mijen District

The study of population data and GRDP is needed to project the amount of waste produced until 2031. The GRDP used as the basis for this planning is agricultural GRDP, industrial GRDP, and GRDP per capita at constant prices in Semarang City. These three factors can determine the value of urban growth, which is one factor in calculating the growth rate of waste generation (Damanhuri & Padmi, 2019). Projection of population data and GRDP uses mathematical methods (arithmetic, geometric and exponential).

2.3 Assessment of Waste Generation Data

The study of waste generation, composition, and characteristics are needed to determine the projected waste generation to be managed by Purwosari MRF and the amount of organic and inorganic waste generated in the service area of Purwosari MRF. Data on waste generation, composition, and characteristics were obtained by sampling waste at waste sources, namely residential and non-domestic facilities. Places of worship, health facilities, offices, and other facilities using secondary data. Sampling was carried out for eight consecutive days, from December 24, 2020, to January 2, 2021. Waste samples were taken based on SNI 1994-3694-19 concerning Methods for Collection and Measurement of Samples of Generation and Composition of Urban Waste by taking samples from 28 houses. Living, 21 shops, 18 food stalls, and five minimarkets. Then a projected waste generation is carried out for the next ten years.

2.4 Planning

Planning for optimizing waste management at the Purwosari MRF from 2021 to 2031. This planning consists of calculating the dimensions and space requirements and planning for storage and transportation, regulations, community participation, and financing. After that, the economic feasibility is calculated by calculating the Net Present Value (NPV), Economic Internal Rate of Return (EIRR), and Benefit-Cost Ratio (BCR).

3. Result and Discussion

3.1 Existing Condition of Purwosari MRF

From the results of the field survey that has been carried out, Purwosari MRF currently operates as a waste bank serving RW 02 Purwosari Village, Mijen District. The waste that enters the MRF is a non-organic waste for sale, while another waste is collected in waste containers and immediately disposed of at the Jatibarang Landfill. MRF facilities in the form of a MRF building covering 200 m2 were established in 2019 and are still in good condition, consisting of office buildings, sorting tanks, and 6 m3 waste containers. In the institutional aspect, Purwosari MRF already has a management structure, namely KSM Sidorahayu. In terms of regulations, Purwosari MRF does not yet have written regulations regarding waste processing procedures MRF. In community participation, the community of RW 02 Purwosari Village has separated waste into two, namely organic waste that is worth selling and other waste. In addition, the residents carry out the transportation of waste to the MRF directly, and there is a waste fee of Rp. 4,000/KK/month.

3.2 Assessment of Population Data and GRDP

The population of Mijen District is projected for the next ten years, starting from 2020 to 2031, using the arithmetic method. From the projections made, the population of Mijen District continues to grow every year. The population growth rate of Mijen District is 6.11% per year until in 2031, the population of Mijen District is 120,509 people.

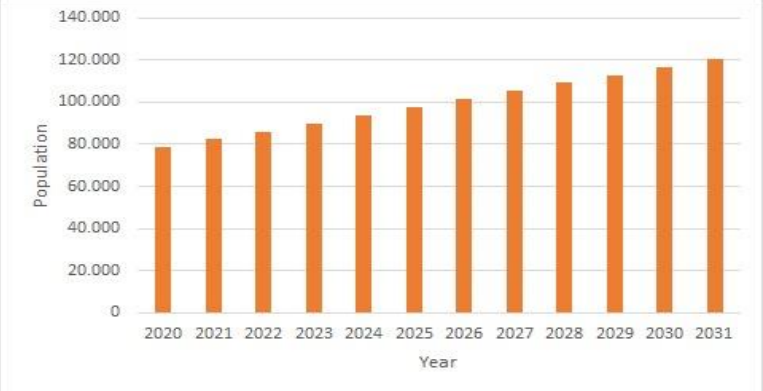

Figure 2. Mijen district population projection

In addition to carrying out population projections, the GRDP projection of Semarang City is also carried out. The GRDP projection of Semarang City is carried out using the geometric method. The projection is carried out from 2020 to 2031, with a per capita GRDP growth rate of 5.56% per year, an industrial GRDP growth rate of 5.86% per year, and an agricultural GRDP growth rate of 1. 48% per year

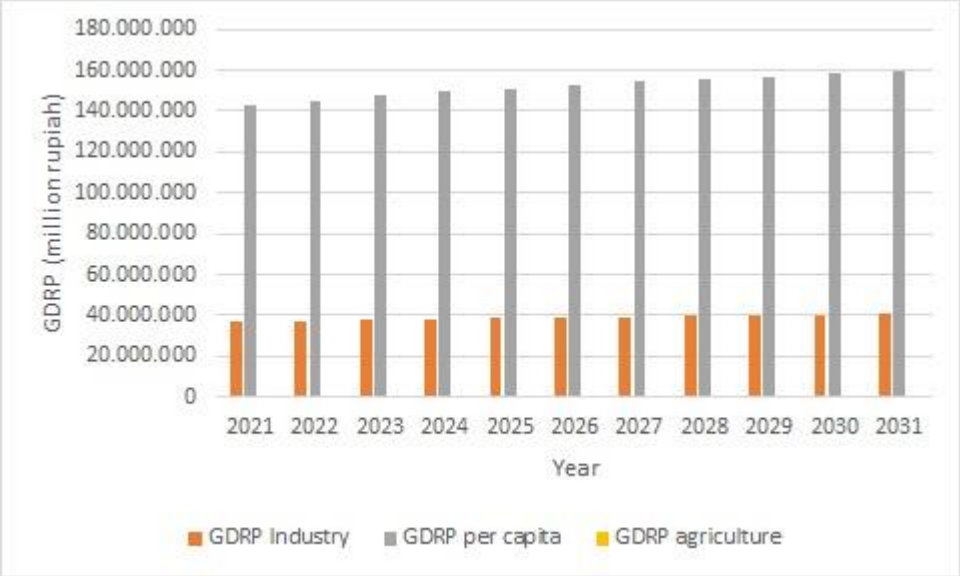

Figure 3. Projected gross regional domestic product (GRDP)

3.3 Waste Generation Data Assessment

The results of waste generation from sampling for eight days at residential facilities resulted in an average generation weight of 0.27 kg/person/day and an average generation volume of 1.875 l/person/day. Then for commercial facilities, the average weight of waste generation for shops is 1,029 kg/day with a volume of waste of 1.34 l/day, food stalls of 3,469 kg/day with a volume of generation of 7,899 l/day, and minimarkets of 1,119 kg. /day with a generation volume of 4.997 l/day.

The largest composition of waste obtained from residential facilities is food waste with 63.5%, followed by plastic waste at 26.8%. As for commercial waste, the largest composition of waste is food waste at 57.92%, followed by plastic waste at 36.10%. Then, if the composition of waste between residential and commercial waste is combined, we get 60.85% food waste, 31.45% plastic, and so on, as illustrated in Figure 4. Then projected waste growth from 2021 to 2031 with the result of generation at the end of 2031 for residential (domestic) facilities of 235,649 m^3/day and non-domestic facilities of 8,062 m^3/day.

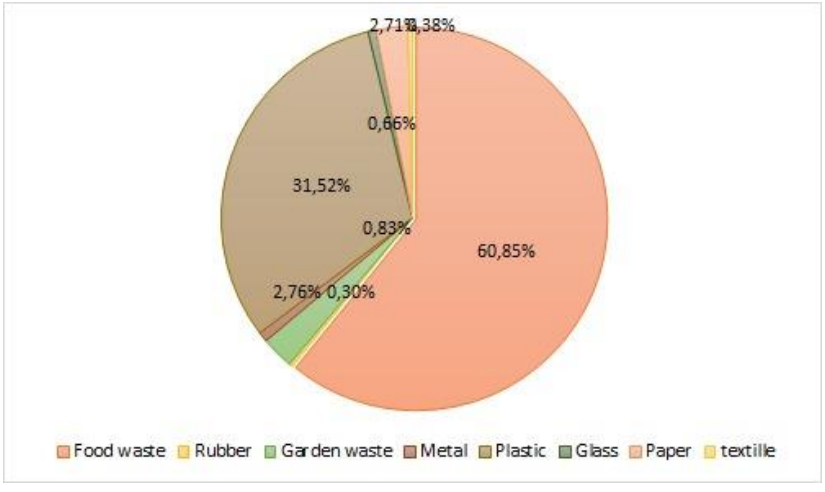

Figure 4. Mijen district waste composition

Figure 5. Waste generation projection

3.4 Planning

3.4.1 MRF Concept

In 2031, the Purwosari MRF is planned to have a service percentage of 70% with an incoming waste of 170.597 m³/day or equivalent to 22.20 tons/day. The MRF is planned to have a Waste to Energy (WTE) concept by processing organic waste into RDF and recycle it by selling inorganic waste to collectors.

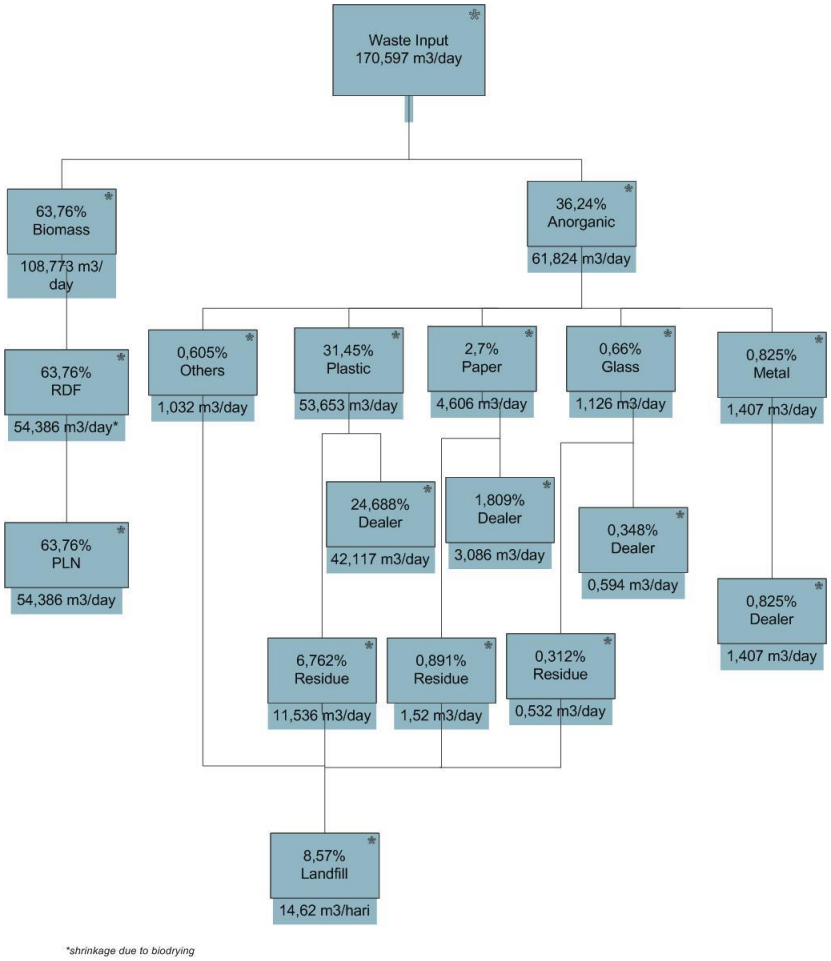

Figure 6. Waste mass balance planning at Purwosari MRF

In Figure 6, the waste that enters the Purwosari MRF is 170.597 m^3/day or equivalent to 20.22 tons/day. The waste is entered in a state that has been separated into organic waste and inorganic waste. The organic waste will then be processed into RDF (Refused Derived Fuel) bio briquettes, while the inorganic waste will be further separated to be sold to collectors. By taking into account the existing buildings that are in good condition, the MRF is planned to have the following buildings:

- Existing building (consisting of inorganic space, office, and residue area)
- Main building (consisting of pre-processing area, RDF area, and toilets)
- Supporting building (consisting of guard post and parking lot)

3.4.1.1 Loading Rate

The loading rate is the amount/capacity of waste to be processed at the MRF every hour. Purwosari MRF operational time is 7 hours, starting at 08.00 – 12.00; 13.00 – 16.00 (break at 12.00 – 13.00). So the loading rate can be calculated as follows:

$$Loading\ Rate(LR) = \frac{Waste\ Volume\ (\frac{m^3}{day})}{Process\ Time\ (\frac{hour}{day})} \quad (1)$$

$$Loading\ Rate\ (LR) = \frac{170{,}597\ m^3/day}{Seven\ hour/day} \quad (2)$$

$$Loading\ Rate\ (LR) = 24{,}37\ m^3/hour \quad (3)$$

3.4.1.2 Main Building

1. Pre-processing room

The pre-processing room is planned to have an area of 43.8 m2 which is the reception room, the area for dropping and unloading waste from garbage trucks, and the first stage waste sorting area. The reception area or tipping floor has the length of the planned area that allows for the truck arm roll to reverse direction, so it is designed to have a room width of 6 m. While garbage enters the reception area in a segregated state in the garbage sorting area, garbage with opaque (organic) sacks will be placed in the biomass waste reception room. In contrast, waste with transparent (inorganic) sacks is removed from its container, and officers will separate salable inorganic waste from the residue with the help of conveyor belts.

2. RDF room

The RDF room is planned to have 540 m2 consisting of a biomass waste reception area, a bio drying room, an enumeration room, and a pellet room. In the biomass waste reception room, biomass waste from the pre-processing room will be placed in the biomass waste reception room before the bio drying process is carried out. This space must be able to accommodate the incoming hourly biomass waste generation. While in the biodrying room, waste is carried out to remove moisture content and odors in the waste. Biodrying is done by '*peuyeumization*.' Waste disposal is carried out by placing waste into bamboo cages measuring 2 m x 1.25 m x 1 m with 1 liter of bio activator per bamboo cage. The *peuyeumization* process lasts for approximately ten days to remove the water content in the waste so that the waste shrinks by two-thirds of its initial weight (Supriadi et al., 2019).

The waste counting room is used for waste counting activities after the bio drying process is carried out. Waste counting was carried out using three shredders with a capacity of 1 ton/hour. With the dimensions of the chopping machine 1.5 m x 0.8 m x 1.2 m and a moving area of 1 m, the enumeration area is 8 m2. The chopped waste is then put into the waste pellet machine to be made into pellets. In this plan, the pellet machine used has a capacity of 300 kg/hour, so that it takes eight pellet machines with dimensions of 1.2 m x 0.8 m x 1.25 m and a moving area of 1 m to obtain a room area of 16.28 m^2.

3.4.1.3 Supporting Building

Supporting buildings consist of toilets, parking, and guard posts. Parking is located on the left side of the TPST building, restrooms are located at the back of the main building, and the guard post is located in front adjacent to the gate. The total space required for Purwosari MRF is as follows:

Table 1. Dimensions of the Purwosari MRF rooms

Buildings	Wide (m^2)
A. Existing buildings (offices, warehouses, residues)	*200*
B. Main building	
Pre-processing room	43,8
RDF room	540
Toilet	6
Total main building	590
C. Supporting buildings (guard post and parking lot)	*94*
Total	**884**

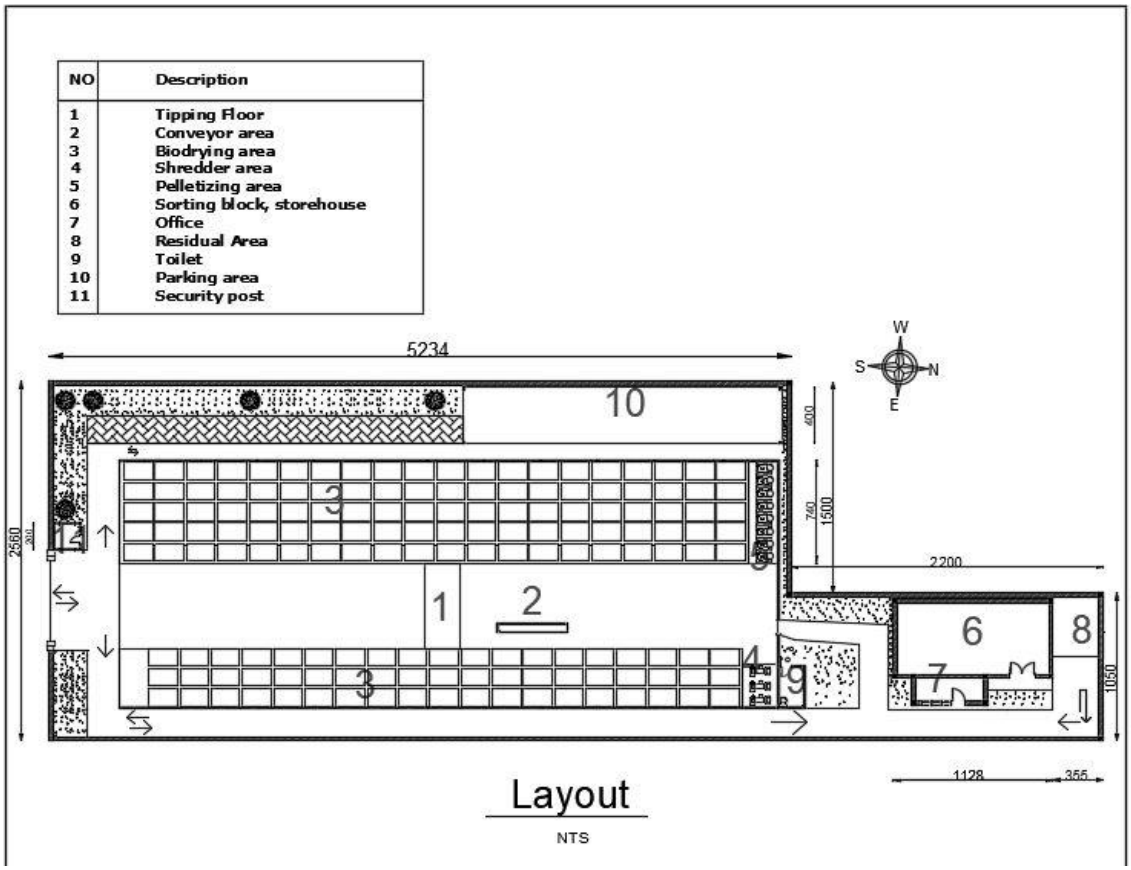

Figure 7. Purwosari MRF planning layout

3.4.2 Container and Transport

To support the achievement of segregation at the source of waste, the waste container is divided into two, namely organic and inorganic waste. The waste container used is used sacks. Organic waste containers are used opaque sacks, while inorganic waste containers are transparent used sacks. This storage using plastic bags and sacks is intended to prevent waste from being scattered and prevent leachate from dripping during the collection and transportation process. Transportation is divided into two, namely individual transportation and communal transportation. Waste transportation in Purwosari

and Polaman Villages, close to the MRF, uses a three-wheeled motor. In contrast, transportation other than in the village uses transfer by using an arm roll truck.

3.4.3 Regulation

To manage the waste management process at the Purwosari MRF, a Standard Operational Procedure (SOP) was made which regulates the sorting at the source of waste, the collection, and transportation of waste from the waste source to the MRF, sorting of salable waste, making RDF, packing, and an overview of the MRF building and machine operating procedures, such as chopping machines, pellet machines, and conveyors.

3.4.4 Community Participation

With the existence of a MRF in the community, it is hoped that the community can provide support in waste management at the MRF. The expected role of the community is planned to pay waste fees, segregate waste into two types (organic waste and non-organic waste), apply the concept of reducing waste by not using bottles, containers, and disposable shopping bags, and reusing packaged products, become household utensils, as well as re-growing vegetable waste. For the community to play a role in waste management, regular socialization and guidance from KSM are required at least once a month.

3.4.5 Financing

The financing aspect includes investment costs, operational costs, sales proceeds, and community contributions.

3.4.5.1 Investment Cost

Investment costs consist of construction and non-construction investment costs, and construction investment costs are MRF construction costs, consisting of constructing the main building, security post, parking area, and construction of a perimeter fence. The construction investment cost required is Rp. 1,283,211,761.40, and non-construction investment costs in the form of purchasing waste processing machines, staff equipment, and vehicles require a cost of Rp. 365,650,100, so the total investment cost is Rp. 1,602,837,997.09

3.4.5.2 Operating costs

Operational and maintenance costs include asset depreciation and MRF operational costs: MRF worker salaries, waste processing equipment maintenance costs, electricity costs, and water costs, with a total operational cost in 2031 of Rp. 3,027,779,278, or Rp. 307,741,30 tons/day. Compared to typical waste operational costs (Tchobanoglous & Kreith, 2002), the operational and maintenance costs for recycling and RDF are around 20 to 40 USD/ton/day or converted into rupiah in March 2021 it is equivalent to Rp. 290.740/ton/day until Rp. 581,480/ton/day, the operational and maintenance costs of the Purwosari MRF, according to the typical cost of the dam, are still within reasonable numbers.

3.4.5.3 Sales results

The products produced from waste processing at the Purwosari MRF include RDF, salable plastic, salable paper, salable metal, and salable glass. By projecting prices up to 2031, the sales results in 2031 can be calculated as follows:

RDF	= Rp. 647/kg x 16,993.6 kg x 20 days x 12 months	= Rp. 2,642,149,698.85
Plastic	= Rp. 3,239/kg x 152.6 kg x 240 days	= Rp. 118.656.565,16
Paper	= Rp. 2,600/kg x 190 kg x 240 days	= Rp. 1,952,731,79
Metal	= Rp. 3,510/kg x 14.8 kg x 240 days	= Rp. 1,185,618,45
Glass	= Rp. 260/kg x 63.7 kg x 240 days	= Rp. 37,096.68

From the above calculation, the total sales revenue in 2031 is Rp. 2,821,719,616,48

3.4.5.4 Community Dues

The ideal community contribution is obtained from operational costs divided by the number of families served, but to ease the burden of expenses incurred by the community, 70% of the operating costs are taken from the sales of products, so the number of community contributions can be calculated as follows:

$$\text{Fees} = \frac{\text{Total operating expenses} - 70\% \text{ of sales}}{Number\ of\ KK}$$

$$= \frac{Rp\ 3.027.779.278 - (70\%\ x\ Rp\ 2.821.719.616{,}48)}{32163\ KK}$$

Contribution fee = Rp. 37,432/KK/year

Contribution fee = Rp. 3,119/KK/month

3.5 Calculation of Economic Feasibility

Feasibility analysis is used to assess whether the project is feasible or not. In the MRF optimization plan, the feasibility analysis carried out is the Net Present Value (NPV), Benefit-Cost Ratio (BCR), and EIRR (Economic Internal Rate of Return). With an interest rate (i) of 11.59% calculated from the average interest rate for the last five years, the NPV, EIRR, and BCR values are obtained as follows:

$$NPV = \sum_{t=0}^{T} \frac{Ct}{(1+i)^t} - Co = Rp\ 4.836.965{,}67$$

$$EIRR = i_1 + (i_2 - i_1)\frac{NPV_1}{NPV_1 - NPV_2} = 12\%$$

$$BCR = \frac{Present\ value\ benefit}{Present\ value\ cost} = 1{,}810$$

From the calculations that have been carried out, the NPV value is Rp. 4,836,965.67 (NPV>0), which means that the profit generated from the project is greater than the required expenditure. The EIRR of the project is 12%, higher than the interest/discount rate used, and the BCR is 1,810 (BCR>0), which means that the Purwosari MRF optimization planning project is feasible to run.

4. Conclusion

Optimization of Purwosari MRF in the form of expansion of the sub-district scale, inorganic waste will be sold to collectors. In contrast, organic waste is used as RDF, increasing the building area to 1,571 m², a total investment cost of Rp. 00/KK/month. The NPV value was Rp 4,836,957 (positive), the EIRR value was 12% (greater than the discount rate), and the BCR value was 1.81 (positive).

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