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Waste-Derived Fuels as a Renewable Energy Source (Physical-Chemical Quantity-Quality) Compared to Coal

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Abstract

DKI Jakarta Province produces ±7,500 tonnes of waste per day, and this municipal waste is transported daily to the Bantargebang integrated waste management facility. The existing waste capacity of Bantargebang has reached 39 million tonnes. This waste can be used as a renewable energy source and replace the use of coal. This research aimed to see the ability of waste derived fuel to substitute coal. The data was collected through a literature review and processed using the literature review method. The literature was searched using SINTA, Google Scholar and Scopus Index. Refuse Derived Fuel (RDF) can substitute coal in terms of the calorific value (CV) produced, but the water and ash content in RDF is relatively high compared to coal.

Keywords: *Bantargebang, Municipal Waste, Refuse Derived Fuel.*

1. Introduction

DKI Jakarta Province is one of the largest waste-producing provinces in Indonesia. With a recorded population in 2023 of 10.68 million people (BPS, 2022). The daily waste generated by DKI Jakarta province reaches ±8,000 tonnes a day. Waste generated in DKI Jakarta Province (except Kepulauan Seribu) will be distributed and managed at TPST Bantargebang.

TPST Bantargebang is located in the city of Bekasi, West Java. It has been used to accommodate waste disposal from the DKI Jakarta area since 1989. TPST Bantargebang is managed by the DKI Jakarta local government with the concept of an Integrated Waste Management Centre (TPST). TPST Bantargebang has an area of 110 ha and has been owned by the DKI Jakarta provincial government since 1999. TPST Bantargebang, consists of six disposal zones based on the origin of waste and the type of waste disposed from DKI Jakarta (zones I - V) and Bekasi City (zone VI) (Mulana et al., 2014). The maximum capacity of TPST Bantargebang is ± 49 million tonnes (Sukwika & Noviana, 2020).

The volume of waste generated by DKI Jakarta province in a day can reach ± 8,000 tonnes / day, where the waste generated is 60% dominated by domestic or household waste and throughout the year recorded 3.11 million tonnes. Based on data from the Environmental Agency in 2022, the composition of waste entering Bantargebang TPST consists of 49.87% biodegradable waste, 17.24% paper, 3.18% wood, 1.48% glass, 1.08% metal, 0.90% cloth, 0.78% masks, 0.70% leather and 0.42% domestic hazardous waste. These wastes are distributed and managed based on their type to several temporary

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disposal sites and then end up in the Bantargebang integrated waste processing centre (TPST). The waste distributed to TPST Bantargebang is around 7,500 tonnes/day after undergoing processing before being transported. The waste processing system at TPST Bantargebang in several zones has been carried out with a landfill mining system.

Waste management in urban areas aims to establish a hygienic environment and prevent numerous health issues caused by waste. Waste is generally perceived by society as a physical and chemical nuisance; however, it presents economic and energy-related opportunities. The management of waste is hampered by technological and economic constraints. Waste can, however, be exploited as an alternative energy source towards domestic energy requirements, thus reducing reliance on non-renewable natural resources. It is predicted that coal, being an example of non-renewable natural resources, will be depleted by 2086 ((ESDM), 2021). According to the Ministry of Energy and Mineral Resources, Indonesia's coal reserves are projected to deplete in 83 years if the present production levels persist. The country has 149,009 billion tonnes of coal resources and reserves of 37,6014 tonnes, which is the largest (Geology, 2018).

Given this information, there is an urgent requirement to embrace renewable energy as a substitute for non-renewable energy. Therefore, this literature review is focused on examining the ability of waste and its derivatives as a renewable energy source compared to coal.

1.1. Purpose and Benefits

This study aims to analyse the ability of Refuse Derived Fuel (RDF) in terms of quantity - physical and quality - chemical to replace the use of coal as a non-renewable energy source.

The benefit of this research is to provide information and potential for the use of renewable energy sources based on urban waste management.

2. Method

The method used in this research is literature review. The articles used have the following characteristics:

(1) journal articles, conference articles and grey publications;

(2) contains aspects of waste management and its derivatives as a source of renewable energy;

(3) is in the range of 2013 - 2023;

(4) English and Indonesian language. Scientific literature was obtained through google scholar, SINTA and Scopus databases.

Articles were searched using the keywords "Bantargebang TPST waste management", "Refuse Derived Fuel (RDF) at Bantargebang TPST", "Potential renewable energy at Bantargebang TPST" and "Utilisation of waste and its derivatives as renewable energy".

Data analysis The data analysis used is thematic analysis, which is an analysis carried out by grouping the data into specific themes. grouping on specific themes.

3. Results

3.1. Literature Search and Description The initial search of the three selected electronic databases yielded 200 articles. The articles were screened for titles and abstracts, leaving 50 titles accessible. The 10 articles selected met the inclusion criteria and the text was thoroughly reviewed. 40 articles were excluded because they were reviews of waste management at the Bantargebang Integrated Waste Management Site and were not about waste-to-energy technologies.

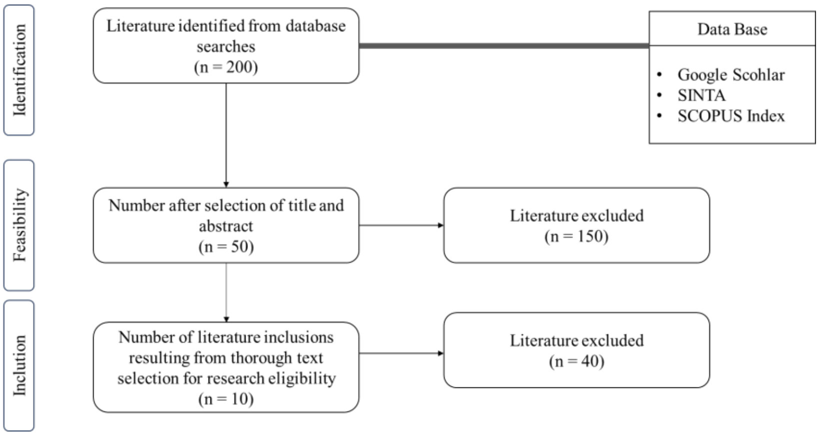

Figure 1. literature search and selection process

3.2. Integrated Waste Management Centre (IWMC) Bantargebang

Based on the results of articles collected and analysed by the author, the Bantargebang Integrated Waste Management Site is an asset of the DKI Jakarta Provincial Government and is the only final waste disposal site in the DKI Jakarta Province. The Environment Agency, (2023) states that the Bantargebang Integrated Waste Management Site has an area of 132.5 ha, consisting of 6 landfill zones covering 81.4 ha and 23.3 ha of infrastructure facilities. The capacity of the Bantargebang Integrated Waste Management Site in 2021 has reached 39 million tonnes. The average daily increase of waste in Bantargebang Integrated Waste Management in recent years is as follows

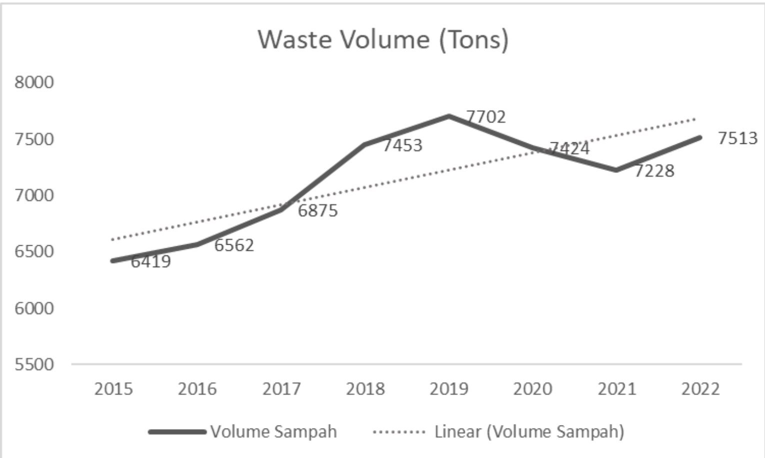

Figure 2. Graph of the waste volume increase

The composition of this waste is 49.87% biodegradable waste, 17.24% paper, 3.18% wood, 1.48% glass, 1.08% metal, 0.90% fabric, 0.78% mask, 0.70% leather and 0.42% household hazardous waste (KLHK, 2022).

Winahyu et al., (2019)The Bantargebang integrated waste management site has a system for using waste and its by-products as a renewable energy source, consisting of refuse derived fuel, a waste-to-energy plant, landfill gas management and composting.

Biogas collection refers to the methane produced through anaerobic processes during organic waste decomposition. It can be captured using a biogas collection system before being released into the atmosphere. The energy derived from biogas is predominantly methane, which can be used for cooking, heating, or electricity generation. This process reduces reliance on fossil fuels. The Bantargebang integrated waste management site employs the utilisation of landfill gas for electrical energy. In 2011, landfill gas management activities commenced, with 11 machines in operation, each with a 16 MW capacity. At present, the electricity production resulting from the landfill gas management activities is 3 MW (UPT TPST Bantargebang, 2023). (UPT TPST Bantargebang, 2023).

Composting is the outcome of the partial or incomplete breakdown of a blend of natural substances, which can be expedited by a diverse microbial population under warm, humid, and oxygen-rich or oxygen-depleted environmental circumstances (Cahaya & Nugroho, 2004). The composting process at the Bantargebang integrated waste management site derives from various landfill mining activities such as waste power generation, refuse derived fuel, and direct composting in the landfill zone. The production of compost can reach up to 3 tonnes/day.

The Waste Power Plant (PLTSa) is a facility that generates electrical energy by using waste as fuel. The process utilises thermal or biological technology to transform the chemical energy present in waste into electricity. The waste power facility located at the Bantargebang Integrated Waste Management Site (TPST) has the capacity to manage 100 tonnes per day and generate 700 kW/hour of electrical output.

The management of waste and its derivatives into solid fuel or also known as Refuse Derived Fuel (RDF) has been operating at the Bantargebang Integrated Waste Management Site. The TPST Bantargebang RDF plant has been in operation since 23 June 2023 and processes up to 2,000 tonnes of waste and solid waste per day at TPST Bantargebang. The RDF product produced is Fluffy with a total production of 700-750 tonnes/day.

The management of municipal waste into renewable energy sources at the Bantargebang integrated waste management site can use the system described by (Nanda & Berruti, 2021) (Figure 3.)

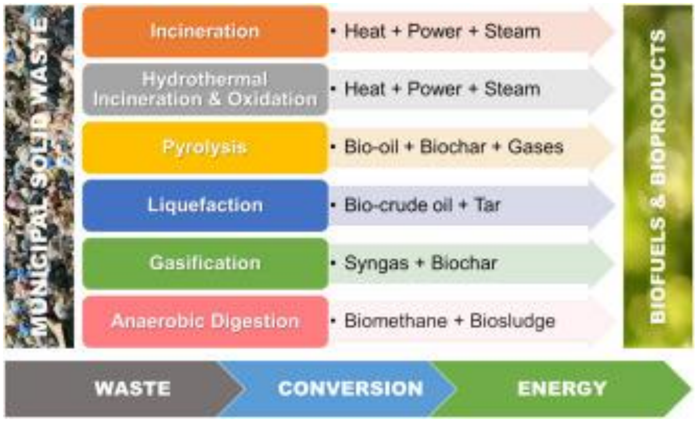

Figure 3. Conversion Of Municipal Waste To Energy

3.3. Refuse Derived Fuel (RDF)

Refuse Derived Fuel (RDF) is an alternative fuel produced from non-hazardous solid waste after certain processing. RDF is produced by taking solid waste such as household, commercial or industrial waste and removing the recyclable content such as paper, cardboard, plastic, metal, etc.

Once the recyclable materials have been separated, the remaining treated solid waste is then converted into fuel by drying it, grinding it into small granules and often compacting it into briquettes or pellets. This RDF can then be used as an alternative fuel for electricity generation or heating, replacing fossil fuels such as coal.

The advantage of using RDF is that it can reduce the amount of solid waste sent to landfill while generating energy. However, there are also challenges related to the quality of RDF, potential pollution and the management of residual waste from the RDF process. (Breeze, 2018).

RDF quality standards used in some continental European countries (Widyatmoko, 2018) (Table 1).

Table 1. Quality Standart of RDF

States	CV	Moisture	Ash	Sulfur	Chlorine
Finland	3,107-3,824 Kcal/kg	25-35%	5-10%	0.1-0.2%	0.3-1.0%
Italy	3,585 Kcal/kg	Max. 25%	20%	0.6%	0.6%
United Kingdom	4,4694 Kcal/kg	7-28%	12%	0.1-0.5%	0.3-1.2%

In Indonesia, the quality standard used to assess the quality of RDF refers to SNI 8966 of 2021 (Table 2.).

Table 2. Quality Standart RDF in Indonesia

Parameters	Unit	Class 1	Class 2	Class 3
Organic material	%	95	87.5	80
calorific value (CV)	Kj/Kg	20,000	15,000	10,000
Carbon	%	15	10	5
Volatile	%	65	70	75
Water content	%	15	20	25
Ash	%	15	20	25
Total sulfur	%	1.5	1.5	1.5
Chlorine	%	0.2	0.6	1.0
Mercure	Mg/Mj	0.02	0.03	0.08
Potassium	%	5	10	15

Based on the research of Anggraini & Purnomo, (2022) at the Taman Village Integrated Waste Processing Site, it is suggested that the calorific value of RDF derived from a mixture of organic, inorganic waste and paraffin glue can produce a calorific value of 5,218 Kcal/kg, 1.04% moisture content, 17.34% ash content and 7.4% volatile matter.

Ramadhan & Oktavia, (2022) stated that the quality of RDF produced at the Griyo Mulyo Jabon Waste Final Processing Site has a calorific value of 8.996 cal/gram with a moisture content of 5.5% and an ash content of 4.9%.

The quality of RDF produced at TPS Gresik Regency has a calorific value of 3604 Kcal/kg with an ash content of 9.61% and a moisture content of 36.62% (Aninuddin & Rosariawari, 2021).

Research based on municipal waste in several European countries found a calorific value of 5,101 Kcal/Kg and an ash content of 10.69% (Gallardo et al., 2014). A comparison of the calorific value of RDF in several Asian and European countries is shown in the table below.

Table 3. Comparasion Calorific Value (CV) in asia and europe

States	Calorific Value (CV) Kcal/Kg
Sri Lanka	7377.08

States	Calorific Value (CV) Kcal/Kg
Taiwan	3077.33
Thailand	8941.92
Korea	8871.70
Europe	5.101
Indonesia	5,218-8,996

3.3.1. Coal Condition and consumption in Indonesia

Indonesia's coal energy resources have a huge capacity of 125.25 billion tonnes and recoverable reserves of 32.36 billion tonnes. The increase in coal production in Indonesia in 2003-2016 increased by 11% per year. Coal utilisation in Indonesia includes the PLTU sector, cement industry, metarulgi industry, fertiliser industry and briquettes.

Based on data from the Directorate General of Minerals and Coal (2016), coal consumption in PLTU averaged 46.15 million tonnes for each year from 2010 to 2014, but to support the government's 35,000 MW programme, PLN will need additional coal consumption of 13.41 million tonnes and 21.00 million tonnes in 2015 and 2016, respectively, bringing total consumption to 61.41 million tonnes in 2015 and 69.00 million tonnes in 2016.

The cement industry consumed 10.54 million tonnes of coal in 2010, rising to 12.04 million tonnes in 2016.The development of coal demand in the metallurgical industry fluctuated between 2010 and 2016. The metallurgical industry consumed 3.58 million tonnes of coal in 2010 and increased to 4.64 million tonnes in 2016.The fertiliser industry consumed 1.31 million tonnes of coal in 2010 and 1.98 million tonnes in 2016.In the period 2010-2016, coal consumption in the briquette industry was stable at 30 thousand tonnes.

3.3.2. RDF at the Bantargebang integrated waste management site

The RDF processing system at the Bantargebang integrated waste processing site is a new application system. In 2023, the RDF plant began operating with a daily processing target of 2,000 tonnes of waste. The government supports the development of the RDF plant in Bantargebang by collaborating with the cement industry, which will use the RDF plant's production. The Bantargebang-designed RDF plant will also be established in various locations, specifically the Rorotan and Pegadungan RDF plants. These two extra RDF plants are projected to handle 2,500 tonnes of waste on a daily basis. The RDF plant at the Bantargebang integrated waste management site processes 2,000 tonnes of waste per day. 1,000 tonnes/day of old waste and 1,000 tonnes/day of new waste are processed. The RDF produced from these 2,000 tonnes of waste is 700-750 tonnes in fluff form.

Excavated waste at the Bantargebang integrated waste management site has the potential to be used as RDF because it is dominated by combustible waste material and has a relatively high calorific value (7.31 Mj/Kg) (Rifai & Ardiatma, 2022).

The calorific value analysis carried out showed the following results (Widyatmoko, 2018):

Table 4. Briquette Calorific Value

Peer Component	6,235.39 cal/g
Briquette CV	9,867.12 cal/g
Avarage of CV	8,051.25 cal/g

CV-Diference	1,851.86 cal/g
Deviation	22,55%

Residue produced;

Table 5. Briquete of waste residu

Residu Type	Persentage
Moisture	33.86%
Ash Content	44.72 %
CV	9867.10 cal/g

Based on the findings of the literature review performed to ensure high-quality RDF with low residue and high calorific value, it is essential to carry out preliminary treatment of waste that will serve as raw material.. The RDF produced requires pre-treatment to reduce moisture content (shredding or drying), the use of waste particles >10 mm in diameter, or the blending of waste quantities to achieve high calorific value and low ash content, and the removal of hazardous materials from the waste. (Resmianty et al., 2022).

3.4. RDF in Coal Energy Substitution

Indonesia's reliance on coal in its industrial sector can be mitigated by transitioning towards the use of renewable energy sources. Refuse Derived Fuel (RDF) can be employed as one of the measures to substitute dependence on coal energy. The ability of RDF to replace coal can be assessed by the calorific value (CV) of the two energy sources. The CV of coal is determined by the type of coal used by the industry. In general, the calorific value of coal is as follows (Arisandy et al., 2017):

- Peat, calorific value (CV) below 1,700-3,000 Kcal/Kg, hygroscopic by nature.
- Lignite, calorific value (CV) below 1500-4500 Kcal/Kg, hygroscopic by nature.
- Bituminous coal, calorific value (CV) 7000-8000 Kcal/Kg, black colour, non-hygroscopic, low ash and water content (5-10%).

The transition from coal to RDF must take into account the physical and chemical properties of RDF. It is essential to ensure that the calorific value produced is equivalent, and the residue in the form of moisture and ash content is considered. A comparison of the physical and chemical properties of Coal and RDF can be found in the following table. (Table 5.)

Table 6. Comparison of RDF and coal

Parameters	Units	Calorific value (CV)
Briquette (Widyatmoko, 2018)	Kcal/Kg	9,867,12
RDF landfill mining	Kcal/Kg	4819,220
(Rifai & Ardiatma, 2022)		
Coal lignite	Kcal/Kg	1,500 – 4,500
Coal Bituminuos	Kcal/Kg	7,000-8,000

Here's a comparison of water and ash content (Table 6.)

Table 7. Ash content and Moisture

Parameters	Ash Content	Moisture
RDF	44,72%	33.86%
Peat Coal		90%
Lignite Coal	10-40%	25-40%
Bituminuos Coal	5-15%	3-15%

In terms of moisture and ash content, RDF has a higher content than lignite and bituminous coal.

4. Conclusions and Suggestions

4.1. Conclusions

In general, the use of RDF from municipal waste can reduce and produce renewable energy sources. The calorific value produced by RDF can replace the use of lignite and bituminous coal, but the moisture content and ash content are relatively high compared to coal.

4.2. Suggestions

Further research needs to be carried out on the ability of RDF to reduce existing waste at the Bantargebang Integrated Waste Management Site and to analyse the potential of RDF after pre-treatment of water content reduction and shredding.

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