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Feasibility of Waste-to-Energy Plants for STT-PLN Campus Canteen

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ABSTRACT

The pellets of waste produced by Society Electric [*Listrik Kerakyatan* (LK) 2] at the STT-PLN have not been efficiently utilized in terms of energy. The STT-PLN canteen consists of 14 stalls with an installed electricity capacity of 1300 VA, each with 12h of use/day. This study aimed to convert LK 2 waste pellets into electrical energy to supply electricity to the STT-PLN canteen. This research method uses quantitative methods, i.e., by calculating the amount of energy produced adjusted to the needs of the canteen. Gasification technology was chosen due to its high efficiency and lower emission impacts in the waste combustion technique. Based on the analysis, the gasifier engine that complies with this requirement was TG30-1 with a maximum capacity of 25 kVA and requires a flow rate of 10 $kg.h^{-1}$ of waste pellets. The amount of waste pellets used for this plan was 120 $kg.day^{-1}$. The assessment results of this plan indicated a net present value of IDR 302,218,609.33, an internal rate of return of 25.7983%, and a PBP of 5.66 years. Based on the economic analysis, the establishment of plants for the conversion of waste to power was declared feasible to operate.

INTRODUCTION

In Indonesia, especially in the capital city, a lot of waste is generated by the public. The DKI Jakarta Sanitation Department records 7,000 tons of waste produced every day (Komara 2018). The waste is generated from a wide variety of settlements to offices. It was estimated that waste production reaches 0.5-0.8 $kg.person^{-1}.day^{-1}$ (Supriyanti 2014). Waste classified as biomass can be used as fuel for electricity generation. In a previous study, it was observed that processing waste into waste pellets could increase the calorific value of waste fuel, i.e., 2,700-3,350 $kcal.kg^{-1}$ (Sirait 2018).

Society Electric (*Listrik Kerakyatan* (LK) 2) is an innovative development project initiated by the Technical College of State Electrical Company (*Sekolah Tinggi Teknik–Perusahaan Listrik Negara* (STT-PLN)). LK 2 can be utilized to generate income if electricity generated from waste fuel can be used for the school's canteen, i.e., it could be used to supply energy to 14 kiosks of the STT-PLN canteen. Therefore, this study discusses the economic and technical feasibility of LK for supplying energy. This study also compares how much costs can be minimized if the electricity requirements for the STT-PLN canteen are supplied from LK. In addition, this would also facilitate LK in realizing 23% achievement in the project of renewable energy utilization by 2025 (Humas EBTKE 2019).

MATERIALS AND METHODS

Waste as fuel for a 15-kilowatt (kW) waste-to-energy (WtE) plant (*Pembangkit Listrik Tenaga Sampah* (PLTSa)) is evaluated to supply electricity to the STT-PLN canteen. The study is carried out at LK Campus 2 (STT-PLN), Jakarta, Indonesia. The STT-PLN canteen consists of 14 stalls, each with a power capacity of 1,300 VA. This plan was carried out to provide an overview using waste pellets in LK 2. The pellets are then used in specific generators to produce energy.

Electric Power Distribution Planning

This electricity distribution starts from the generator to the miniature circuit breaker (MCB) installed in each stall. This distribution system was designed with PLTSa as the main supplier of electricity in mind, but PLN is still used PLN in case PLTSa needs to undergo any kind of equipment maintenance in the future. The power distribution system sources from PLTSa use a TR (low voltage) system because the generator output voltage is 220/380 V.

Operation and Maintenance of Gasification PLTSa

The operation and maintenance of gasification PLTSa are based on engine operations and engine maintenance related to generation. The operational necessities of the engine are calculated by the fuel needed by the gasifier and generator to generate the electricity needed according to its capacity. The operation of a generator requires operators or workers of LK.

Cost Analysis

In development planning or project expansion, it was necessary to assess the cost and economic factors before reaching the stage of development/project implementation. Based on the results of the operational study, we can achieve the estimated project costs and its economic analysis. The analysis includes an evaluation of the net present value (NPV), internal rate of return (IRR), and payback period (PP).

NPV

According to Candra (2011), NPV is the difference between the present value of incoming cash flows and the present value of cash outflows at a given time (Gallo 2015). NPV can be interpreted as Equation (1):

$$NPV = \sum_{t=0}^{n} \frac{CIFt}{(1+k)^t} - COF \qquad \ldots(1)$$

Where,

k : Discount rate (%),

COF : Cash outflow or initial investment,

CIFt : Cash inflow at the period, and

n : Last period cash flow is expected

IRR

IRR is the rate of return that results in an NPV of cash inflows equal to the NPV of cash outflows (Sari et al. 2018). IRR is expressed as a percentage (%) per period, which is usually positive (I > 0). The project is considered profitable if the IRR yield is greater than the interest rate.

PP

PP is the length of time required to return the investment funds and can be calculated as Equation (2) (Candra 2011):

$$PPKum = Pkum + \left(\frac{|Akum|}{A\ after\ Akum}\right) \qquad \ldots(2)$$

Where,

PPKum : Period of the last cumulative negative cash flow,

|AKum| : Absolute value of the last negative cumulative cash flow, and

A after Akum : Next cumulative cash flow after the cumulative cash flow has the last value

RESULTS AND DISCUSSION

LK 2 STT-PLN Waste Pellet Production

Based on the local waste management method analysis, LK 2 produces 300–400 kg of waste pellets per day. This waste

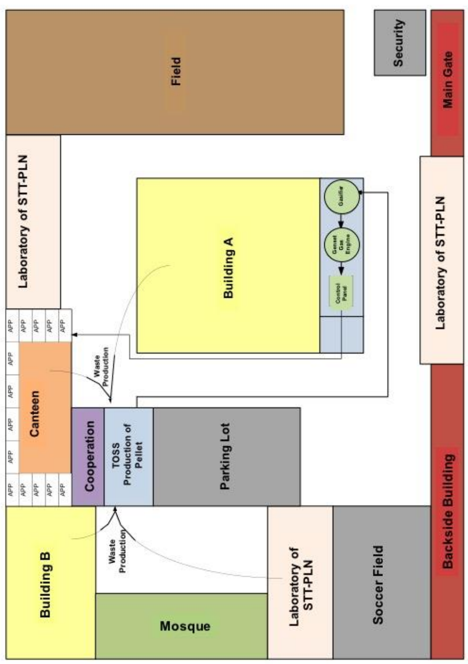

Fig. 1: Layout of PLTSa LK 2 area in the STT-PLN Campus.

pellet is sold in the range of IDR 500–600 per kg, excluding transportation costs. Meanwhile, the selling price of waste pellets in LK 2 including transportation costs is around IDR 900–1,000 per kg.

Electricity Requirement of STT-PLN Canteen

The total capacity of the 14 stalls is as follows: 1300 VA × 14 stalls = 18200 VA = 18.2 kVA. Assuming insulation factors of cos $^{\varphi}$, 0.8, the power capacity in the canteen is 18.2 kVA × 0.8 = 14.56 kW. The canteen operates 12 h per day and 26 days per month.

Electricity Requirement of STT-PLN Canteen

The STT-PLN canteen area is located close to LK 2, thereby reducing the electricity distribution costs. Fig. 1 shows the layout of the STT-PLN campus area and the placement of PLTSa equipment.

As shown in Fig. 1, the various locations in the school can be used to collect waste materials. When there is a shortage of material, waste can also be obtained from outside of the area. Waste is then processed in the TOSS pellet production plant and is then continued to the PLTSa.

Single Line and Wiring Diagram

As shown in Fig. 2, a single wiring through a Three Pole Double Throw (3PDT) switch can be used. The two electricity sources, which can be used together or interchangeably, can be managed by this device. The design then uses, for 1300 VA capacity, a miniature circuit breaker (MCB 1P), due to its small 6 A rating. Therefore, the use of the device is adequate. The MCB capacity is determined using Equation (3) for source output from the generator or PLN as follows:

$$I = \frac{P}{\sqrt{3}\ x\ V\ x\ Cos\varphi} \qquad \ldots(3)$$

$$I = \frac{15000\ W}{\sqrt{3}\ x\ 380\ V\ x\ 0{,}8} = 28{,}478\ A$$

$$28{,}478\ A\ x\ 120\% = 34{,}1736\ A$$

The above calculation shows that it requires a molded-case circuit breaker (MCCB) for capacity that is placed after the power source, assuming operation at the generator load of 75% (15 kW). Based on the analysis, MCCB 3P with a capacity of 40 A for the generator or PLN output can be used.

Fig. 3 shows that the circuit uses a 3 PDT switch (power source), which can be connected to Throw 1 or Throw 2.

Cost Comparison between PLN and PLTSa Power Sources

The canteen is open from 6:00 to 18:00, not at peak load time (past peak load time), and 26 days per month. The basic electricity tariff of PLN in March 2019 was IDR 1467.28 (LWBP) (attached). This sums up to 18.2 kVA for the 14 stalls, and it decreases to 14.56 kVA due to insulating factors. The canteen load is estimated to be 70% as it is the average load used by the facility. This shows a total of IDR

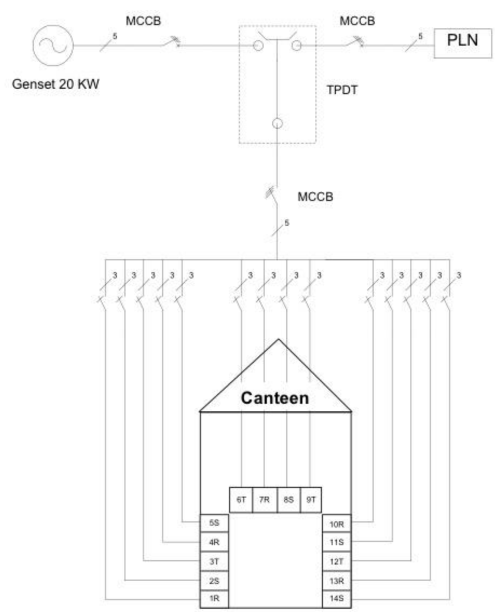

Fig. 2: PLTSa distribution diagram using direct distribution line.

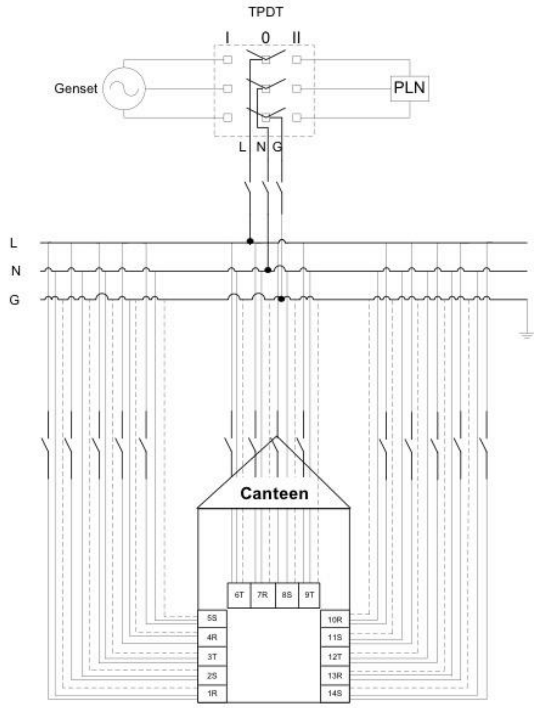

Fig. 3: Wiring diagram of PLTSa electricity distribution.

Fig. 4: Trillion gasifier (TG30-1).

179.454,213,-/day = IDR 4.665.809,5,-/month paid to the PLN.

For calculations with the tariff using the PLTSa, the production cost per kilowatt-hour is calculated from the raw material cost of IDR 500/kg, the operational cost of IDR 1.500.000/month, and supporting the cost of 10%. This gives a cost of IDR 687.17/kWh. With this production cost, the selling electricity price to the STT-PLN canteen can be set at IDR 1400/kWh with a profit of IDR 712.83/kWh. The total cost of the canteen in a month would be IDR 4.451.856,6/month, with a monthly saving of IDR 213,952,938 /month compared to PLN.

PLTSa Operational Equipment

Gasification technology (gasifier): Gasification is the process of processing solid organic material into flammable gases, such as methane, carbon monoxide, and hydrogen. A 30-hp trillion gasification unit (TG30-1, shown in Fig. 4) is utilized based on the listed specifications from the study of Sirait (2018). The design uses 510-kW PLTSa using a gasifier with TG30-1 and a 33-kVA generator installed for 3 × 8 h, where it takes 10 kg of waste pellets per hour to run gasification devices and generate electricity. The canteen load is assumed to be on for 12 $h.day^{-1}$ (6:00–18:00 West

Fig. 5: Green power genset gas engine GP25NG.

Indonesia Time), and the pellets needed per day were 10 kg × 12 $h.day^{-1}$ = 120 kg. day^{-1}.

Genset gas engine capacity: The PLTSa generator utilized in the design planning is the Green Power Engine Generator type RMG3000 GP25NG (Fig. 5), which uses gas fuel. Only one set of generator sets is needed because PLN will continue to be connected as an electricity supplier to the canteen when PLTSa equipment maintenance is held or when there is an interruption. The gas generator capacity used was 25 kVA/20 kW. The generator was planned to operate at a load of 75% of the power capacity owned by the generator (15 kW). Table 1 summarizes the specifications of the generator.

Economic Analysis

Initial investment: The initial investment represents all costs that must be incurred for development from the preparation stage to the operation phase of the plant. The data in Table 2 is obtained from interviews and observations in the field.

In this plan, it is assumed that land and buildings are already available, so no land acquisition or building costs are needed.

Expenses: This expenditure includes the cost of pellet fuel, which was assumed to be sold at the price of IDR. 500/kg (Table 3 and Table 4).

Table 1: Genset gas specification.

Generator Engine	RMG3000
Type	Four-cycle, water-cooled, gas engine
Cylinder arrangement	In-line
No. of cylinders	4
Bore × Stroke	101.6 mm × 91.4 mm
Prime-rated power (PIDR)	25 kVA/20 kW
Limited time-running power (LTP)	27.5 kVA/22 kW
Rated current	45 A
Rated voltage	400 V/230 V
Land use type of unit	Low noise, automatic type
Dimension (L × B × H)	150000 mm × 1500 mm

DISCUSSION

Income

The revenue obtained is the result of electricity sales to the STT-PLN canteen. PLTSa set a price of IDR 1400/kWh. The electricity tariff determined in this study is assumed to increase by 4% every year because it refers to PLN's electricity tariff, which also goes up annually.

The generator is planned to operate at 75% (15 kW). Every year, it is estimated that there is a decrease in the electricity production performance to anticipate the addi-

Table 2: Initial investment development.

Initial investment		
No	Item	Total (IDR)
1	Mechanical and electrical equipment	160,000,000
2	Distribution network	15,500,000
Total		175,500,000
Tax 10%		17,550,000
Total + Tax		193,050,000

Table 3: Operational cost.

Operational			
No	Remark	Monthly (IDR)	Yearly (IDR)
1	Fuel	1.716.000	20.592.000
2	Operational (operator, admin/overhead)	1.500.000	18.000.000
Expenses		38.592.000	3.216.000

Table 4: Operating costs with a 10% increase rate.

The assumptions increase operational costs every 5 years (in IDR)			
1st	6^{th}	11th	16th
20,592,000	22,651,200	24,916,320	27,407,952
18,000,000	19,800,000	21,780,000	23,958,000
38,592,000	42,451,200	46,696,320	51,365,952
28,692,000	32,551,200	36,796,320	41,465,952

tional costs of maintaining the generator annually. The total income multiplied by the factor is around IDR 2.232 billion for 20 years.

Based on the evaluation of the feasibility of the project with a value of NPV > 0, the requirements have been met based on the calculation results. Furthermore, the IRR value obtained from calculations using the Microsoft Excel formula was 18.519%, which was higher than the initial interest rate (10%). Meanwhile, the PP calculated using Equation (2) resulted in the 4.45th year.

Qualitative Impact Analysis

PLTSa is part of the development of renewable energy in Indonesia. Local waste management such as this study would help reduce waste transport fees including those toward a dumping site. Transport could generate more emissions and requires more manpower, which could be reduced using this method. The biological–chemical processing such as anaerobic digestion and sanitary landfills can also produce biological gas energy and the risk of accumulation of gas deposits and low energy efficiency (Woodard & Curran, Inc. 2006). Waste and sewage treatment through a modern gasification process can increase efficiency by up to 90%, reducing many environmental impacts (Sikumbang et al. 2018). Therefore, although the PP is not as fast as other businesses, the environmental impact could be better.

Analysis of the environmental impact is as follows:

1. Promote, support, and develop the use of EBT in Indonesia.
2. Payment for canteen electricity was cheaper per kWh.

CONCLUSİONS

Based on the results of this research, the following can be concluded:

1. 120 kg of waste pellets per day was needed for the operation of the TG30-1 as a supplier of gas (fuel) for the GP3NG type GP25NG Green Power Engine, which was planned to operate at 75% of the capacity of the generator, i.e., 15 kW.
2. A three-phase MCCB with 40-A capacity was needed for the output of the generator set. Meanwhile, to distribute electricity to the canteen, the connection switch panel was designed with a 3PDT switch that functions to change the source flow from PLTSa (I) to PLN (II), if at any time there was maintenance or disruption in distribution at PLTSa.

With a selling price of IDR 1400/kWh, the profit gained by the canteen will be IDR 213,952,938/month so that it will not burden consumers. In this plan, NPV > 0 is IDR 302,218,609.33, the IRR value > interest rate (10%) is 25.7983%, and the return on investment of this PLTSa planning is 4.45 years. Therefore, this study is feasible to proceed.

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