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Techno-Economic Analysis of Gasification Technology With Various Types of Biomass in Mobile Biomass Gasifier P2

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Abstract: The purpose of this study is to determine the value of LCOE for gasification systems with several types of biomass fuel, to know the economic feasibility of gasification systems with several biomass fuels, and to know the most economical type of biomass to be used as Mobile Biomass Gasifier P2 fuel. The research methods used in this study include quantitative approaches and several stages of research. The stages of research consist of the formulation of the problem, where the research problem is identified and formulated to determine the methods and analysis to be used. This research resulted in bagasse being the most economical biomass choice with an LCOE value of Rp 1,050.17/kWh, followed by cotton waste, straw, corn cobs, and rice husks. In addition, gasifier systems with bagasse biomass also show good economic feasibility based on NPV, IRR, PBP, and BCR parameters.

Keywords: Teknologi gasifikasi, Mobile Biomass Gasifier P2, Biomassa, LCOE (Levelized Cost of Energy)

INTRODUCTION

Fossil energy is currently still a primary energy source in meeting energy needs in the world. Along with the growth of the economy and the world population, of course, the need for fossil energy also increases. On the other hand, fossil energy is a major factor causing global warming where the burning of fossil fuels accounts for 85% of CO_2 emissions released into nature worldwide[1]. So in 2015, delegates from 196 countries

[1] Sangita Choudhary, Tapan Panda, and Abhishek Behl, "Modelling the Linkage between Fossil Fuel Usage and Organizational Sustainability," *Journal of Cleaner Production* (2023): 137440.

around the world gathered together at the UN Climate Change Summit held in Paris, France to discuss the issue of global warming and climate change. The outcome of the conference was the Paris Agreement which aimed to limit global warming to below 2ºC, preferably 1.5ºC when compared to pre-industrial levels[2]. The agreement also aims for each country to set targets, make plans and provide progress reports on the plans. Indonesia targets a New Renewable Energy (EBT) mix of 23% by 2025. The policy of the National Energy Council (DEN) aims to contribute to reducing greenhouse gas emissions and increasing resilience toward Indonesia's energy independence and sovereignty[3]. The 2021 report states that currently, the NRE mix has only reached 11.5%. One of the efforts to accelerate the achievement of the national energy mix in 2025 is to encourage a circular economy with the support of research and innovation.

Biomass is a promising source of renewable energy and deserves to be a priority to pursue Indonesia's energy mix target, which currently only accounts for 10% of the total NRE mix in Indonesia. Biomass has a large and varied supply, besides that biomass technology itself is similar to existing fossil fuel technology so that biomass fuel can be combined with fossil fuel technology and slowly replace fossil fuels. Biomass energy was traditionally used for cooking 80,000 years ago and still accounts for 7.5% of the world's total energy use. In electricity generation technology, biomass accounts for 2.2% of the world's total electricity production, not much different from solar cell technology (2.4%) [4].

Indonesia itself as a tropical country has abundant biomass reserves. The Indonesian Biomass Energy Society (MEBI) recorded the potential of generating resources from Biomass reaching 32.6 GW. Even so, Biomass Power Plants (PLTBM) have only reached 5.5 GW. In 2012 conducted a survey of Indonesia's biomass energy potential whose results showed that the largest biomass energy potential was in rice agricultural waste, which was 150 GJ/year. The rice agricultural waste in question includes all parts of rice farming residues such as rice stalks and rice husks. Xiong state that 20% of rice production is chaff[5]. Rice husks can produce energy of 3,053 Cal / Ton according to FAO data (2015) shows that Indonesia produced 14

[2] J Delbeke et al., "The Paris Agreement. Towards a Climate-Neutral Europe: Curbing the Trend. 24-45," 2019.

[3] Republik Indonesia, "Peraturan Pemerintah Republik Indonesia No. 79 Tahun 2014 Tentang Kebijakan Energi Nasional," *Lembaran Negara RI Tahun*, no. 300 (2014).

[4] Sigrid Kusch-Brandt, "Urban Renewable Energy on the Upswing: A Spotlight on Renewable Energy in Cities in REN21's 'Renewables 2019 Global Status Report'" (MDPI, 2019).

[5] Liangming Xiong et al., "Influence of Impurity Ions on Rice Husk Combustion," *Journal of metals, materials and minerals* 19, no. 2 (2009).

million tons of rice husks in 2014. The Biomass Gasification Laboratory of the University of Indonesia focuses on research in the process of biomass energy conservation through the gasification process. Gasification is a thermochemical process that converts organic matter into a combustible gas through partial oxidation. The main product is called producer gas consisting of H2, CO, and CH4 with by-products of ash, biochar, and tar. Gasification has the advantage of simplicity compared to other biomass utilization technologies. Gasification can convert a variety of biomass into combustible fuels relatively quickly and can be turned into a wide range of scales[6]. Therefore, gasification technology is one of the most promising technologies today that can utilize biomass to produce energy[7]. When compared to combustion, gasification has its advantages, namely an increase in power generation efficiency that can reach 60% greater and the ability to utilize syngas for products other than electricity[8].

The Gasification Laboratory of the University of Indonesia has a Mobile Biomass Gasifier P2 with a capacity of 10 kW of electricity. The tool can be used to directly convert raw husks into electrical energy or heat. However, a byproduct of gasification is tar, which is a compound of harmful organic matter that can interfere with electricity generation. Therefore, gasifiers are designed to have high efficiency with low tar content. The type of gasifier used is a downdraft type gasifier that is simple to produce and operate and can be directly integrated into an ICE generator due to the low tar content of the gas producer as shown[9]. Gagliano show that the use of small-scale downdraft gasifiers for the industry is a good and environmentally friendly option[10]. Several studies have been conducted to determine the most optimal operating parameters for rice husk fuel, but the ability of this tool for other fuels is not yet known. So, this study focuses on knowing the most economical fuel as fuel for the Mobile Biomass Gasifier P2 tool simulated using the Ansys Computational Fluid Dynamics (CFD) application. The analysis and simulation using the CFD application are discussed separately, then the results of the analysis will be used in this

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[6] U B Kaupp and K-W Koch, "Cyclic GMP Releases Calcium from Leaky Rod Outer Segments," *Vision Research* 24, no. 11 (1984): 1477–1479.

[7] Steffen Heidenreich and Pier Ugo Foscolo, "New Concepts in Biomass Gasification," *Progress in energy and combustion science* 46 (2015): 72–95.

[8] Samsudin Anis and Z A Zainal, "Tar Reduction in Biomass Producer Gas via Mechanical, Catalytic and Thermal Methods: A Review," *Renewable and sustainable energy reviews* 15, no. 5 (2011): 2355–2377.

[9] Juan Daniel Martínez et al., "Experimental Study on Biomass Gasification in a Double Air Stage Downdraft Reactor," *Biomass and Bioenergy* 35, no. 8 (2011): 3465–3480.

[10] Antonio Gagliano et al., "Evaluation of the Performance of a Small Biomass Gasifier and Micro-CHP Plant for Agro-Industrial Firms," *International Journal of Heat and Technology* 33, no. 4 (2015): 145–154.

study to analyze the economic aspects. The economics of fuel use is reviewed from several economic analyses such as Levelized Cost of Energy (LCOE) as a basic parameter and several other analyses such as NPV, IRR, and PBP.

The purpose of this study is to determine the value of LCOE for gasification systems with several types of biomass fuel, to know the economic feasibility of gasification systems with several biomass fuels, and to know the most economical type of biomass to be used as Mobile Biomass Gasifier P2 fuel. This research has far-reaching benefits, both in terms of science, industry, and the general public. By utilizing the results of this research, it can be expected that there will be an increase in the development of sustainable gasification technology and contribution to climate change mitigation efforts.

LITERATUR REVIEW

Gasification Technology

Gasification is one method of converting energy from solid fuels to gas. Biomass gasification technology is one of the modern technologies developed through thermochemical conversion. Biomass gasification has been widely developed in various countries. One technology to convert waste into renewable energy is using thermochemical processes or gasification[11]. The gasification process can be done using several media such as oxygen, water vapor, and air. In addition, there are several types and parameters of the gasification process that need to be considered such as types of gasifiers, gasification process parameters, and gasification processes from MSW, Biomass, and Coal[12].

Biomass gasification has several advantages such as being able to produce gas that can be used as an alternative fuel, reducing solid waste, and reducing greenhouse gas emissions[13]. However, there are several challenges in the development of gasification technology such as high costs, limited availability of raw materials, and technical problems in operation[14]. Therefore, it is necessary to conduct further research and development to

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[11] Samarjeet Singh Siwal et al., "Recovery Processes of Sustainable Energy Using Different Biomass and Wastes," *Renewable and Sustainable Energy Reviews* 150 (2021): 111483.

[12] Özgün Tezer et al., "Biomass Gasification for Sustainable Energy Production: A Review," *International Journal of Hydrogen Energy* 47, no. 34 (2022): 15419–15433.

[13] Muhammad Amin et al., "Hydrogen Production through Renewable and Non-Renewable Energy Processes and Their Impact on Climate Change," *International journal of hydrogen energy* 47, no. 77 (2022): 33112–33134.

[14] Anh Tuan Hoang et al., "Characteristics of Hydrogen Production from Steam Gasification of Plant-Originated Lignocellulosic Biomass and Its Prospects in Vietnam," *International journal of hydrogen energy* 47, no. 7 (2022): 4394–4425.

improve efficiency and overcome challenges in the development of gasification technology.

Biomass

Biomass is organic matter obtained from plants and used as a source of energy in large quantities. Biomass can come from a variety of sources such as trees, plants, and agricultural and urban waste[15]. The use of biomass as a renewable energy source has several advantages such as helping to diversify energy supply, create growth and employment, and reduce greenhouse gas emissions. In addition, biomass production from waste is more profitable, of course, it can also provide added value from the waste produced. However, there are some disadvantages in the use of biomass such as biomass energy is not as efficient as fossil fuels, is not completely clean, and can lead to deforestation[16]. Therefore, further research and development is needed to improve efficiency and overcome shortcomings in the use of biomass.

Biomass can be used as a source of fuel power and used as building materials, animal feed, and others. In addition, biomass materials can also be sold and exported as a source of income[17]. Many benefits of biomass can be felt in everyday life such as minimizing air pollution, increasing state income, and reducing environmental pollution because the material is environmentally friendly. In addition, biomass can also save the use of fossil fuels and prevent climate change. In the long run, biomass has great potential to provide a cost-effective and sustainable resource, as well as reduce greenhouse gas emissions[18]. Therefore, the use of biomass as a renewable energy source can be an attractive alternative to overcome the energy crisis and reduce negative impacts on the environment.

Mobile Biomass Gasifier Prototype 3 (P3)

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[15] Thi Thuy Van Nguyen et al., "Valorization of Agriculture Waste Biomass as Biochar: As First-Rate Biosorbent for Remediation of Contaminated Soil," *Chemosphere* (2022): 135834.

[16] Abidur Rahman, Omar Farrok, and Md Mejbaul Haque, "Environmental Impact of Renewable Energy Source Based Electrical Power Plants: Solar, Wind, Hydroelectric, Biomass, Geothermal, Tidal, Ocean, and Osmotic," *Renewable and Sustainable Energy Reviews* 161 (2022): 112279.

[17] Syaifuddin Yana, Muhammad Nizar, and Dewi Mulyati, "Biomass Waste as a Renewable Energy in Developing Bio-Based Economies in Indonesia: A Review," *Renewable and Sustainable Energy Reviews* 160 (2022): 112268.

[18] Shivangi Jha et al., "A Review of Biomass Resources and Thermochemical Conversion Technologies," *Chemical Engineering & Technology* 45, no. 5 (2022): 791–799.

Mobile Biomass Gasifier Prototype 3 (P3) is a biomass conversion tool into gasified gas that can be used as a renewable energy source[19]. This tool was developed by the Biomass Gasification Research Group, Department of Mechanical Engineering FTUI, in collaboration with Development Partner PT Melu Bangun Wiweka. Mobile Biomass Gasifier P3 has advantages as a renewable energy source that can support the renewable energy transition because it meets the concept of carbon neutral, plants that produce biomass can capture CO2 produced in the gasification process. In addition, this technology is also environmentally friendly because it does not cause environmental pollution[20]. In its development, this tool was examined in three prototype stages, namely Prototype 1 (P1), Prototype 2 (P2), and Prototype 3 (P3). The initial stage of development of a mobile gasifier with a capacity of 10 kW thermal and using a 10 kW single cylinder (P1) engine. P1 has been equipped with a semi-controllable system and gas cleaning using indirect condenser.

Biomass gasification is a mature technology that uses a controlled process through heating, steam, and oxygen to convert biomass into hydrogen and other products without combustion. Biomass can come from various sources such as agricultural waste, municipal waste, and animal waste. Biomass can be used to produce hydrogen, along with other byproducts, through gasification[21]. The biomass gasification process involves several stages such as pyrolysis and hydrocarbon reforming with catalysts to produce a clean gas mixture. The development of biomass gasification technology can help reduce greenhouse gas emissions and expand the supply of renewable energy. However, further research and development is needed to improve efficiency and overcome challenges in the development of biomass gasification technology[22].

RESEARCH METHODS

The research methods used in this study include quantitative approaches and several stages of research. The stages of research consist of the formulation of the problem, where the research problem is identified and formulated to determine the methods and analysis to be used.

[19] Hantao Lu et al., "Integration of Biomass Torrefaction and Gasification Based on Biomass Classification: A Review," *Energy Technology* 9, no. 5 (2021): 2001108.

[20] Xiaoqing Li, Zongyi Hu, and Qing Zhang, "Environmental Regulation, Economic Policy Uncertainty, and Green Technology Innovation," *Clean Technologies and Environmental Policy* 23 (2021): 2975–2988.

[21] Sakshi Singh et al., "Life Cycle Assessment of Biomass-Based Hydrogen Production Technologies: A Review," *International Journal of Green Energy* (2023): 1–16.

[22] Hao Song et al., "Recent Development of Biomass Gasification for H2 Rich Gas Production," *Applications in Energy and Combustion Science* 10 (2022): 100059.

Furthermore, research objectives and problem limits are set to ensure that research results are under the scope of the problem studied. A literature study is conducted to search for and study relevant literature on the research topic as a reference. Data collection is done through previous experiments and research, including data on gasifier operations, investment costs, fuel prices, interest rates, and other relevant parameters. The simulated data is then analyzed through calculations and processing using Ansys software. Economic analysis is carried out using the Levelized Cost of Energy (LCOE) method and economic feasibility analysis parameters such as Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PBP), and Benefit Cost Ratio (BCR).

Furthermore, modeling and simulation were carried out using Ansys software based on the input data obtained. The results of data analysis are used to calculate the potential electrical energy of the gasifier system using various types of biomass. Economic analysis is carried out using the Levelized Cost of Energy (LCOE) method, which considers initial investment costs, operational costs, maintenance costs, fuel costs, and resale value. In addition, an economic feasibility analysis was conducted using parameters such as NPV, IRR, PBP, and BCR.

In this study, several assumptions and parameters were used such as gasifier service life, discount rate, power generator efficiency, operating time, working days, maintenance schedule, fuel price, and others. These parameters are used to calculate the economics of making a Mobile Biomass Gasifier. Biomass price lists are also included as data used in economic analysis

RESULTS AND ANALYSIS

1. Analysis of Ansys Model Simulation Results

Analysis and simulation through the Ansys application use main parameters such as fuel consumption rate (FCR) of 12 kg/hour, equivalence ratio (ER) of 0.27, and air-fuel ratio (AFR) of 7.65. Other relevant parameters use the data in Table 3.1. The results of the simulation show the values of the main components that make up the output gas of the reactor including H2, CO, and CH4 which are detailed in Table 1.

Table 1 Composition and Electrical Energy Produced by the Gasification Process

Parameters	Rice Husk	Corn Cobs	Straw	Bagasse	Cotton Dregs	Unit
H2	0.5037	1.2221	1.1556	1.1387	1.1293	kg/hour
CO	0.6941	0.7511	0.7577	0.7660	0.7671	
CH4	0.1020	0.7711	0.7041	0.6796	0.6665	

Own	16.9154	44.9094	42.2864	41.5484	41.1365	Kw

In the results of CFD simulation in the gasification system using rice husks, the composition of the gas produced for H2 is 0.5037 kg/hour, CO 0.6941 kg/hour, and CH4 is 0.1020 kg/hour from this composition can be converted with the content of the calorific value of each component so that the potential of electrical energy of 16.9154 kW can be known. The largest potential for electrical energy is generated in the type of corn cob biomass, where in this biomass the composition of reactor output gas for H2 is 1.2221 kg/hour, CO 0.7511 kg/hour, and CH4 is 0.7711 so that the potential of electrical energy can be known at 44.9094 kW. Furthermore, other biomass such as straw, bagasse, and cotton pulp were successively followed by electrical energy potential of 42.2864 kW, 41.5484 kW, and 42.1365 kW, respectively.

1. Analisa Levelized Cost of Energy (LCOE)

Based on the parameters of the energy analysis results produced, the LCOE value for each type of biomass is calculated. In addition to the project parameters for making Mobile Biomass Gasifiers, the price of each type of biomass is also needed. Biomass prices are obtained from several marketplaces such as Tokopedia, Shopee, and Facebook with each price listed in Table 3.4. The price of each type of biomass will be used to determine the annualize fuel cost.

The stages in calculating LCOE for one type of biomass, namely rice husks, can be described below.

a. Account annualized capital cost (Cac)

The initial capital cost in making Mobile Biomass Gasifier is IDR 200,000,000, so the calculation of annualized investment costs are as follows.

$$C_{ac} = C_c + CRF$$
$$CRF_{(r,n)} = \frac{r(1+r)^n}{(1+r)^n - 1}$$
$$CRF_{(5{,}75\%,10)} = \frac{5{,}75\%(1+5{,}75\%)^{10}}{(1+5{,}75\%)^{10} - 1}$$
$$CRF_{(5{,}75\%,10)} = 0{,}1343$$
$$C_{ac} = \text{Rp } 200.000.000 + 1{,}343$$
$$C_{ac} = \text{Rp } 26.852.653/\text{tahun}$$

b. Perhitungan annualized maintenance cost (Cam)

Maintenance is also focused on cleaning the gasifier from residual ash and rice husks left behind in the reactor. Most of the care taken is for cleaning. The cost of treatment that has been carried out so far is IDR 1,000,000 for one treatment. So annualized maintenance costs can be calculated in the following details.

$$C_{am} = \frac{t_r \times C_m \times 260}{T_m}$$

$$C_{am} = \frac{15\,\frac{\text{hours}}{\text{day}} \times \text{Rp } 1.000.000 \times 260}{375}$$

$$C_{am} = \text{Rp } 10.400.000\ /\text{tahun}$$

c. Account annualized operation cost (Cao)
The operating cost referred to in the operation of the mobile biomass gasifier is assumed to have an operator operating. Although currently still in the form of prototypes operating in laboratories, this operation cost needs to be taken into account to improve the accuracy of LCOE calculations. The operating cost alone is estimated at Rp 26,000,000 for one year.

d. Account annualized fuel cost (Caf)
Fuel requirements are a major aspect of the operation of mobile biomass gasifiers. The fuel used is biomass waste which should be relatively cheap and even free. However, some types of biomass waste that still have useful content for animal feed or as a planting medium has a relatively high market price. Therefore, it is necessary to calculate fuel needs to find out how much fuel affects the economy of electricity generation. The calculation of annualized fuel costs in detail can be described as follows.

$$C_{af} = C_f \times FCR \times t_r \times 365$$

$$C_{af} = \text{Rp } 500 \times 12\,\frac{\text{kg}}{\text{jam}} \times 15\,\frac{\text{jam}}{\text{hari}} \times 365$$

$$C_{af} = \text{Rp } 23.400.000/\text{tahun}$$

e. Account annualized total cost of the system
After calculating each annualized cost component, then the costs are added together to find out the total cost of the entire annualized mobile biomass gasifier system using the following equation. As for this calculation, at the end of the life of the mobile biomass gasifier device, it is assumed that the value is 0.

$$C_t = C_{ac} + C_{am} + C_{ao} + C_{af} - SV$$

$$C_t = \frac{Rp26.852.653}{tahun} - 0 + \frac{Rp\ 10.400.000}{tahun} + Rp\frac{26.000.000}{tahun} + Rp\frac{23.400.000}{tahun}$$

$$C_t = Rp\ 86.652.653/tahun$$

Once the entire total cost of the annualized mobile biomass gasifier system is known, then the cost is divided by the total electrical energy that can be generated by the system for one year.

$$LCOE = \frac{\text{Annualized Total Cost of the System}\left(\frac{\text{Rupiah}}{\text{year}}\right)}{\text{Total Electrical Load served}\left(\frac{\text{kWh}}{\text{year}}\right)}$$

$$LCOE = \frac{Rp\ 86.652.653/tahun}{55.078\ \frac{kWh}{year}}$$

$$LCOE = Rp\ 1.573/kWh$$

Based on the calculations obtained, the LCOE of the mobile biomass gasifier system for the use of rice husk fuel is Rp 2,471 / kWh. LCOE for other fuel uses in detail is shown in Table 2.

Table 2 LCOE Calculation for Multiple Biomass

	Rice Husk	**Corn Cobs**	**Straw**	**Bagasse**	**Cotton Dregs**	**Unit**
Cac	26,852,653					Rp/year
Cam	14,600,000					
Tall	26,000,000					
Caf	23,400,000	70,200,000	42,120,000	28,080,000	32,760,000	
SV	-					
Own	50,529	134,151	126,316	124,112	122,881	Kwh
LCOE	2,471	1,280	1,137	1,044	1,092	Rp/kWh

The LCOE comparison will be converted to USD/kWh to make comparison easier. Data from ACE (ASEAN Centre of Energy) explains the LCOE value of biomass NRE ranges from 2,226.00 IDR/kWh (0.15 USD/kWh) to 3309.32 IDR/kWh (0.223 USD/kWh) for electricity production. The data also explains the techno-economic condition of biomass technology in ASEAN, but unfortunately, Indonesian data is not listed there. Meanwhile, IRENA

(International Renewable Energy Agency) states that the LCOE value for gasifier-based biomass technology ranges from 1113.00 IDR / kWh (0.075 USD / kWh) to 4303.60 IDR / kWh (0.29 USD / kWh).

1. Economic Feasibility Analysis

Economic feasibility analysis is used to evaluate the return on investment of the project being built. The economic feasibility analysis in this study itself is used to evaluate and analyze the feasibility of investing in mobile biomass gasifiers using several economic feasibility parameters, namely, parameters, net present value (NPV), internal rate of return (IRR), payback period (PBP), and benefit-cost ratio (BCR). By using economic feasibility analysis using the above parameters, it can be determined whether or not it is feasible for an investment that has been spent to create and operate a mobile biomass gasifier unit.

a. Net Present Value (NPV) Analysis and Calculation

Net Present Value (NPV) is a parameter that describes an income earned in the future whose interest has been paid upfront or discounted. NPV value is the difference between Future Value or total net income (net benefit) with the present value of the system or initial investment in system development. The purpose of NPV calculation is to calculate capital allocation to analyze profits in a project implemented to build the same project in the future.

The data needed to find the NPV value is in the form of investment costs, maintenance, and repair costs, and net income or net benefit obtained from gross income that has been discounted at the applicable interest rate. Net present value is calculated by looking at the total net income or net benefit to get the future value of a system, then the value of the future value or total net income (net benefit) compared to the value of the present value of the system or the initial investment of mobile biomass gasifier. With the criteria, if the value of NPV is positive, the investment is said to be feasible, with the initial investment cost of mobile biomass gasifier of IDR 200,000,000 and income data for each type of biomass associated with the 2023 reference interest rate of 5.75%, the value of NPV can be found using the equation.

$$\mathrm{NPV} = \left[\sum_{t=1}^{n} \frac{\mathrm{CF_t}}{(1+\mathrm{i})^{\mathrm{t}}}\right] - \mathrm{I_0}$$

So that the calculation illustration for rice husk biomass fuel is described in Table 3 below.

Table 3 NPV Mobile Biomass Gasifier for Rice Husk Fuel

Year	Investment Cost (I0)	Cash in (CFt)	Flower	Cash Value
0	200,000,000		1.00	200,000,000

1		17,309,187	1.06	16,368,025
2		17,309,187	1.12	15,478,038
3		17,309,187	1.18	14,636,443
4		17,309,187	1.25	13,840,608
5		17,309,187	1.32	13,088,045
6		17,309,187	1.40	12,376,402
7		17,309,187	1.48	11,703,453
8		17,309,187	1.56	11,067,095
9		17,309,187	1.65	10,465,339
10		17,309,187	1.75	9,896,301
Total				128,919,750
NPV				(71,080,250)

$$\text{NPV} = \text{Rp } 128.919.750 - \text{Rp } 200.000.000$$
$$\text{NPV} = \text{Rp} - 71.080.250$$

Table 3 above shows the value of the net present value (NPV) of Rp -71,080,250 (negative value). The first column in the table shows the life of the project to be designed, which is for 10 years. The second column in the table represents the initial investment cost in the system, the initial investment value of Rp 200,000,000. The third column shows the net cash flow or net benefit potentially generated by the mobile biomass gasifier before it is discounted from the first year to the 10th year. The fourth column shows how much interest the bank is given each year for 10 years. The last column shows net cash flows that have been discounted to 2023 interest rates. So that the total future value received in the system using husk fuel is Rp. -71,080,250. From the calculation of NPV above, the value produced by the project undertaken is negative which shows that the potential revenue obtained is smaller than the investment value. From the NPV results that are negative or < 0, the mobile biomass gasifier system using rice husk fuel is categorized as infeasible. The NPV calculation results for other types of biomass fuel are summarized in Table 4.

Table 4 NPV Calculation of Multiple Biomass

Types of Biomass	**Investment Cost (I0)**	**Total Cash Value**	**NPV**
Rice Husk	200,000,000	128,919,750	-71,080,250
Corn Cobs		186,245,380	-13,754,620
Straw		338,135,752	138,135,752
Bagasse		426,600,227	226,600,227
Cotton Dregs		382,751,687	182,751,687

It can be seen in Table 4. that biomass other than rice husks have a positive NPV or > 0. The NPV values for corn cob biomass fuel, straw, bagasse, and cotton bagasse were Rp -13,754,620, Rp 138,135,752, Rp 226,600,227, Rp 182,751,687, respectively. So based on this NPV value, the four types of biomass can be categorized as worthy of investment.

b. Analyzes and Calculations Internal Rate of Return (IRR)

The IRR parameter is a parameter used to obtain an interest rate that equates the total present value with the expected cash flow receipts for the total present value required for the investment. where to calculate the IRR value, which is assisted using the Solver facility in Ms. Excel where the locked value is the NPV value = 0 and the value released as a free variable is the interest rate. Then the IRR value can be compared with the value of bank interest rates issued by BI or the applicable investment rate or minimum attractive rate of return (MARR). The decision criteria are determined by the IRR value obtained, if the IRR value is greater than the applicable investment return interest rate or MARR then the project is accepted, and vice versa the project is rejected if the IRR value is less than the applicable return on investment interest rate or MARR. The following results of IRR calculations for some biomass fuels can be seen in Table 5.

Table 5 Calculation of IRR Value for Multiple Biomass

	Rice Husk	**Corn Cobs**	**Straw**	**Bagasse**	**Cotton Dregs**
IRR	-2.54%	4.28%	18.56%	25.74%	22.25%

The results of the IRR calculation above, it is then compared with the value of the investment return interest rate or minimum attractive rate of return (MARR), where the IRR value is greater than the value of the investment return interest rate or minimum attractive rate of return (MARR) which in this case is equated to the reference interest rate value from BI of 5.75%, under the IRR parameter assessment criteria with these results, the use of fuel in IRR value exceeding MARR is the use of corn cob biomass fuel, bagasse, and kaoas bagasse.

c. Analysis and Calculation of Pay Back Period (PBP)

The payback period (PBP) parameter is used to calculate and find out how long the payback on investment capital in a project that has been built from the cash inflows obtained. The calculation of the payback period (PBP) itself is by dividing the investment cost of the entire system which is worth IDR 200,000,000 by the potential cash inflow or profit obtained for 10 years through the sale of electrical energy generated using electricity sales rates of IDR 1,400 / kWh. This profit is derived from the potential revenue generated minus fuel costs, operating costs, and maintenance costs. As an illustration, the PBP calculation will use system data when using rice husk fuel which can be described through the following equation.

$$\text{Payback Period (t)} = \frac{I_0}{CF}$$

$$\text{Payback Period (t)} = \frac{\text{Rp } 200.000.000}{\text{Rp } 17.309.186,82}$$

$$\text{Payback Period (t)} = 11.55 \text{ tahun}$$

From the calculation above, to return the overall investment capital takes 11.55 years, this result shows that the electricity sales rate of Rp. 1,400 / kWh is not acceptable because the total initial investment cost of the mobile biomass gasifier cannot be covered before the expiration of the lifetime or service life of the system for 10 years. PBP data for systems with other biomass fuels can be seen in Table 6.

Table 6 PBP Calculation for Multiple Biomasses

	Rice Husk	Corn Cobs	Straw	Bagasse	Cotton Dregs
Investment Cost (I0)	200,000,000				
Cash Flow (CF)	17,309,187	25,005,913	45,399,211	57,276,740	51,389,492
PBP	11.55	8.00	4.41	3.49	3.89

From the data from the calculation of the payback period above, it is known that the initial investment in the construction of a mobile biomass gasifier system for the use of fuels other than rice husks can return investment costs faster than the life of the tool. The fastest return or PBP is a mobile biomass gasifier system that uses bagasse fuel with PBP estimated for 3.49 years after the device starts operating.

d. Analysis and Calculation of Benefit Cost Ratio (BCR)

The benefit-cost ratio (BCR) parameter is a parameter used as an economic feasibility analysis with the parameter used is the comparison value between the present value for potential benefits or projected income in the next 10 years compared to the present value for potential costs or costs incurred during the life of the mobile biomass gasifier system. The calculation of revenue and cost values for a system using rice husk fuel can be explained through the following equation.

Table 7 Calculation of Present Value and Cost of the System Using Rice Husk Fuel

Year	Income (Bt)	Cost (Ct)	Bt/(1+i)^t	Ct/(1+i)^t
1	77,109,187	86,652,653	72,916,489	81,941,043

2	77,109,187	86,652,653	68,951,762	77,485,620
3	77,109,187	86,652,653	65,202,612	73,272,454
4	77,109,187	86,652,653	61,657,316	69,288,373
5	77,109,187	86,652,653	58,304,791	65,520,920
6	77,109,187	86,652,653	55,134,554	61,958,317
7	77,109,187	86,652,653	52,136,694	58,589,425
8	77,109,187	86,652,653	49,301,839	55,403,711
9	77,109,187	86,652,653	46,621,124	52,391,216
10	77,109,187	86,652,653	44,086,169	49,542,521
Total			574,313,351	645,393,601
BCR			0.89	

$$BCR = \frac{\sum_{t=1}^{n} \frac{Bt}{(1+i)^t}}{\sum_{t=1}^{n} \frac{Ct}{(1+i)^t}}$$

$$BCR = \frac{Rp\ 574.313.351}{Rp\ 645.393.601}$$

$$BCR = 0.89$$

From the calculation results above, the value of BCR for the gasifier system using rice husk fuel is 0.89. Under the BCR parameter assessment criteria, the project is declared accepted or feasible if the value is greater than 1, on the other hand, the project is rejected if the BCR value is less than 1 and the project is declared in a break-even point (BEP) state if the BCR value = 1. As for the gasifier system using other fuels, the calculation results can be shown in Table 8.

Table 8 BCR Calculation for Multiple Biomass

Types of Biomass	**Total Present Value of Revenue**	**Total Present Value Cost**	**BCR**
Rice Husk	574,313,351	645,393,601	0.89
Corn Cobs	980,207,886	993,962,506	0.99
Straw	922,956,915	784,821,163	1.18
Bagasse	906,850,718	680,250,491	1.33
Cotton Dregs	897,859,068	715,107,382	1.26

Based on the results of BCR calculations in Table 4. shows that BCR that is worth more than 1 is a gasifier system with straw biomass fuel, bagasse and cotton pulp so that for systems with this fuel the BCR value is categorized as feasible. As for rice husks and corn cobs, they are still worth below 1 and are declared not worthy of investment.

2. Economic Comparison of the Use of Various Biomasses

After calculating the Levelized Cost of Energy (LCOE), net present value (NPV), internal rate of return (IRR), payback period (PBP), and benefit-cost ratio (BCR) for systems with several types of biomass fuel, it can be compared which gasifier system has the most feasible economic level. The results of economic analysis for various types of biomass that can potentially be used in mobile biomass gasifier systems can be seen in Table 9.

Table 9 Economic Feasibility Parameters of Power Generation

Parameters	Rice Husk (Simulation)	Corn Cobs	Straw	Bagasse	Cotton Dregs
LCOE	1,573.27	1,419.65	1,190.47	1,050.17	1,115.04
NPV	-71,080,250	-13,754,620	138,135,752	226,600,227	182,751,687
IRR	-2.5%	4.3%	18.6%	25.7%	22.2%
PBP	11.55	8.00	4.41	3.49	3.89
BCR	0.97	1.04	1.26	1.44	1.35
Result	**Not Worth It**	**Not Worth It**	**Proper**	**Proper**	**Proper**

In determining the eligibility criteria, in this study, the author determined that the gasifier system is said to be feasible if it meets the four economic parameters. So that the gasifier fuel system that is not economically feasible is a system with biomass fuel, rice husks, and corn cobs. For rice husks themselves as explained in the previous subchapter, it is clear that all economic parameters in this system do not fall into the feasibility limits of each parameter. As for the system with corn cob biomass fuel, two parameters are not economically feasible, namely a negative NPV or < 0 and an IRR value that is smaller than the BI reference bank interest rate or < 5.75%.

Systems with straw, bagasse, and cotton bagasse show that all three systems can meet all economic criteria. In systems with straw waste fuel, the NPV value is Rp 138,135,752 (NPV>0), with an IRR of 18.6% (IRR > 5.75%), PBP of 4.41 years faster than the age of the tool (PBP < 10 years), and for BCR value is 1.26 (BCR > 1). In systems with cotton waste fuel, the NPV value is Rp 182,751,687 (NPV>0), with an IRR of 22.2% (IRR > 5.75%), PBP of 3.89 years faster than the age of the tool (PBP < 10 years), and for BCR value is 1.35 (BCR > 1). Furthermore, the system with the highest economic value is the gasifier system with bagasse fuel, where the NPV value is Rp 226,600,227 (NPV>0), with an IRR of 25.7% (IRR > 5.75%), PBP of 3.89 years faster than the age of the tool (PBP < 10 years), and for the BCR value is 1.44 (BCR > 1).

CONCLUSION

This study examines the economic aspects of using various types of biomass as fuel in a mobile biomass gasifier developed by the Biomass Gasification Technology Research Team of the University of Indonesia. The gasifier used is a downdraft type with a fuel rate of 12 kg/hour. This study tries to evaluate other biomass to assess the economic level and investment feasibility of the tool, with an expected service life of 10 years and an investment capital of 200 million rupiahs. This study concluded that bagasse is the most economical biomass choice with an LCOE value of Rp 1,050.17/kWh, followed by cotton waste, straw, corn cobs, and rice husks. In addition, gasifier systems with bagasse biomass also show good economic feasibility based on NPV, IRR, PBP, and BCR parameters.

In the context of further development, this study recommends several steps, including conducting field experiments to test gasifier operations using bagasse fuel in real conditions; testing the implementation of mobile biomass gasifier technology in the industry to gain a comprehensive understanding of the costs associated with industrial scale; and directing the application of mobile biomass gasifier technology to areas that have biomass sources to obtain lower biomass prices, especially considering that bagasse still has economic value as animal feed. This research shows that mobile biomass gasifier technology has feasible economic potential for commercialization and there are still opportunities for further development.

BIBLIOGRAPHY

Amin, Muhammad, Hamad Hussain Shah, Anaiz Gul Fareed, Wasim Ullah Khan, Eunhyea Chung, Adeel Zia, Zia Ur Rahman Farooqi, and Chaehyeon Lee. "Hydrogen Production through Renewable and Non-Renewable Energy Processes and Their Impact on Climate Change." *International journal of hydrogen energy* 47, no. 77 (2022): 33112–33134.

Anis, Samsudin, and Z A Zainal. "Tar Reduction in Biomass Producer Gas via Mechanical, Catalytic and Thermal Methods: A Review." *Renewable and sustainable energy reviews* 15, no. 5 (2011): 2355–2377.

Choudhary, Sangita, Tapan Panda, and Abhishek Behl. "Modelling the Linkage between Fossil Fuel Usage and Organizational Sustainability." *Journal of Cleaner Production* (2023): 137440.

Delbeke, J, A Runge-Metzger, Y Slingenberg, and J Werksman. "The Paris Agreement. Towards a Climate-Neutral Europe: Curbing the Trend. 24-45," 2019.

Gagliano, Antonio, Francesco Nocera, Francesco Patania, Maurizio Detommaso, and Maria Bruno. "Evaluation of the Performance of a Small Biomass Gasifier and Micro-CHP Plant for Agro-Industrial Firms."

International Journal of Heat and Technology 33, no. 4 (2015): 145–154.

Heidenreich, Steffen, and Pier Ugo Foscolo. "New Concepts in Biomass Gasification." *Progress in energy and combustion science* 46 (2015): 72–95.

Hoang, Anh Tuan, ZuoHua Huang, Sandro Nižetić, Ashok Pandey, Xuan Phuong Nguyen, Rafael Luque, Hwai Chyuan Ong, Zafar Said, and Tri Hieu Le. "Characteristics of Hydrogen Production from Steam Gasification of Plant-Originated Lignocellulosic Biomass and Its Prospects in Vietnam." *International journal of hydrogen energy* 47, no. 7 (2022): 4394–4425.

Indonesia, Republik. "Peraturan Pemerintah Republik Indonesia No. 79 Tahun 2014 Tentang Kebijakan Energi Nasional." *Lembaran Negara RI Tahun*, no. 300 (2014).

Jha, Shivangi, Jude A Okolie, Sonil Nanda, and Ajay K Dalai. "A Review of Biomass Resources and Thermochemical Conversion Technologies." *Chemical Engineering & Technology* 45, no. 5 (2022): 791–799.

Kaupp, U B, and K-W Koch. "Cyclic GMP Releases Calcium from Leaky Rod Outer Segments." *Vision Research* 24, no. 11 (1984): 1477–1479.

Kusch-Brandt, Sigrid. "Urban Renewable Energy on the Upswing: A Spotlight on Renewable Energy in Cities in REN21's 'Renewables 2019 Global Status Report.'" MDPI, 2019.

Li, Xiaoqing, Zongyi Hu, and Qing Zhang. "Environmental Regulation, Economic Policy Uncertainty, and Green Technology Innovation." *Clean Technologies and Environmental Policy* 23 (2021): 2975–2988.

Lu, Hantao, Yan Gong, Chinnathan Areeprasert, Lu Ding, Qinghua Guo, Wei-Hsin Chen, and Guangsuo Yu. "Integration of Biomass Torrefaction and Gasification Based on Biomass Classification: A Review." *Energy Technology* 9, no. 5 (2021): 2001108.

Martínez, Juan Daniel, Electo Eduardo Silva Lora, Rubenildo Viera Andrade, and René Lesme Jaén. "Experimental Study on Biomass Gasification in a Double Air Stage Downdraft Reactor." *Biomass and Bioenergy* 35, no. 8 (2011): 3465–3480.

Van Nguyen, Thi Thuy, Anh N Phan, Tuan-Anh Nguyen, Trung Kim Nguyen, Son Truong Nguyen, Arivalagan Pugazhendhi, and Ha Huynh Ky Phuong. "Valorization of Agriculture Waste Biomass as Biochar: As First-Rate Biosorbent for Remediation of Contaminated Soil." *Chemosphere* (2022): 135834.

Rahman, Abidur, Omar Farrok, and Md Mejbaul Haque. "Environmental Impact of Renewable Energy Source Based Electrical Power Plants: Solar, Wind, Hydroelectric, Biomass, Geothermal, Tidal, Ocean, and Osmotic." *Renewable and Sustainable Energy Reviews* 161 (2022): 112279.

Singh, Sakshi, Gaurav Pandey, Gourav Kumar Rath, Hari Prakash Veluswamy, and Nadezhda Molokitina. "Life Cycle Assessment of Biomass-Based

Hydrogen Production Technologies: A Review." *International Journal of Green Energy* (2023): 1–16.

Siwal, Samarjeet Singh, Qibo Zhang, Nishu Devi, Adesh Kumar Saini, Vipin Saini, Bhawna Pareek, Sergejs Gaidukovs, and Vijay Kumar Thakur. "Recovery Processes of Sustainable Energy Using Different Biomass and Wastes." *Renewable and Sustainable Energy Reviews* 150 (2021): 111483.

Song, Hao, Guang Yang, Peixuan Xue, Yuchen Li, Jun Zou, Shurong Wang, Haiping Yang, and Hanping Chen. "Recent Development of Biomass Gasification for H2 Rich Gas Production." *Applications in Energy and Combustion Science* 10 (2022): 100059.

Tezer, Özgün, Nazlıcan Karabağ, Atakan Öngen, Can Özgür Çolpan, and Azize Ayol. "Biomass Gasification for Sustainable Energy Production: A Review." *International Journal of Hydrogen Energy* 47, no. 34 (2022): 15419–15433.

Xiong, Liangming, Kazuya Saito, Edson H Sekiya, Pornapa Sujaridworakun, and Shigetaka Wada. "Influence of Impurity Ions on Rice Husk Combustion." *Journal of metals, materials and minerals* 19, no. 2 (2009).

Yana, Syaifuddin, Muhammad Nizar, and Dewi Mulyati. "Biomass Waste as a Renewable Energy in Developing Bio-Based Economies in Indonesia: A Review." *Renewable and Sustainable Energy Reviews* 160 (2022): 112268.