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Preliminary Research on the Feasibility of Producing 1.8 Million Tons/Year Biomethanol from Empty Fruit Bunch (EFB) as Raw Material of A20 Biofuel in Indonesia

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ABSTRACT

A20, a low-emission fuel with a combination of 80% gasoline, 15% methanol, and 5% ethanol was developed by Pertamina. This development was in response to the Regulation of the Minister of Energy and Minerals Resources regarding the obligation to use biofuel as a combination of vehicle fuel. However, since Indonesia only has one methanol producer with a capacity of 660,000 tons/year, alternative ways are needed to meet the demand in A20. Empty fruit bunch (EFB) is a widely generated waste accounting for over 20% of the total fresh fruit bunch from oil palm processed by the industry. EFB is an organic material rich in carbon content and can be used as a raw material for making biomethanol, a key component of biofuel through a gasification process. Therefore, this research aimed to examine the economic feasibility of establishing a biomethanol manufacturing plant using EFB as the feedstock. Three indicators namely NPV, PP, and IRR were used to calculate feasibility. Based on the results, a biomethanol plant was deemed feasible with an NPV of Rp 4,334,875,634,343.80, PP within 4.87 years, as well as an IRR of 15.90%.

I INTRODUCTION

The government issued a regulation mandating the use of biofuel for vehicles to reduce gasoline imports. Since 2015, ethanol has been required as part of the gasoline fuel combination according to Energy and Mineral Resource Minister Regulation (12/2015). The implementation target was set to reach 20% by 2025 [1]. However, this obligation has not been fully met due to the limited availability of domestic ethanol and its non-inclusion in the economic value. One of the initiatives currently being developed to overcome this challenge is applying a mixture of methanol and ethanol with gasoline. The economic value of the product will benefit from the lower price of methanol than ethanol.

Pertamina developed A20 or low-emission fuel using a combination of 80% gasoline, 15% methanol, and 5% ethanol. Additionally, this product incorporates PGA additives including PGA-01, PGA-02, and PGA-03. PGA-01 serves as a corrosion prevention agent in engines, improves vehicle power performance, and reduces oil consumption [2]. PGA-02 can effectively withstand the increase in saturated vapor pressure,

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reduce the occurrence of air resistance, improve storage stability, and ensure stable combustion of methanol gasoline in the engine [3]. Meanwhile, the PGA-03 additive stabilizes the pHe (ASTM D6423) of methanol before blending, prevents the spreading of corrosive acids, provides corrosion inhibition and metal protection in the fuel distribution system, and ultimately reaches the end users [4].

The A20 program was developed to produce gasoline at a lower price with efficient combustion. In addition, it aims to comply with the Paris Agreement, made a few years ago in anticipation of climate change. Indonesia is committed to reducing emissions down to 29% by 2030, as mandated by the Ministry of Environment Regulation No. 20 of 2017 which recommends a minimum standard of RON 91 for gasoline product in line with the EURO 4 standard [5].

Methanol, also known as methyl alcohol or spiritus, is the simplest form of alcohol obtainable from natural gas and coal. The production process involves three stages, namely gasification to produce syngas, synthesis of raw methanol, and refining. Meanwhile, when methanol is obtained from natural gas, there is no need for the gasification process since the raw material is already in the form of syngas. This implies that the synthesis of raw methanol and purification can be directly carried out [6].

With the declining availability of natural gas, new process technologies have been developed to derive syngas feedstock from biomass. A gasification process is used to convert solid materials into gas, which can be further processed into methanol [7]. The synthesis process involves reacting CO and H_2 [8], then the crude product is purified to obtain pure methanol. The purification is carried out using a distillation column to separate the remaining water from the previous process.

Empty fruit bunch (EFB), a by-product in the form of solids produced by the palm oil processing industry, is used as biomass feedstock to produce syngas through the gasification process. The composition consists of various fibers, with cellulose content at 22.24%, hemicellulose at 20.58%, and lignin at 30.45%. EFB also contains ash and extractive content of 8.28% and 18.45%, respectively [9].

EFB is a viable raw material for making methanol, and one ton of oil palm can produce up to 210 kg as a by-product [10]. This choice is based on the increasing production of palm oil across most provinces in Indonesia from 2018 to 2021, such as 9.25% in Aceh, and 11.97% in Riau [11]. Additionally, about 40 to 50 million tons of EFB are produced annually [12].

Based on the current demand and production capacity, there is a gap that needs to be fulfilled in the domestic methanol supply. The proposed plant capacity of 1.8 million tons/year is expected to help fulfill the demand and reduce the dependence on imported methanol. In 2020, the demand for methanol reached 1.2 million tons/year and was predicted to increase every year [13]. The current sole methanol producer in Indonesia with a maximum capacity of 660,000 tons/year is located in East Kalimantan [14]. The target plant capacity of 1.8 million tons/year is crucial to meet the A20 combination with 15% methanol, as the existing producers alone cannot fulfil the demand. To achieve this goal, methanol plant needs to reach a capacity three times larger than ethanol plant, to accommodate their combined amount. Fortunately, the abundant availability of EFB as biomass raw materials further support the development of large-scale methanol plant. This can also provide additional economic value to palm oil industry and support programs established by the government to promote the use of renewable energy as well as reduce greenhouse gas emissions.

II RESEARCH METHOD

The economic evaluation process commenced by computing the overall investment required, which was divided into two categories, namely Capital Expenditure (Capex) and Operating Expenditure (Opex) [15]. This was followed by computing the revenue before tax, also called Before Tax Cash Flow (BTCF) derived by subtracting the total operating costs (Opex) from the total sales generated from the product, including biomethanol and H_2.

Equation 1 was used to calculate After Tax Cash Flow (ATCF) which referred to the income after tax has been deducted. ATCF was employed in this calculation of economic feasibility analysis.

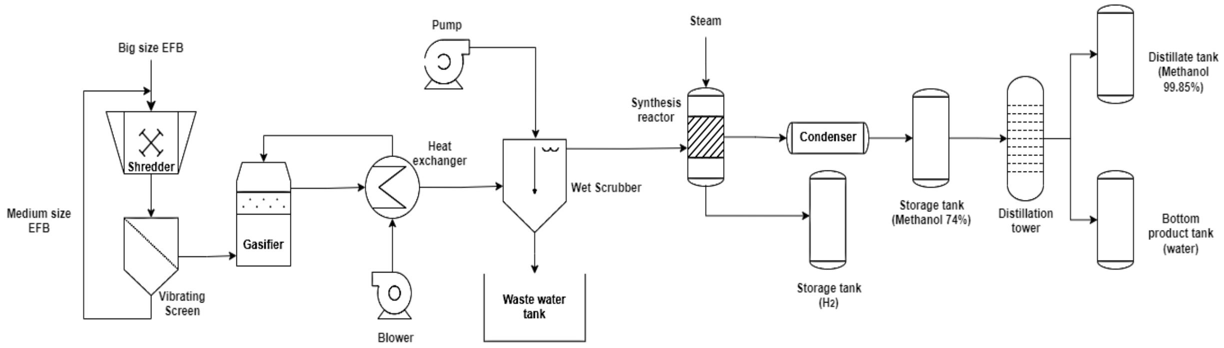

Figure 1. *Scheme of biomethanol production*

$$\mathrm{ATCF}_k = \mathrm{BTCF}_k - CFIT_k \quad (1)$$

Where ATCF_k, BTCF_k, and CFIT_k denote after tax cash flow, before tax cash flow, and cash flow for income tax in year k, respectively. As shown in the equation, it is necessary to ascertain BTCF value and CFIT_k to calculate ATCF.

$$CFIT_k = T_k - i \quad (2)$$

$$T_k = BTCF_k - d_k \quad (3)$$

BTCF_k is revenue while d_k is the amount of non-cash expenses (depreciation) during year k. BTCF was obtained based on the amount of sales deducted by Opex.

The feasibility analysis was conducted by determining Net Present Value (NPV), which can be defined as the present value of all cash flows from inception to the end of the project. The project was accepted and considered feasible when NPV was > 0 or the largest NPV [17]. NPV was calculated using Equation 4 as shown below:

$$NPV = -P + A\left(\frac{P}{A}, i, n\right) \quad (4)$$

The second feasibility analysis was Payback Period (PP), which can be defined as the period of return of the initial cost. The faster the return, the more interesting the alternative compared to others [17]. Equation 5 shows the correlation between PP, total investment, and ATCF.

$$PP = \frac{Total\ Investment}{ATCF} \quad (5)$$

Internal Rate of Return (IRR) was also utilized in this research as an indicator of the interest rate the investment can provide compared to the generally accepted bank interest rate (market interest rate or Minimum Attractive Rate of Return/MARR).

IRR is the interest rate at which NPV equals 0, in other words, IRR represents the interest rate that an investment can yield, resulting in an NPV of 0. To consider a project feasible, IRR must exceed the Minimum Acceptable Rate of Return (MARR) interest rate [16]. In this study, IRR was calculated using Equation 6.

$$IRR = \left((i_2 - i_1) \times \left(\frac{NPV_1}{NPV_1 - NPV_2}\right)\right) \quad (6)$$

III RESULT AND DISCUSSION

Figure 1 shows the comprehensive scheme of biomethanol manufacturing process, detailing the equipment used in each stage to convert EFB into biomethanol through the gasification process. The production process involves several stages, firstly, EFB is shredded using a shredder and gasified into syngas with a gasifier. Air heating is required during gasification, which is accomplished using a heat exchanger, then the syngas is cleaned of impurities and particulates with wet scrubbers. The methanol synthesis is performed using synthesis reactors, followed by biomethanol cooling with condensers, and purification through distillation towers. Additionally, several utility tools are required in the process, including belt conveyors, filters (screeners), bucket elevators, blowers, pumps, storage tanks, wastewater reservoirs, and laboratory equipment. The list as well as amount of the equipment and utilities required for the processes, which was determined by a short calculation method are summarized in Table 1.

Table 1. *Tools and Utilities Required in Biomethanol Production*

Tools	Amount	Size	Unit
Shredder	7	2	ft
Gasifier	2	83.30	ton/hr
Heat Exchanger	1	2,300	ft^2
Synthesis Reactor	1	2,600	cfm
Condenser	5	4,680,000	gallons
Distillation Tower	5	81,000	ft^2
Belt Conveyor (primary)	1	194,000	lb
Belt Conveyor (secondary)	7	1	hP
Bucket Elevator	7	0.75	hP
Wet Scrubber Pump	7	20 x 8	in
Condenser Pump	7	2	in
Distillation Tower Pump	5	10	in
Blower	1	37,000	ft^3/minute
	1	70,000	ft^3/minute
Screener	7	160	ft^2
Storage Tank before Distillation Tower	5	27,000	gallons
H_2 Storage Tank	5	5,000,000	gallons
	1	300,000	gallons
Biomethanol Storage Tank	1	2,540,000	gallons
Bottom Product Storage Tank	3	5,000,000	gallons
	1	2,100,000	gallons
Laboratory Tools	1		

Based on the process knowledge and the equipment purchased as listed in Table 1, Capex and Opex were calculated before the economic analysis. Total Capex and Opex are summarized in Tables 2 and 3, respectively.

The prices of the equipment highlighted in this research were obtained from one of the pages on Matche.com. The page provides information that assists with research, development, and operations for the production of new and existing product or procedures related to chemical, energy, manufacturing, and metallurgical processes [18]. In addition, the page presents the price of equipment from abroad, meaning that all tools used in this research are classified as being internationally purchased.

The basis used on the page was the price of equipment in 2014, hence, to calculate the price in 2022, the Marshall and Swift equipment cost index was used by entering the price in the purchase and reference year, as well as the price index in both years.

The revenue comprises sales of the main product, namely biomethanol with a purity of 99.85% and by product in the form of H_2. Biomethanol is sold to PT Pertamina, a company that specializes in innovating blending A20 fuel. On the other hand, H_2 is sold to PT Pupuk Kaltim Wilayah Kalteng as an ammonia manufacturing plant. The annual production of the two product is approximately 1.8 and 0.443 million tons, respectively. Based on market prices in Indonesia in December 2022, biomethanol is sold for IDR 15,600/kg (Alibaba.com), while H_2 is sold at IDR 10,900/kg (SG H_2 *Energy*). The total sales revenue is shown in Table 4.

Table 2. *Component and Total Capex*

No	Component Price	Amount
	***Fixed Capital Investment* (FCI)**	
1	*Purchased Equipment Cost* (PEC)	Rp 6,212,432,206,963.87
2	*Delivered Equipment Cost* (DEC)	Rp 1,553,108,051,740.97
3	Installation	Rp 2,671,345,848,994.46
4	Piping	Rp 2,236,475,594,506.99
5	Instrumentation	Rp 1,863,729,662,089.16
6	Insulation	Rp 496,994,576,557.11
7	Electricity	Rp 621,243,220,696.39
8	Building	Rp 42,686,600,000.00
9	Land	Rp 81,921,000.00
10	*Engineering & Construction Cost*	Rp 3,139,619,536,509.79
11	*Contractor's Fee*	Rp 753,508,688,762.35
12	*Contingency*	Rp 1,883,771,721,905.87
	***Working Capital* (WC)**	
1	Material Storage	Rp 20,230,560,000.00
2	*Inprocess Inventory*	Rp 1,643,971,965,185.94
3	Product Storage	Rp 1,315,177,572,148.27
4	*Extended Credit*	Rp 3,285,506,204,834.30
5	*Available Cash*	Rp 1,315,177,572,148.15
	Total	**Rp 29,055,061,504,043.10**

Table 3. *Component and Total Opex*

No	Component Cost	Amount
	***Manufacturing Cost* (MC)**	
	***Direct Manufacturing Cost* (DMC)**	
1	Material	Rp 202,305,600,000.00
2	Worker	Rp 706,218,000,00
3	Supervisor	Rp 70,621,800,00
4	*Maintenance*	Rp 4,294,999,529,945.39
5	*Plant Supplies*	Rp 644,249,928,891.81
6	*Royalties & Patents*	Rp 1,642,753,102,417.15
7	Utility	Rp 604,569,161,737.93
	***Indirect Manufacturing Cost* (IMC)**	
1	*Payroll everhead*	Rp 105,932,700.00
2	*Laboratory*	Rp 70,621,800.00
3	*Plant overhead*	Rp 388,419,900.00
4	Packaging	Rp 3,285,506,204,834.30
5	Delivery	Rp 328,550,620,483.43
	***Fixed Manufacturing Cost* (FMC)**	
1	Depreciation	Rp 1,717,999,810,278.16
2	Property Tax	Rp 214,749,976,297.27
3	Insurance	Rp 214,749,976,297,27
	***General Expense* (GE)**	
1	Administration	Rp 985,651,861,450.29
2	Sales Expenses	Rp 4,928,259,307,251.45
3	Research	Rp 919,941,737,353.61
4	Monetary	Rp 871,651,854,121.30
	Total	**Rp 20,857,280,472,659.40**

Table 4. *Product Sale Revenue*

No	Product	Price/ kg (Rp)	Income (Rp)
1	Biometanol 99.85%	15,600	28,013,400,000,000
2	H_2	10,900	4,841,662,048,343.02
	Total		**32,855,062,048,343**

The annual profit was determined by subtracting the production cost the from revenue generated by product sale. Based on Table 5, the annual production cost or Opex for both products was Rp 20,857,280,472,659.40, resulting in an annual profit of Rp 11,997,781,575,683.70.

Equation 2 calculates the deduction between revenue and depreciation, which remain constant each year (Tk) due to the age of the project. On the other hand, Equation 3 calculates the multiplication of Tk and the prevailing interest rate of 25%. The result showed the amount of tax that must be paid annually, amounting to Rp1,751,636,844,503.36. The gain, or the profit before tax (BTCF) and after tax (CFTI) were calculated using Equations 2 and 3. The amount of profit (ATCF) obtained after deducting tax was Rp 10,246,144,731,180.30. The calculation was based on the assumption that the plant will be operated for 10 years. Table 5 shows the calculation results of Tk, CFTI, and ATCF, presented in units of trillions.

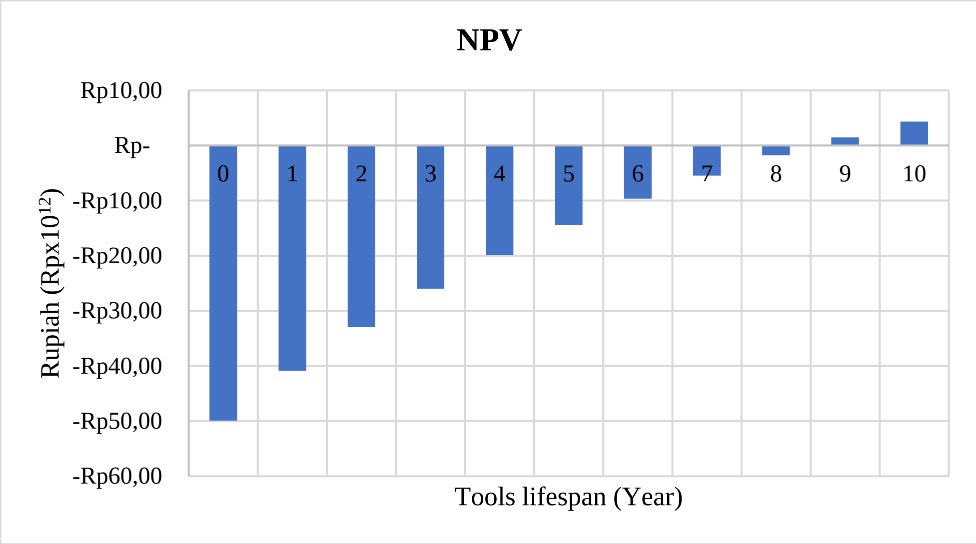

Figure 2. *NPV per year*

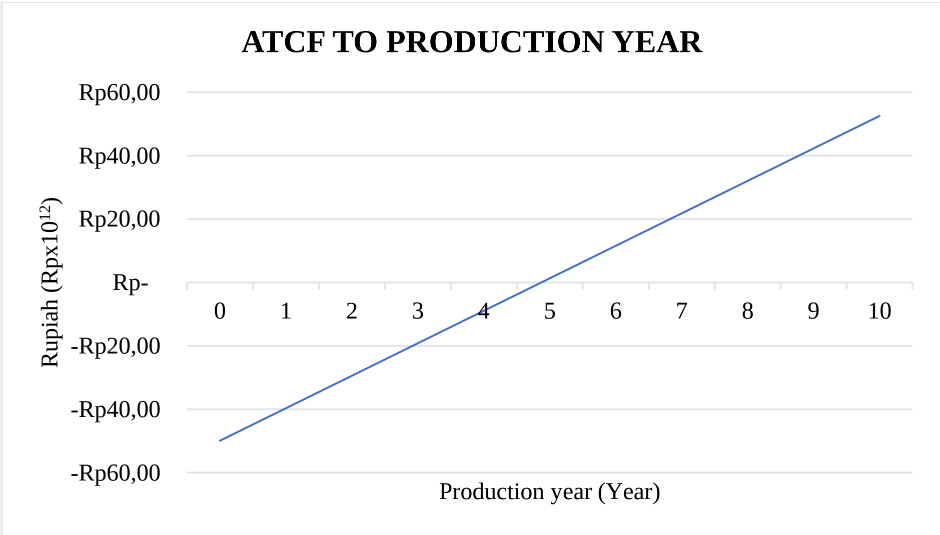

Figure 3. *PP biomethanol factory*

Table 5. *Calculation Results BTCF, Dk, Tk, CFTI, and ATCF in 10 years*

EOY	BTCF	Dk	Tk	CFTI	ATCF
0	-Rp 49.91				-Rp 49.91
1	Rp 12.00	Rp 4.99	Rp 7.01	Rp 1.75	Rp 10.25
2	Rp 12.00	Rp 4.99	Rp 7.01	Rp 1.75	Rp 10.25
3	Rp 12.00	Rp 4.99	Rp 7.01	Rp 1.75	Rp 10.25
4	Rp 12.00	Rp 4.99	Rp 7.01	Rp 1.75	Rp 10.25
5	Rp 12.00	Rp 4.99	Rp 7.01	Rp 1.75	Rp 10.25
6	Rp 12.00	Rp 4.99	Rp 7.01	Rp 1.75	Rp 10.25
7	Rp 12.00	Rp 4.99	Rp 7.01	Rp 1.75	Rp 10.25
8	Rp 12.00	Rp 4.99	Rp 7.01	Rp 1.75	Rp 10.25
9	Rp 12.00	Rp 4.99	Rp 7.01	Rp 1.75	Rp 10.25
10	Rp 12.00	Rp 4.99	Rp 7.01	Rp 1.75	Rp 10.25

NPV at the end of the production life (10 years) was calculated to be Rp 4,334,875,634,343.80, as shown in Figure 1. This shows that the factory is considered feasible to be built since there will be a positive total cash amount at the end of the production life after deducting the investment costs, meeting the feasibility requirements based on NPV.

The second economic feasibility test was PP, referring to when the company can pay back the investment spent, or in other words, the time of return on capital. A shorter PP indicates a more feasible and attractive project. The value was calculated by adding up ATCF that had been reduced by the initial investment cost (Equation 5), and PP occurred when the amount was 0. Based on the calculation, PP for the establishment of biomethanol plant was 4.87 years or 58 months 14 days

(Figure 2), indicating that the factory can return the initial capital or investment costs within a period of 58 months 14 days. This period is still far from the end of production life, which is in the 10th year. Therefore, the factory is considered feasible for an establishment based on PP analysis.

The last economic feasibility test was IRR referring to the interest rate at which NPV of an investment becomes 0. IRR value must be greater than MARR or minimum interest rate for annual returns. When IRR is smaller than MARR, the company may lose the opportunity to realize its annual returns. Using Equation 6, the calculation results showed that an IRR of 15.9 0% was obtained with the applicable MARR of 13.62% (loan interest rates and inflation). Therefore, biomethanol plant was considered feasible to be built based on IRR. Eligibility requirements and calculation results of NPV, PP, and IRR are shown in Table 6.

Based on Table 6, it can be concluded that biomethanol plant is feasible to be established economically. NPV value was positive, indicating that the project will generate a profit. PP value implies that the project can pay back the initial investment within a reasonable time frame. Finally, IRR value was greater than MARR, meaning that the project was capable of providing sufficient returns to cover the initial investment and generate profits.

Table 6. *Requirement and Result of Economic Feasibility Test Calculation*

Feasibility Test	Condition	Calculation Result
NPV	> 0	Rp 4,334,875,634,343.8
PP	< 10	4.87
IRR	> 13.62%	15.90%

IV CONCLUSION

In conclusion, the establishment of biomethanol factory utilizing biomass to fulfill the capacity of A20 was deemed appropriate based on NPV of Rp 4,334,875,634,343.80, PP within 4.87 years or 58 months 14 days, and IRR of 15.90%.

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