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Analysis of Electrical Energy Potential from Palm Oil Frond Bioethanol: Case Study of North Bagan Sinembah Village Rokan Hilir Regency, Riau

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Abstract. North Bagan Sinembah village in Riau province contributes a land area of 7.376,4443 ha which produces frond biomass 6,3 tons of oil palm fronds per year, North Bagan Sinembah Village so far has not had access to PLN electricity and only uses a generator with a running time of 6 hours per day. This research aims to find the electricity needs of North Bagan Sinembah village with a homogeneous sample, the sampling method used is simple random sampling. This research too test the potential of palm frond bioethanol using the fermentation method using the SuperPro Designer application, calculate potential energy and electrical power with method from a variety of mixed fuels E10%, E30%, E50%, E100%. The electricity needs of North Bagan Sinembah Village are 867,62 kWh with volumetric flow potential of 15,72 L/ha/day, 1.641,66 L/ha/month and 18.053,72 L/ha/year. By using a variety of fuel mixtures E10 produce 172,68 kWh/day, 5.261,88 kWh/month, 57.866,3 kWh/year. E30 produce 161,77 kWh/day, 4.855,16 kWh/month, 53.392,6 kWh/year. E50 produce 1.632,9 kWh/day, 50.400,66 kWh/month, 538.747,9 kWh/year and E100 produces electrical power of 1,257.30 kWh/day, 38,808.48 kWh/month, 414,835.88 kWh/year. The potential electrical power for the fuel mixture is E10 4,144.32 Watts/day, 126,285.12 Watts/month, 1,388,791.2 Watts/year. E30 produces 3,882.48 Watts/day, 116,523.84 Watts/month, 1,281,422.4 Watts /year, E50 39,189.6 Watts/day, 1,209,615.84 Watts/month, 12,929,949.6 Watts/year and E100 produces 30,175.2 Watts/day, 931,403.52 Watts/month, 9,956,061.12 Watts/year. It can be concluded that with variations in the fuel mixture of dexlite and ethanol at each percent of the mixture, it has a large potential for E50 (50% Dexlite and 50% ethanol) per year of 12,929,949.6 watts, due to harvesting palm fronds twice a month, the production bioethanol is carried out every month with a potential electrical power of 1,209,615.84 watts/month.

Keywords: oil palm frond, bioethanol, electricity, sustainability, power plants, biofuel

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1. Introduction

Riau Province is the region with the largest area of oil palm plantations in Indonesia, contributing 19%, equivalent to 2.7 million ha of oil palm land and experiencing an increase in area of 2.86 million ha in 2021 [1][2]. Rokan Hilir Regency is located on the east coast of the island of Sumatra which is located in the northern part of Riau Province. This district has an oil palm plantation area of 193,771 ha with a production output of 513,425 tons with a number of farmers of 61,640 in 2020 [3].

If you look at the new renewable energy potential above, the potential that can be developed is biomass/lignocellulose from oil palm trees by utilizing the stems. The reason for using lignocellulosic materials as an alternative energy source is because in making bioethanol it is divided into three, namely sugar, starch and cellulose [7]. Meanwhile, so far bioethanol production has been sourced from sugar and starch which have the potential to be used as food ingredients, if used continuously it will contradict food security. Palm fronds or Oil Palm Frond (OPF) per hectare of palm oil produces 6.3 tonnes/year of palm fronds, The utilization of oil palm fronds has not been optimal, so far the fronds have only been left behind and left to rot on plantation land. Even though palm fronds have the potential to be converted into bioethanol, because palm fronds have a fairly large cellulose content, namely 35.88% [8]. This cellulose content will be broken down into glucose in the hydrolysis process and then a fermentation process will be carried out to convert the glucose into bioethanol with saccharomyces cerevisiae.

Regarding research on bioethanol from oil palm fronds, previously there were studies that had carried out experiments such as in the research [7] where this research aims to determine the weight of saccharomyces cerevisiae and the fermentation time in making palm frond bioethanol using a factorial randomized block design method with each factor consisting of 3 levels of weight of saccharomyces cerevisiae 0.52 grams, 0.65 grams, 0, 78 grams with a duration of 24 hours, 48 hours, 72 hours, so this research results using an alcohol meter shows that the treatment using 0.5% saccharomyces cerevisiae and fermentation for 48 hours is able to produce the highest ethanol content, namely 4.03%. Ethanol content tends to increase with increasing weight of saccharomyces cerevisiae and fermentation time. On research [9] This research aims to study the organosolv pretreatment process using ethanol as a solvent and acid hydrolysis for the conversion of palm fronds into sugar. The method used begins with a delignification process and continues with a hydrolysis process. The delignification process takes place under conditions with varying ethanol concentrations of 35%, 55%, 75% and 90% v/v, temperatures of 100 and 120°C and times of 60 and 90 minutes. then the hydrolysis process uses sulfuric acid with varying concentrations of 1%, temperatures of 60.70, 80,900 and reaction times of 15,30,45,60 and 75 minutes, resulting in delignification conditions with a C_2H_50H concentration of 75%, a temperature of 120°C, for 60 minutes, as well as 1% catalyst (H_2SO_4) and under 1% H_2SO_4 hydrolysis conditions, a time of 30 minutes and a temperature of 90°C, the highest total sugar yield was obtained at 93.65 mg/L.

On research [12] this research aims to determine the effect of acid concentration and hydrolysis time on total sugar content and reducing sugar content. The method used is a factorial randomized block design with 2 factors, namely H_2SO_4 concentration and hydrolysis time. Observation results showed that the highest total sugar content during the hydrolysis process was 0.6M H_2SO_4 treatment with a time of 100 minutes, namely 10.7%. This research [13] aims to discuss the potential of South Kalimantan palm oil lignocellulosic waste for the production of bioethanol and xylitol against the background of the lack of utilization of palm oil waste from empty palm fruit bunches and palm fronds. The results of this research are that the potential for developing TKS and PKS as G2 bioethanol and xylitol faces obstacles including technology that is not yet supported, the price of bioethanol is expensive compared to fuel so it cannot compete, and the use of xylitol is still minimal.

Regarding some of the research above, it only focuses on the processing and potential of palm frond bioethanol, but has not yet reached the aspect of calculating the electrical energy produced from palm frond bioethanol. Therefore, this research aims to calculate the electricity needs of Bagan Sinembah Utara village, analyze the potential of palm frond bioethanol, calculate the energy and electrical power potential of palm frond bioethanol.

The method used to determine the potential of ethanol produced from oil palm fronds can be done by a fermentation process. This method is then simulated with the help of the Superpro designer application to determine the amount of volumetric flow. The results of the simulation then calculate the energy potential and electrical power using variations in the fuel mixture E10, E30, E50, E100.

2. Methods

North Bagan Sinembah Village is one of the villages in Bagan Sinembah Raya District which has an area of 7,376,443 ha located in Rokan Hilir Regency with the entire area being oil palm plantations. The population in this village is around 1,197 people consisting of 417 heads of families (KK) in 2017, the majority of whom work as oil palm farmers. Bagan Sinembah Utara Village has two hamlets, namely Ampaian Rotan Hamlet and Mekar Jaya Hamlet, this village is one of the villages in Rokan Hilir Regency that does not yet enjoy access to electricity from PLN [4].

In need of a source of electrical energy for their homes, village residents use Diesel Power Plants (PLTD) for 320 residents' homes which are managed by individuals (Private) with 3 diesel engines. The type of fuel for this machine uses diesel as fuel and can only operate from 18.00 WIB to 24.00 WIB and restarts from 04.30 WIB to 06.00 WIB. The residents of this village use their electrical energy sources for lighting at night, TV and water machines. In order to enjoy this electricity, village residents are charged an electricity price of Rp. 4,000/kWh with load costs of IDR. 150,000/month for operational costs for oil wages, management wages and maintenance to meet the electrical energy needs in this village [4][5].

To overcome the problem of electrical energy deficit in North Bagan Sinembah village, the solution is to utilize the potential of New Renewable Energy. The potential for renewable energy that can be developed is from solar, wind and biomass. According to [6] this village has an average potential for solar radiation of 4.80 kWh/m^2/day, for the wind potential North Bagan Sinembah village has an average wind speed of 1.22 m/s per day. If you look at the solar potential, this village is very suitable if it can be developed as an energy source, however, this land and plantation area produces shading (modules are exposed to shadows) which hinders its development. Meanwhile, the wind potential in this village is categorized as low potential with a range below 5 m/s so it is not suitable for development in this village. The flow of this research consists of identifying problems and conducting literature studies. Once this has been fulfilled, the next step is to collect data on village conditions such as data on land area and number of houses. From the explanation above, the data needed in this research are:

2.1. Data Collection

Data collection stages and process parameters are carried out using primary and secondary data types. The method used is obtained directly from personal interviews and on-site observations as well as using the method by obtaining data from agency sources and publications on village conditions issued by third parties.

Table 1. Condition of North Bagan Sinembah Village[4][5]

Condition	Year	Amount
Land area	2020	7.376,443 ha
Resident	2019	1.197 souls
House	2019	310

The area of oil palm land in North Bagan Sinembah village is estimated to be as large as the village area with almost all of the oil palm trees covering an area of 7,376,443 ha. This data will be used as input for the number of fronds that will be input into the simulation on superpro to test the potential of bioethanol. This amount is adjusted to research [11] which states that one hectare of oil palm produces 6.3 tons of fronds per year. BPS data states that this village had 210 houses in 2019, this number will be tested to find out the amount of electricity load data used per day.

2.2. Process Parameters

Table 2. Value of Mixed Fuel Characteristics [15]

Fuel% composition by volume	LHV (Low Heating Value)	Density (g/m³)
Dexlite (E10)	41.400 BTU/gal	834,2
Dexlite (E30)	38.200 BTU/gal	840,7
Dexlite (E50)	35.000 kj/kg	833,3
Solar (E100)	43.000 kj/kg	0,832
Etanol (E100)	26.950 kj/kg	0,7190

Table 3. Daft List of Non/Subsidized Fuel Prices in North Bagan Sinembah Village [16][17]

No	Fuel Type	Total
1	Pertamax	Rp.14.250
2	Pertamina dex	Rp.16.900
3	Dexlite	Rp.16.250
4	Solar	Rp.16.800

2.3. Electrical load calculation

The type of data collection was carried out using interviews and on-site observations. The method of collection was simple random sampling, taken from 20 houses with homogeneous house conditions, namely the same type of house condition. The collection method uses the Solvin method, which is a method for finding the sample size of electricity load data in order to get a representative sample from all houses and be more certain. The electricity load is taken during existing conditions on a 6 hour/day pattern (18.00-22.00 and 04.00-06.00) using a centralized generator and when 24 hour electricity conditions in North Bagan Sinembah village can be met. The formula used to find the total load is.

$$\text{Electrical load} = (\text{Equipment Power (Watts)} \times \text{Number of Equipment} \times \text{Usage Time (hours/day)} \qquad (1)$$

In the same way, the electrical load calculations for 20 other samples were carried out. The load data obtained from the 20 samples is then added up and then the average electricity load for each house is calculated using calculations.

$$\text{Average electricity load} = \frac{\text{Electricity Load}}{\text{20 Houses}} \qquad (2)$$

2.4. Calculation of bioethanol potential of oil palm fronds

Calculation of bioethanol potential in this research was carried out by calculating the number of palm fronds, namely 525 kg or 6,3 tons, these results were obtained from research [13]. To calculate bioethanol, it is necessary to carry out a fermentation method using microbial fermentation of sugar to become bioethanol. In this research, calculating bioethanol was carried out using the SuperPro Designer software. SuperPro designer is a process simulator specifically developed to simulate bioprocess unit operations. The initial stages of making palm frond bioethanol in SuperPro Designer v10 can be seen in Figure 1.

Figure 1. Bioethanol Manufacturing Process Flow in the SuperPro Designer Application

a. Determination of the Process Model

In the initial stage of the SuperPro Designer application, there are two process model options, namely batch and continuous. The process used is a batch process because the batch plan time is calculated and the flow rate is displayed on each batch basis.

b. Preparation of Procedure Units

Table 4. Unit Procedures

Procedure Units	Operating Units	Process
Mixing	Bulk Flow	3-Stream
Size Reduction	Grinding (Bulk)	Grinding
Batch Vessel Procedure	In a Reactor In a Fermentor In a Seed Fermentor	Vessel Procedure Fermentation Seed Fermentation
Storage Blending	Bulk Batch	In a Flat Bottom Tank
Heat Exchanging	Heat Exchanging	Heat Exchanging
Distillation	Continuous (Short-Cut)	Distillation
Adsorption	GAC Adsorption (Liquid Streams)	GAC Adsorption

c. Filling Pure Components and Stock Mixture in The SuperPro Designer Application

Table 5. Content of Pure Components in Palm Oil Fronds [15]

No	Component	Composition (%)
1	Amylopectin	69,3%
2	Amylose	0,2%
3	Lmp	14,4%
4	Proteins	2,2%
5	Fat	3,04%
6	Water	10%

Tabel 6. Determination of Stock Mixture Value

No	Component	Content
1	Water	69,3%
2	air	0,2%

2.5. Validation of Simulation Results

The validation stage in this research is by conducting research comparisons [13] using the SuperPro Designer application.

Table 7. Validation of Research Results

Parameter	Research [13]	Validation
Raw material	Palm Fronds	Palm Fronds
Composition	Cellulose 34%, Hemicellulose 27%, Lignin 19%, Extractive Substances 9%, Water 8%,	Cellulose 34%, Hemicellulose 27%, Lignin 19%, Extractive Substances 9%, Water 8%,
Input Value	400 gram	0,4 kg
Ethanol Content	161,98 L	228 L

The results of research simulation validation [13] show that with the same raw materials and composition, the ethanol content in the study was 161.98 L and 228 L from the simulation results. With an input value of 400 grams in research [13] and palm fronds of 0.4 kg in simulation using Superpro. The validation results of the bioethanol content comparison showed an error value of 49%, because the comparison was between experimental research and software, so it was concluded that the results produced different values because in the experimental process in research [13] in each process there were parameter values and loss during the experiment.

2.6. Calculation of electrical energy potential, power potential oil palm frond bioethanol fuel consumption and fuel costs and savings

The mathematical calculations used are [19][20]:

Electrical Energy = Volumetric Flow x LHV (3)

Electrical Energy : Output Energy produced from biomass sources (kWh/day)
LHV : Low Heating Value Heat when water and hydrogen are in the vapor phase (BTU/Gal) 1 BTU/Gal = 0.000293071 kWh, (KJ/kg) (1 KJ/kg = 0.000277778 kWh)
Volumetric Flow: Volume Flow Rate (Gal)
Electric Power Potential (P) = $Elecreical\ Energy\ (E) \times Time\ (t)$ (4)

3. Results and Discussion

The electricity load requirement for this village is taken by calculating the number of equipment usage loads used in each house by calculating it in existing conditions 18.00 WIB to 24.00 WIB and restarts from 04.30 WIB to 06.00 WIB [4] and if it is in 24 hour conditions. By calculating equation (1) and (2), this calculation uses mathematical calculations that refer to research [18] and the electrical load results obtained using a sample of 20 houses out of 310 obtained the electrical load which can be seen in table 8.

Table 8. Electricity Needs of North Bagan Sinembah Village

No	Sector	Existing	24 jam
1	Household	296,16 kWh	862,91 kWh
2	Public facilities	1,568 kWh	4,713 kWh
3	Total	297,72 kWh	867,62 kWh

From table 8 above, the load profile of electrical energy requirements in existing and 24 hour conditions in North Bagan Sinembah village shows that the total electrical energy requirement is 297.72 kWh. 6 hours per day, while in 24 hour conditions it was 867.62 kWh, this increase was due to additional usage time and electrical equipment. Next, after the electrical load requirements are obtained, the next step is to run a simulation using the SuperPro Designer application which can be seen in the following single line diagram image.

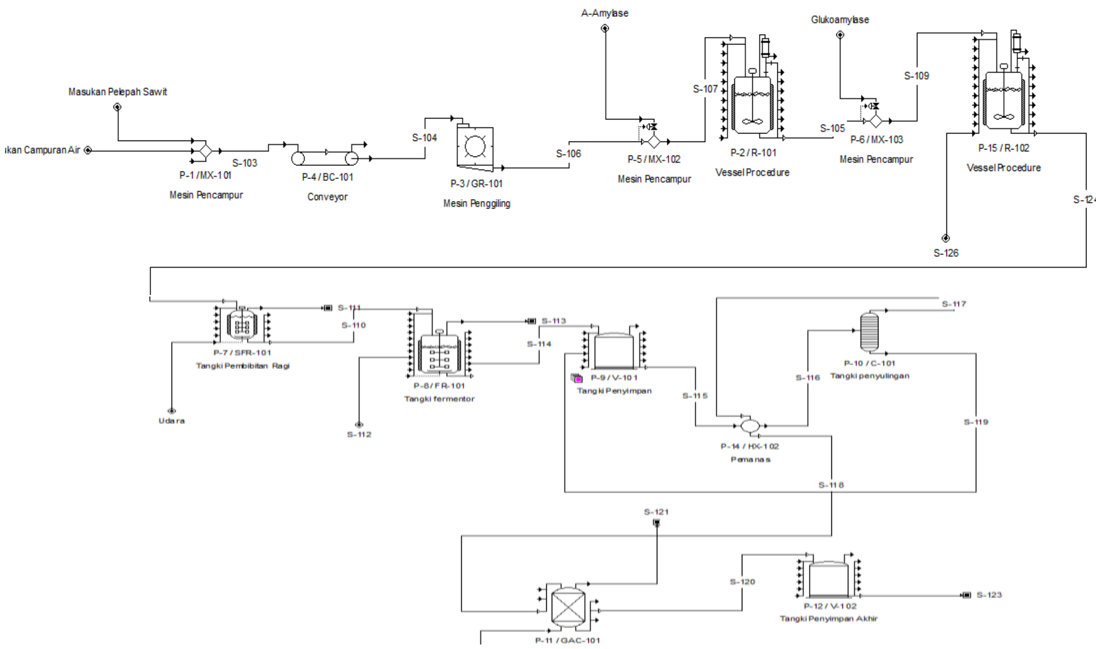

Figure 2. Single line diagram of the oil palm frond simulation process using Superpro Designer

The image above shows a series of initial stages of the simulation process of converting palm fronds into bioethanol, with the initial stage inputting the number of palm fronds and inputting the composition of the frond content into the application using the fermentation process. The results of the bioethanol potential of palm fronds can be seen in the following table.

Table 9. Simulation Results of Bioethanol Potential

No	Component	Ethyl Alcohol	Water
1	Flowrate (kg)	42,34627	0,51536
2	Mass Comp (%)	99,9876	1,2024
3	Concrentation (g/L)	2,345570	0,028546
4	Mass Flow (kg)	42,8616	
5	Volumetric Flow	54,72 L/ha/day 1.641,66 L/ha/month 18.053,72 L/ha/year	

After the simulation was run using the SuperPro Designer application with an input of 6.3 tons per year or 525 kg per month, you can see in the table above the results of the volumetric flow from the input of the number of oil palm fronds, resulting in a volumetric flow of 54.72L/ha/day, 1,641.66 L /ha/month and 18,053.72 L/ha/year with ethanol content of 99.98%. After the bioethanol potential has been obtained, the next step is calculating the potential energy and electrical power using equations (3) and (4). These results can be seen in the following table.

Table 10. Potential Results of Electrical Energy

Fuel%	Energy/day (kWh/day)	Energy/month (kWh/month)	Energy/year (kWh/year)
E10	172,68	5.261,88	57.866,3
E30	161,77	4.855,16	53.392,6
E50	1.632,9	50.400,66	538.747,9
E100	1.257,30	38.808,48	414.835,88

The results of the energy potential above were obtained from the calculation results of equation (3). This calculation uses calculations from previous research [19] by multiplying the volumetric flow by the LHV (Low Heating Value) value from variations in the mixture of E10, E30 fuel content. E50, E100. The results of each electrical energy obtained at any time with variations in the fuel mixture are still in hectares and have not been multiplied by the total land area of Bagan Sinembah village of 7,376,443 ha. So the results of the electrical energy potential in the table above, can be concluded that from the potential of bioethanol and the area of oil palm land produced, it can meet the electrical energy needs in North Bagan Sinembah village, both in terms of daily, monthly and annual potential with the village's electrical energy needs amounting to 867.62 kWh. Next, after we get the results of the electrical energy, we then look for the potential electrical power which can be seen in the following table.

Table 11. Results of Electric Power Potential

Fuel%	Power (P)/day (Watt/day)	Power (P)/month (Watt /month)	Power (P)/year (Watt /year)
E10	4.144,32	126.285,12	1.388.791,2
E30	3.882,48	116.523,84	1.281.422,4
E50	39.189,6	1.209.615,84	12.929.949,6
E100	30.175,2	931.403,52	9.956.061,12

The results in the table above using equation (4) show that the electrical power potential of oil palm fronds produces great potential. These calculations are in accordance with research calculations [20] so that they can meet the electrical energy needs in Bagan Sinembah Utara village. The electric power potential in the table above shows that E10, E30, E50 and E100 each month have great potential if applied as potential electrical energy in the village of Bagan Sinembah Utara and it can be concluded that with variations in the mixture of dexlite and ethanol fuel in each percent of the mixture has a large E50 potential (50% Dexlite and 50% ethanol) per year of 12,929,949.6 watts, due to harvesting two palm fronds time. a month, bioethanol production is carried out every month with a potential electrical power of 1,209,615.84 watts.

4. Conclusion

From the results obtained, it was concluded that the electrical energy need for Bagan Sinembah Utara village is 867.62 kWh in 24 hour conditions. From a total of 6.3 tons of palm fronds and a land area of 7,376,443 ha, the fermentation method using the SuperPro Designer application produced a flow volume of 15.72 L/ha/day, 1,641.66 L/ha/month and 18,053.72 L/ ha/year. If we look at the potential and value of energy and electrical power, this value has the potential to meet the village's daily, monthly and annual electricity needs, namely by using E50 (50% Dexlite and 50% ethanol). The difference between this research and previous research is that the source of bioethanol comes from oil palm fronds and there are differences in variations in the mixture of E10, E30, E50 and E100 ethanol fuel. The results of variations in the fuel mixture produce electrical energy and power per day, month and year. Suggestions for future researchers regarding the characteristics and economic analysis of palm frond bioethanol.

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