

## Analysis of the Costs and Benefits of Solar Power Plants in Supporting the Energy Needs of the Medan State Polytechnic Building

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### ABSTRACT

Because the cost of installing solar power plants is relatively large, careful planning and design is needed, including the calculation of load needs and the determination of capacity and placement of solar power plants so that the system can work effectively and efficiently. This research aims to determine the capacity of solar power plants to supply the existing load economically in the Medan State Polytechnic building based on the availability of existing land. The data obtained was processed using HOMER software to simulate the optimal capacity of solar PV. Furthermore, an economic analysis was carried out. The results of the study show that solar power plants are one of the alternative solutions to support energy efficiency while supporting the campus's commitment to the application of new and renewable energy

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## INTRODUCTION

In the use of solar panels, several supporting devices are needed that function to smooth the current and voltage generated by the solar panel to the load. One of them is the battery, naterai plays a very important role in the design of solar panels. Because the battery functions as a storage device for the energy generated by solar panels before being channeled to the load. There are different types of batteries, and there are also different types of storage capacity. However, batteries are tools that are highly susceptible to damage. Things that can cause damage to the battery include the battery being charged while the battery is full, then charging the battery too low is not in accordance with the battery capacity. These 2 things often make the battery life not long or quickly damaged.

Because the level of use of solar power plants includes a relatively large cost, it is recommended to install solar power plants starting with the planning and design process. This planning and design includes the calculation of the existing load needs at the location to be supplied by the solar power plant to the capacity of the solar power plant that can supply the existing load needs at the location where the solar power plant is to be installed. So that the use of solar power plants can work effectively and efficiently after going through design and planning. The results of solar PV planning also include an estimated picture of the laying of solar PV, this is needed because the placement of solar power plants must be strategic, namely facing direct sunlight. This is done so that the output power of the solar power produced is relatively effective and the output power is maximum. In answering the problem, this research aims to determine the capacity of solar power plants to supply the existing load economically in the Medan State Polytechnic building based on the availability of existing land.

The installation of solar power plants requires planning in advance to find out how much solar power capacity is needed and able to supply the specified load at a location. The level of land availability, including the roof of the building, is also a consideration for the installation of solar PV, because solar PV also requires a large and strategic enough land (not obstructed by objects) to produce maximum output power. In this study, planning will be carried out for the use of solar power plants to supply the existing load in the Medan State Polytechnic building, where this planning includes a design drawing of the solar power plant which is assumed to be installed in accordance with the needs of the load and land availability at the Medan State Polytechnic as well as economic analysis in the planning that will be carried out

## LITERATURE REVIEW

### *Power on PLTS*

Load is the minimum amount of demand that must be met by an electric power system in a certain period of time, for example in hours and minutes or even days and months. To determine the load on electricity the formula is used:

$$L = P \times t \quad (2.1)$$

Where:

- P = Power (watts)
- t = Load Usage Time (Hours)
- L = Load / Beban (Watt-hour)

To determine the output power value of the solar panel used, the following equation can be used:

$$P = V \times I \quad (2.2)$$

Where:

- P = Power (watts)
- V = Solar Power Output Voltage (Volts)
- I = Solar Power Output Current (Ampere)

Then to determine the average current and voltage on each day of data collection with the equation:

$$\text{Document rate} = \frac{I_{total}}{n} \quad (2.3)$$

$$\text{Gate-War} = \frac{V_{total}}{n} \quad (2.4)$$

Where:

- Average = Average - Average Current (Ampere)
- Average = Average - Average Voltage (Volts)
- n = Total data retrieval

## 1. Economic Planning PLTS

### 1.1. Life Cycle Cost

$$M = 1\% \times \text{Total Investment Cost}$$

Life cycle costs (LCC) are calculated with the following formula:

$$LCC = C + Mpw$$

Where:

- LCC = Life Cycle Cost
- C = Initial investment cost
- Mpw = Total maintenance and operating costs for n years

The present value of the annual costs to be incurred in the next few years (over the life of the project), with a fixed amount of expenses, is calculated by the following formula:

$$Mpw = M \left[ \frac{(1+i)^n - 1}{i(1+i)^n} \right] \quad (2.7)$$

Where:

- Mpw = Present Value Annual Cost Over the Life of the Project
- M = Annual Fee
- I = Discount Rate
- N = Project Age

### 1.2. Cost Of Energy

The capital recovery factor is calculated with the following formula:

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (2.8)$$

According to Wengqiang *et al.*, (2004), the formulation of energy costs is as follows:

$$COE = \frac{LCC \times CRF}{AKWH} \quad (2.9)$$

Where:

COE = Cost Of Energy  
LCC = Life Cycle Cost  
CRF = Recovery Factor  
AKWH = Annual generated energy

### 1.3. Payback Periode

To obtain a period of return at a certain rate of return, the following formula model is used:

$$0 = -P_w + \sum_{t=0}^N Awt \left( \frac{P_w}{F_w}, i \%, t \right) \quad (2.10)$$

Or also the same annual income using the equation:

$$PBP = \frac{\text{Total Biaya Investasi}}{\text{Pendapatan/Tahun}} \times 1\text{Tahun} \quad (2.11)$$

Where:

PBP = Pay Back Period  
Awt = Cash Flow That Occurs in Period t  
N = Herding period  
t = Return Time

### 1.4. Break Even Point

The BEP point can be expressed in the equation:

$$BEP = \frac{FC}{P-VC} \quad (2.12)$$

Where:

BEP = Break Even Point (Rupiah)  
FC = Fixed costs (Rupiah)  
VC = Variable Cost (Rupiah)  
P = Price Per Unit (Rupiah)

## 2. Electrical Load

When power is measured in watt hours, then:

$$W = P \times t \quad (2.13)$$

With:

p = Active Power (Watts)  
t = Time (Hours)  
W = Energy (Joul or Wh)

Average load is defined as the ratio between the energy used and the time in the period. Or written according to equation 1 annual period:

$$\text{Average} = L_{\text{seyear}} / (365 \times 24) \quad (2.14)$$

Where:

Average = Average Load (Watthour)  
Lyear = Total load for a year (Watthour)  
365 = Constant Days in a year  
24 = The constant of the number of hours for one ehu.

The high reactive power will increase this angle and as a result the power factor will be lower. The power factor is always smaller than or equal to one. The definition can be written as follows:

$$\text{Cos } \phi = \frac{P}{S} \quad (2.15)$$

$$P = V \cdot I \cdot \text{Cos } \phi \quad (2.16)$$

$$S = V \cdot I \quad (2.17)$$

Where:

- Cos  $\phi$  = Power Factor
- P = Real Power (Watts)
- S = Moot Power (VA)
- V = Tegangan (Volt)
- I = Arus (Ampere)

### 3. HOMER

HOMER is a simulation model software that simulates a viable system for all possible combinations of equipment considered.

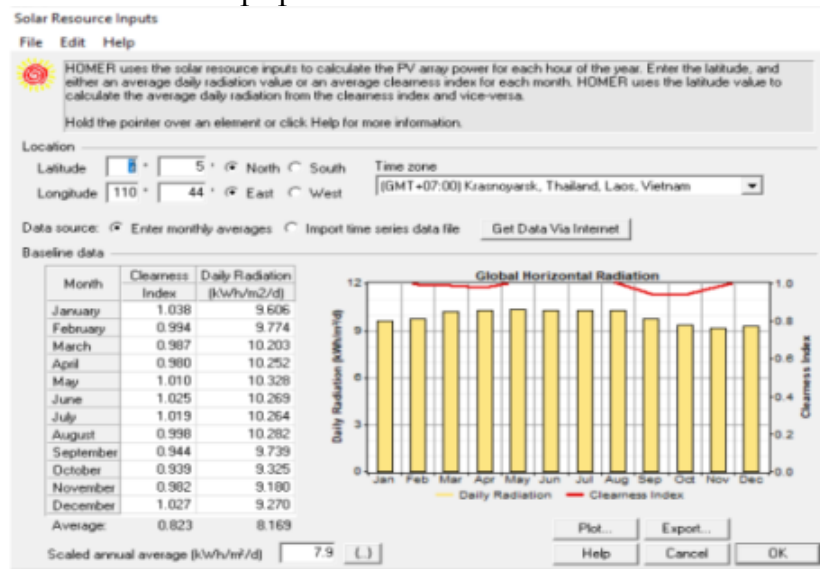


Figure 2 HOMER Display Example

### METHODOLOGY

This research began with a literature study of various journals and previous research that discussed Solar Power Plants (PLTS), charging systems, and calculations of electrical power needs. After that, data was collected which included the intensity of sunlight at the PLTS planning location, the area of land to be used, and data on the consumption of electricity load at the Medan State Polytechnic Building. The data obtained is then processed using HOMER software to simulate the optimal capacity of solar PV to meet the needs of electrical loads. Furthermore, an economic analysis was carried out to evaluate the feasibility of solar power as a power backup system for the building.

## RESEARCH RESULT

### *Economic Analysis of Solar Power Plants (PLTS)*

The initial construction and operation costs of solar power plants (PLTS) can be seen in Table 4.1 below:

Table 1. PLTS Component Prices

No	Name	Quantity	Installed Capacity	Unit Price (RP)	Total Price (RP)
1	Panel Surya Peimar SG100MFB 100 WP	2757	1516 kWp	2.200.000	6.065.400.000
2	Inverter 130 kW	12	1560 Kw	166.000.000	1.992.000.000
3	Bahan Operasional Pembangunan	-	-	-	500.000.000
<b>Total</b>					8.557.400.000

#### a. Maintenance and Operational Cost PLTS

The maintenance and operational costs of solar power plants to supply lighting and electronic loads are:

$$\begin{aligned}
 M &= 1\% \times \text{Total Investment Cost} \\
 &= 1\% \times \text{Rp. . 8.557.400.000} \\
 &= \text{Rp. 85,574,000,-/Year}
 \end{aligned}$$

#### b. Life Cycle Cost

The present value for the maintenance and operational costs (MPW) of solar power plants during the project life of 25 years with a discount rate of 4.25% is:

$$\begin{aligned}
 P &= M \left[ \frac{(1+i)^n - 1}{i(1+i)^n} \right] \\
 &= 85,574,000 \left[ \frac{(1+0,0425)^{25} - 1}{0,0425(1+0,0425)^{25}} \right] \\
 &= 85,574,000 \left[ \frac{1,8308}{0,1203} \right] \\
 &= \text{Rp. 1,302,318,197,83,-}
 \end{aligned}$$

The life cycle costs (LCC) for solar PV installed during the project life of 25 years are as follows:

$$\begin{aligned}
 \text{LCC} &= \text{COE} + P \\
 &= 8.557.400.000 + 1.302.318.197,83,- \\
 &= \text{Rp. 9.859.718.197,83,-}
 \end{aligned}$$

#### c. Energy Cost PLTS (c)

The capital recovery factor to convert all life-cycle cost (LCC) cash flows into a series of annual costs, is calculated as follows:

$$\begin{aligned}
 \text{CRF} &= \frac{i(1+i)^n}{(1+i)^n - 1} \\
 &= \frac{0,0425(1+0,0425)^{25}}{(1+0,0425)^{25} - 1} \\
 &= \frac{0,1203}{1,8308} \\
 &= 0,0675
 \end{aligned}$$

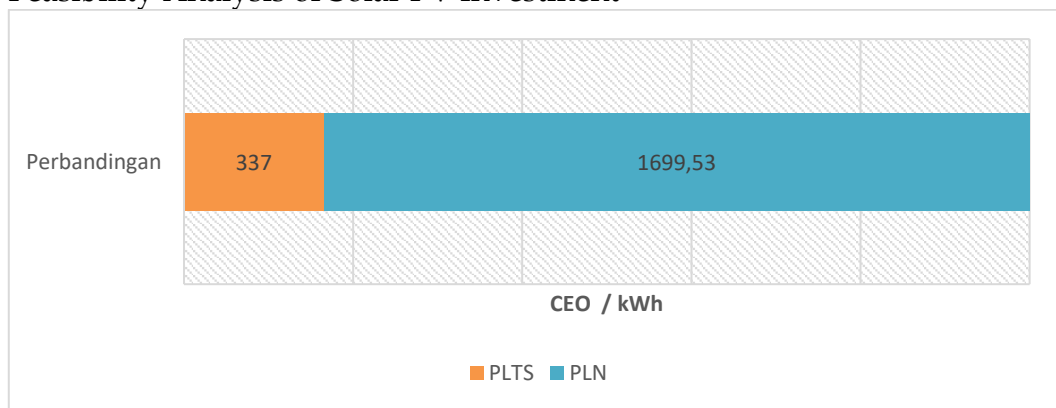
The electrical energy requirement in the Medan State Polytechnic building is 5410 kWh/day, so the annual energy consumption of solar PV is calculated as follows:

$$\begin{aligned} AKWH &= \text{kWh harian} \times 365 \text{ [kWh]} \\ &= 5410 \times 365 \\ &= 1,974,650 \text{ kWh} \end{aligned}$$

The amount of energy cost (COE) for solar PV is:

$$\begin{aligned} COE &= \frac{LCC \times CRF}{AKWH} \\ &= \frac{9.859.718.197,83 \times 0,0675}{1.974.650} \\ &= \text{Rp. } 337,03 \text{ /kWh} \end{aligned}$$

d. Feasibility Analysis of Solar PV Investment



Based on the comparison in the graph above, it can be concluded that the production cost of solar power plants at the research site is much lower than the price given by PT. PLN. There is a difference of Rp, 1,362.53,- COE PLTS is cheaper than COE by PT PLN. From this data, it can be questioned that the construction of solar power plants to supply the load on the Medan State Polytechnic building can be said to be feasible.

e. Pay Back Periode (PBP)

For electrical power in lighting is:

Known:

$$\begin{aligned} \text{Electricity Cost} &= 1699/\text{kWh} \\ \text{Load Output Power / day} &= 5410 \text{ kWh} \\ 1 \text{ year} &= 365 \text{ Days} \end{aligned}$$

$$\begin{aligned} \text{Saving for the cost of using electrical loads every year is} \\ &= 5410 \times 1699 \times 365 \\ &= \text{Rp. } 3,354,930,350 \end{aligned}$$

So PBD is:

$$\begin{aligned} PBP &= \frac{\text{Total Investment Cost}}{\text{Revenue/Year}} \times 1 \text{ Tahun} \\ &= \frac{8.557.400.000}{3.354.930.350} \times 1 \text{ Year} \\ &= 2.55 \text{ Years} \end{aligned}$$

Economic Analysis of the HOMER Simulation

The first step is to input the load data into the homer software as shown in Figure 3 below:

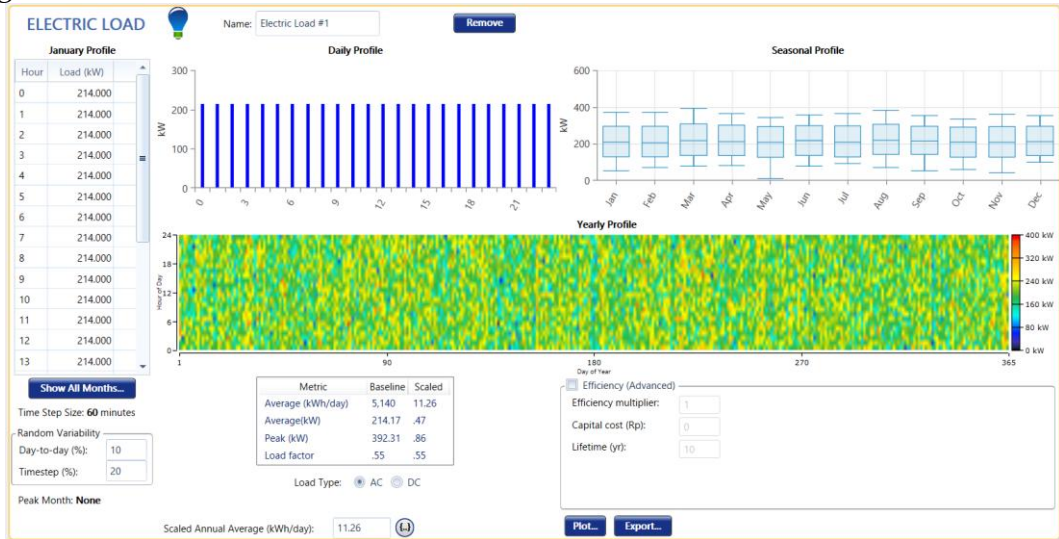
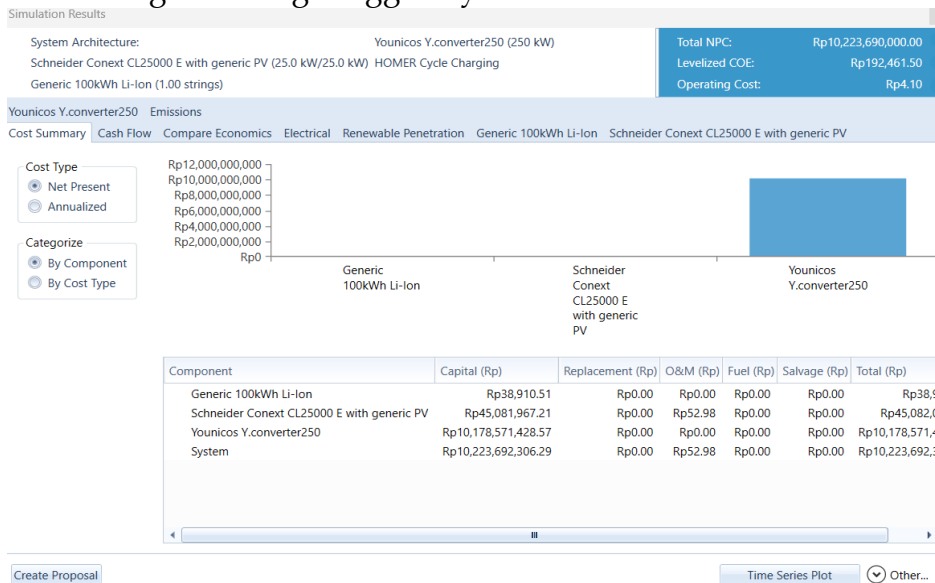


Figure 3. Load Input On HOMER

a. Initial capital (NPC)

The need for the cost of COE power plants to supply lighting loads at the BKD Building in Tebing Tinggi City is as follows :

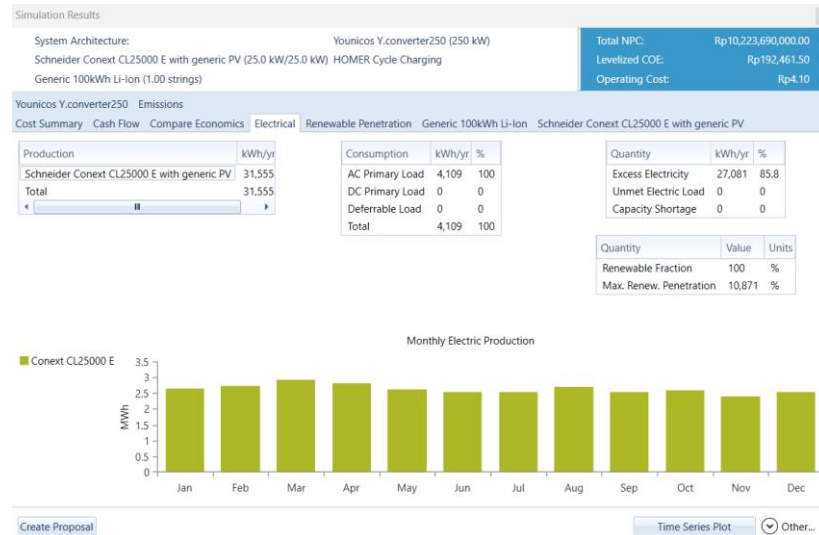


Picture 4. initial development capital PLTS

In figure 4, it can be seen that the NPC or initial capital needed to build a solar power system as an energy supply for lighting costs is Rp.10,223,690,000,-.

b. Electric Power Production

The output power produced by the solar power plant after the simulation on HOMER is as follows:



**Figure 5. Output Power PLTS**

From figure 5, it can be seen that the output power of solar power plants every year is 31,555 kWh/year. With a *levelized COE* or the cost needed per kWh is Rp.192,461. This shows that the cost of electricity production per kWh if using solar PV according to HOMER is much more expensive than PLN, where PLN's basic tariff is Rp.1,700/kWh

## CONCLUSIONS AND RECOMMENDATIONS

### Conclusion

From the results of the analysis of the determination of the capacity of solar power plants that can supply the total load at the research site. The conclusions that can be drawn are as follows:

1. From the results of the survey on the use of installed loads in the Medan State Polytechnic building, the total installed power is 1,352,570 W or 1,352.6 kW. Where the largest use is in building Z, which is 150900 W and the smallest load usage is in building T, which is 1050 W. If it is assumed that the average power usage time is 4 hours, then the power used at the research site is 5410 kWh/day.
2. From the results of the economic analysis calculation, the maintenance and operational costs of solar PV to supply lighting and electronic loads are Rp. 85,574,000,-/Year. The solar power plant is assumed to operate for 25 years, the determination of the age of this project refers to the warranty guarantee issued by the existing 16 devices on the solar power plant. The amount of discount (i) used to calculate the present value in this study is 4.25%. The determination of this discount rate refers to the Bank Indonesia loan interest rate as of November 16, 2022. The present value for the maintenance and operational costs (MPW) of solar power plants during the project life of 25 years with a discount rate of 4.25% is Rp. 1,302,318,197.83,-. The life cycle cost (LCC) for solar PV installed during the project life of 25 years is Rp. 9,859,718,197.83,-. The amount of energy cost (COE) for solar PV is Rp. 337.03 /kWh.
3. Based on calculations, it can be concluded that the production cost of solar power plants at the research site is much lower than the price given by PT.

PLN. There is a difference of Rp, 1,362.53,- COE PLTS is cheaper than COE by PT PLN. From this data, it can be questioned that the construction of solar power plants to supply the load on the Medan State Polytechnic building can be said to be feasible.

4. To return the initial capital of Rp. 8,557,400,000,- with savings on lighting expenses of Rp. 3,354,930,350 the building takes 2.55 years (without interest). If it is assumed that the initial construction cost is made to borrow from the bank with an interest rate of 12%/year and the repayment period time is adjusted to the value of the pay back period

#### *Recomendation*

The follow-up research plan can be a suggestion with sustainability such as the Design and Implementation Study of the Integrated Solar Panel System (Pilot Project), The research focus includes system design, inverter and battery selection, as well as testing energy performance and system efficiency.

#### **ADVANCED RESEARCH**

After conducting research on the technical and economic analysis of solar panel needs at the Medan State Polytechnic, the next research step is directed to the development of real implementation, system optimization, and integration of smart technology in renewable energy systems in the campus environment. Thus, the results of the technical and economic analysis that have been carried out become the strategic foundation for the implementation, optimization, and digitalization of the solar energy system at the Medan State Polytechnic. This series of advanced research is not only oriented towards energy efficiency, but also supports the development of green campuses and the sustainable application of renewable electricity technology.

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