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Energy Efficiency Analysis of the Implementation of On-Grid Solar Power System at Pertamina Labuhan Deli Fuel Depot

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ABSTRACT

Economic growth and the increasing demand for electrical energy require a breakthrough in the provision of electrical energy, one of which is the use of renewable and environmentally friendly energy. Solar energy is one of the renewable energies that can be used as a solar PV system. This solar PV system can also be combined with the PLN network (grid) and generators to meet electrical energy needs. This study aims to find out the amount of electrical energy efficiency value that can be produced by the plant every month, and whether it can affect the electricity bill paid by PT Pertamina Patra Niaga every month. Methods This research uses observation methods and collects various data related to the installation of Solar Power Plants on the Grid starting from April to September 2024. This research contains the results of the total electrical energy produced by the solar power plant, the efficiency of the solar power plant as well as the saving costs generated after the installation of the solar power plant at the Pertamina Labuhan Deli Fuel Depot.

Introduction

The need for electrical energy is one of the most important things for the community and companies today. Along with the development of technology, there are also more and more breakthroughs in the field of energy investment (Rifaldi, Alham, Izzah, Ihsan, & Sugianto, 2023). Solar Power Plants (PLTS) are one of the technological breakthroughs that utilize solar energy as a source and are also one of the infinite renewable energy alternatives. The solar PV work system is divided into 3, namely: Grid Solar PV, Grid Solar Power Plant (Grid Tied), and Hybrid Solar Power Plant. This paper discusses Solar Power Plant On Grid which is a battery-free solar PV system that is effective in use from morning to evening or when there is sunlight. Because it does not have a battery, this system is very suitable for buildings that are more widely used during the day such as offices, factories, or others (Acosta & Suresh, 2016). Pertamina Labuhan Deli Fuel Depot is a state-owned office located at Jl. K.L.

Yos Sudarso km 20 which uses an On-Grid solar power plant with a capacity of 81 kW through a form of collaboration between PT Pertamina (Persero) Patra Niaga and PT Pertamina (Persero) Power Indonesia as one of the implementations of renewable electrical energy which is a commitment and work program of the company PT Pertamina (Persero) which is an energy company that is not only engaged in the field of fossil energy but also innovation and application of renewable energy in the field of transportation and industry in Indonesia (Rahmanta et al., 2023).

In solar PV, there are always components called solar panels also called photovoltaic (PV) modules and also inverters. Solar panels or photovoltaic (PV) modules are useful for converting solar energy into DC electrical energy. The inverter is used to convert the DC generated by the solar panel into AC that will be used by the load. (Diantari, Suyanto, & Hidayat, 2023). With the installation of Solar Power Plants On the Grid at the Pertamina Labuhan Deli Fuel Depot location, which will be implemented from April 2024, this study was conducted to find out the amount of electrical energy efficiency value that can be produced by the plant every month whether it can affect the electricity bills paid by PT Pertamina Patra Niaga every month.

Method

This study uses observation methods and collects various data related to the installation of Solar Power Plants on the Grid starting from April to September 2024. The data collected in this study included a cooperation agreement between Pertamina Patra Niaga and Pertamina Power Indonesia, data on the specifications of solar PV components, solar power production power, and electricity bills from PLN. The flow of this research is contained in the form of a research flow diagram as follows:

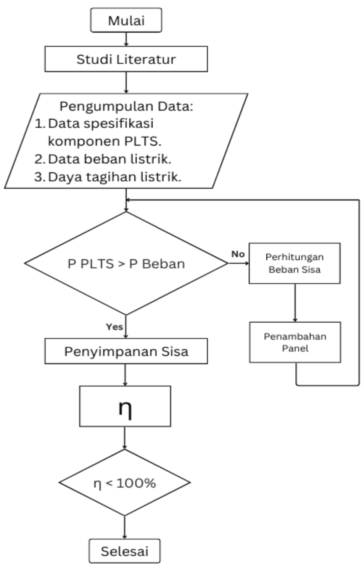

Figure 1. Research Flow

Solar PV System Implementation

The data collection in this study was taken from the implementation of the solar PV system consisting of solar panel modules, inverters, distribution panels, kWH meters, and office electricity loads. Solar panels are the main part of the solar PV system that functions to convert energy from sunlight into direct current (DC) electricity. When sunlight falls on solar panels, a process called photovoltaics occurs where light energy is absorbed and converted into electrical energy. (Kusumaningtyas, Nadhiroh, Sukatno, Siadari, & Dewantara, 2024). The power and electricity inputs that enter the solar panel will depend on the intensity of sunlight radiation while the power output produced by the solar panel is mostly influenced by environmental factors such as the presence of shadows that cover, the angle of inclination, and the cleanliness of the solar panel. In this installation, a solar panel module with the Techlan brand type THM6-NH144 is used in as many as 10 strings with each string consisting of 18 solar panels with detailed specifications as shown in Table 1.

Table 1

Solar Panel Specifications

It	Criterion	Capacity
1.	*Maximum Power Watt*	450 W
2.	*Maximum Power Voltage*	41.40 V
3.	*Maximum Power Current*	10.87 A
4.	*Open Circuit Voltage*	50.30 V
5.	*Short Circuit Current*	11.46 A
6.	Solar Panel Size	2.1 m x 1.0 m
7.	Solar Panel Weight	24 kg

The inverter serves to convert the DC electric current generated by the solar module into AC electric current which is used as a power source by electronic devices. In this inverter device, there is also an MPPT (Maximum Power Point Tracking) device that functions to keep the output power at maximum because the solar radiation factors and environmental factors mentioned above can cause non-linear input to the system. This solar PV system uses 2 inverter capacities with the Huawei Smart PV Controller brand, namely type SUN2000-50KTL-M0 with a capacity of 50 kilowatts and SUN2000-15KTL-M0 with a capacity of 15 kilowatts with details listed in Table 2 below.

Table 2

Inverter Specifications

It	Criterion	Capacity	
		SUN2000-50KTL-M0	SUN2000-15KTL-M0
1.	Rated Output Power	50,000 W	15,000 W
2.	Max Input Voltage	1.100 V	1,080 V
3.	Operating voltage range	200 V – 1,000 V	160 V – 950 V
4.	Max Current per MPPT	22 A	22 A
5.	Max Output Current	83.6 V	25.2 A
6.	Max Total Harmonic Distortion	<3%	<3%
7.	Inverter Weight	74 Kg	25 kg

Results and Discussion

Solar PV System Configuration

The configuration scheme of this solar PV system functions as an implementation flow where the power generated by solar panels will be converted by the inverter from DC to AC so that it can be used to supply office electricity load during the day. This installation also uses monitoring equipment to monitor the amount of power, voltage, and current generated by solar panels called power meters. (Gaol, Lubis, & Dalimunthe, 2024). On the inverter, there is also a monitoring device called a smartlogger which functions to monitor the power, voltage, and current converted by the inverter and can be accessed through a digital device application. This installation system is also equipped with an energy meter (kWh meter) to measure the power used by the load with specifications as zero export which serves to limit the power generated by the plant so that excess power is not exported to the grid. (PraveenKumar, Agyekum, Kumar, & Velkin, 2023).

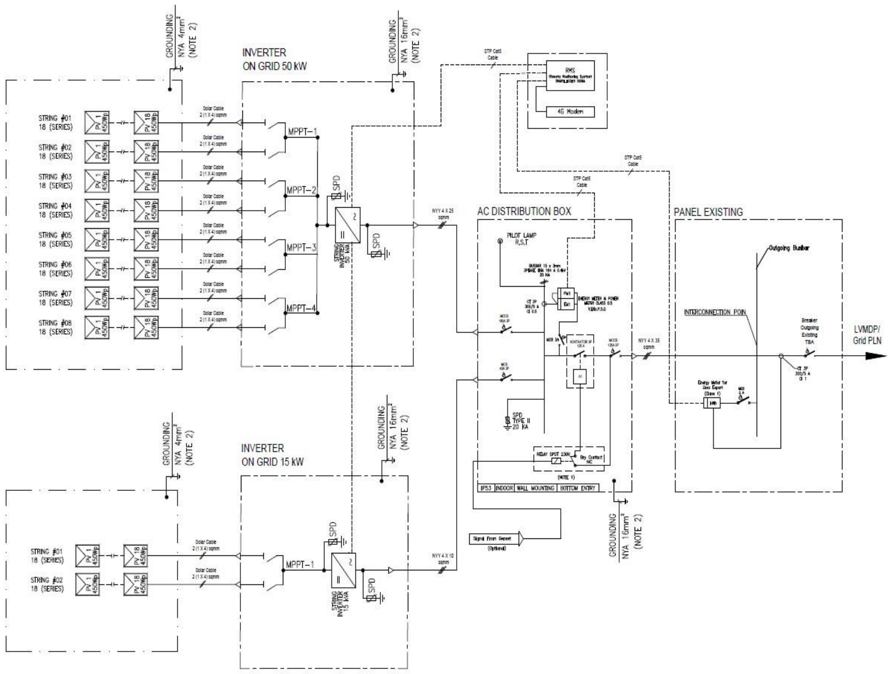

Figure 2

Single Line Diagram Solar Power Plant On Grid

In this installation scheme, the solar panels consist of 10 string groups divided into 2 inverter groups, namely a 50-kilowatt inverter and a 15-kilowatt inverter, each string is assembled in parallel, with each string consisting of 18 solar panels assembled in series. (Muslim, Khotimah, & Azhiimah, 2020). This series and parallel series of solar panels are intended so that the amount of voltage and current generated by the solar panel can pass the minimum requirements to activate the inverter in the system. For the next discussion, data from the SUN2000-50KTL-M0 type inverter with a capacity of 50 kilowatts was used.

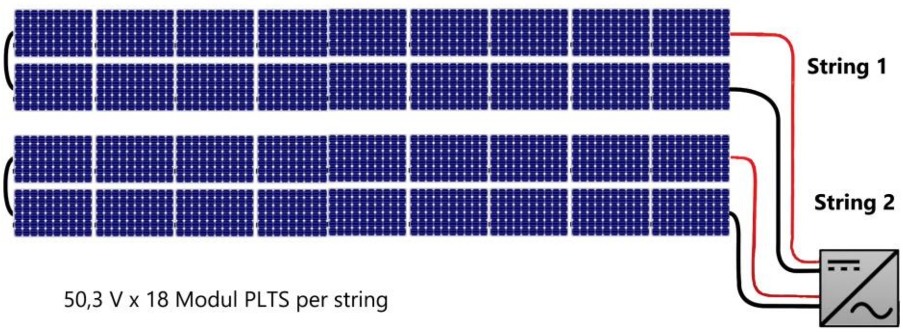

Figure 3

Solar Panel String

According to Table 1 of the Solar Panel Specification, the voltage value of one solar panel module when no-load (Voc) is 50.30 volts and the maximum voltage that a solar panel can produce when operating at maximum power with load (Vmp) is 41.40 volts. So the calculation of the voltage generated by the solar panel circuit is:

1. Voltage per string of solar panels (series circuit):

$$Voc\ string = Voc\ x\ 18\ modul == 50{,}30\ x\ 18 = 905{,}4\ Volt$$
$$Vmp\ string\ = Vmp\ x\ 18\ modul == 41{,}40\ x\ 18 = 745{,}2\ Volt$$

2. The voltage of 8 strings assembled in parallel that goes into a 50 kilowatt inverter is:

$$\textit{Input Voltage} : V\ in = Voc\ string = 905{,}4\ Volt$$
$$\textit{Operating Voltage} : V\ op = Vmp\ string = 745{,}2\ Volt$$

So the voltage value that enters the inverter system is 905.4 volts, which is still lower than the maximum input voltage value of the 50 kilowatt inverter, which is 1,100 V as seen in Figure 4 about the voltage comparison graph with the 50 kW inverter specification. (Artha, 2024). The maximum operating voltage value of 745.2 volts is still included in the operating voltage range of the MPPT inverter, which is 200 volts – 1,000 volts.

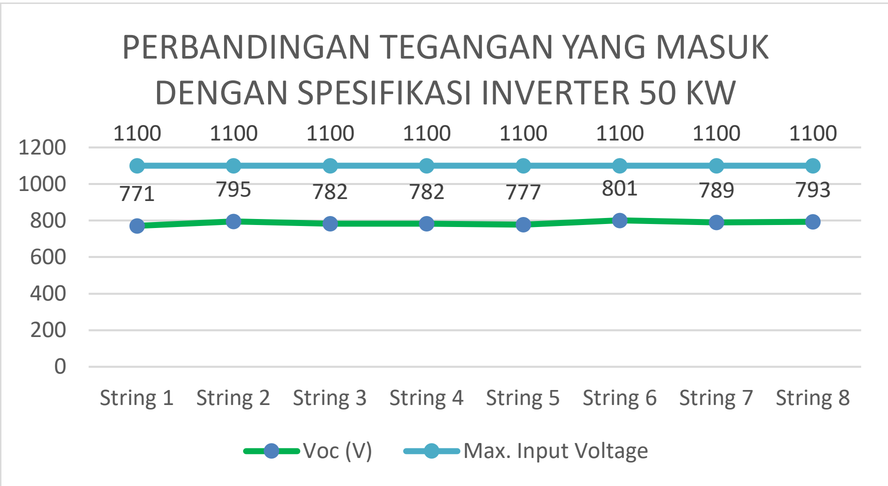

Figure 4

Voltage Comparison Chart with 50 kW Inverter Specifications

Meanwhile, if the whole series is assembled without a parallel series, then the voltage value is as follows:

Input Voltage : $V\ in = Voc\ x\ 144\ modul = 50{,}30\ x\ 144 = 7.243{,}2\ Volt$

Operating Voltage: $V\ op = Vmp\ x\ 144\ modul = 41{,}40\ x\ 144 = 5.961{,}6\ V$

With the above value, it is too large and passes the maximum operating value of the inverter specification as listed in Table 2.

While the maximum current value that can be produced by solar panels when operating at maximum power with load (Imp) is 10.87 A, then by the inverter specifications where the inverter has several MPPT units and every 2 strings are connected to 1 MPPT unit, so the calculation of the current value that enters 1 MPPT unit is:

1. Current per string of solar panels (series series):

$$Imp\ string = Imp\ modul = 10{,}87\ Ampere$$

2. The current on 2 parallel strings that go into 1 unit of MPPT 50 kilowatt inverter is:

$$System\ Current : I\ op = Imp\ string\ x\ 2\ string = 10{,}87\ x\ 2 = 21{,}74\ A$$

With this current value, it meets the specifications of a 50 kilowatt inverter where the maximum value that enters the MPPT is 22 A as seen in Figure 5 regarding the current comparison chart with the specifications of a 50 kW inverter.

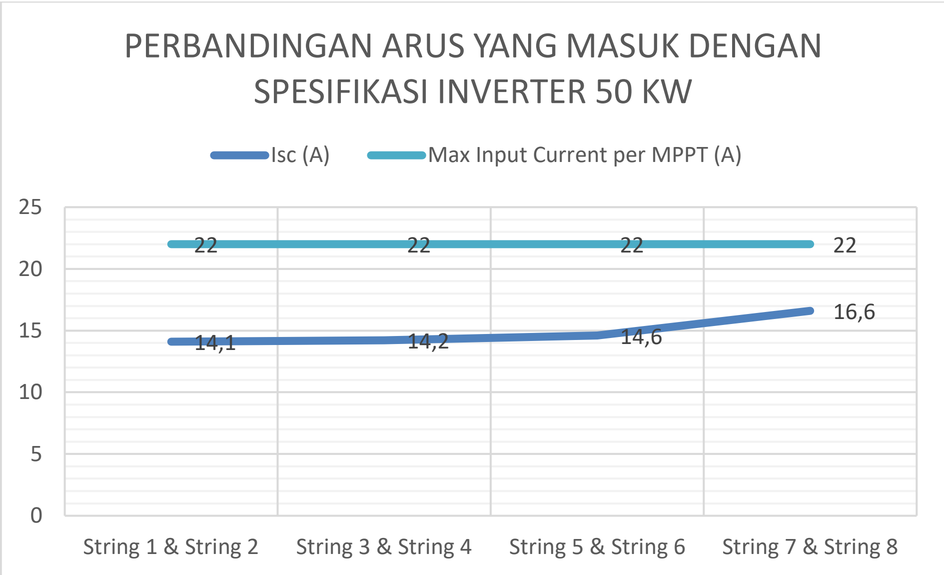

Figure 5

Current Comparison Chart with 50 kW Inverter Specifications

Based on the results of the calculation above, the results of the no-load measurement carried out in the field with the following data:

Table 3

Measurement Results of No-Load Solar Power Plant String on a 50 kW Inverter

No. String	Number of Modules	Irradiation (W/m2)	Temp. PV (C)	Voltaire (V)	Is (A)
1	18	733	43	771	4,3
2	18	669	35	795	9,8

3	18	706	35	782	7,1
4	18	823	42	782	7,1
5	18	723	34	777	6,2
6	18	733	34	801	8,4
7	18	733	43	789	6,7
8	18	823	42	793	9,9
TOTAL		5943		6290	59,5

How Inverter on Grid Works

The On Grid inverter used in this solar PV system consists of several components with different functions to support the maximum performance of the inverter. The initial device contained in the inverter is an MPPT consisting of a DC - DC converter also known as a DC Switch which functions to maximize the variable power before entering the MPPT system. This circuit of switches regulates the current given into the inductor, which then generates a magnetic field. (Sulistiawati & Yuwono, 2019). This magnetic field will produce a higher or lower voltage, depending on how the switch is arranged. The voltage generated is then smoothed using a capacitor and regulated using a control circuit integrated with the converter. In MPPT, there is also an algorithm logic that can maximize the irregularity and inaccuracy of the values generated from solar panels and can synchronize frequencies according to the frequency of the PLN network.

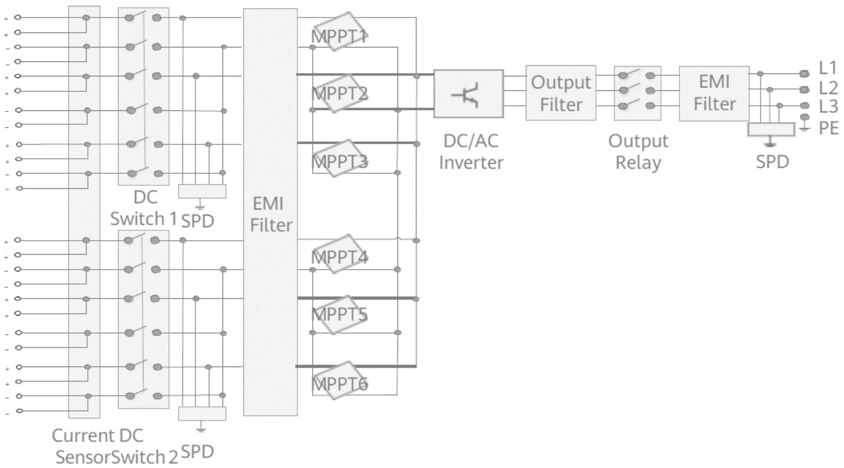

Figure 6

Circuit Diagram Inverter on Grid SUN2000-50KTL-M0

The inverter also has a safety device called a Surge Protecting Device (SPD) that protects electrical components from current surges due to faults in the system or the consequences of lightning. Then there are various types of filters including EMI Filter and

Output Filter which function to filter the interference of the transmitted electrical signal, minimize ripples in sinusoidal waves, and also be able to filter high-frequency voltages from the DC-DC converter so that the *total harmonic distortion* value obtained is low. Based on Table 2 of the Inverter Specifications, it is stated that the maximum *total harmonic distortion* or the percentage between the harmonic amount and the fundamental amount that can be achieved by this inverter is <3%.

Comparison of Electrical Energy Consumption Before and After Solar Power Plant Installation

Electrical energy consumption at the Pertamina Labuhan Deli Fuel Depot office can be compared between before the installation of the solar power plant and after the installation of the 81 kW On-Grid solar power plant in the same month period from April to September in the last two years shown in Table 4.

Table 4
Electrical Energy Consumption Before and After Solar Power Plant Installation

Electrical Energy Consumption (kWh)			Difference 2023 – 2024 (kWh)	Solar PV Production (kWh)
Moon	Before Solar PV is Installed (2023)	After the Solar Power Plant is Installed (2024)		
April	158.368	158.528	160	9018,70
May	156.816	155.216	1.600	7382,10
June	167.072	126.873	40.199	8423,20
July	160.256	120.172	40.084	8422,60
August	164.880	161.509	3.371	7372,20
September	162.912	162.606	306	7935,52
Total	**970.304**	**884.904**	**85.400**	**48.554,32**
Average	161.717	147.484	14.233	8.092,39

In the table above, there is a stable difference in electrical energy from the period June to July, while in the period of April – May, it is estimated that the consumption of electrical energy is quite large due to the number of holiday events so that Pertamina carries out a task force (task force) on holidays so that many use electronic devices such as air conditioners, lighting, and others, especially during Peak Load Time (WBP).

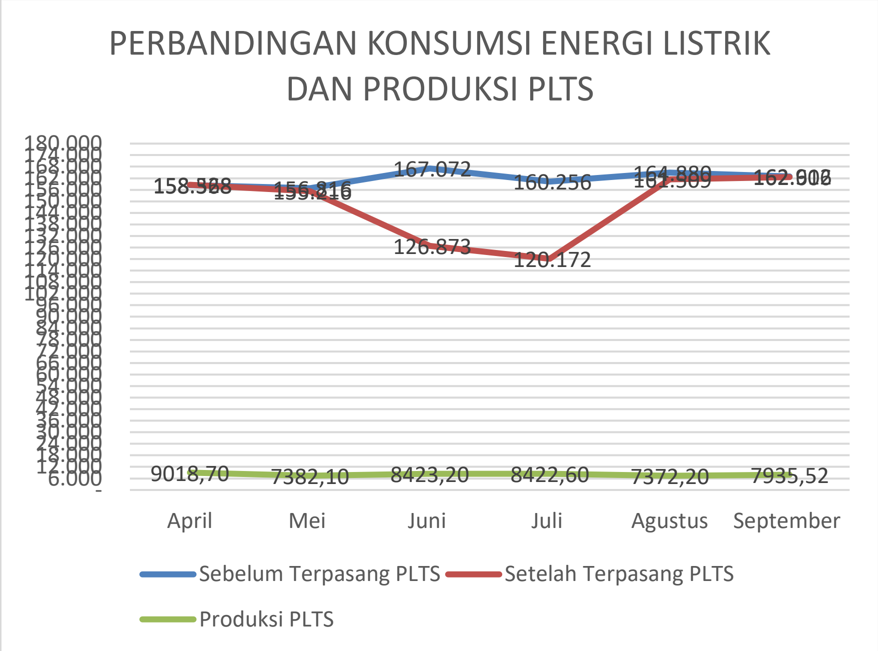

Figure 7

Comparison Chart of Electrical Energy Consumption and Solar Power Plant Production

Meanwhile, from August to September, there is a 3 x 10,000 KL storage tank construction project that requires a lot of electrical energy use, especially in that period until the project is completed. As seen in Figure 4, which is a comparative graph of electrical energy consumption in the period of 6 months from April to September before the installation of solar power plants (2023) and after the installation of solar power plants (2024), where there was the largest decrease in electrical energy consumption in June and July where before the installation of solar power plants the total usage was 327,328 kWh, but after the installation of solar power plants the consumption of electrical energy was 247,045 kWh so that a total decrease was achieved up to 80,283 kWh.

Efficiency of Saving Electrical Energy Costs at 81 kWp On-Grid Solar Power Plant

A comparison of the costs incurred before and after the installation of *the 81 kW On Grid* Solar Power Plant at the Pertamina Labuhan Deli Fuel Depot office can be seen in Table 5. Savings on electricity costs at a percentage rate can be measured after comparison.

Table 5
Electricity Account Payment (Rp) Before and After Solar Power Plant Installation

Moon	Year (2023)	Year (2024)	Savings (Rp)	Percentage (%)
April	197.209.198	198.640.231	-1.431.033	-0,73%
May	195.012.516	194.575.002	437.514	0,22%
June	207.727.750	195.484.665	12.243.085	5,89%

July	199.989.230	186.143.752	13.845.478	6,92%
August	205.120.900	202.112.083	3.008.817	1,47%
September	203.316.156	203.586.867	-270.711	-0,13%
Total	**1.208.375.750**	**1.180.542.600**	**27.833.150**	**13,65%**

Reduction of Carbon Dioxide (CO2) Emissions

Based on PLN RUPTL data 2021 – 2030, the emission factor in the Sumatra region in 2021 is 0.850 kg CO_2/kWh or equivalent to 236,111,106 kg CO_2/TJ and in accordance with the energy production data produced by *the 81 kW On Grid Solar Power Plant which is used in the calculation of reducing CO 2 gas emissions* for 5 months starting from April to September, it can be seen in Table 6.

Table 6
Solar PV Production from April to September 2024

Moon	Total Production
April	9.018,70
May	7.382,10
June	8.423,20
July	8.422,60
August	7.372,20
September	7.935,52
Total	**48.554,32**

Based on the data in Table 6, from the production of 81 kW *of Solar Power Plants on the Grid*, the total production from April to September was 48,554.32 kWh, or equivalent to 0.173 TeraJoule. Thus, CO2 gas emissions can be calculated based on the following equation:

CO Gas Emissions$_2$ (kg) = 236,111,106 kg CO2/TJ x 0.173 TJ

= 40,847,221 kg CO2 e

Based on the results of calculations from environmental emissions, the production of 81 kWh of electrical energy produced by PTLS *On Grid* at the Pertamina Labuhan Deli Fuel Depot Office is 48,554.32 kWh for 6 months, equivalent to reducing CO 2 gas emissions by 40,847,221 kg of CO_2 e and contributing to reducing carbon dioxide emissions and climate change indirectly.

Conclusion

Based on the results and discussion of the research at the Pertamina Labuhan Deli Fuel Depot Office, it can be concluded that the installed electrical system in the form of

Solar Power Plant On Grid with a capacity of 81 kW has a total of 180 PV modules grouped into 10 strings, where each PV module has a power of 450 Watts. The system is equipped with two on-grid inverter units with a capacity of 50 kW and 15 kW respectively, as well as monitoring equipment such as power meters, kWh meters, and smartloggers that are connected to digital device applications. PV modules in solar PV are assembled in series and parallel so that the voltage and current generated are to the specifications of the inverter used, while the inverter is equipped with MPPT to adjust the voltage generated by the solar panels to suit the needs of electrical equipment. During the six months in 2024, this solar power plant produced a total of 48,554.32 kWh of energy, which provides electricity cost savings of IDR 27,833,150 with a difference of 13.65%. In addition, energy production can reduce CO2 gas emissions by 40,847,221 kg CO2e, thereby contributing to efforts to reduce carbon emissions and mitigate climate change indirectly.

Bibliography

Acosta, L., & Suresh, S. (2016). Solar energy and inclusive green growth in India: A study of policy impacts on green employment generation in the private sector along the solar energy value chain. *Case Study Prepared for Deutsche Gesellschaft Für Internationale Zusammenarbeit (GIZ) GmbH*.

Artha, Roy Sukma. (2024). *Analisis Penghematan Energi PLN Untuk Akomodasi Pariwisata dengan Sistem Tenaga Surya yang Terintegrasi dengan Sistem IoT*. Politeknik Negeri Bali.

Diantari, Retno Aita, Suyanto, Heri, & Hidayat, Syarif. (2023). Analysis Inverter of PLTS On Grid. *2023 7th International Conference on Electronics, Materials Engineering & Nano-Technology (IEMENTech)*, 1–6. IEEE.

Gaol, Hagai Fernando Lumban, Lubis, Zulkarnain, & Dalimunthe, Muhammad Erpandi. (2024). An Analysis Of The Potential Of Renewable Energy Solar Panels In Ecotourism Development Planning. *Jurnal Scientia*, *13*(03), 450–462.

Kusumaningtyas, Ajeng Bening, Nadhiroh, Nuha, Sukatno, Gilang Satrio, Siadari, Hezkia Putra Rendy, & Dewantara, Muhamad Catur. (2024). Analisis Daya Luaran Protipe Pembangkit Listrik Tenaga Surya Terapung. *Seminar Nasional Teknik Elektro*, *10*(1), 215–221.

Muslim, Supari, Khotimah, Khusnul, & Azhiimah, Alfiantin Noor. (2020). analisis kritis terhadap perencanaan pembangkit listrik tenaga surya (PLTS) tipe photovoltaic (PV) sebagai energi alternatif masa depan. *Rang Teknik Journal*, *3*(1), 119–130.

Praveen Kumar, Seepana, Agyekum, Ephraim Bonah, Kumar, Abhinav, & Velkin, Vladimir Ivanovich. (2023). Performance evaluation with low-cost aluminum reflectors and phase change material integrated to solar PV modules using natural air convection: An experimental investigation. *Energy*, *266*, 126415.

Rahmanta, Mujammil Asdhiyoga, Adhi, Andrew Cahyo, Tambunan, Handrea Bernando, Digwijaya, Wigas, Damanik, Natalina, & Al Hasibi, Rahmat Adiprasetya. (2023). An analysis of national position, opportunity, and challenge of Indonesia’s nuclear program to support net-zero emissions by 2060. *Energies*, *16*(24), 8089.

Rifaldi, Muhammad, Alham, Nur Rani, Izzah, Nurul, Ihsan, Muhammad Nur, & Sugianto, Muhammad. (2023). Analisis Efisiensi Sistem Pembangkit Listrik Tenaga Surya sebagai Sumber Energi Baru Terbarukan. *Jurnal Rekayasa Tropis, Teknologi, Dan Inovasi (RETROTEKIN)*, *1*(1), 16–24.

Sulistiawati, Eka, & Yuwono, Bambang Endro. (2019). Analisis tingkat efisiensi energi dalam penerapan solar panel pada atap rumah tinggal. *Prosiding Seminar Intelektual Muda*, *1*(2).