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Evaluation Analysis of Small Capacity Rooftop Solar Electricity (PLTS) Development Plans at PT Pertamina Gas

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ABSTRACT

Solar Power Plant (PLTS) is one type of new and renewable energy (EBT) generated from the Sun. Indonesia is a country that has considerable solar energy development potential of 4.8 Kw h/m2, but currently its utilization is still very low at only 0.01%. This study aims to evaluate the development plan of small-capacity rooftop solar power plants at oil and gas facilities owned by PT Pertamina Gas (Pertagas). This study uses PVSyst and Helioscope software to analyze the potential and efficiency of rooftop solar power plants. The results show that the planned installation of small-capacity rooftop solar power plants (±0.15 kW) in several Pertagas operational areas can support electricity supply for oil and gas distribution in Indonesia. The utilization of solar energy, which is one of the new renewable energy (EBT), is expected to increase the national energy mix in accordance with the government's target. This research provides evaluation and recommendations for the development of rooftop solar power plants at oil and gas facilities to support national energy independence and security.

Keywords: New and Renewable Energy, Solar Power Plants, Efficiency, Oil and Gas Facilities

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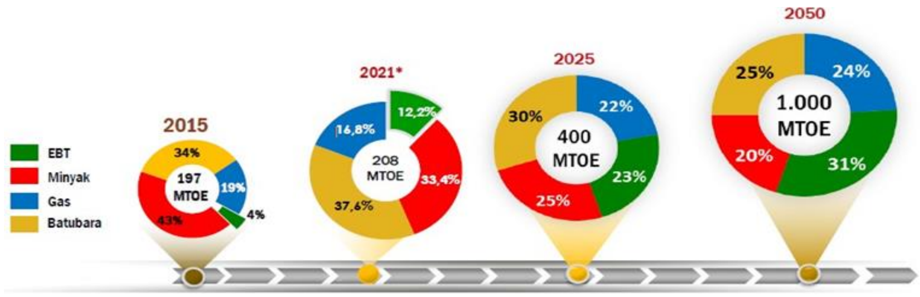
INTRODUCTION

Energy is a very important need in people's daily lives so that it can improve the quality of life in an area (Gatersleben & Vlek, 2014). Besides that, energy availability greatly influences a country's economic performance, so it is necessary to choose energy sources that combine environmentally friendly and sustainable concepts (Santoso, 2017). This can be achieved by encouraging the use of new renewable energy (EBT), one of which is in accordance with the regulations of the Government of the Republic of Indonesia through Government Regulation Number 79 of 2014 concerning National Energy Policy (KEN), which has stated that by 2025 the use of new renewable energy (EBT) will be at least 23 % and in 2050 at least 31% as long as the economy is met (Pelengkahu et al., 2024). In line with this thinking, the Government of the Republic of Indonesia is strengthening the national energy mix target through Presidential Regulation Number 112 of 2022 concerning the Acceleration of Renewable Energy Development for the Supply of Electric Power (Yudiartono et al., 2023). With these new regulations, the Government hopes that the renewable energy mix target in the national energy mix is in accordance with PP No. 79 in 2014 can be achieved (Obeng-Darko, 2019).

According to data from the 2021 Economic Energy Handbook of Indonesia, until 2021, the role of EBT in the national energy mix has reached 12.2%, where the role of non-EBT primary energy sources still dominates with the role of coal at 37.6%, while for petroleum it is 33.4 %, then for natural gas it is 16.8%. The achievement of these figures shows that it is necessary to increase the role of EBT by 10.8% within the next 4 (four) years.



Picture 1. Target and Realization of National Energy Mix
(Source : Handbook Economic Energy of Indonesia 2021)

In this regard, new steps and strategies are needed to ensure that the target is achieved by 23% in 2025 and 31% in 2050. These policies and steps need to accommodate that the importance and target of energy supply and utilization is to realize energy independence. and national energy security to support national development. The 2020 National Energy Mix Book states that the supply and utilization of energy relies on four aspects, namely affordability, accessibility, availability and acceptability (Ofélia de Queiroz et al., 2024). These four aspects play an equally important role in achieving the target role of EBT in the national energy mix.

The acceptability aspect has so far been accommodated through several regulations including the General National Energy Plan (RUEN) and the General Regional Energy Plan (RUED) itself, several articles related to community participation, such as in RUEN Article 3, Paragraph (2) Letter d, it is stated that " society to participate in the implementation of national development in the energy sector.", the quote clearly illustrates this. Community participation also has the potential to increase the achievement of the role of EBT in the national and regional energy mix. research by Cohen et al (2021) shows that in the case example in the United States a number of projects based on community investment financing have reached a capacity of 119 MegaWatt (MW) in the period 2010 to 2016 in 112 (one hundred and twelve) projects, and is estimated at 14 MW added every year (Cohen et al., 2021). The success of community participation in EBT-related activities actually needs to be studied further, considering that according to data from the Ministry of Energy and Mineral Resources, community participation in "traditional" EBT development through the use of biogas in livestock centers has been common since the 1970s in rural areas (Oyewunmi, 2022).

Community participation in the use of EBT, especially solar energy, can be further encouraged in line with the issuance of Minister of Energy and Mineral Resources Regulation number 26 of 2021 concerning Rooftop Solar Power Plants Connected to the Electric Power Network for Business Permit Holders Providing Electricity for Public Use which opens up opportunities for the community as a whole. wide area to utilize solar energy through the use of Rooftop PLTS independently (Ariani et al., 2014).

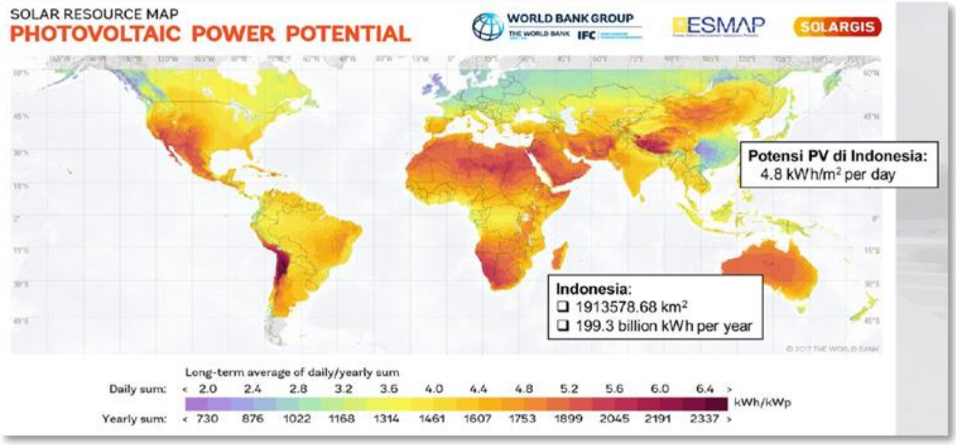
Apart from that, in the General National Energy Plan (RUEN), through Presidential Regulation No. 79 of 2014, the Indonesian Government has established a policy of increasing the share of renewable energy in the national energy mix to 23% by 2025 (Nugroho, 2019). To support these efforts, especially in the field of solar energy utilization, the government has issued several technical policies as a basis for its implementation, one of which is through Minister of Energy and Mineral Resources (ESDM) Regulation No. 49 of 2018, jo. Minister of Energy and Mineral Resources Regulation No.13 of 2019, jo. Minister of Energy and Mineral Resources Regulation No.16 of 2019, concerning the use of rooftop solar power generation systems by PT customers State Electricity Company (PLN) Persero.

This rule is intended to open up opportunities for all PT customers PLN (Persero) from the household, business, government, social and industrial sectors to participate in the use and management of renewable energy to achieve energy security and independence, especially solar energy (EBTKE, 2018). To encourage its implementation on a massive scale in Indonesia, the government has issued Circular Letter of the Minister of Energy and Mineral Resources No. 363/22/MEM.L/2019 to the Working Cabinet ministers, attorney general, TNI commander, head of the Indonesian police, heads of non-ministerial government institutions, governors and regents/mayors in Indonesia. The circular contains an appeal to install rooftop PLTS installations in areas including offices, official residences, warehouses, parking lots and other facilities.

In addition to the plan to install PLTS, the Government is also targeting the construction of rooftop PLTS to reach 2,145 megawatts (MW) throughout 2021-2030. Of this amount, the construction of rooftop PLTS will be dominated by BUMN buildings and facilities, namely 742 MW (Nugroho, 2019). The household group followed with 648.7 MW. Industry and business will be the sectors that enjoy rooftop PLTS with a capacity of up to 624.2 MW. Construction of rooftop PLTS for PLN customers and social groups is targeted at 68.8 MW. Meanwhile, the construction of rooftop PLTS for government buildings reached 42.9 MW.

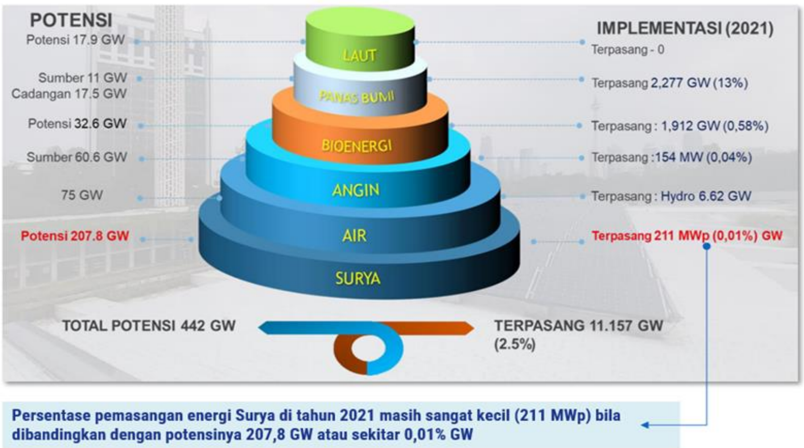
Based on the explanations above, there are several things that could serve as references/background related to this research, including:

1. Indonesia has solar energy potential that reaches 4.80 KWh/m2/day and is spread evenly throughout Indonesia.

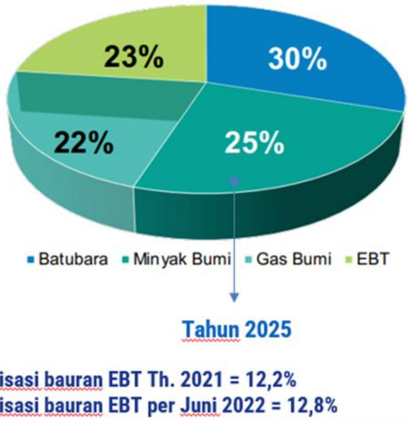


Picture 2. Solar Energy Potential in Indonesia
Source : http//globalsolaratlas.info

2. Based on data from the Ministry of Energy and Mineral Resources and IRENA for 2022, the potential for installing solar energy compared to other EBT in Indonesia is still very minimal. The percentage of solar energy installations in 2021 is still very small (211 MWp) when compared to the potential of 207.8 GW or around 0.01% GW.

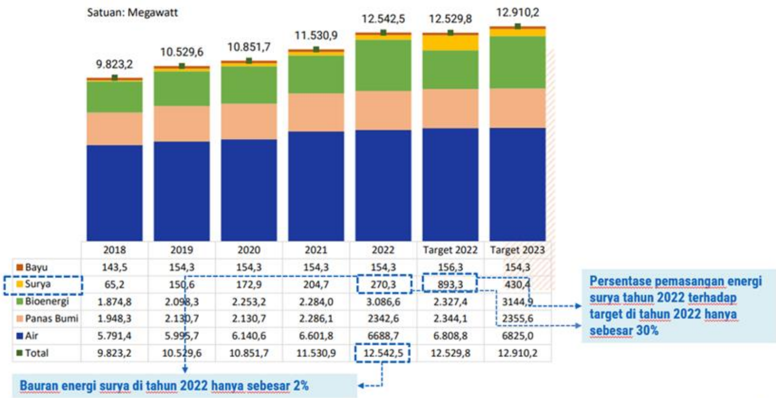


Picture 3. The potential for installing PLTS is still very minimal
Source : Ministry of Energy and Mineral Resources & IRENA, 2022



Picture 4. The EBT Mix Target is stated in PP No. 79 of 2014
Source : Ministry of Energy and Mineral Resources, 2022 & 2023

3. Then, referring to ESDM performance data for 2022, the installed capacity of PLTS in Indonesia has not grown significantly, namely only 30% (target versus realization) and the solar energy mix in 2022 will only be 2%.



	2018	2019	2020	2021	2022	Target 2022	Target 2023
Bayu	143,5	154,3	154,3	154,3	154,3	156,3	154,3
Surya	65,2	150,6	172,9	204,7	270,3	893,3	430,4
Bioenergi	1.874,8	2.098,3	2.253,2	2.284,0	3.086,6	2.327,4	3144,9
Panas Bumi	1.948,3	2.130,7	2.130,7	2.286,1	2342,6	2.344,1	2355,6
Air	5.791,4	5.995,7	6.140,6	6.601,8	6688,7	6.808,8	6825,0
Total	9.823,2	10.529,6	10.851,7	11.530,9	12.542,5	12.529,8	12.910,2

Picture 5. The installed capacity of PLTS in Indonesia in 2022 will not increase
Source : ESDM Performance Achievements in 2022 and Targets in 2023

In line with these matters, PT Pertamina (Persero) through Subholding New and Renewable Energy (PNRE) is targeting the installation of solar power plants (PLTS) at several company operational locations with a total potential installed capacity of 500 MW. This plan is in line with the energy mix target as well as reducing greenhouse gas emissions at Pertamina Group by 30% by 2030, and electricity cost efficiency.

The PLTS installation plan will be carried out at core operational facilities such as upstream oil and gas working areas, oil refineries, fuel terminals and gas stations (Junior, 2021). Apart from that, there are also supporting facilities such as offices, housing and other assets spread across the upstream to downstream business ecosystem.

Based on the matters above, there are directions from PT Pertamina (Persero) for the implementation of PLTS within the Pertamina Group. In connection with this, the author sees the need for massive development of Rooftop PLTS, one of which is within PT Pertamina Gas as an affiliate of PT Pertamina (Persero). PT Pertamina Gas itself has operational areas spread across several islands in Indonesia, such as Sumatra, Java, Kalimantan, Sulawesi and Papua. Regarding the plan to install Rooftop PLTS, this could be an alternative energy solution other than PLN.

Subholding (SH)	Indikasi Kapasitas (MWp)	Konfirmasi SH (MWp)
Upstream (SHU)	319,19	60,31
Refining & Petrochemical (SH R&P)	277,5	13,95
Commercial & Trading (SH C&T)	21,27	16,4
Gas (SHG)	**5,11**	**5,23**
Integrated Marine & Logistic (SH IML)	3,46	3,34
New & Renewable Energy (SH PNRE)	0,06	0,04
Non SH	4,51	0,88
Total	631	100

Pembahasan tesis akan difokuskan kepada Sub Holding Gas dan hanya mengerucut pada PT Pertamina Gas

Table 1. Initial plans for installing PLTS Rooftops at Pertamina Group

Source : Workshop on Accelerating PLTS Implementation within Pertamina Internally in 2022

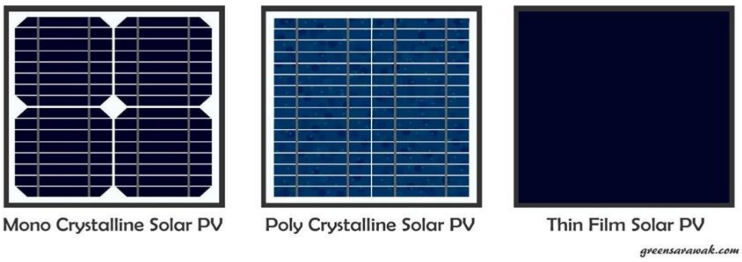
Based on previous research regarding the use of PLTS systems according to Erik et al. (2022) stated that there was a savings in electricity costs of IDR. 538,880 for 6 months, Electricity produced by PLTS with an On grid system can be distributed to PLN at a low price of 65% of the TDL, by installing PLTS, BPR BKK Mandiraja can reduce electricity costs by 22.1% by capital participation as investment in EBT projects such as The investment model in Germany is a high risk investment. The research gap is that research is carried out in areas in the banking sector, research is carried out on interest in community participation and investment in EBT projects, and the installed capacity is larger, namely 3x400 Wp (1.2 MWp). According to Kadek et al. (2022) stated that there were savings generated in the 6 month installation period of IDR. 36,055,301 and the gap in this research is that the research was carried out in government buildings, not oil and gas facilities and the electricity capacity produced was only 25 Kwp (Kijo-Kleczkowska et al., 2022).

In previous studies, assessing aspects of the community's desire to participate did not focus on supporting buildings for oil and gas facilities. This is because oil and gas facilities require stable electrical energy to avoid operational failures. Regarding the Research Gap, it is explained in more detail as follows: 1) Research conducted by Erik et al. (2022) illustrates that there are savings in electricity costs when compared to PLN electricity supply with a collection period of 6 months (Colbert, 2017). 2) Research conducted by Cohen et al. (2021) illustrates that people in Europe are interested in taking a role as investors in EBT-based power generation projects developed by the Government for commercial purposes (Cohen et al., 2021). 3) Research conducted in Indonesia, specifically at Anyar Beach, Special Region of Yogyakarta by Rachmawatie et al. (2019) shows that the PLTH pilot project by the Government can have a significant impact on the income of local residents, however this research studies the impact on communal power plants so that community participation in using it independently is not yet visible (Rachmawatie et al., 2019). 4) Research conducted by Anwar et al. (2016) illustrates that the angular position of the solar module when following the direction of the sun's movement can produce greater power than if the position of the solar module is horizontal. This research is only a small scale with a capacity of 50 Wp. 5) Research conducted by Kadek et al. (2022) illustrates that there is a total savings in electricity costs of Rp. 36 million when compared to PLN's electricity supply with a collection period of 6 months using an electricity capacity of 25 KWp (Brahma et al., 2021). 6) Research conducted by Sigit et al (2015) in the Gunung Kidul area illustrates that the design for developing a PLTS with a capacity of 10 MW requires a land area of around 6.4 Ha and is estimated to be able to produce electricity of 14,237 MWh. Taking into account the above, this research was carried out at a location that received a pilot PLTS Rooftop, so it is necessary to obtain further analysis whether technically and economically small scale PLTS Rooftop can significantly reduce energy costs in the PT Pertamina Gas area.

Related research: Evaluation analysis related to the installation of PLTS at PT Pertamina Gas aims to analyze the potential for cost savings related to plans for developing/installing PLTS Rooftops at PT Pertamina Gas, making designs/simulations related to plans for developing/installing PLTS Rooftops at PT Pertamina Gas, analyzing the feasibility of related investments. Rooftop PLTS development plan at PT Pertamina Gas. The benefits that can be obtained from the results of this research, namely providing insight into the potential cost savings resulting from the development/installation of PLTS at PT Pertamina Gas, providing insight into design/simulation using software related to plans for developing/installing PLTS at PT Pertamina Gas and providing insight regarding the feasibility of investing in PLTS construction at PT Pertamina Gas.

Solar Power Plant (PLTS) is an electricity generation technology that converts photon energy from sunlight into electrical energy. This conversion is carried out on solar panels consisting of Photovoltaic cells. PLTS utilizes sunlight to produce DC (direct current) electricity, which can be converted into AC (alternating current) electricity when needed. Therefore, even if the weather is cloudy, as long as there is light, PLTS can still produce electricity. PLTS is basically a power supply (a device that provides power), and can be designed to supply small to large electricity needs, either independently or in a hybrid manner, either by a decentralized one house one generator method or by a short centralized method. Indonesia has great potential in the solar power generation sector. With a large area and high intensity of sunlight, electricity supply from solar power can be a mainstay. According to data from the Indonesian Energy Outlook, BPPT, in 2015, it was stated that the potential for solar energy in Indonesia was very large, namely around 4.8 KWh/m2 or the equivalent of 112,000 GWp. Meanwhile, only around 10 MWp has been utilized. To increase the acceleration of solar energy development, the government has issued a roadmap targeting the installed PLTS capacity by 2025 to reach 0.87 GW or around 50 MWp per year. This number is an illustration of the quite large market potential in the development of solar energy in the future.

Another type of solar panel, namely thin film, is made from a thin film of semiconductors applied to glass, plastic or metal. The films are very thin, often up to 20 (twenty) times thinner than the crystalline silicon wafers used for monocrystalline and polycrystalline panels. This manufacturing process makes these solar panels tend to be more flexible and lighter than other types of solar panels. If a comparison is made, solar modules or panels made from silicon crystal wafers have better efficiency than the thin film type. This causes the use of thin film solar panels to require more panels and more area to produce the same power as crystalline silicon-based solar panels. According to Yuliarto, 2011 on the Indonesian Ministry of Energy and Mineral Resources news archive page, monocrystalline and polycrystalline solar panels are more often found on the market.



Picture 6. Differences in the Physical Appearance of Monocrystalline and Polycrystalline Solar Panels and Thin Film (Source : greensarawak.com/2018)

Table 2. Advantages and Disadvantages of Monocrystalline, Polycrystalline and Thin Film Solar Panel Types

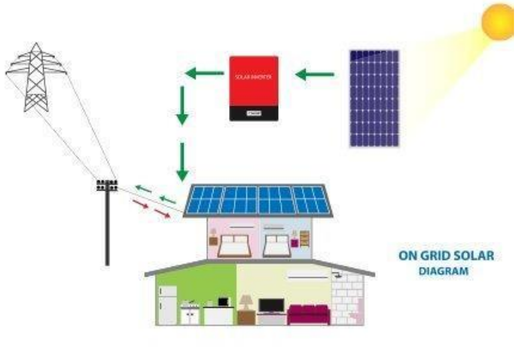
No	Panel Type	Advantages	Weakness
1.	Monokristalin	• Highest energy efficiency (up to 22.5%) • Save space • Life cycle is generally longer • Tends to be more efficient at hot temperatures/ • warm climate	Tends to be more expensive than other types of panels
2.	Polikristalin	• Lebih mudah dibuat • Biaya cenderung lebih rendah • Mampu mempertahankan efiensi di suhu yang tinggi	• Easier to make • Costs tend to be lower • Able to maintain efficiency at high temperatures

No	Panel Type	Advantages	Weakness
3.	*Thin Film*	• Easier to mass produce • Uniform color so it is more aesthetic • Flexible • High temperatures and shading tend to be less impactful than panel types • another sun	• Lowest area and energy efficiency • Life cycle tends to be lower than other panel types • Tends to have the lowest warranty compared to other types of panels

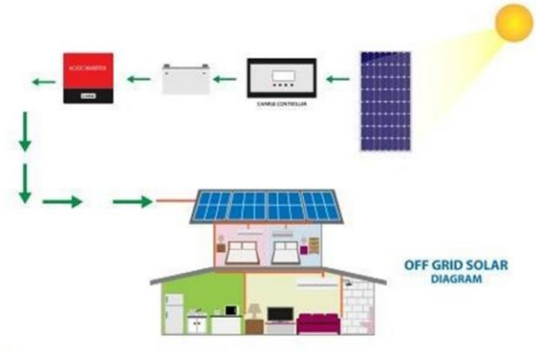
PLTS with an on-grid system means integrating the PLTS system with the main electricity supply network, in Indonesia it means connecting with the PT network. PLN. Literally, the energy produced by your PLTS system will be channeled to the main network to meet your electricity needs, or if there is excess it can be "sold" to the electricity supply company you use, depending on regulations in each country. The on grid system does not require power storage facilities because the power produced is channeled through the main electricity supply network. Meanwhile, the off grid PLTS system is an independent system that is separate from the main electricity supply network. This system clearly requires power storage facilities, because the power produced is not channeled to any network other than the internal electricity network of the building or structure where the PLTS system is installed.

Table 3. Comparison of On Grid, Off Grid and Hybrid PLTS Systems

PLTS On Grid	PLTS Off Grid	PLTS Hybrid
The system operates without batteries	The system operates using batteries	The system operates using batteries
Connected to the PLN network	Not connected to PLN network	Connected to the PLN network
Does not provide Backup power during outages	Provides backup power During a blackout	Provides backup power During a blackout
Locations that have installed Kwh meters exim or which will be and are currently in the process of installing Kwh meters exim	Remote, isolated locations, outer islands and archipelagos, borders, inland forests, which do not have an independent electricity source	Locations that have installed Kwh meters exim or which will be and are currently in the process of installing Kwh meters exim



Picture 7. Skema PLTS On Grid
(Source : solarwc.co.za/2020)



Picture 8 Skema PLTS Off Grid
(Source : solarwc.co.za/2020)

RESEARCH METHOD

The research was carried out at 13 (Thirteen) points in the PT Pertamina Gas area spread across the islands of Sumatra and Java. The research location can be reached using land or air vehicles. Details of the sampling locations are as follows:

Table 4. Location of PLTS Installation Plan at PT Pertamina Gas

No.	Area	Location
1	West Java	Mundu Gas Compressor Station
2	West Java	Bitung Compressed Natural Gas
3	West Java	Muara Tawar Metering Station
4	East Java	Gresik Metering Station
5	North Sumatera	Rantau Panjang Metering Station
6	North Sumatera	Belawan Metering Station
7	North Sumatera	KEK Sei Mangkei Metering Station
8	Central Sumatera	Tempino Gathering Station
9	Central Sumatera	KM 03 Metering Station
10	Central Sumatera	Gas Compressor Station 27
11	Central Sumatera	Gas Compressor Station 52
12	Central Sumatera	Gas Compressor Station 77
13	Central Sumatera	Gas Compressor Station 174

This type of research is included in Quantitative research. Quantitative methods were implemented in the design and simulation of Rooftop PLTS energy production results at 13 (Thirteen) points in the PT Pertamina Gas area spread across the islands of Sumatra and Java.

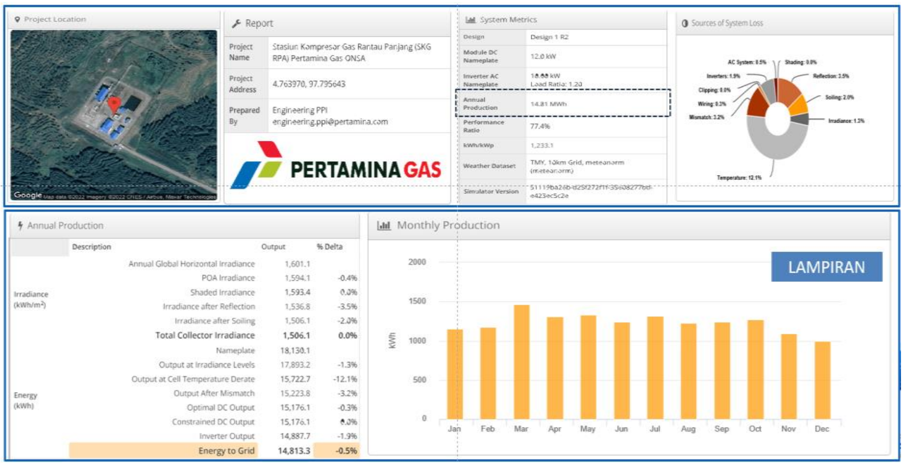
DATA COLLECTION TECHNIQUES (PRE-INSTALLATION SURVEY OF ROOF PLTS)

At this stage a field survey was carried out to observe and measure the parameters used to design the Rooftop PLTS including: location coordinates, roof condition, shading potential and installed electricity capacity in the PT Pertamina Gas area. The location coordinates will be retrieved using GPS to determine the exact point in order to search for global irradiation data and calculate the roof area which will be calculated using the geotagging method. In simple terms, calculating the roof area can be done using Google Earth software.

Once the data has been collected, a simulation will then be carried out using Helioscope software so that the PLTS Rooftop design will be known. The purpose of this analysis is to ensure that the existing roof area can support PLTS of the specified capacity. This analysis stage includes analysis of the structure and type of roof as well as calculating the area of the building's roof using GIS (rooftop tagging) then measuring lux over time as data to calculate the energy output produced by PLTS Rooftops in the PT Pertamina Gas area using helioscope software.

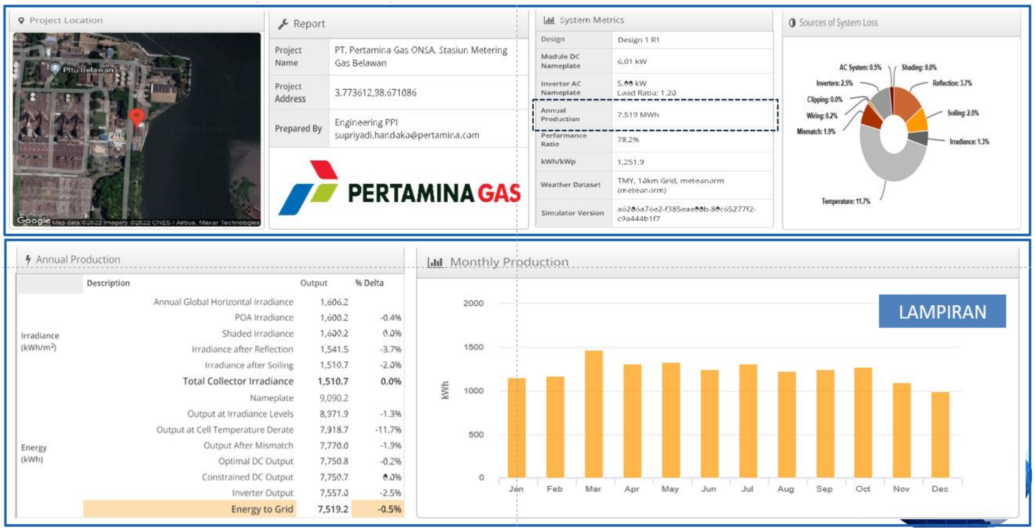
RESULTS AND DISCUSSION

1. Rantau Panjang Gas Compressor Station (North Sumatera)



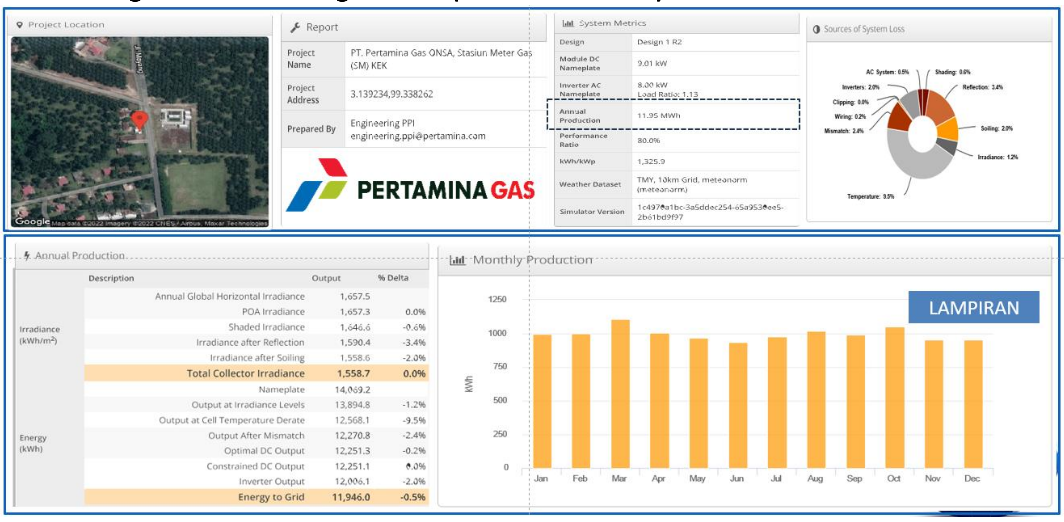
Based on simulation results with Helioscope software, the PLTS development plan at the Rantau Panjang Compressor Station (North Sumatra) can produce annual energy production reaching 14.81 MW/year. Besides that, the DC current that can be produced by the solar panels reaches 12 kW. Furthermore, regarding the Performance Ratio value that can be produced is 77.4%, this is due to several estimated losses, including the largest such as the temperature around the solar panels reaching 12%, mismatch (loss in the system) reaching 3.2%, and Reflection (reflection of sunlight away from the panel) reached 3.5% as well as several other losses as listed in the Pie chart above.

2. Belawan Gas Metering Station (North Sumatera)



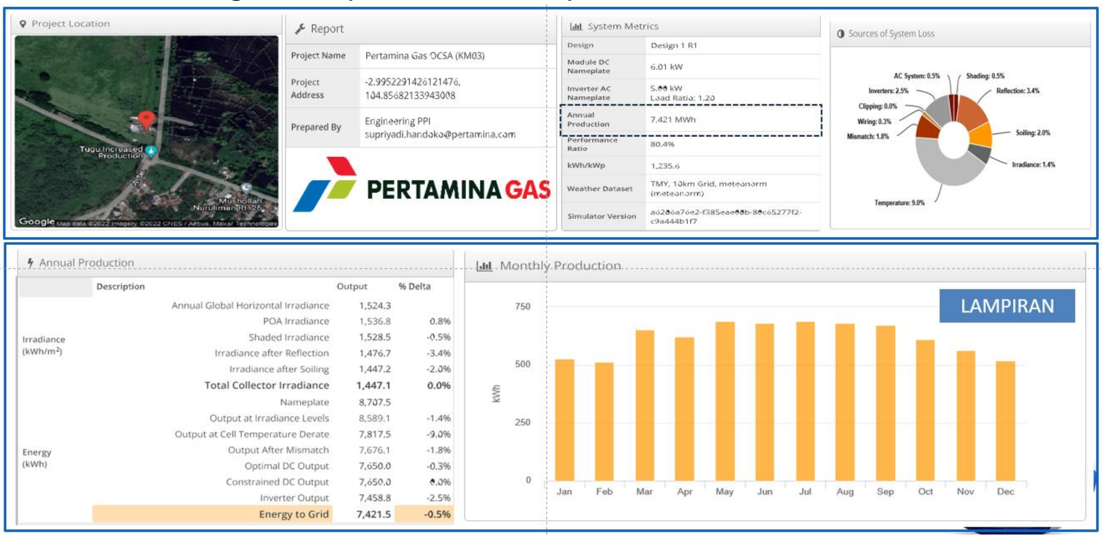
Based on simulation results with Helioscope software, the PLTS development plan at the Belawan Gas Metering Station (North Sumatra) can produce annual energy production of up to 7.51 MW/year. Apart from that, the DC current that can be produced by the solar panels reaches 6 kW. Furthermore, regarding the Performance Ratio value that can be produced is 78.2%, this is due to several estimated losses, including the largest such as the temperature around the solar panels reaching 11.7%, losses in the inverter reaching 2.5%, and Reflection (reflection of sunlight away from the panel) reached 3.7% as well as several other losses as listed in the Pie chart above.

3. KEK Sei Mangkei Gas Metering Station (North Sumatera)



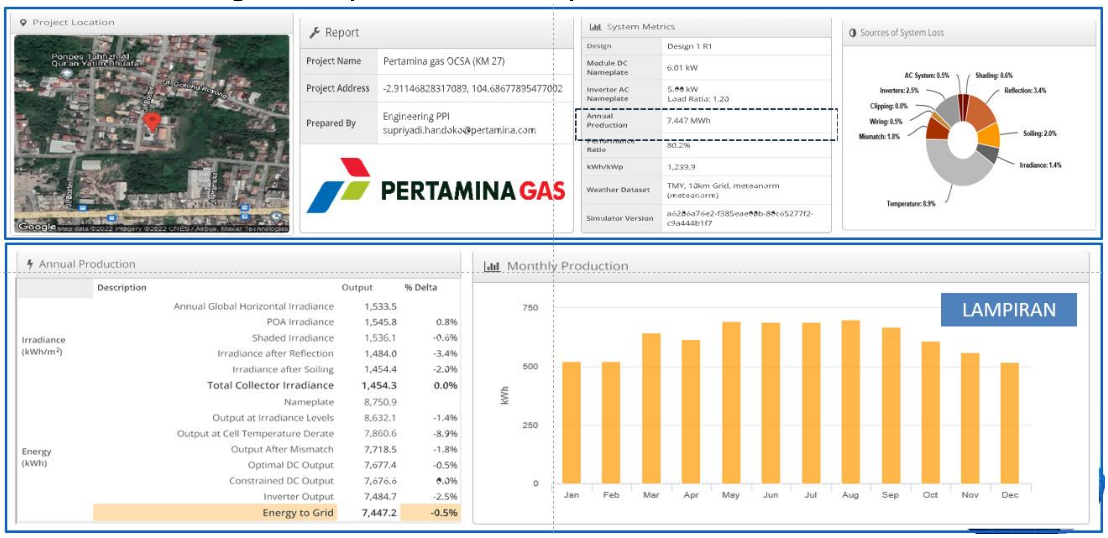
Based on simulation results with Helioscope software, the PLTS development plan at the Sei Mangkei KEK Gas Metering Station (North Sumatra) can produce annual energy production of up to 11.95 MW/year. Apart from that, the DC current that can be produced by the solar panels reaches 9 kW. Furthermore, regarding the Performance Ratio value that can be produced, it is 80.2%, this is due to several estimated losses, including the largest, such as the temperature around the solar panels reaching 9.5%, mismatch (loss in the system) reaching 2.4 %, and Reflection (reflection of sunlight away from the panel) reached 3.4% as well as several other losses as listed in the Pie chart above.

4. Km 03 Gas Metering Station (Central Sumatera)



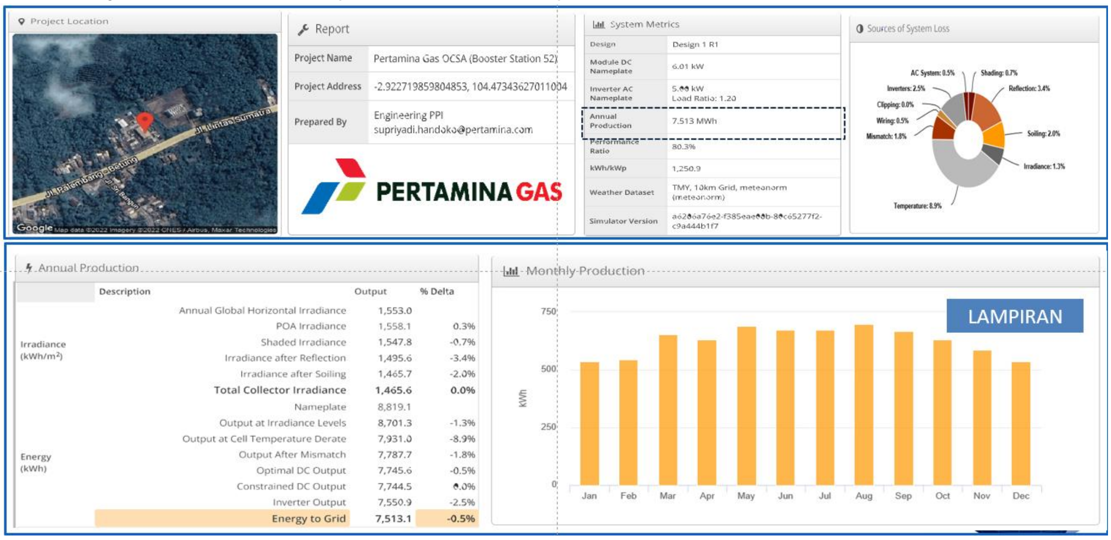
Based on simulation results with Helioscope software, the PLTS development plan at the Km 03 Gas Metering Station (Central Sumatra) can produce annual energy production of up to 7.42 MW/year. Apart from that, the DC current that can be produced by the solar panels reaches 6 kW. Furthermore, regarding the Performance Ratio value that can be produced, it is 80.4%, this is due to several estimated losses, including the largest, such as the temperature around the solar panels reaching 9%, losses in the inverter reaching 2.5%, as well as Reflection (reflection of light). the sun moving away from the panel) reached 3.4% as well as several other losses as listed in the Pie chart above.

5. Km 27 Gas Metering Station (Central Sumatera)



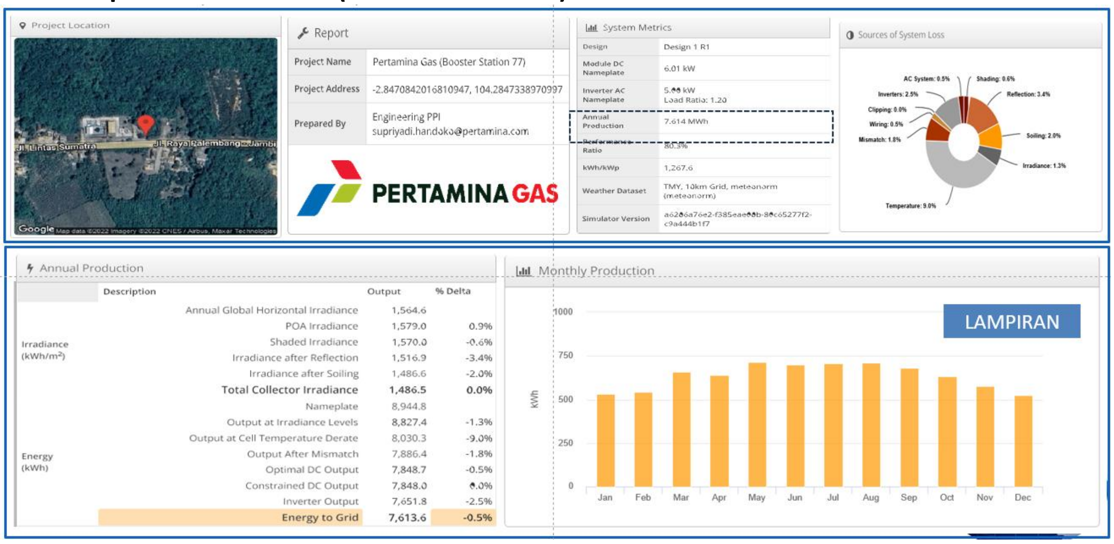
Based on simulation results with Helioscope software, the PLTS development plan at the Km 27 Gas Metering Station (Central Sumatra) can produce annual energy production of up to 7.44 MW/year. Apart from that, the DC current that can be produced by the solar panels reaches 6 kW. Furthermore, regarding the Performance Ratio value that can be produced, it is 80.2%, this is due to several estimated losses, including the largest, such as the temperature around the solar panels reaching 8.9%, losses in the inverter reaching 2.5%, and Reflection (reflection of sunlight away from the panel) reached 3.4% as well as several other losses as listed in the Pie chart above.

6. Gas Compressor Station 52 (Central Sumatera)



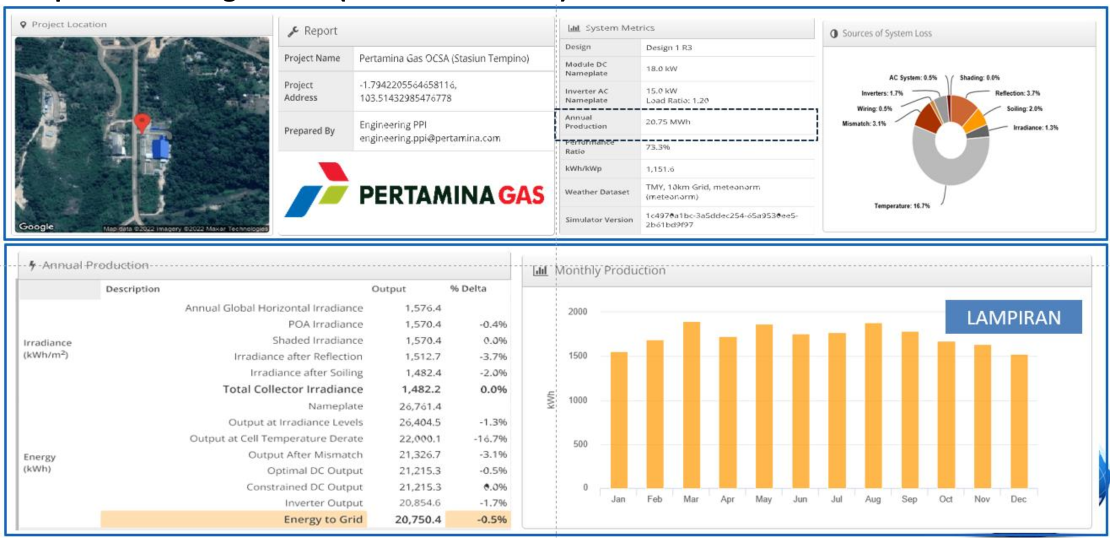
Based on simulation results with Helioscope software, the PLTS development plan at the Km 52 Compressor Station (Central Sumatra) can produce annual energy production of up to 7.51 MW/year. Besides that, the DC current that can be produced by the solar panel reaches 6 kW. Furthermore, regarding the Performance Ratio value that can be produced, it is 80.3%, this is due to several estimated losses, including the largest, such as the temperature around the solar panels reaching 8.9%, losses in the inverter reaching 2.5%, and Reflection (reflection of sunlight away from the panel) reached 3.4% as well as several other losses as listed in the Pie chart above.

7. Gas Compressor Station 77 (Central Sumatera)



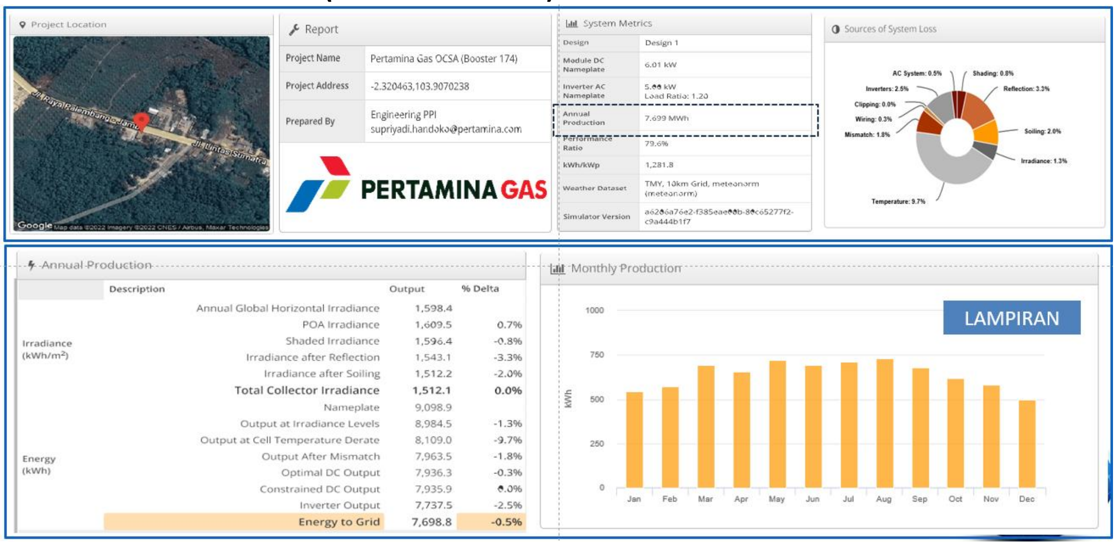
Based on simulation results with Helioscope software, the PLTS development plan at the Km 77 Compressor Station (Central Sumatra) can produce annual energy production of up to 7.61 MW/year. Besides that, the DC current that can be produced by the solar panel reaches 6 kW. Furthermore, regarding the Performance Ratio value that can be produced at 80.3%, this is due to several estimated losses, including the largest, such as the temperature around the solar panels reaching 9%, losses in the inverter reaching 2.5%, as well as Reflection (reflection of light). the sun moving away from the panel) reached 3.4% as well as several other losses as listed in the Pie chart above.

8. Tempino Gathering Station (Central Sumatera)



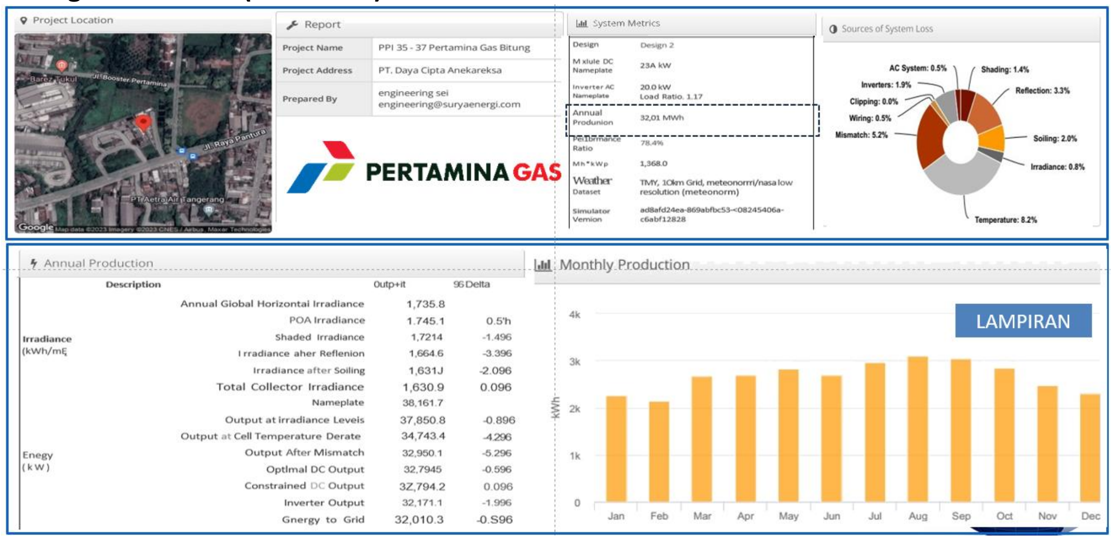
Based on simulation results with Helioscope software, the PLTS development plan at the Tempino Oil Station (Central Sumatra) can produce annual energy production of up to 20.75 MW/year. Besides that, the DC current that can be produced by the solar panel reaches 18 kW. Furthermore, regarding the Performance Ratio value that can be produced, it is 73.3%, this is due to several estimated losses, including the largest, such as the temperature around the solar panels reaching 16.7%, mismatch (losses in the system) reaching 3.1%, and Reflection (the reflection of sunlight away from the panel) reached 3.7% as well as several other losses as listed in the Pie chart above.

9. OCSA Booster Station 174 (Central Sumatera)



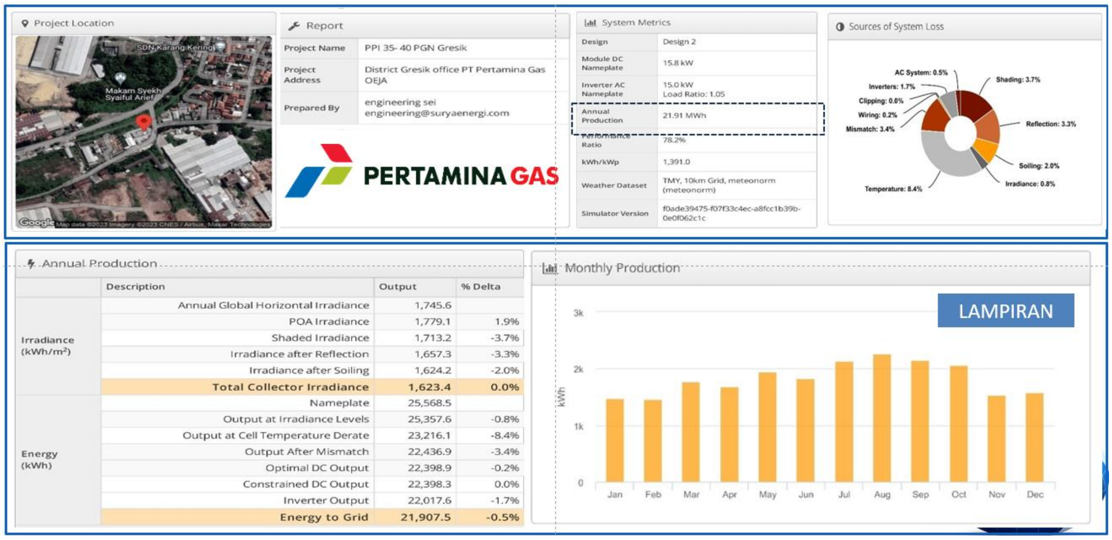
Based on simulation results with Helioscope software, the PLTS development plan at OCSA Booster 174 Station (Central Sumatra) can produce annual energy production of up to 7.69 MW/year. Besides that, the DC current that can be produced by the solar panel reaches 6 kW. Furthermore, regarding the Performance Ratio value that can be produced, it is 79.6%, this is due to several estimated losses, including the largest, such as the temperature around the solar panels reaching 9.7%, losses in the inverter reaching 2.5%, and Reflection (reflection of sunlight away from the panel) reached 3.3% as well as several other losses as listed in the Pie chart above.

10. Bitung CNG Station (West Java)



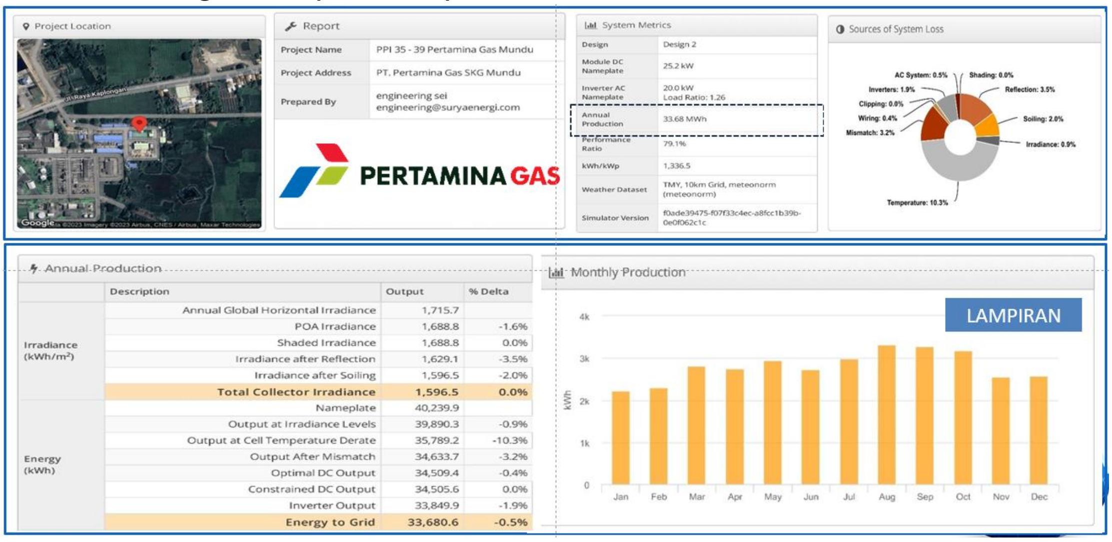
Based on simulation results with Helioscope software, the PLTS development plan at Bitung CNG Station (West Java) can produce annual energy production reaching 32.01 MW/year. Besides that, the DC current that can be produced by the solar panel reaches 23 kW. Furthermore, regarding the Performance Ratio value that can be produced, it is 78.4%, this is due to several estimated losses, including the largest, such as the temperature around the solar panels reaching 8.2%, mismatch (losses in the system) reaching 5.2%, and Reflection (the reflection of sunlight away from the panel) reached 3.3% as well as several other losses as listed in the Pie chart above.

11. Gresik Gas Metering Station (East Java)



Based on simulation results with Helioscope software, the PLTS development plan at the Gresik District Office (East Java) can produce annual energy production reaching 21.91 MW/year. Besides that, the DC current that can be produced by the solar panel reaches 15.8 kW. Furthermore, regarding the Performance Ratio value that can be produced, it is 78.2%, this is due to several estimated losses, including the largest, such as the temperature around the solar panels reaching 8.4%, mismatch (losses in the system) reaching 3.4%, and Reflection (the reflection of sunlight away from the panel) reached 3.3% as well as several other losses as listed in the Pie chart above.

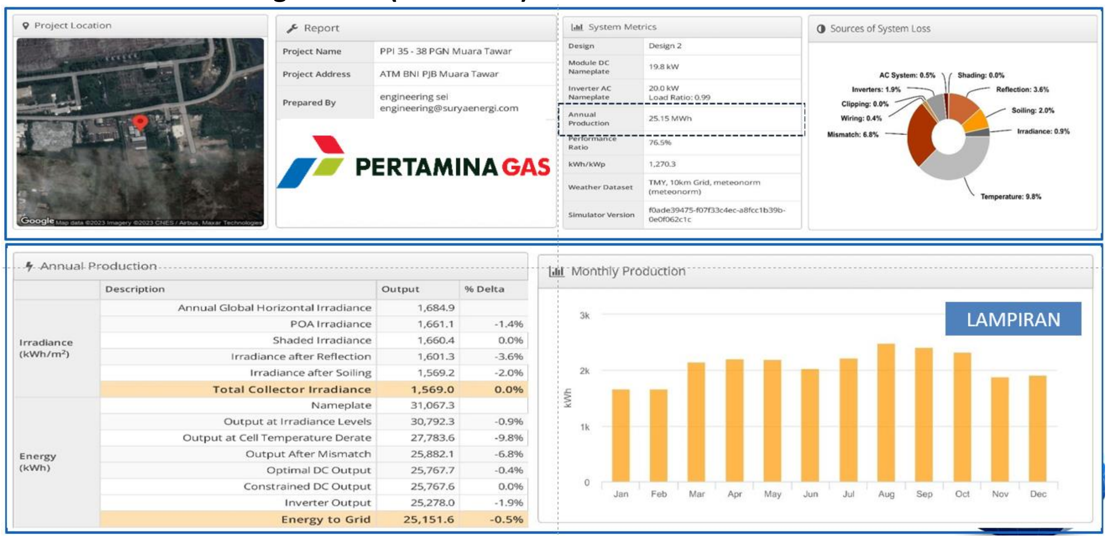
12. Mundu Gas Metering Station (West Java)



	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,715.7	
	POA Irradiance	1,688.8	-1.6%
	Shaded Irradiance	1,688.8	0.0%
	Irradiance after Reflection	1,629.1	-3.5%
	Irradiance after Soiling	1,596.5	-2.0%
	Total Collector Irradiance	1,596.5	0.0%
Energy (kWh)	Nameplate	40,239.9	
	Output at Irradiance Levels	39,890.3	-0.9%
	Output at Cell Temperature Derate	35,789.2	-10.3%
	Output After Mismatch	34,633.7	-3.2%
	Optimal DC Output	34,509.4	-0.4%
	Constrained DC Output	34,505.6	0.0%
	Inverter Output	33,849.9	-1.9%
	Energy to Grid	33,680.6	-0.5%

Based on simulation results with Helioscope software, the PLTS development plan at the Mundu Gas Metering Station (West Java) can produce annual energy production reaching 33.68 MW/year. Besides that, the DC current that can be produced by the solar panel reaches 25.2 kW. Furthermore, regarding the Performance Ratio value that can be produced, it is 79.1%, this is due to several estimated losses, including the largest, such as the temperature around the solar panels reaching 10.3%, mismatch (losses in the system) reaching 3.2%, and Reflection (the reflection of sunlight away from the panel) reached 3.5% as well as several other losses as listed in the Pie chart above.

13. Muara Tawar Gas Metering Station (West Java)



	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,684.9	
	POA Irradiance	1,661.1	-1.4%
	Shaded Irradiance	1,660.4	0.0%
	Irradiance after Reflection	1,601.3	-3.6%
	Irradiance after Soiling	1,569.2	-2.0%
	Total Collector Irradiance	1,569.0	0.0%
Energy (kWh)	Nameplate	31,067.3	
	Output at Irradiance Levels	30,792.3	-0.9%
	Output at Cell Temperature Derate	27,783.6	-9.8%
	Output After Mismatch	25,882.1	-6.8%
	Optimal DC Output	25,767.7	-0.4%
	Constrained DC Output	25,767.6	0.0%
	Inverter Output	25,278.0	-1.9%
	Energy to Grid	25,151.6	-0.5%

Based on simulation results with Helioscope software, the PLTS development plan at the Mundu Gas Metering Station (West Java) can produce annual energy production reaching 25.15 MW/year. Besides that, the DC current that can be produced by the solar panel reaches 19.8 kW. Furthermore, regarding the Performance Ratio value that can be produced, it is 76.5%, this is due to several estimated losses, including the largest, such as the temperature around the solar panels reaching 9.8%, mismatch (losses in the system) reaching 6.8%, and Reflection (the reflection of sunlight away from the panel) reached 3.6% as well as several other losses as listed in the Pie chart above.

Based on the simulation results above using Helioscope software, the following summary is presented as follows:

No.	Area	Lokasi	Energi Yield/year	DC Capacity	Performance Ratio
1	West Java	GCS Mundu	14,81 MWh	12 kW	77,4%
2	West Java	CNG Bitung	7,51 MWh	6 kW	78,2%
3	West Java	GMS M. Tawar	11,95 MWh	9 kW	80,2%
4	East Java	GMS Gresik	7,42 MWh	6 kW	80,4%
5	North Sumatera	GMS R. Panjang	7,44 MWh	6 kW	80,2%
6	North Sumatera	GMS Belawan	7,51 MWh	6 kW	80,3%
7	North Sumatera	GMS S. Mangkei	7,61 MWh	6 kW	80,3%
8	Central Sumatera	GS Tempino	20,75 MWh	18 kW	73,3%
9	Central Sumatera	GMS KM 03	7,69 MWh	6 kW	79,6%
10	Central Sumatera	GCS 27	32,01 MWh	23 kW	78,4%
11	Central Sumatera	GCS 52	21,91 MWh	15,8 kW	78,2%
12	Central Sumatera	GCS 77	33,68 MWh	25,2 kW	79,1%
13	Central Sumatera	GCS 174	25,15 MWh	19,8 kW	76,5%

*Keterangan :
GCS = Gas Compressor Station ; GMS = Gas Metering Station ; GS = Gathering Station
CNG = Compressed Natural Gas

CONCLUSIONS AND RECOMMENDATIONS

The evaluation analysis of the small capacity PLTS development plan at PT Pertamina Gas yields several conclusions. The planned PLTS capacity is approximately 158.57 kWh per year, with an estimated total production of around 205.44 mWh annually. The determination of Direct Current (DC) capacity and AC Inverter is based on the energy yield at each point, where values differ. The performance ratio, based on simulations using Helioscope software, ranges from 73.3% to 80.4%, with the highest value at SMG Gresik (East Java) and the lowest at SP Tempino (Central Sumatra). The performance ratio is influenced by several loss factors, with temperature being the most significant, ranging from 8.2% to 16.7%, affected by local weather conditions. The highest temperature loss percentage is at Tempino Oil Station (Central Sumatra), and the lowest is at the CNG Station (West Java). Mismatch losses, influenced by the condition of installed solar panels, range from 2.4% to 6.8%, with the highest at Muara Tawar Gas Metering Station and the lowest at KEK Sei Mangkei Gas Metering Station. Inverter losses are consistently 2.5% at several points, including Belawan Gas Meter Station and KM 03 Gas Metering Station. Reflection losses range from 3.3% to 3.7%, highest at the Tempino Collection Station and lowest at the Gresik Office. Future improvements could include economic calculations to determine savings from PLTS installation compared to existing electricity sources (PLN) and measuring conditions before and after PLTS installation to ascertain real savings.

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