

Analysis of Solar Power Plant Development Potential in Adipala - Cilacap

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ABSTRAK

PT Pertamina (Persero) akan mengembangkan sumber energi terbarukan guna mencapai kemandirian energi nasional. Salah satu langkah yang sudah ditempuh olehnya yaitu melalui Unit Pengolahan IV Cilacap adalah membangun Pembangkit Listrik Tenaga Surya (PLTS). Salah satu lokasi pembangunan PLTS yang strategis di kawasan lahan kosong yang dekat dengan Jaringan Listrik Sutet 500 kV Adipala yaitu berlokasi di kabupaten Cilacap dengan nilai global horizontal irradiation (GHI) matahari rata-rata sebesar 1908 kWh/m². Dengan nilai tersebut maka instalasi PLTS atap menjadi solusi yang tepat untuk mendukung produksi listrik menggunakan energi terbarukan. Konsumsi beban listrik dari kota dalam satu tahun adalah sebesar 1785.6 KWh dan saat ini seluruhnya disuplai oleh PLN. Dalam penelitian ini dilakukan suatu perancangan PLTS di lahan kosong sekitar perumahan yang dapat dihasilkan dalam satu tahun. Desain dan perhitungan dilakukan menggunakan bantuan software PVSyst dan RETScreen. Dari hasil simulasi, hasil yang diperoleh yaitu PLTS yang telah didesain dapat menghasilkan 463 kWh per tahun yang dapat memenuhi 25.9% kebutuhan listrik di lokasi perancangan dengan rasio kinerja PLTS yaitu 85.74% dimana PLTS dapat menghasilkan energi listrik sebesar 1531 KWh per tahun.

ABSTRACT

PT Pertamina (Persero) as the vanguard of the archipelago's energy has committed to finding and developing new and renewable energy sources to support national energy independence and sovereignty. One of the concrete steps taken by PT Pertamina through the Cilacap Processing Unit IV is to build a Solar Power Plant. One of the strategic solar power plant construction sites in an empty land area close to the 500 kV Adipala Sutet Power Network is located in Cilacap regency with an average global horizontal irradiation (GHI) value of 1908 kWh/m². With this value, the installation of solar rooftops is the right solution to support electricity production using renewable energy. The electricity load consumption from the city in one year is 1785.6 KWh and is currently entirely supplied by PLN. In this study, a Solar Power Plant design was carried out on vacant land around housing that can be produced in one year. The design and calculations were carried out using the help of PVSyst and RETScreen software. From the simulation results, the results obtained are a Solar Power Plant that has been designed to produce 463 kWh per year which can meet 25.9% of electricity needs at the design site with a Solar Power Plant performance ratio of 85.74% where Solar Power Plant can produce electrical energy of 1531 KWh per year.

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INTRODUCTION

Indonesia's geographical location crossed by the equator offers many advantages, one of which is good sunlight intensity throughout the year. According to data from the National Energy Council (DEN), the potential of solar energy in Indonesia averages 4.8 kWh/m²/day, or equivalent to 112,000 GWp compared to the potential of Indonesia's territory or 10 times the potential of Germany. and Europe. With such great potential, the development of solar power plants must be a priority (ESDM, 2021). In addition, as solar technology develops, higher solar module efficiency and lower cost will facilitate the realization of solar energy potential.

Seeing this enormous potential, the government took action by making a National Energy Policy (KEN) which became the basis for the birth of the National Energy General Plan (RUEN). RUEN is a government policy related to the national energy management plan, which is an interdisciplinary KEN development and implementation plan to achieve KEN goals. KEN's target is to increase the use of new and renewable energy (EBT) by 2025 by 23% or 92.2 MTOE, where the target of solar energy use is 6.5 GW. However, currently, nationally the capacity to use solar power plants is still 137 MW (Bayuaji Kencana et al., 2018).

Electricity supply in the Cilacap area, Central Java has reserves that can be said to be quite abundant. With a capable power of 7,042 MW and the highest peak load in 2022 at 4,851 MW, it means that there is still a power reserve of around 30 percent to support industrial needs in Central Java (Santikaaristi, 2022). When viewed from the amount of existing electricity supply reserves, it can be said that the Central Java area, especially Cilacap, does not need other power plants. But keep in mind that the main electricity supply obtained in the Cilacap area is the electricity supply produced by the Karangandri PLTU.

PLTU Karangandri itself has been built since December 29, 2003, by PT Sumber Segara Primadaya (S2P) together with Chenda Engineering from China. With an investment value of 510 million USD. Until now, PLTU Karangandri has three units and expansion units (Teknologi, 2012). Units I and II have a capacity of 600MW, unit III has a capacity of 660MW, and expansion units have a capacity of 1000MW. If totaled, the Karangandri PLTU has a total capacity of 2160 MW. PLTU Karangandri is operated by PLN's subsidiary PT Pembangkit Jawa Bali, PT Sumber Segara Primadaya, and a joint venture PT Sumberenergi Sakti Prima.

Steam power plants utilize the water-steam-water cycle. In a closed system, water coming from the condenser will be pumped into a tube or tube. In the tube, the water will be heated so that the water will turn into water vapor. In this process, the heat source used comes from fuels such as coal or fuel oil. Furthermore, the steam will continue to be heated so that the steam will become superheated. This steam is used to drive high-pressure turbine blades and for turbine blades to drive turbine shafts. A moving turbine will generate electricity (Onainor, 2019). In the working process of this steam power plant, what is often in question is fuels such as coal or fuel oil because the combustion process itself will produce air pollution in the surrounding area, such as carbondioxide (Karyono et al., 2022). There has been an increase in carbon dioxide emissions even though the pandemic has decreased. Some of the consequences are like the result of coal in the combustion of steam power plants. Where it is known that this is the raw material in generating electricity. This can be reduced by utilizing renewable energy, such as solar power plants (Karyono et al., 2020) .

During the operation of the Karangandri PLTU, there were several complaints from residents around the PLTU. In October 2019, residents of Winong Hamlet, Slarang Village, Kesugihan District, Cilacap Regency, Central Java who joined the Winong Community Forum for Environmental Care (FMWPL) held a protest because they considered the waste management action from the Karangandri PLTU very bad. In addition, production waste is considered to interfere with activities around residents. Although in 2022 the performance of waste management has been assessed as good, it cannot be denied that the power plant will continue to produce pollution and waste (Eviyanti, 2012).

By conducting this research, it is hoped that the Cilacap area and its surroundings can utilize alternative energy in the form of renewable energy, namely solar energy as a substitute for

energy sources from PLTU. So that slowly the use or production of other power plants that use fossil fuels and others as well as power plants that produce waste or pollution can switch to renewable energy sources. This research is conducted by using two software, there are PVSyst and RETScreen.

RESEARCH METHODS

This simulation was carried out using PVSyst and RETScreen software. PVSyst is software used for the process of learning, measuring (sizing), and analyzing data from a complete PV system (Siregar et al., 2020). PVSyst was developed by the University of Geneva and features simulation of grid-connected systems, stand-alone systems, pumping systems, and direct current networks for public transport (DC-grid). PVSyst also features a database of extensive and diverse meteorological data sources, as well as data on PV components (Ramoliya, 2015). Some examples of meteorological data sources that PVSyst can use are MeteoNorm V7.1 (interpolation 1960-1990 or 1981-2000) NASA-SSE (1983-2005), PVGIS (for Europe and Africa), Satel-Light (for Europe), TMY2/3 and Solar PV design systems, SolarAnywhere (for USA), EPW (for Canada), RETScreen, Helioclim and Solar GIS (paid) (Winardi et al., 2020). RETScreen is software developed by the Government of Canada to assist in the economic and technical analysis of renewable energy and energy efficiency projects. RETScreen is used by energy professionals, advisors, and project developers around the world to evaluate the potential of renewable energy and energy efficiency projects, as well as to make decisions based on comprehensive analysis (Owolabi et al., 2020) (Thevenard et al., 2000) (Psomopoulos et al., 2015).

By using both software, it can be simulated the installation or construction of solar power plants at the location you want to build. Simulations are carried out to be able to find out data such as electricity capacity produced, long-term development and investment costs, performance work efficiency, and so on.

The initial stage of this research is to observe the value of Global Horizontal Irradiance (GHI) and find out the latitude and longitude data using <https://globalsolaratlas.info/map> website. Then use <https://geoportal.esdm.go.id/> website to determine the nearest location of the substation for the installation of on-grid solar power plants. Then the Google Earth Pro application to determine the construction area of solar power plants. As well as using the PVSyst application to find out the results of the construction of solar power plants. The final stage of this research is to observe and analyze the number of solar panels, cost, effectiveness, amount of electrical energy production from the design design that has been arranged and carried out.

RESULTS AND DISCUSSION

PVSyst Simulation

Tilt & Azimuth

The geographical position of an area is very decisive for optimizing the azimuth direction and tilt angle of the photovoltaic panel so that the setting of the azimuth direction and tilt angle for each region is different. Based on Figure 1, the geographical position of Adipala in the Cilacap Regency area is located at coordinates -07.661955° , 109.133329° which is used as a field location for photovoltaic research. From the location of the geographical position, PVSyst software can determine the parameter field, namely the Tilt value of 12 degrees and Azimuth of 0 degrees. That is, the slope of the PV module from the horizontal line of the ground is 12 degrees and the PV module is placed on the north because the azimuth is 0 degrees. adjust the position of sunlight to the geography of the PV module location. The best azimuth for fixed PV modules is north-facing. An azimuth of 0 degrees indicates that the PV module is oriented in a northerly direction.

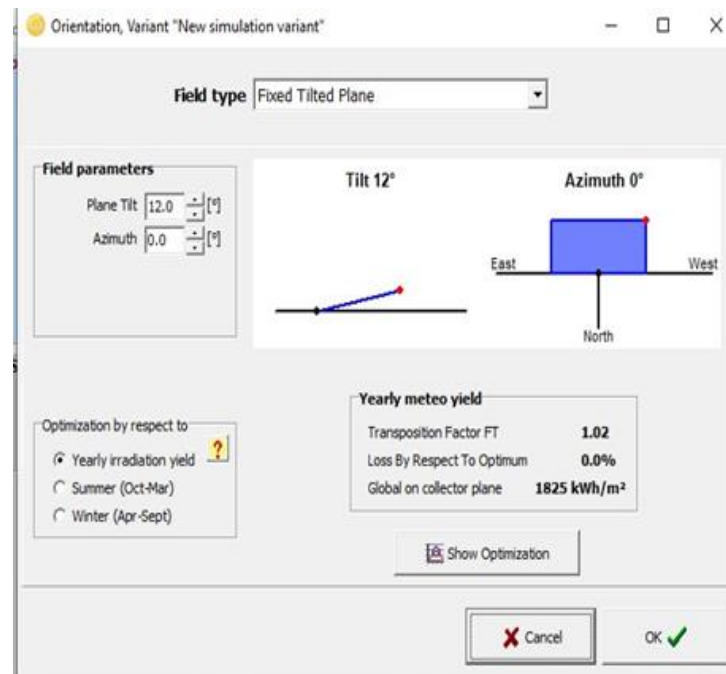


Figure 1. Geographical Data of the Project Location

Solar Power Plant Location

Based on the data from Google Earth Pro in Figure 2, a solar power plant will be built on vacant land with an area of 1,710 m or 1.71 km around the housing area of Adipala, Cilacap regency. It is known that the distance between the vacant land and the 500 kV SUTET Power Network is close to each other, so the location is very strategic for the construction of an on-grid solar power plant connected to the PLN network.

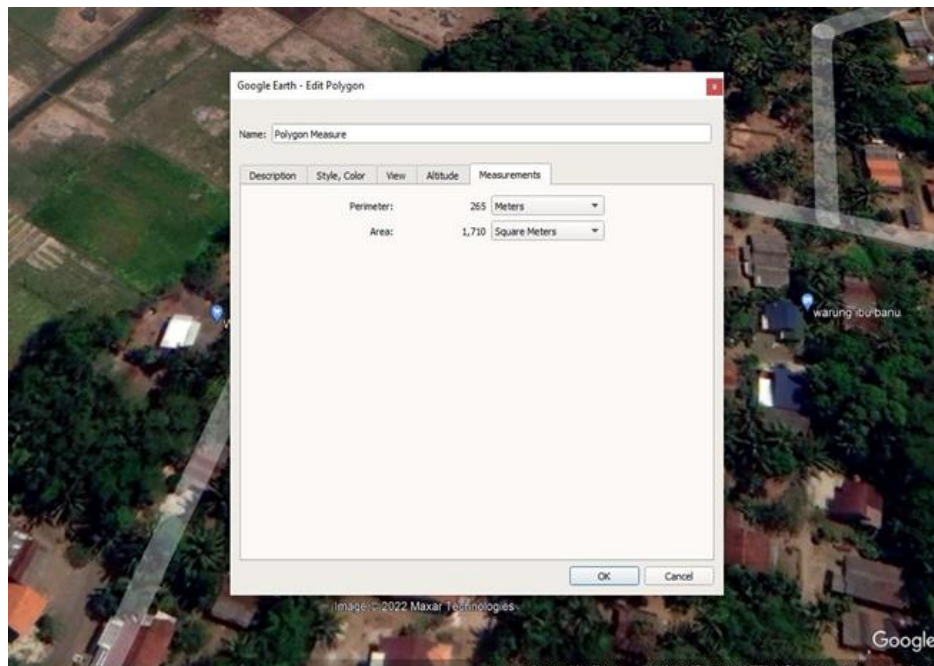


Figure 2. Location Data from Google Earth Pro

Results Overview PVSyst

Based on simulations conducted using the PVSyst application such as figured in Figure 3, it is known that the solar power plant system to be built can produce electrical energy of 463 MWh per year. The energy produced is divided by the Nominal power of the array (P_{nom} in STC) or the specific production of the solar power plant at 1.531 kWh/kWp per year. This is an indicator of the potential of the system, taking into account radiation conditions (orientation, location of the location, and meteorological conditions). The performance ratio of Solar Power Plants is 0.844 or 84.4%. So solar power plants can produce 4.19 kWh/kWp per day with array losses of 0.7 kWh/kWp per day and system losses of 0.07 kWh/kWp per day. Array losses represent all events that penalize the available array output energy with respect to the nominal power of the PV module as cited by the manufacturer for STC conditions.

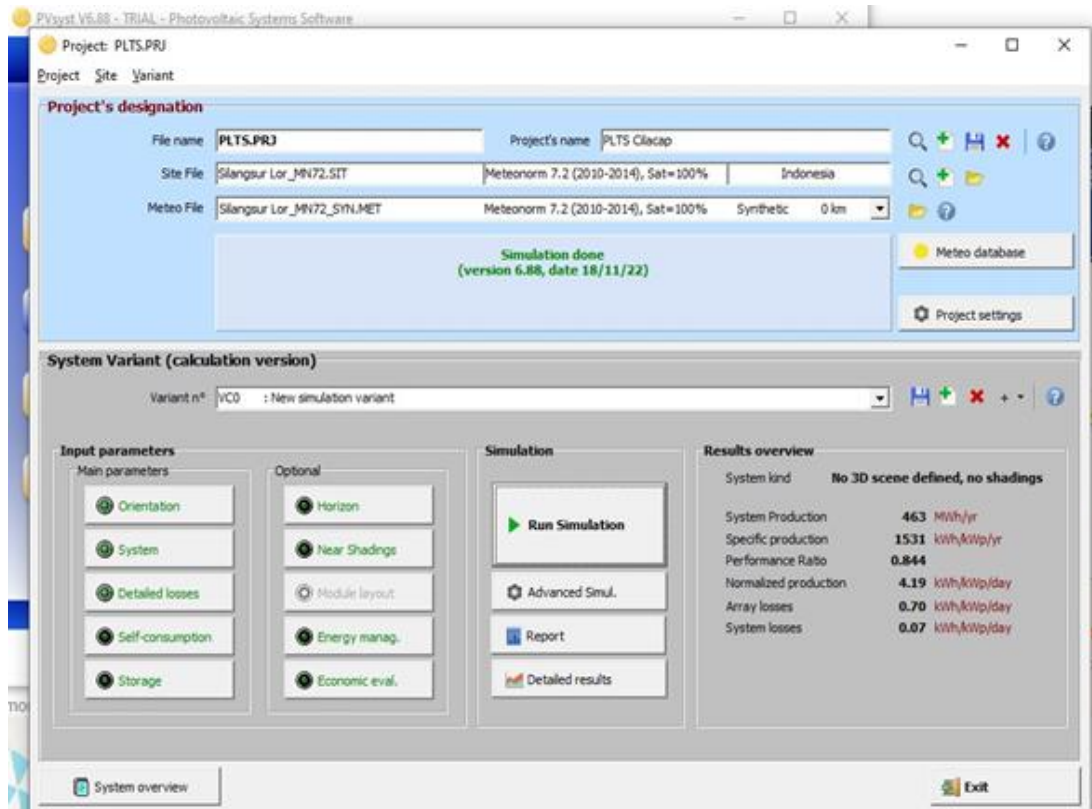


Figure 3. Results Overview from PVSyst

PV Array

Photovoltaic Array (PV Array) is a complete power generation unit, consisting of a number of PV modules and panels. The performance of PV modules and arrays is generally rated according to the maximum DC power output (watts) under Standard Test Conditions (STC). Based on Figure 4, the construction of the solar power plant will use solar cells with the type of Longi Solar 300 Wp 28V Si-mono combined with 4 inverters type SMA Sunny Tripower 60-US-10 (400VAC) which can produce an output voltage of 400V Tri 60Hz, so that the operating voltage is around 570 – 800 V with a maximum input voltage of 1000V. The plane irradiance is 1,000W/m², $I_{mp}(STC)$ is 439 A and $I_{sc}(STC)$ is 459 A, and I_{sc} (at STC) is 459 A. It is known that the maximum operating power is 274 kW at 1,000W/m² at 50 degrees Celsius. Then the nom power array (STC) is 302 kWp. Standard Test Conditions (STC) are solar irradiation conditions of one kilowatt (kW) per square meter, module temperature of 25 degrees Celsius, and solar irradiation angle of 45 degrees. The number of PV modules to be used is between 21-22 units of modules where PV is assembled in series with the number of Nbre strings between 38-48, so it is known that 1000 Nb. modules will be used to generate electricity in an area of 1705 m². We use Longi Solar type PV modules because they have higher efficiency due to superior cell technology than

their competitors at the same price range. In addition, we also use the Sunny Tripower 60-US-10(400VAC) inverter because Sunny Tripower has a relatively affordable cost that is equivalent to the performance and quality offered and can generate electricity from both front and rear sides, adding 10%-25% higher yield at similar price levels. PV systems can work optimally by combining the performance of 4 inverters, thus providing maximum convenience and comfort for users.

Figure 4. PV Array Data

RETScreen Simulation

Energy

Figure 5 shows the energy produced and the funds needed to install a solar power plant with the desired module. Based on these data, it can be known that the power capacity produced by the planned solar power plant that has been designed is 110 kW. The RETScreen simulation, uses Trina Solar 220W solar panels with 500 modules and an efficiency of 13.4%. With an estimated amount of funds needed is around 231,000 USD. With an estimated annual savings of around 2,750 USD. The electrical energy that can be channeled to the grid is 129 Mwh. When compared to the results obtained in the PVSyst simulation, the energy produced is 274 kW is indeed less. This can be because the type of solar panel used is different and can also be due to different efficiency or other factors.

The screenshot displays the 'Photovoltaic' data entry interface in RETScreen Software. It includes a 'Description' field with 'Photovoltaic' entered, a 'Note' field, and buttons for 'Level 1', 'Level 2', and 'eLearning'. The 'Photovoltaic - Level 1' section contains the following data:

Parameter	Unit	Value
Power capacity	kW	110
Manufacturer		Trina Solar
Model		mono-Si - TSM - DC05 / 220 W
Number of units		500
Capacity factor	%	13,4%
Initial costs	\$/kW	2.100
	\$	231.000
O&M costs (savings)	\$/kW-year	25
	\$	2.750
Electricity export rate		Electricity export rate - annual
Electricity exported to grid	MWh	129
Electricity export revenue	\$	0

Figure 5. Photovoltaic Data in RETScreen Software

Emission Reduction

Based on Figure 6, it can be seen how much gas emissions can be reduced when the installation of this design solar power plant. If the installation of solar power plant is carried out, it can be predicted that the total emissions that can be removed are 259.5 tCO₂ or 93% or equivalent to 47.5 cars or mini trucks are not used when compared to conditions before installation. Indeed, at first glance, the amount of emissions reduced is not too significant, but keep in mind again the area and number of solar panels used are very small when compared to other solar power plant in Indonesia.

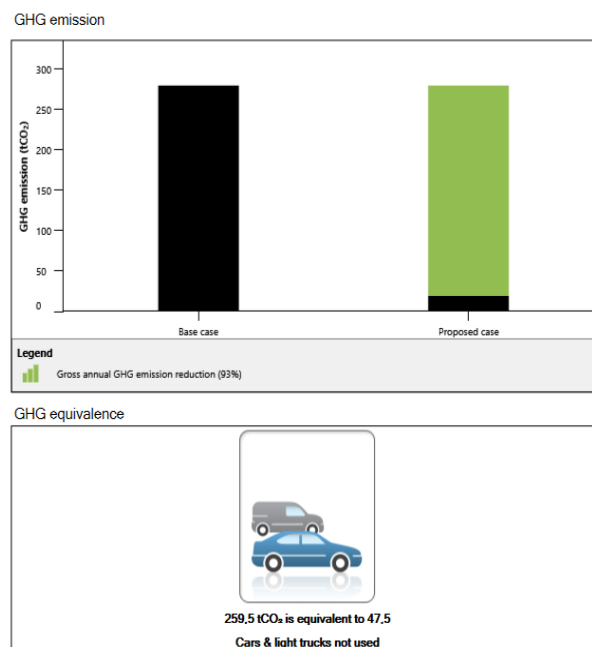


Figure 6. GHG Emission Data

Based on graphic data, Figure 7 shows the results of emissions produced by this planned solar power plant. It can be seen that the emissions produced each year are very small. Every year the solar power plant only produces GHG emissions of around 30-40 GHG emissions. Indeed, the average solar power plant does produce small emissions. When compared to PLTU in general,

where to run a power plant, fuel such as coal or oil is needed which if burned will produce high emissions and pollution.

Annual bar graph - GHG emission - Target

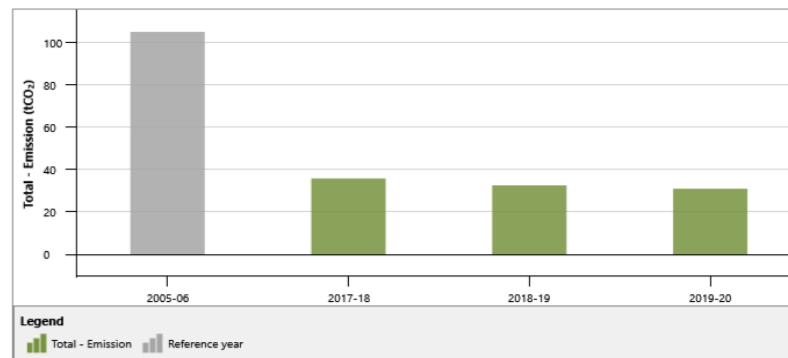


Figure 7. Annual Bar of Emission

Financial Analysis

Figure 8 shows the economy of the planned solar power plant. Financially, the planned solar power plant has poor finances without any income. The cash flow of this solar power plant during the first year of installation will experience losses, the next year will improve and in the next 10 years, it will be constant and eventually will increase again until there is almost no loss. Cumulative costs will continue to decline for about 15 years, and will slightly improve but still decrease.

Financial viability

Financial parameters

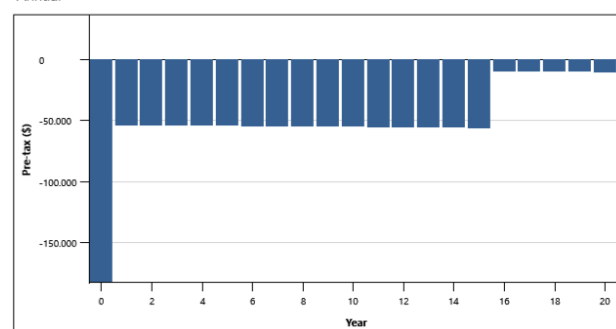
General		
Inflation rate	%	2%
Discount rate	%	9%
Reinvestment rate	%	9%
Project life	yr	20
Finance		
Incentives and grants	\$	0
Debt ratio	%	70%
Debt	\$	426.888
Equity	\$	182.952
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	\$/yr	46.870

Annual revenue

Electricity export revenue		
Electricity exported to grid	MWh	341
Electricity export rate	\$/kWh	0
Electricity export revenue	\$	0
Electricity export escalation rate	%	

Cash flow

Annual



Cumulative

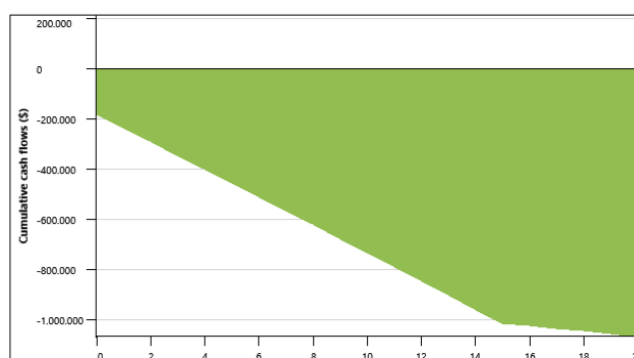


Figure 7. Financial Analysis

Comparison of Solar Performance Results Between PVSyst and RETScreen Software

Based on simulations that have been carried out using PVSyst and RETScreen software, electricity production results per day are obtained, costs, effectiveness, and so on. This is because the two software has different formats. Each software has different indicators, so the simulation results will not be the same. PVSyst focuses more on the energy results to be produced, while RETScreen in addition to calculating energy also calculates other factors such as cost or finance, emissions, water or fuel consumption, etc.

The comparison of PVSyst and RETScreen results is as follows. The maximum total energy generated in the PVSyst simulation is 274 kW, the Tilt and Azimuth are 12 and 0. While the RETScreen energy capacity that can be produced is 110 kW. In PVSyst, the type of solar panel used is Longi Solar 300 Wp 28V Si-mono with SMA inverter type. While the type of solar panel used in the Tri Solar RETScreen simulation is mono-Si-TSM-DC05 / 220W type. The difference in the type of solar panel is also one of the factors in the difference in the results of the two simulations.

CONCLUSION

Based on the results of the analysis that has been carried out, it is known that simulations have been successfully carried out using PVSyst and RETScreen software with the conclusion, namely the maximum total energy produced in PVSyst simulations is 274 kW, while RETScreen energy capacity that can be produced is 110 kW. The simulation conducted at PVSyst used Longi Solar 300 Wp 28V Si-mono type solar panels and SMA inverters, for RETScreen with Tri Solar mono-Si-TSM-DC05/220W solar panel types. In the RETScreen simulation, the amount of emission reduction and emissions produced by solar power plants was obtained. The emission reduction is equivalent to 47.5 cars or mini trucks and the emissions produced are only around 30-40 GHG. Economically, solar power plants that will be built in the next 10-15 years will experience losses but after that, it will continue to improve. Keep in mind that the planning of this solar power plant is only carried out on land measuring about 1,700. In addition, the energy produced is also said to be small.

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