European Commission

Clean energy for EU islands: PV evaluation

Pantelleria, Italy

Clean energy for EU islands

PV evaluation in Pantelleria

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Clean energy for EU islands

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Executive Summary

Pantelleria is an Italian island and commune in the Strait of Sicily in the Mediterranean Sea, 100 kilometres southwest of Sicily and 60 km east of the Tunisian coast. Administratively, Pantelleria commune belongs to the Sicilian province of Trapani.

The objective of this study is to evaluate the best solution for a 7MW solar plant at Pantelleria airport, achieving the highest IRR. The study focuses on providing sufficient information on the solution and thus identifies the highest financial savings over a 20-year period, taking into account the specific costs.

The installation will essentially consist of photovoltaic modules located in the area with the best sun exposure, with the least environmental impact and close to the electrical grid connection point located within the airport area.

The renewable energy produced will be injected into the main grid at medium voltage (MV) for self-consumption of the island through the existing electrical installation.

The present technical study aims to use the area indicated optimising the available space, ensuring the requirements and good installation practices, such as distances, minimising shading and maintenance paths. All materials and equipment must comply with applicable Italian standards or, in their absence, European standards (EN) and be suitable for the site, use and method of installation.

Overall, it is found that a 7MVA (8,5MWp) solar PV system, with an annual energy yield of 13 176 MWh can have a positive impact on the environment by reducing carbon footprint and greenhouse gas emissions for 3 426 tonnes CO_2 per year, increasing energy independence and reducing water consumption.

Introduction

Pantelleria (Figure 1) is located in the Strait of Sicily, about 110 km south of Sicily and 65 km northeast of Tunisia. It has an approximate area of 84.5 km^2, being the fifth largest island in Italy, as well as the biggest among the smaller non-interconnected islands. The maximum length of the island is 13,7 km, while the maximum width is around 8 km. The number of inhabitants in the Pantelleria is 7 665 (data from 1 January 2019).

Figure 1 - Map of Pantelleria (image from Google Earth).

Pantelleria is an island off the grid, not interconnected to the mainland. Solar photovoltaic (PV) energy is a cost-effective source of electricity and can help the island save money on electricity costs in the long term. A PV system can provide the island with a reliable source of electricity, increasing its energy independence and reducing its dependence on external energy sources.

Additional benefits of installing solar photovoltaic power:

- Job creation: Installation and maintenance of a solar PV system can create local jobs and stimulate economic growth on the island;
- Environmental benefits: Solar power is a clean and renewable source of energy, which can help to preserve the natural environment of the island;
- Grid reliability: By interconnecting the solar PV system to the grid, it can provide the grid with a reliable source of power during the day when the sun is shining and reduce the need for expensive peak power generation;
- Scalability: Solar PV systems can be easily scaled up or down as needed, making it easy to add more capacity as the island's energy needs grow.

In this context, the objective of this study is to evaluate the best solution for a 7MW solar plant at Pantelleria airport, achieving the highest IRR. The study focuses on providing sufficient information on the solution and thus identifies the highest financial savings over a 20-year period, taking into account the specific costs.

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The Clean energy for EU island Secretariat's collaboration with Pantelleria started in 2020 with the Clean energy transition agenda, and continued in the first call of the technical assistance (see summary of the technical assistance here). Pantelleria was awarded in the first CE4EUislands Gamechanger Award with extra technical assistance, which is reported in this study.

PV project

Location

Recently Italy enacted a law that facilitates the installation of PV panels at airport areas. Taking this law into account, the municipality of Pantelleria, together with the airport administration, defined a suitable area where the plant would be implemented. The selected area is located in the Airport of Pantelleria Island in a horizontal and clean open field (red in Figure 2).

Figure 2 - Total fenced area and horizontal and clean available area.

There are several restrictions for new constructions near airports runways.
These restrictions may vary depending on the country or region where the airport is located, and may also be subject to change over time as regulations are updated or modified. In Italy, the restrictions for new constructions near runways at airports are similar to those in other countries and are primarily governed by national and local regulations, as well as international standards. Some of the specific restrictions for new constructions near runways in Italy may include:

- Height restrictions: Buildings and other structures near a runway must be limited in height to ensure that they do not obstruct the flight path of aircraft.
- Safety zones: There are designated safety zones around the perimeter of Italian airports, within which new constructions are prohibited.
- Building codes: Construction near runways must comply with local building codes and regulations, which may include specific requirements for fire safety, structural integrity, and other factors.
- Airport Master Plan: The airport master plan defines the future land use, zoning, and land development of the airport. Any construction must be compatible with the airport's master plan.

- ENAC regulations: The Italian Civil Aviation Authority (ENAC) has regulations that new constructions near the runway must comply with. These regulations include specific requirements for building materials, lighting, and markings to ensure the safety of aircraft operations.
- FAA regulations: Federal Aviation Administration regulations may also apply, which may include specific requirements for lighting, markings, and other factors that are designed to ensure the safe operation of aircraft.
- Environmental factors: Environmental factors like noise, wildlife, and pollution are also considered while construction near the runway.

For the purpose of this study a safety clearance zone of 50m was considered on each side of the runway (in yellow in the Figure 3). **However, the safety requirements due to airport operation must be verified and validated by the responsible entities, and if this project does not comply with some requirements, it must be adapted accordingly.**

Figure 3 - Airport runway clearance area considered in yellow.

For the location of the solar plant two possible areas were identified taking into account the existing constructions, namely access roads, buildings and other small technical constructions. A smaller area next to the main runway (East-West) with a total area of 41 236 m^2 and to the South an area with 130 537 m^2 (Figure 4).

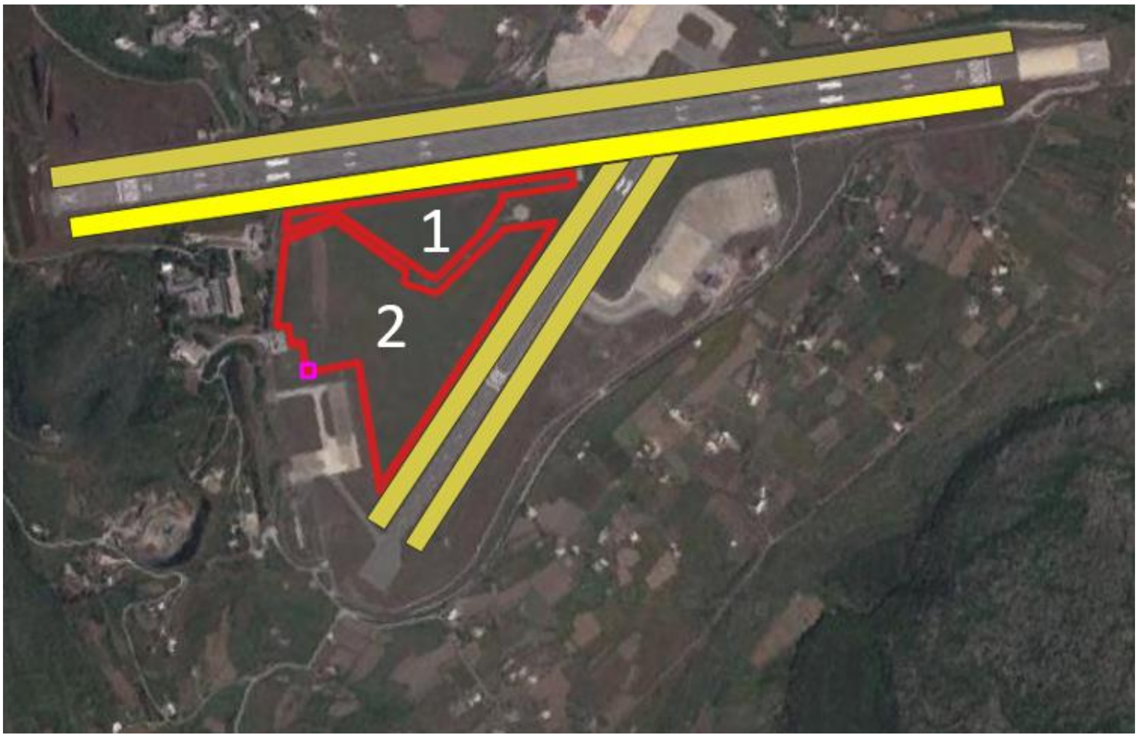

Figure 4 - Available areas for solar plant in red.

Solar Modules

Crystalline silicon (c-Si) technology is the most common type of PV technology used in solar modules.

To the development of the 7MVA power plant, the best PV module technology to use would likely be high-efficiency monocrystalline silicon (mono-Si) modules. These modules have the highest efficiency levels among c-Si modules, which means they can convert more of the sunlight that hits them into electricity.

For the purpose of this study a 560Wp PV module was chosen as it has a higher output per area and better temperature coefficient, making them ideal for high-power plants where available area is limited. Additional criteria were to choose a module currently available in the market.

Another option to consider would be using multi-crystalline silicon (mc-Si) modules, which are slightly less expensive to produce than monocrystalline modules but still have a high efficiency. Studies show that mc-Si technology results in a slightly longer energy payback time than mono-Si. A thorough analysis of these factors should be conducted before making a final decision depending on factors such as cost and availability.

Table 1 - Module specification.

Rated Maximum Power (PMax)	**560 Wp**
Module type	Mono-facial with anti-reflective coating
Open circuit voltage (Voc)	50,47 V
Maximum Power Voltage (Vmp)	41,77 V
Short Circuit Current (Isc)	14,15 A
Module efficiency	21,68 %

Dimensions	2278 mm x 1134 mm x 35 mm
Weight	28 Kg
Frame	Anodized Aluminium Alloy
Durability	High salt mist and ammonia resistance.

Note on pilot blur effect: Solar modules have higher radiation absorption for power generation purposes, in addition, recommended modules should have an anti-reflective coating - ARC - which helps to avoid blur for aviation pilots (see for example the report "Sitting solar Photovoltaic at Airports. Preprint. Alicen Kandt and Rachel Romero, National Renewable Energy Laboratory).

Considering the layout of the solar power plant in this study, no blurring effect on pilots is predicted on the main runway when approaching from the east or west side, due to the south facing orientation of the modules. On the secondary runway, when coming from south to north only, pilots would experience little impact of the blur effect minimised by ARC technology.

Inverters

For a 7MVA solar plant, suitable inverter technologies would be central or string inverters. Central inverters are large (from 1 MW to 3 MW usually) centralised units that convert the direct current (DC) electricity generated by the PV modules into alternating current (AC) electricity that can be fed into the grid. String inverters are smaller inverters installed either near the PV modules (decentralised) or in the electrical room (centralised). For this size of PV plant, they should range from 50kW to 320Kw units.

When choosing central inverters for a 7MVA solar plant, it is important to consider factors such as efficiency, reliability, and compatibility with the PV modules being used. It is also important to consider the specific requirements and conditions of the site, such as the local grid connection, voltage levels, and power factor, as well as cost, market availability and power flexibility.

A 7MVA power plant is a significant investment, so it's crucial to consult with a professional, experienced solar power system provider or an engineer to evaluate the best options for your specific situation, and make sure that the inverter technology you choose is compatible with the PV modules and will meet the requirements of your power plant.

For this plant we recommend string inverters of 320KVA due to the fact that, in case of a failure of one inverter, the plant continues to produce with the remaining inverters. Also, operation and maintenance of the plant is simpler and therefore can be more easily provided by local technicians.

Inverter with the ability to handle high voltage considered and recommended features:

Table 2 - Inverter specification.

Central high voltage inverter with MPP trackers	
AC output power	**320KVA @40ºC**
Max. AC output current	**254 A**
Nominal AC voltage	**3 / PE, 800V**
Max. PV input voltage	1500 V
Nominal PV input voltage	1080 V
Maximum Efficiency (European efficiency)	98,8 %
Operating voltage range	500 – 1500 V

Central high voltage inverter with MPP trackers	
Minimum start-up voltage	200 V
Number of inputs per MPP	2
Number of MPP trackers	12

Solar inverters are designed to maximise the efficiency of the solar PV system, by ensuring that the generated electricity is matched to the load demand. Maximum Power Point tracking – MPP capability is required to guarantee the constant operation of the modules at the point of maximum power.

For the Pantelleria Island 7MVA solar plant study it was sized 24x high-voltage inverter, each with a power of 295kVA, total of 7080 kVA.

Important characteristics of this crucial equipment are:

- Grid compatibility: By converting the electricity to AC, the inverter ensures that the electricity generated by the solar PV system can be easily integrated into the existing grid.
- Safety: Solar inverter will include safety features that protect the system from power surges and other potential hazards, ensuring that the system is safe to use.
- Monitoring and management: Solar inverter will include monitoring and management capabilities, which allow for the monitoring of system performance and troubleshooting of any issues that may arise.

Solar radiation at the horizon

The available terrain is a typical airport flat field, free from shadowing obstacles. For the purpose of this study, it was considered standard horizon free output according to sun height at local latitude and longitude represented in Figure 5.

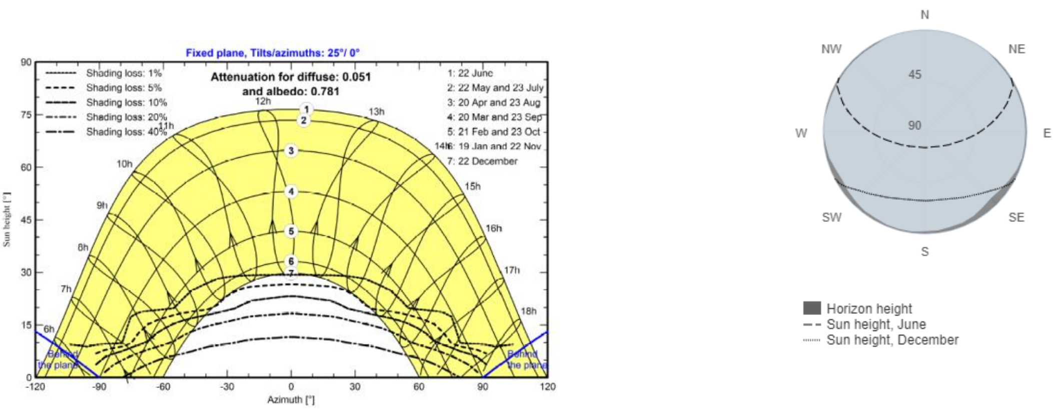

Figure 5 - Solar radiation considerations.

Fixing Structure

It was considered an easy to install and robust ground mounting structure with fixed tilt, where the main parameters to vary and validate are the distance between rows (corridor), the module angle (tilt) and the number and position of the module (horizontal/landscape or vertical/portrait).

The material of the structure will be aluminium with a high degree of corrosion resistance. The structure will be fixed to the ground by means of a bolted fixing system as shown in Figure 6.

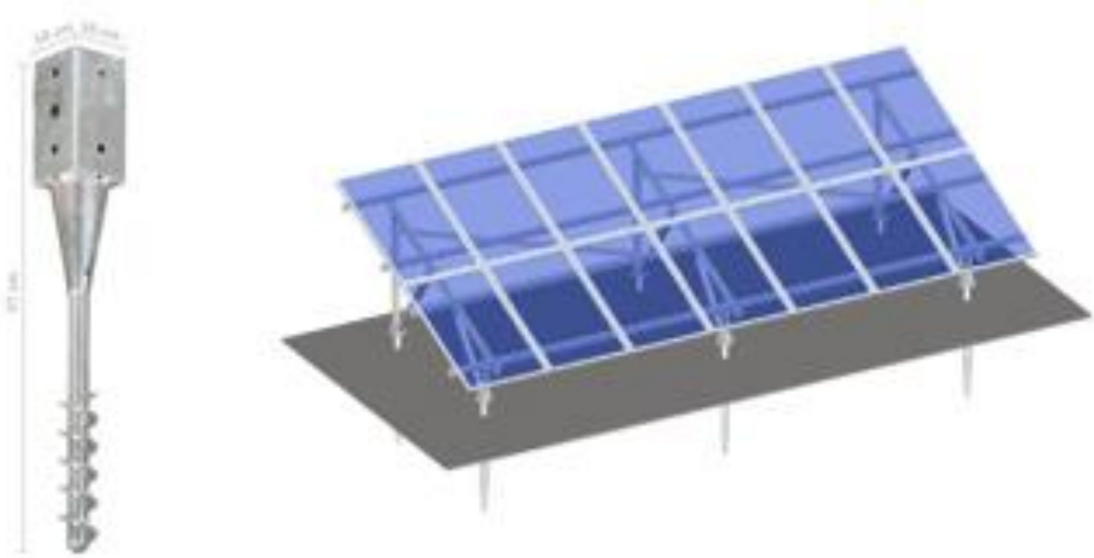

Figure 6 - Ground bolt fixing and anodised aluminium triangles mounting system.

Orientation and modules tilt

In the northern hemisphere, the general rule for solar panel placement is facing true south, in order to optimise the available area to perform at its maximum power production capabilities. Usually this is the best direction because solar panels will receive direct light throughout the day. Particularly for the Pantelleria Island, taking in consideration solar radiation, greenfield development with total flexibility and absence of surrounding obstacles, the south orientation (0º azimuth) was chosen.

Concerning the modules tilt, energy simulations were carried with tilt angle being the variable considering a ground mounting fixing system with two modules in portrait position.

Table 3 - Modules characterisation.

Pantelleria airport, modules facing South			
	Tilt [º]	**Energy production [kWh/kWp]**	**Line spacing[1] [m]**
2 modules Portrait position	10	1 503	1,5
2 modules Portrait position	15	1 531	2,25
2 modules Portrait position	20	1 552	3
2 modules Portrait position	**25**	**1 564**	**3,6**
2 modules Portrait position	30	1 567	4,3
2 modules Portrait position	35	1 563	5

The corridor size affects the shading losses: the bigger the corridor, the lower the shading loss. In this study it was considered the trade-off of a minimum corridor width for fixed-tilt structures in order to maximise the land usage and, also important, shortening as possible the distance to the grid connection point, and finally to facilitate the maintenance tasks.

[1] line spacing between rows to avoid row shadowing

According to the table above a good performance considering the available area is reached with modules tilted 25° with relation to the horizontal with line spacing of 3,6m in between rows.

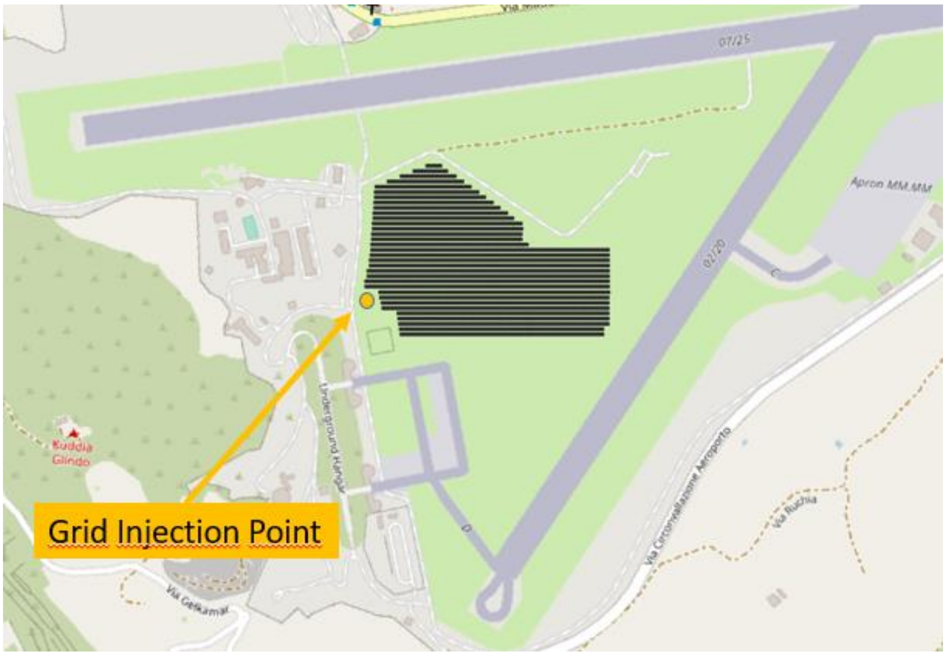

Figure 7 - South faced solar panel layout with ground mounting structure. Location of grid injection point.

To reach a high specific performance in the available space a 7,08 MVA was designed with a layout of 15 184 modules, total peak power 8,5MWp accommodated as close as possible to the injection point. The modules have south facing orientation, 25° tilt and 3,6m of corridor between rows.

Grid connection

DC system

The electrical connection of the modules will be carried out from the DC solar field to the building where the central inverters will be located, the closest to the grid injection point.

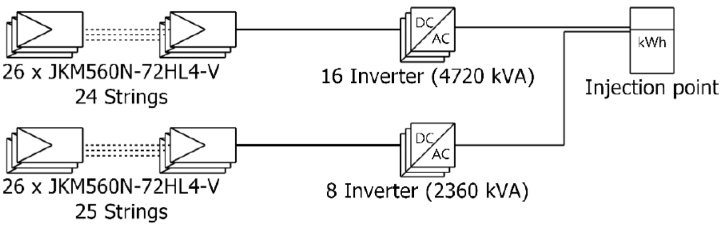

Figure 8 - Schematic of module distribution connecting to inverters.

The solar power plant connection to the grid will be carried out at Medium Voltage. The central inverters plant design consists of 24x inverters located near the grid injection point and for best performance and long life it is recommended to install the inverters inside a dedicated building equipped with an HVAC system. The building should be located aside of the grid connection point.

AC system

Connection of inverters: four (4) appropriately sized solar solar-switchboards will receive power for every six (6) inverters. In total, four AC solar-switchboards are required. Each AC switchboard is then connected to a transformer located outside the building.

An LV switchboard to provide 400V three-phase power for local auxiliary services is also considered.

Transformers

The transformers will be located outside the inverters building and then connected to the grid at medium voltage.

A step-up transformer, from 800V up the local medium voltage (10KV or more, adequate power capacity according to the electrical design and requirements) will be required for each solar-switchboard, for a total of four 2000 KVA step-up transformers.

In addition, one 800V–400V step-down transformer with 50KVA is considered for ancillary services. The latter then connected to the Main LV switch-board located inside the building.

The four transformers should be interconnected through equipment such as Ring Main Unit (RMU) to enable one point of connection to the main grid, as well as provide a way to isolate in case of operation and maintenance services.

General equipment description and quantities:

- 24x Inverters 320kVA each;
- 4x Solar-switchboard (for each 6 inverters), each one with the following protection:
  - 6x Circuit breaker 800V /400A;
  - 1x Circuit breaker 800V /2500A;
- 1x LV ancillary services switchboard;
- 4x Step-up 2000KVA transformer 800V - local medium voltage (adequate power capacity according to the electrical room design and requirements);
- 1x Step-down 50KVA transformer 800V-400V;
- 1x RMU.

Earthing system

It is advisable to keep the cable voltage drop to a maximum 1,5% voltage drop, on both AC and DC cables, and accordingly define the size of the cables.

Equipotentiality must be guaranteed between the existing electrical installations and the photovoltaic system, and in the latter, in all metallic structures. A buried earth system must be provided near the solar plant rows to connect all metal parts.

Remote monitoring system

A monitoring system consisting of advanced equipment with remote metering capabilities, a direct connection to the inverter for data retrieving, and a robust communication unit is foreseen to be implemented. The system must be fully compliant with the inverter and able to generate detailed reports of energy production, both in real-time and over specified time periods. Additionally, the system must have the ability to emit configurable notifications for any events that may occur. This monitoring system will enable remote monitoring of the system's performance and energy production, allowing for efficient and effective management of the solar PV system.

Most inverters come with capability of remote monitoring, to check the performance and energy production remotely.

Solar energy output

To calculate the energy production, a simulation with PVSyst software using local latitude and longitude and Meteonorm irradiance database was used. For such the following assumptions were considered:

General parameters

Grid-Connected System		**Sheds, single array**			
PV Field Orientation					
Orientation		**Sheds configuration**		**Models used**	
Fixed plane		Nb. of sheds	18 units	Transposition	Perez
Tilt/Azimuth	25 / 0 °	Single array		Diffuse	Perez, Meteonorm
		Sizes		Circumsolar	separate
		Sheds spacing	8.00 m		
		Collector width	4.58 m		
		Ground Cov. Ratio (GCR)	57.2 %		
		Top inactive band	0.02 m		
		Bottom inactive band	0.02 m		
		Shading limit angle			
		Limit profile angle	26.9 °		
Horizon		**Near Shadings**		**User's needs**	
Free Horizon		Linear shadings		Unlimited load (grid)	

Figure 9 - Assumptions adopted.

PV Array Characteristics

Total PV power		**Total inverter power**	
Nominal (STC)	8503 kWp	Total power	7080 kWac
Total	15184 modules	Number of inverters	24 units
Module area	39224 m²	Pnom ratio	1.20
Cell area	36099 m²		

Array losses

Array Soiling Losses
Loss Fraction 3.0 %

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 29.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 2.1 mΩ
Loss Fraction 1.5 % at STC

LID - Light Induced Degradation
Loss Fraction 2.0 %

Module Quality Loss
Loss Fraction -0.8 %

Module mismatch losses
Loss Fraction 2.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.1 %

IAM loss factor
Incidence effect (IAM): User defined profile

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	1.000	1.000	1.000	0.989	0.971	0.931	0.737	0.000

Figure 10 - Assumptions adopted (continuation).

As for the energy production results the simulation output was according to the figure below.

System Production

Produced Energy	13176263 kWh/year	Specific production	1550 kWh/kWp/year
		Performance Ratio PR	84.56 %

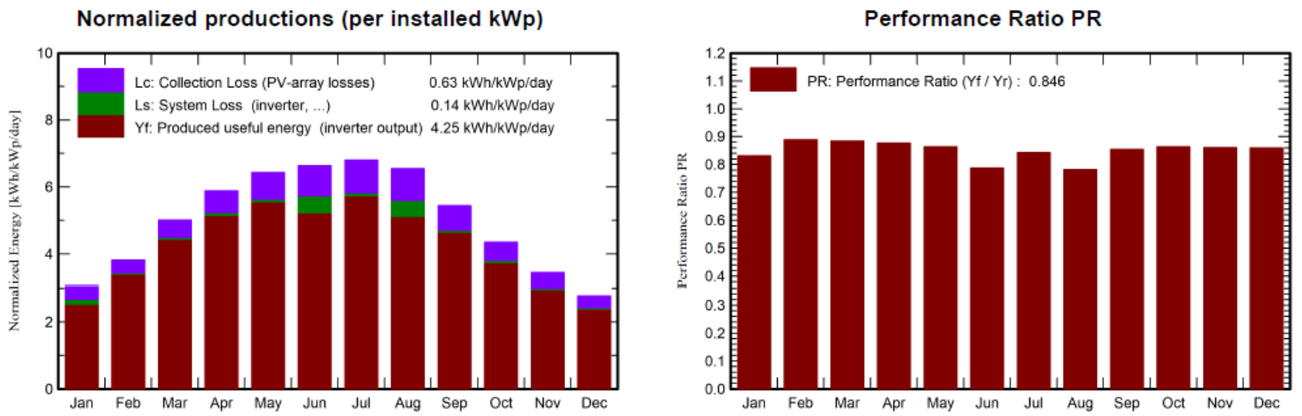

Figure 11 - Model output: energy production.

Based on assumptions and according to the PVGIS energy simulation it is expected a total of energy production of 13 176 MW/year being December the month with less production and July the highest.

Table 4 - Monthly energy injected into the grid.

Month	Energy injected into the grid (kWh)
January	668 518
February	807 548
March	1 168 510
April	1 315 205
May	1 464 282
June	1 331 909
July	1 512 788
August	1 348 786
September	1 185 521
October	988 412
November	755 546
December	629 238
TOTAL	**13 176 263**

Cost estimation and economic analysis

The cost of the solar PV system can vary greatly depending on current variable transportation costs and equipment available. CAPEX costs include design, engineering, tendering process, licences, procurement, import, installation, supervision, testing, commissioning. For the 7 MVA (8,5 MWp) power plant it would likely be in the range of €5 000 000 – €8 000 000.

The return on investment (ROI) can vary depending on the cost of electricity in the area, the cost of the system, and the amount of electricity produced by the system. Typically, the ROI for a solar PV system is between 5-10 years, but it can be more or less depending on the specific circumstances. Assuming an installation cost of €6 000 000 and a cost of electricity at €0,08/kWh, the system would produce 13 176 263 kWh/year, generating a simple annual revenue of €1 054 000. With an annual maintenance cost of €35 000, the simple net annual revenue would be €1 019 000.

It represents a simple IRR of 14% and a ROI period around 5 years. Financial costs should be included in a detailed financial analysis such as bank loan interest rates of 4%, 15% tax on profit, land rental, insurance.

It is important to note that these are rough estimates, and actual costs and returns on investment can vary significantly depending on the specific circumstances. The Italian government also has incentives and subsidies for the development of renewable energy which can reduce the payback period. It's also important to consider additional benefits such as environmental benefits and energy independence. A detailed financial analysis and consultation with experts in the field would be necessary to determine the specific costs and returns for a given system. Further studies to determine a more detailed financial analysis are not part of the current study scope but can be provided at a later stage of the project.

Environmental analysis

Carbon footprint reduction is one of the several environmental benefits of a solar photovoltaic system installation. Solar PV systems do not produce any emissions or pollutants during operation,

and thus do not contribute to air or water pollution. By generating electricity from a renewable source, the system reduces the carbon footprint of the power generation.
Considering greenhouse gas emissions, it is estimated that the 8,5 MWp solar system will contribute to a reduction of 3 426 tonnes CO_2 per year, an equivalent to a forest of 6 565 trees.

Other relevant environmental considerations are:

Reduced water consumption: Solar PV systems do not require water for cooling or other operations, and therefore reduce the overall water consumption of power generation. For cleaning of the solar modules, water can be used but we recommend it to be kept as a minimum as there are efficient dry cleaning methods that can be used.

Land-use efficiency: Solar PV systems can be installed on a wide range of surfaces, including rooftops, parking lots, and other areas not suitable for other land uses, as is the case for this airport development.

Installation

The following activities must be carried out before installation:

- Obtain permits from the city council and/or other entities such as aviation or civil defence that are necessary for the installation of the Photovoltaic System;
- Survey from the local DSO and electrical connection project and permit;
- Verification and measurements of voltage in the network at the injection site, which must safeguard the limits established in the Regulation of Service quality;
- Additional studies like geological/soil, archaeological, environmental that might be required.

Final results and conclusion

The best solution for the 7MVA solar plant located at Pantelleria Island airport is with a ground structure with a fixed inclination of 25° and 3,6m between rows (corridor). Each row will be composed of 2 photovoltaic modules with vertical orientation (portrait). On total 15 184 modules connected to 24 inverters for a total installed power of 8,5 MWp. In the figure below is shown a general layout of the photovoltaic plant. The final layout will be defined in the design and engineering phase and may suffer small variations, since for this study the worst case scenario was always considered.

A simple financial analysis has been conducted and it is projected that an investment of 6 million euros will achieve an internal rate of return (IRR) of 14% over a period of five years, this investment is expected to be profitable and the costs will be recouped in 5 years.

Finally, the 8,5 MWp solar system will contribute to a reduction of 3 426 tonnes CO_2 per year equivalent to a forest of 6 565 trees.

Figure 12 - South faced solar panel layout with ground mounting structure, and injection point location.

The project has the potential for expansion and growth in the future, as long as the necessary regulatory and technical requirements are met. Because there is still available land, it is possible to increase the installed power in the future if there is grid reception capacity, confirmed by the local DSO, and if the technical limits at the injection point are respected.