European Commission

Clean energy for EU islands: Technical assistance

Mathraki, Greece

Clean energy for EU islands

PV evaluation in Mathraki

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Authors: Leandro Vaz (RdA)
Reviewers: Andries De Brouwer (3E), Jan Cornillie (3E)

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Clean energy for EU islands

www.euislands.eu | info@euislands.eu

Table of Contents

List of Figures

List of Tables

Executive Summary

Mathraki is a Greek island interconnected to the mainland. The island plans to develop energy supply from a solar photovoltaic energy system to contribute to the transformation of the local harbour into a smart marina. The local harbour will be upgraded to accommodate small electric boats, connecting Mathraki to the nearby islands.

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

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.

Overall, it is found that the 44,55kWp solar PV system, with an annual energy yield of 64 277 kWh, can have a positive impact on the environment by reducing carbon footprint and greenhouse gas emissions for 38,4 ton CO_2 per year, increasing energy independence and reducing water consumption.

Introduction and technical assistance objective

Diapontia islands (Figure 1) are a Greek archipelago located at the northwest of Corfu, in the Ionian Sea. The archipelago consists of 12 islands or islets, which only three are inhabited - Othoni, Ereikoussa and Mathraki.

Figure 1 - Map of Diapontia Islands.

This report is focused on Mathraki island, which has an area of 3,53 km^2 and a maximum length of 3,42 km and a width of 0,85 km. According to the Greek census, the island has a population of 329 people. It is also important to note that the Mathraki Island is interconnected with the mainland.

The overall project on Mathraki aims to develop energy supply from a solar photovoltaic energy system to contribute to the transformation of the local harbour into a smart marina. The local harbour will be upgraded to accommodate small electric boats, connecting Mathraki to the nearby islands. The overall project is one of many initiatives promoted by the Municipality in the direction of clean energy transition, tourism activity increase, and decarbonisation of its archipelago power sector.

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

Diapontia Islands were awarded in the first CE4EUislands Gamechanger Award extra technical assistance. The technical assistance from the Islands secretariat (presented in this report) aims to develop a preliminary sizing and production estimation of solar PV based on the indicated locations. More concretely, it 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 Greek standards or, in their absence, European standards (EN) and be suitable for the site, use and method of installation.

The renewable energy produced will be injected into the main grid at low voltage (LV) through the existing electrical installation.

There are several benefits of installing solar photovoltaic power:

- Reduced dependence on fossil fuels: By generating electricity from solar power, the island can reduce its dependence on fossil fuels and decrease its carbon footprint;
- Cost savings: Solar power is a cost-effective source of electricity, and can help the island save money on electricity costs in the long run;
- Energy independence: A solar photovoltaic (PV) system can provide the island with a reliable source of electricity, increasing its energy independence and reducing its dependence on outside sources of energy;
- 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;
- 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.

PV Project

Location

The selected area is located on the central south side of Mathraki Island in a horizontal and clean open field in the mountain. The site is surrounded by a rocky cliff on the North - Northeast side, creating shade during the early hours of the day. From the South - South West side it is free of shading obstacles. The total area of the land that is fenced is 754 m^2. The cleared and horizontal area available for solar panel installation is 478m^2 considered to be flat with no slope.

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

Solar radiation at the horizon

For the correct sizing an energy output estimation, it was assumed some horizon obstacles and respective heights surrounding the area, mainly at the North, East and South-east side.

For the following energy simulations, the identified obstacles that can affect available solar radiation on the modules were the North rocky cliff and some bushes or trees at the East-side of the field.

Calculated horizon shadow effect considered in the simulation is represented in this figure.

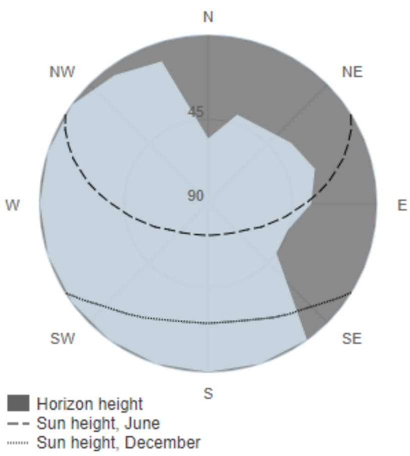

Figure 3 - Shadow effect.

Orientation angle

In order to optimise the available area in relation to maximum performance, taking in consideration not only the surrounding obstacles but the maximum solar radiation in relation to the azimuth, three energy simulations were made, testing different azimuth. The azimuth, or orientation, is the angle of the PV modules relative to the direction due South. -90° is East, 0° is South and 90° is West. For this comparison, for all simulations it was considered the same solar module, a module tilt of 20° and 0,6 m row spacing:

a) Facing South-West (orientation to the sea).

- Azimuth 48°
- 50 kWp
- 1 439 kWh/kWp

b) Facing South

- Azimuth 0°
- 44,5 kWp
- 1 443 kWh/kWp

c) Facing South-East

- Azimuth -41°
- 46,8 kWp
- 1 325 kWh/kWp

Figure 4 - Scheme of the simulations performed.

Within the available space the maximum power that can be accommodated is achieved with simulation a) which although free of obstacles, the orientation of 48° West results in a low specific power production year on year. The best specific performance results 1 443 kWh/kWp are obtained with simulation b) with 44,5 kWp, the lowest power. The third simulation, although with more installed power than the previous one, is affected by the existing shading obstacles considered in the surroundings and by the eastern orientation.

Solar Modules

To maximise the power production, it was considered 81 solar modules of unit 550 Wp of the below specifications and implementation layout:

Table 1 - Characteristics of the solar modules.

Rated Maximum Power (PMax) [Wp]	**550**
Cell type	Mono
Open circuit voltage (Voc) [V]	49,90

Maximum Power Voltage (Vmp) [V]	41,96
Short Circuit Current (Isc) [A]	14
Module efficiency [%]	21,3
Dimensions	2 279mm x 1 134 mm x 35 mm
Weight	28,6 kg

The layout is one module in landscape position and 0,6 metre between rows in order to avoid shading among panels.

Figure 5 - 44,55 kWp solar modules layout, south facing.

Inverters

A solar inverter is an essential component of a PV system, as it converts the direct current (DC) electricity generated by the solar panels into alternating current (AC) electricity that can be used. 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 – MPPT capability is required to guarantee the constant operation of the modules at the point of maximum power.

For the Mathraki island solar photovoltaic technical assessment two string inverter with a power of 15kW each, was considered. The inverter is prepared to inject produced energy to the 3phase – 400 V grid.

Recommended features are:

Table 2 - Recommended features for the inverters.

String inverter with MPP trackers	
Maximum Input power	**15 kW**
Maximum Efficiency	98,65% or higher
Operating voltage range	160 – 950 V
Minimum start-up voltage	200 V
Number of inputs	2
Number of MPP trackers	2
Type	Three-phase

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.

Fixing Structure

Assuming that the terrain can be rocky and make it difficult to anchor metal structures, an easy and sustainable mounting solution was envisaged using prefabricated concrete supports for solar panels on flat surfaces. The choice of concrete instead of metal structures brings the following benefits:

- Easy assembly and adjustment, saving time when installing;
- No foundations required to perform anchor or support;
- High durability;
- Instead of metal, the use of reinforced concrete has an important advantage with regard to the high potential for corrosion on the island;
- To regularise some areas of the land in order to level it, if necessary, it is sufficient to create a rubble bed with gravel or pebbles.

Figure 6 - Flat surface concrete mounting system.

Recommended features are:

Table 3 - Recommended features for the fixing sctruture.

Concrete solar mounting system	
Material	Reinforced concrete, with high density and resistance to chemical and atmospheric agents.
Tilt	20°
Dimensions	1 000 x 410 x 160 mm
Weight	60 Kg

Main Switch-Board

The Main Photovoltaic switch-board will be located behind and under the shade of the solar panel near the site entrance. The switchboard will receive the inverter wiring and is fitted with a four-pole main switch and a 300mA differential protection (lower values are permitted to allow this device to be adapted to existing protective earth values) and a circuit breaker suitable for the maximum output current of the drive. The main board is connected to the grid on a three-phase low voltage output.

Main board characteristics:

- Mounting method: surface mounted;
- Index of protection against mechanical shocks IK: 08;
- IP protection rating: IP65;
- Protection class: Class II.

A DC switch will be installed between the solar field and the inverter, capable of cutting the maximum current of the inverter.

Equipotentiality must be guaranteed between the existing electrical installations and the photovoltaic system, and in the latter, in all metallic structures.

Figure 7 - Location of electrical grid injection point.

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.

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

Solar energy output

For the energy simulation of the 44,55kWp solar photovoltaic system, in addition to tilt and orientation criteria described previously, the PVGIS-SARAH2 database was used together with the following calculation assumptions:

Table 4 - Assumptions adopted.

Provided inputs:	
Location [Lat/Lon]	39,767N; 19,518E
Horizon	User defined
Database used	PVGIS-SARAH2
PV technology	Crystalline silicon
PV installed (kWp)	44,55
System loss (%)	14
Slope angle	20
Azimuth angle	0°
Tilt angle	20
Changes in the output due to:	
▪ Angle of incidence (%)	-2,45
▪ Spectral effects (%)	NaN
▪ Temperature and low irradiance (%)	-2,22
▪ Total loss (%)	-17,97

Based on assumptions and according to the PVGIS energy simulation, it is expected a total of energy production of 64,3 MWh/year being December the month with less production and July the highest.

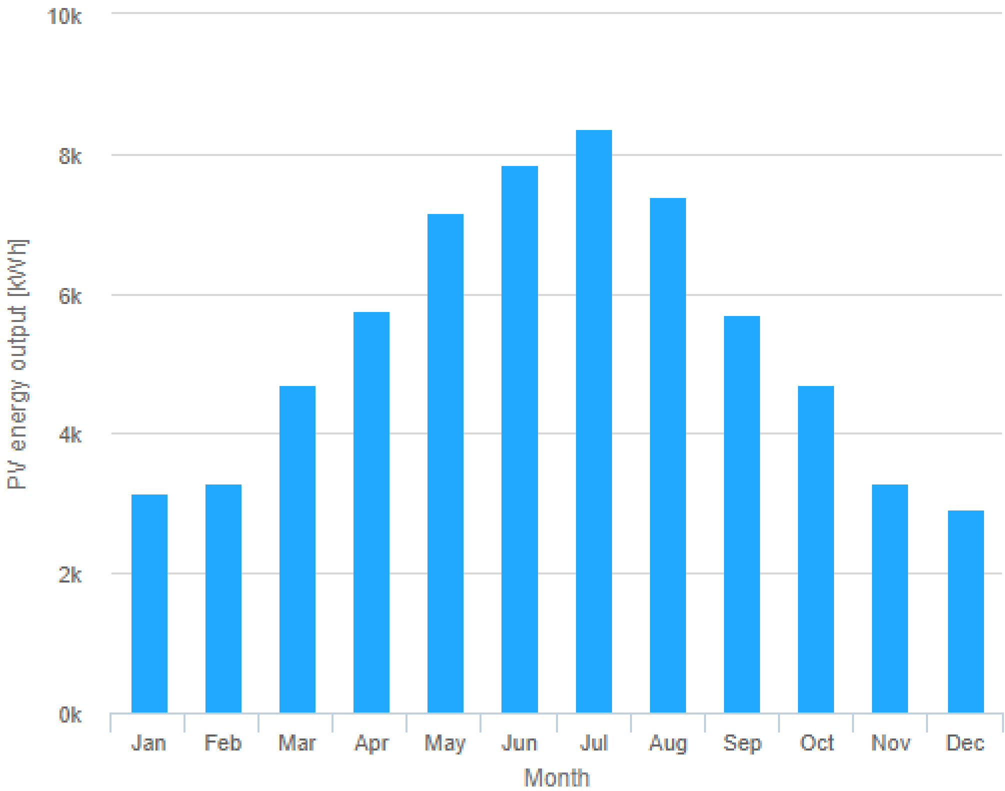

Figure 8 - Monthly energy output from fix-angle PV system.

Table 5 - Monthly energy production (kWh).

Month	Energy production (kWh)
January	3 151,64
February	3 286,45
March	4 710,42
April	5 754,05
May	7 161,56
June	7 841,77
July	8 374,92
August	7 391,39
September	5 692,42
October	4 702,99
November	3 299,73
December	2 909,94
TOTAL	**64 277,28**

Cost estimation and economic analysis

The cost of the solar PV system can vary greatly depending on current variable transportation costs and equipment available. The cost for a 44,55 kWp system would likely be in the range of €40 000 - €60 000, excluding VAT.

The pay-back period 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 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 €50 000 and a cost of electricity at €0,20/kWh, the system would produce 64 277 kWh/year, generating an annual revenue of €12 000 on average during the lifetime period. With an annual maintenance cost of €900, the net annual revenue would be €11 100. With an investment of €50 000, the simple payback period would be about 5 years.

It's important to note that these are rough estimates, and actual costs and returns on investment can vary significantly depending on the specific circumstances. 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.

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 44,55 kWp solar system will contribute to a reduction of 38,4 ton CO_2 per year[1].

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.

Land-use efficiency: Solar PV systems can be installed on a wide range of surfaces, including rooftops, parking lots, and other areas that are not suitable for other land uses.

Installation

The following activities must be carried out before installation:

- Obtain licences from the city council and/or other entities that are necessary for the installation of the Photovoltaic System;
- Repair/Installation of any type of fence or other protection for the Photovoltaic System;
- Verification and measurements of voltage variation in the network at the injection site, which must safeguard the limits established in the local Regulation of Service quality. This can be relevant as the inverter will disconnect when voltage and frequency are outside the operating limits. Disturbances can occur in locations where the electrical grid is old and/or in a grid-end-point cases;
- On-site survey of the current situation regarding technical aspects that may affect the cost, such as ground condition, deciding on connection cabling routing, trees or bushes

[1] Using a conversion factor of 598 gCO2 per kWh generated (Source: European Environment Agency).

maintenance at the surroundings to avoid shading, as well as remaining elements required for detailed design and installation planning.

It is of utmost importance to comply with the CE certifications with logos that must appear on the equipment label. Particular care must be taken in the selection of corrosion resistant materials and equipment that will withstand external weather conditions and attention must always be present during execution.

Conclusions

From this preliminary sizing and production estimation of solar PV in Mathraki island, the main conclusions are:

- The best performance is obtained with 1 443 kWh/kWp and 44,55kWp, facing south.
- The total yearly production is 64 277,28 kWh.
- July is the month with highest production with 8 374,92 kWh, while December is the least productive month with 2 909,94 kWh.
- The cost would likely be in the range of €40 000 - €60 000.
- Assuming an installation cost of €50 000 and a cost of electricity at €0,20/kWh, the system would produce 64 277 kWh/year, generating on average an annual revenue of €12 000. With an annual maintenance cost of €900, the net annual revenue would be €11 100. With an investment of €50 000, the simple payback period would be about 4 to 5 years.