School of Social Sciences

Master in Business Administration

Postgraduate Dissertation

"Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece"

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Supervisor: Andrianos Tsekrekos

Patras, Greece, May 2026

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“Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece”

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"This dissertation is dedicated to my family."

Abstract

The thesis focuses on the evaluation process of a photovoltaic (PV) power plant and analyzes the feasibility of a utility scale PV project according to the Greek Energy Market. The goal is to develop a well-established construction and operation business plan, taking into account the current regulatory framework in Greece.

The case study is based on a hypothetical 40 MW PV project which successfully participated in the last Bidding Procedure for RES, according to RAE Announcement No. 2/2022.

The thesis includes technical analysis (technology selection, energy production), economic evaluation (CAPEX, OPEX) and financial simulation using indicators (LCOE, NPV, PP, IRR, etc.) in order to examine the following four (4) construction scenarios of utility scale PV project:

- Construction of PV project with fixed structures.
- Construction of PV project with tracking structures.
- Construction of PV project with fixed structures in combination with Battery Energy Storage System (BESS).
- Construction of PV project with tracking structures in combination with Battery Energy Storage System (BESS).

The main target of the thesis is to assess the importance of choosing the right operating and financing model for the financial viability of a PV project according to the latest market trends.

Keywords

PV, BESS, LCOE, NPV, IRR, PP, ROI

Περίληψη

Η διατριβή επικεντρώνεται στη διαδικασία αξιολόγησης ενός φωτοβολταϊκού (Φ/Β) σταθμού παραγωγής ενέργειας και αναλύει τη σκοπιμότητα ενός Φ/Β έργου μεγάλης κλίμακας σύμφωνα με την Ελληνική Αγορά Ενέργειας.

Στόχος είναι η ανάπτυξη ενός καλά εδραιωμένου επιχειρηματικού σχεδίου κατασκευής και λειτουργίας, λαμβάνοντας υπόψη το ισχύον κανονιστικό πλαίσιο στην Ελλάδα.

Η μελέτη περίπτωσης είναι βασισμένη σε ένα υποθετικό Φ/Β έργο 40 MW που συμμετείχε με επιτυχία στην τελευταία Διαγωνιστική Διαδικασία για ΑΠΕ, σύμφωνα με την Ανακοίνωση της ΡΑΕ με αριθμό 2/2022.

Η διατριβή περιλαμβάνει τεχνική ανάλυση (επιλογή τεχνολογίας, παραγωγή ενέργειας), οικονομική αξιολόγηση (CAPEX, OPEX) και οικονομική προσομοίωση χρησιμοποιώντας δείκτες (LCOE, NPV, PP, IRR, κ.λπ.) προκειμένου να εξεταστούν τα ακόλουθα τέσσερα (4) σενάρια κατασκευής Φ/Β έργου μεγάλης κλίμακας:

- Κατασκευή Φ/Β έργου με σταθερές βάσεις στήριξης.
- Κατασκευή Φ/Β έργου με κινητές βάσεις στήριξης.
- Κατασκευή Φ/Β έργου με σταθερές βάσεις στήριξης σε συνδυασμό με Σύστημα Αποθήκευσης Ενέργειας Μπαταρίας (ΣΑΗΕ).
- Κατασκευή Φ/Β έργου με κινητές βάσεις στήριξης σε συνδυασμό με Σύστημα Αποθήκευσης Ενέργειας Μπαταρίας (ΣΑΗΕ).

Κύριος στόχος της διπλωματικής εργασίας είναι η αξιολόγηση της σημασίας της επιλογής του σωστού λειτουργικού και χρηματοδοτικού μοντέλου για την οικονομική βιωσιμότητα ενός φωτοβολταϊκού έργου σύμφωνα με τις τελευταίες τάσεις της αγοράς.

Λέξεις – Κλειδιά

Φ/Β, ΣΑΗΕ, LCOE, NPV, IRR, PP, ROI

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List of Abbreviations & Acronyms

EU: European Union

LNG: Liquefied Natural Gas

RES: Renewable Energy Sources

NECP: National Energy and Climate Plan

PV: Photovoltaic

BESS: Battery Energy Storage System

CO_2: Carbon dioxide

HEnEx: Hellenic Energy Exchange

RAAEY: Regulatory Authority for Waste, Energy and Water

IPTO: Independent Power Transmission Operator

SMP: System Market Price

ETA: Environmental Terms Approval

HEDNO: Hellenic Electricity Distribution Network Operator

FiT: Feed in Tariff

FiP: Feed in Premium

AC: Alternative Current

DC: Direct Current

MV: Medium Voltage

EMS: Energy Management System

BMS: Battery Management System

LCOE: Levelized Cost Of Energy

PP: Payback Period

NPV: Net Present Value

IRR: Internal Rate of Return

ROI: Return On Investment

1. Introduction

The year of 2025 was recorded as a turning point for the European energy landscape, as critical decisions and developments accelerated the transition to a new, more complex and demanding environment. The final decision of the European Union (EU) to stop imports of Russian natural gas created a new perspective for our country, as a hub for the transport of American LNG. In the same context, mobility in the hydrocarbon sector was rekindled, bringing back to the public debate the issue of domestic production and its contribution to energy security.

In the renewable energy sector in Greece, the installation of new projects, mainly photovoltaics, is maintained at high levels and investment interest remains strong. At the same time the combination of increased energy production curtailment, frequent phenomena of zero or negative prices in the energy market and the gradual withdrawal of support mechanisms reinforces the concern about the sustainability of investments and the limits of the existing development model.

Energy storage has gained particular importance, which is evolving into the most critical tool for balancing the system, creating a new dynamic market. At the same time, the need to increase interconnections and strengthen networks in European level, with an acceleration of the relevant investments, has been established.

This new environment constitutes a challenge for the business community, which highlights as a basic condition for a smooth development, the existence of clear, stable and transparent rules for the operation of the markets.

2. Renewable Energy Systems in Greece

2.1. General Information

Greece, due to its geographical location and its particular geomorphology, is an energy-rich country as it has a high potential in renewable energy systems (RES), such as solar, wind, hydraulic, wave, but even medium and high enthalpy geothermal energy. The main advantages of RES are the production of energy from sources that are inexhaustible, do not pollute the environment (with the exception of biomass combustion) and can operate autonomously, without connection to the electricity grid. However, RES have disadvantages, most notably the high initial cost of some systems, as well as the variation in their availability (solar energy, wind energy, etc.), which depends on the climate, morphology and location of an area. The cost of a RES installation is increased significantly when it includes storage systems (accumulators for electrical energy or heaters/tanks for thermal energy). (TEE, 2021)

2.2. National Energy and Climate Plans

The development of RES projects is carried out in line with the National Energy and Climate Plan (NECP). NECPs are the first ever integrated medium-term planning tools required to be prepared by Member States to help them achieve the objectives of the European Union and in particular the agreed EU 2030 energy and climate targets. NECPs outline the plans of actions of each Member State for contributing to the common objectives of the Energy Union. NECPs are also required to comply with a binding structure laid down in the Regulation on the Governance of the Energy Union and Climate Action to ensure comparability and coherence of policies, as well as fueling up a wide European debate on energy and climate priorities. The NECPs therefore reflect the logic of the key dimensions of the Energy Union: energy efficiency, a fully integrated internal energy market, the decarbonization of the economy, energy security and solidarity and trust, research, innovation and competitiveness. For each dimension, Member States are expected to include objectives, targets or contributions, as well as policies and measures to be used to achieve the national targets. The NECPs should be developed on an evidence-based analysis of the likely impact of the policies and measures proposed. The NECPs should also be a subject of discussions with national stakeholders as well as neighboring Member States. The NECPs are fundamental instruments of the clean energy transition as well as of investments security for Europe's industry. All EU Member States were to submit their draft NECPs by 31 December 2018 with an ultimate deadline for submission of the final plans on the 31st December of 2019. (European Commission, 2019)

2.3. Solar Energy

The solar potential in Greece varies depending on the geographical location (latitude, longitude and altitude) and the geomorphology of an area. It ranges annually from 1,400 kWh/m² to 1,900 kWh/m², while in some areas it is even higher. Solar energy is utilized in many areas in Greece,

mainly through solar thermal collectors and though photovoltaics (PV) for the production of electricity.
For the sizing of a solar system, a basic requirement is the determination - estimation of the available solar energy and more specifically, depending on the case:
• The average hourly, monthly or annual solar energy, depending on the orientation and inclination of the installation of a solar system,
• The average number of maximum cloudy days per month in an area,
• The solar geometry per season to determine the reduction in available solar energy, due to possible shading of the systems by natural or artificial obstacles in the surrounding area. (TEE, 2018)

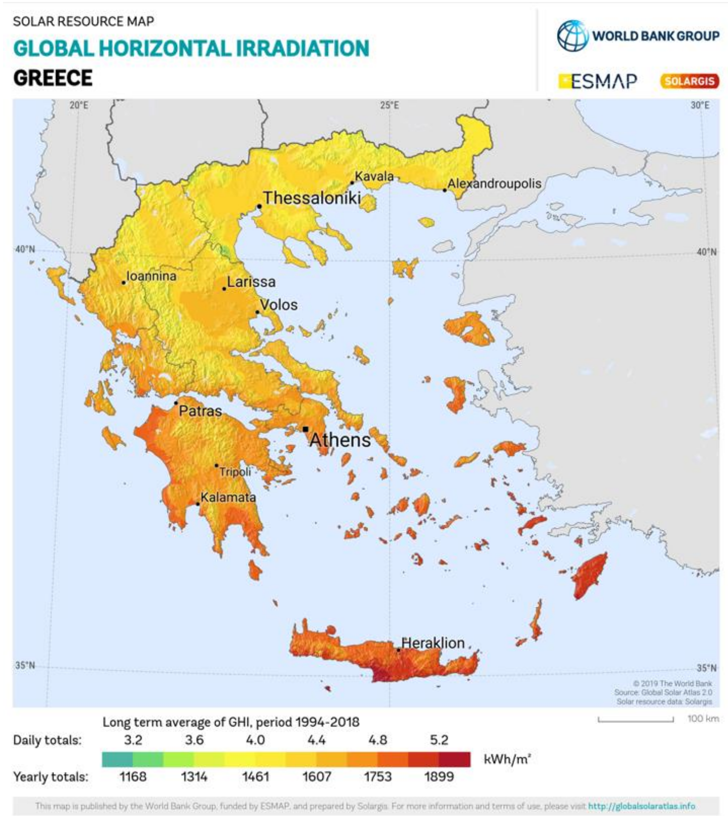


Figure 1: Map of Greece with the average annual total solar energy in horizontal plane (kWh/m²)

2.4. National Solar Energy Market

In 2025, the Greek PV market installed more megawatts (MWp) than any other technology supported by the huge investment interest that was undiminished. (SolarPower Europe, 2025)

Connected PV systems	GWp
New capacity connected in 2025	2,5
Cumulative capacity at the end of 2025	12,2

Table 1: Capacity of interconnected photovoltaic systems in Greece

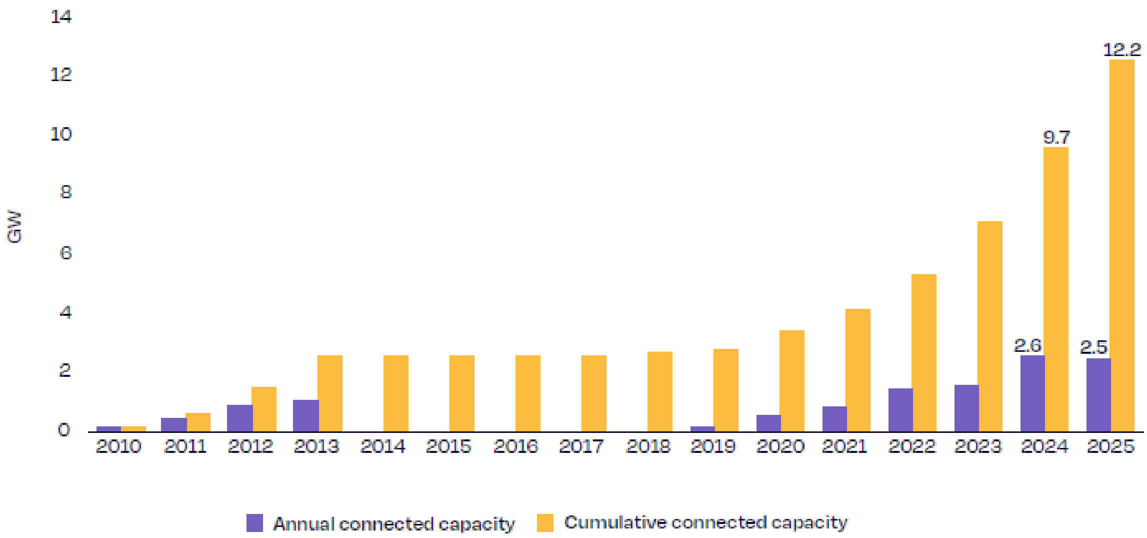


Figure 2: Greek photovoltaic market

In 2024 the overall market of residential systems grew by 40% compared to the previous year. A number of 9.091 (around 60 MW) small battery energy storage systems (BESS) were interconnected, among others, in the framework of the "Photovoltaics on the Roof" program. The annual installed capacity of market shares is shown in the figure below.

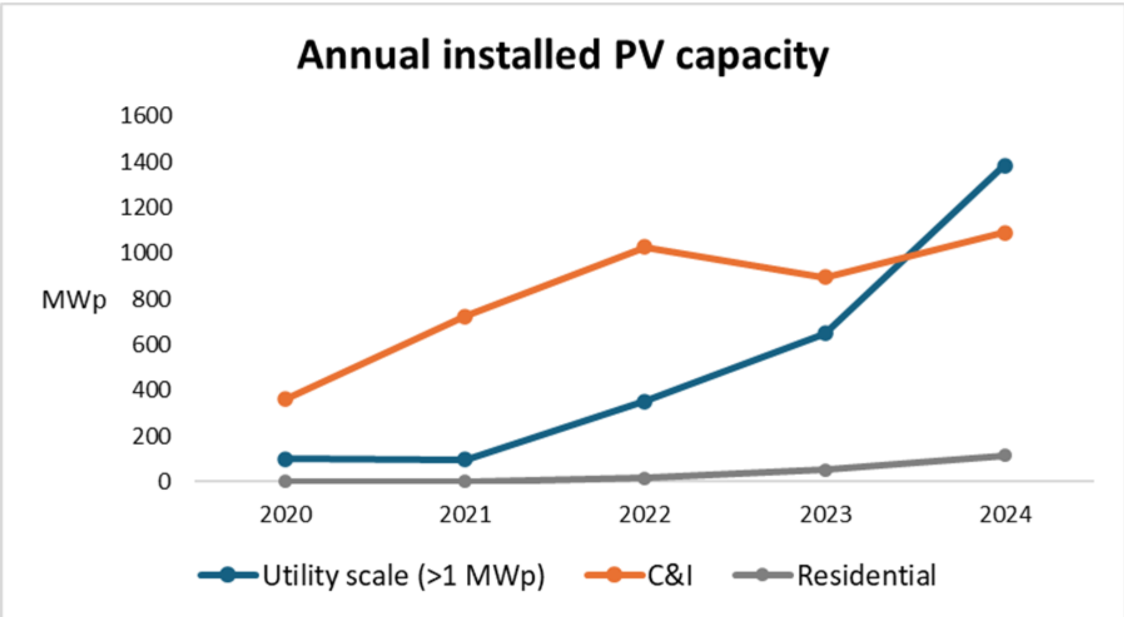


Figure 3: Annual installed photovoltaic capacity

PV systems are by far the most popular power generation technology with approximately 87.000 systems of all sizes installed across the country by end of 2024, with a rapidly increasing number.

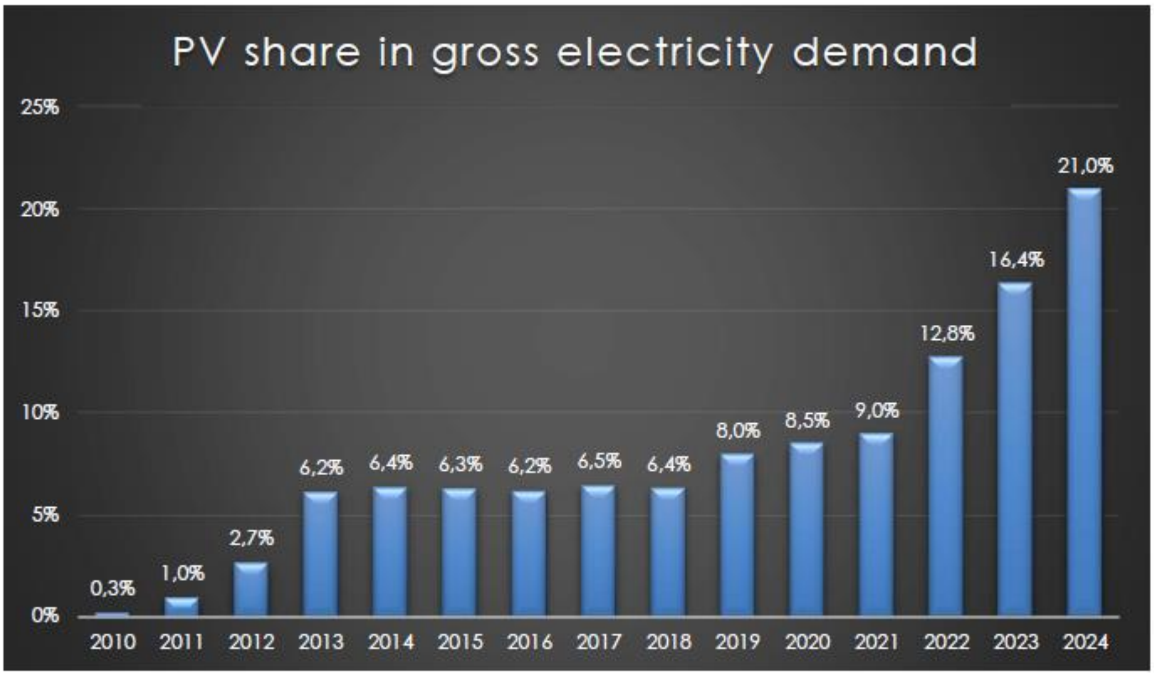


Figure 4: Share of photovoltaics in gross electricity consumption

In the year of 2024, 1,6 million euros were invested in our country in new photovoltaic projects.

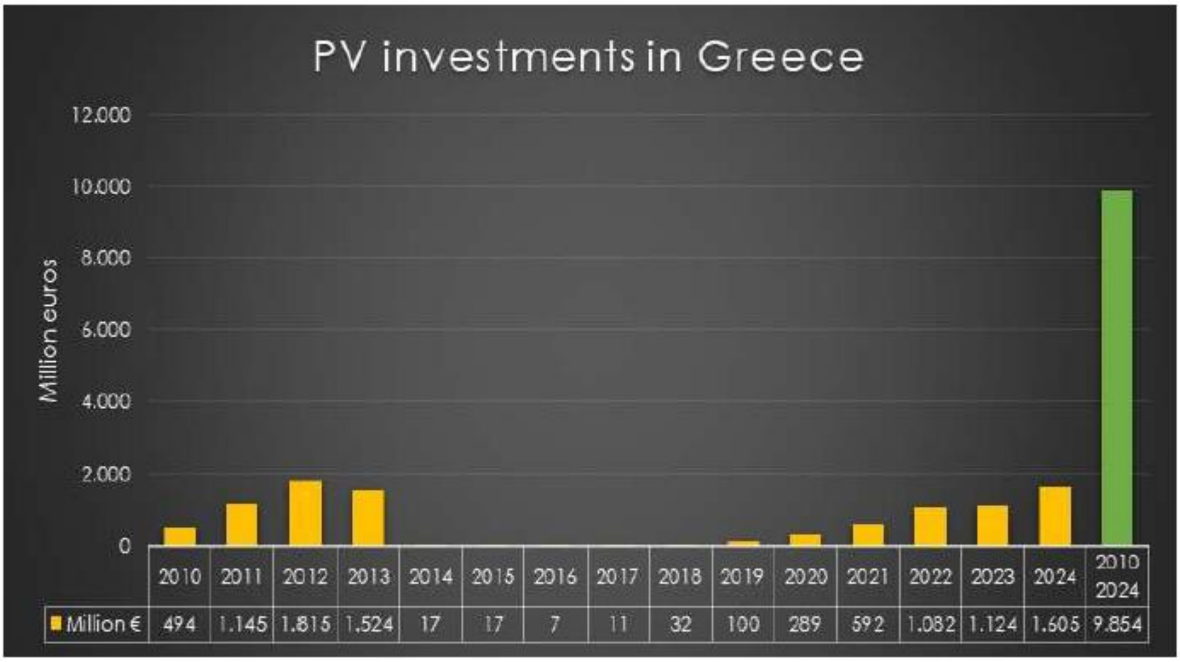


Figure 5: Investments of photovoltaic systems in Greece

In addition, the yearly average energy efficiency of photovoltaics in Greece as shown in Figure 6.

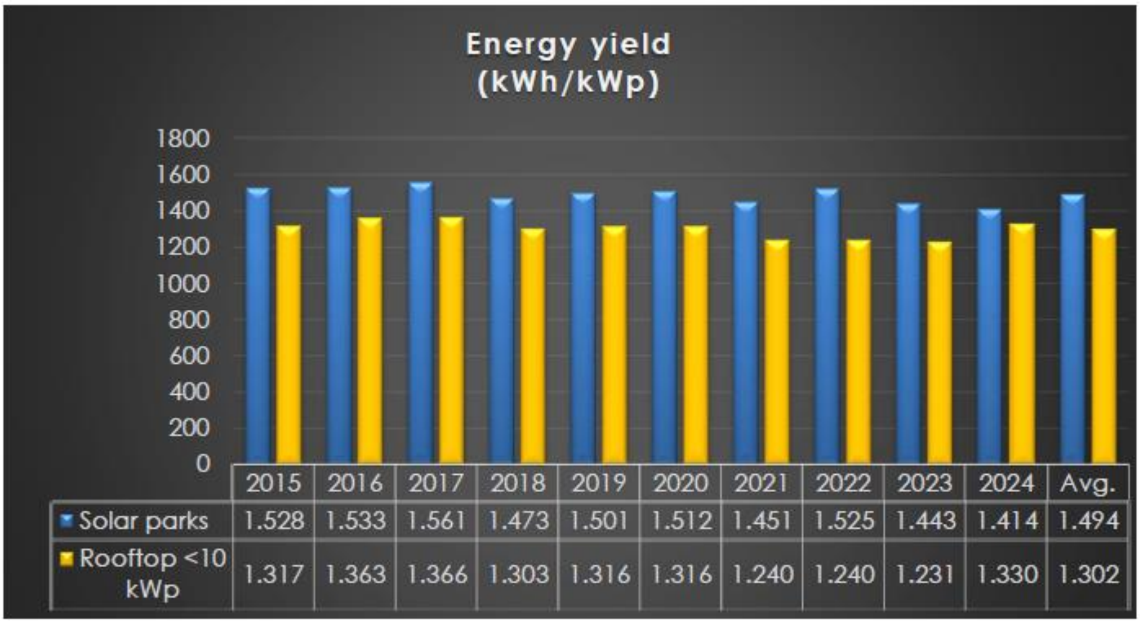


Figure 6: Average energy efficiency of photovoltaic systems (kWh/kWp)

Due to the energy production of photovoltaics, the emission of 6,4 million tons of carbon dioxide (CO2) was avoided in 2024. This is the amount of CO2 emitted by 5.1 million new cars with internal combustion engines that drive for 10.000 kilometers on average. The environmental benefit is the equivalent of planting 165,8 million conifers or 101,1 million deciduous trees in the urban fabric and allow them to grow for 10 years.

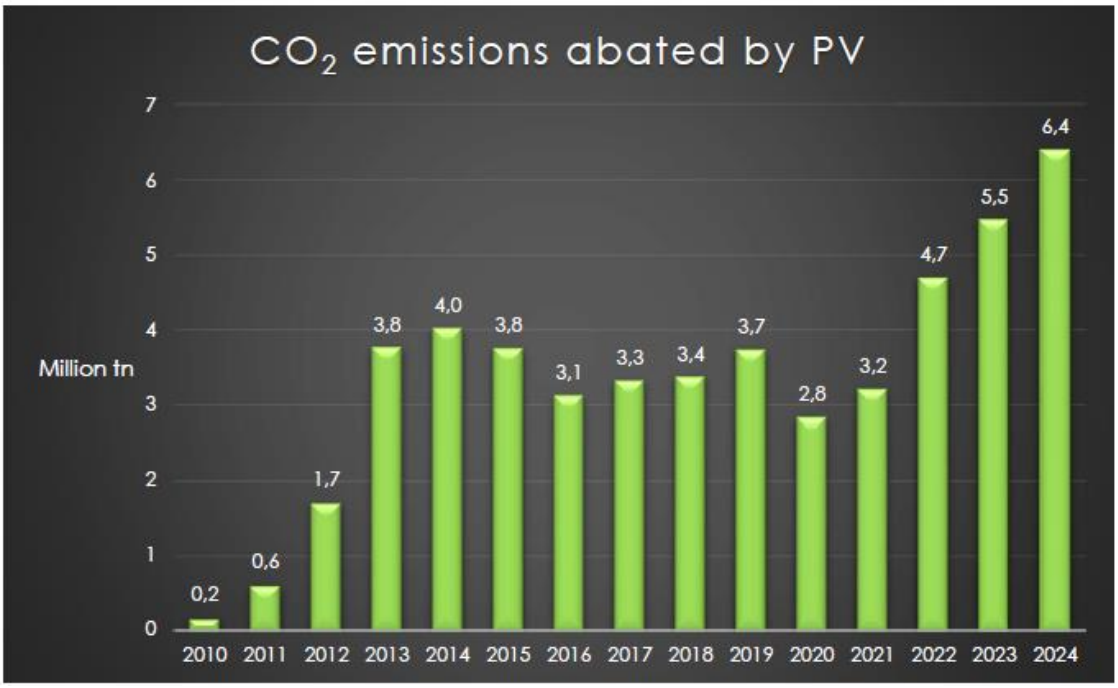


Figure 7: Decrease in CO_2 emissions due to photovoltaic systems

2.5. Greek Electricity Market

The Hellenic Energy Exchange (HEnEX) was founded on 18/6/2018 after the separation of the electricity market sector from LAGIE S.A., which was subsequently renamed DAPEEP S.A. HEnEX has gained experience from over a decade of continuously and consistently operating the daily energy planning trading system. Moreover, HEnEX was appointed by the Regulatory Authority for Energy, Waste and Water (RAAEY) as the Nominated Electricity Market Operator (NEMO) for the operation of the day-ahead market and the intraday electricity market. Since 16/3/2020 HEnEX is operating energy financial market.
The Greek electricity market model is in full conformity with the European model, also referred to as the "Target Model". The Target Model ensures the optimization of the use of the transmission system capacity through coordinated practices of the transmission system operators, the achievement of reliable prices and liquidity in the allocation of interconnection capacity for the day-ahead market, the effective operation of forward markets and the effective planning of intraday markets for the allocation of interconnection capacity.
According to Law 4512/2018, the following wholesale energy markets are defined, within the meaning of Regulation (EU) n. 1227/2011:

• Energy financial Market ('Forward Market')
• Day-ahead Market ('Day-ahead Market')
• Intra-day Market ('Intra-day Market')
• Balancing Market ('Balancing Market').

HEnEX operates the first three markets, while IPTO manages and operates successfully the balancing market as well as other key processes of the electricity market as a whole, such as the calculation and allocation of long-term interconnection capacity and the long-term allocation of capacity in the day-ahead market and the intraday markets managed by HEnEX.

Figure 8: Time series of purchases based on the target model

The task of the balancing market is to ensure the balance of supply and demand and overall security of the system and at the same time to achieve the highest quality operation of the electricity system through the most efficient use of the interconnections. It seeks to foster competition and offers large incentives to the entry and more efficient integration of new technologies into the market, such as renewable energy sources, demand response and storage. (IPTO, 2018)

2.6. Supply of Electrical Energy

In the first ten months of 2025, RES ranked first in electricity generation with 22.568 GWh cumulatively and a decade-high, while recording an increase of 5,5% compared to the corresponding period of 2024. This was followed by fossil gas with 19.079 GWh, recording a high and an increase of 12,6% compared to the first ten months of 2024. The country's net exports were also at historically high levels, reaching 1.932 GWh for the first ten months of 2025, almost tripling the corresponding performance of 2024 (752 GWh).
In third place in electricity generation after RES and gas was oil with 3.228 GWh. Large hydropower plants followed with 2.738 GWh, the lowest ten-month production in the last five years. Lignite came in last place with 2.111 GWh, the lowest ever ten-month electricity production, 11,6% less than the previous historic low of the ten-month period of 2024.

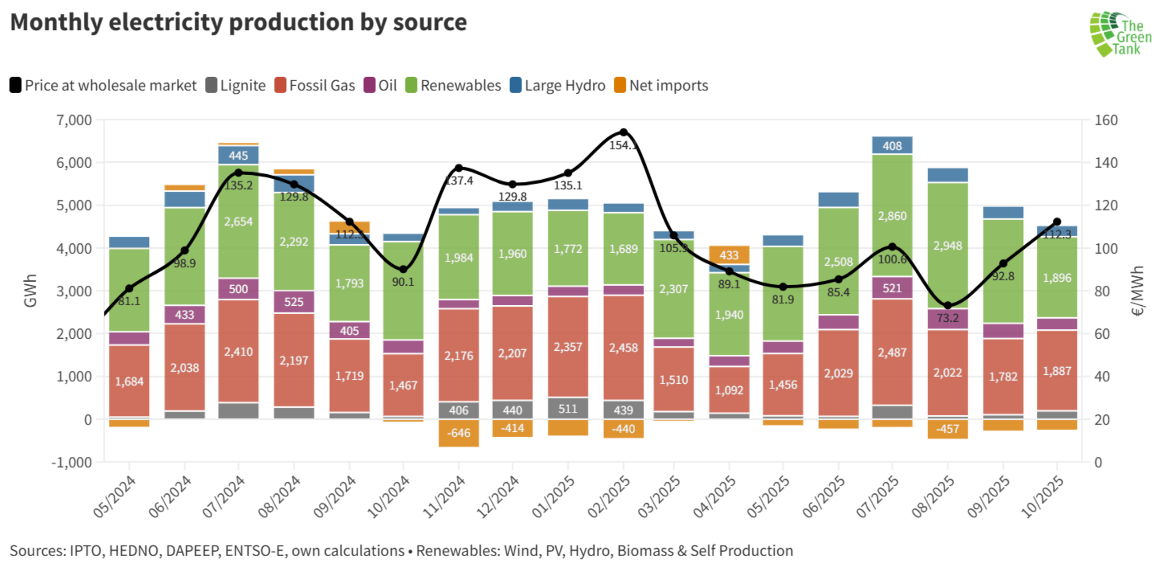


Figure 9: Monthly comparison of electrical energy sources

2.7. Demand of Electrical Energy

It is widely known that the continuous increase in the human population has resulted in an increasing demand for energy and more specifically for electricity. This is because there is a need to satisfy the daily obligations that may arise, while all businesses consume energy in order to be able to operate. The need for energy is crucial because it helps humans satisfy social and economic needs, as it tends to increase over time. The shift to the production of electricity through renewable energy sources is very important, due to the fact that they do not produce greenhouse gases in the environment, keeping it clean, promoting a sustainable economy. However, various difficulties appear that prevent the sustainability of renewable energy sources, such as insufficient information about all the positive effects that arise in the environment from the use of renewable sources. At the same time, a very important difficulty that appears is the lack of raw materials for the development of renewable sources in the future, as well as many errors and market failures. It is necessary to emphasize that, from the increasing introduction of renewable energy sources in the production of electricity, not only advantages arise, but there are also many impacts. RES reduce the demand for other energy sources, increasing their own

market share. Therefore, the increasing penetration of renewable sources contributes positively to the energy production market, as it tends to change the balance by working negatively for other sources. In addition, the energy mix tends to be more secure and reliable as more electricity production sources appear. This is because in case of absence of high levels of strong winds, and therefore low electricity production from renewable sources, electricity production from lignite and gas contributes significantly to meeting demand. However, it is worth to be mentioned that energy production from solar panels is more affordable, due to the low cost of production in combination with the increase in the price of fuels used in the production of electricity. The increasing use of renewable energy sources in production has as a direct consequence the shift of the demand and supply curves. More specifically, the equilibrium point is the intersection of the demand curve and the supply curve, while if one of the two curves is affected, then they will shift and the equilibrium point will change. Prices in the wholesale energy market are determined by its participants, namely electricity producers who own thermal or hydroelectric power plants, electricity traders who import or export energy and load representatives (suppliers). The price of electricity production in the wholesale market is negotiated for each day and per time of day. In the end, a price (System Marginal Price – SMP) is determined as a result of supply and demand. RES do not participate in this entire process, since their energy is available at a zero price. On the contrary, they are compensated at the end with the same price that a lignite or natural gas electricity producer is compensated. In conclusion, the participation of RES directly contributes to the reduction of electricity prices, resulting in suppliers buying cheaper and being given the opportunity to pass on (due to competition, not out of generosity) these low prices to the invoices of their customers, i.e. Greek households and businesses. (Katsiki, 2019)
According to Aurora, electricity prices in 2024 declined by 15% despite a 4,8% increase in demand compared to 2023. Moreover, in 2025 electricity prices increased by 34% with an increase in demand compared to 2024. (Aurora, 2025)

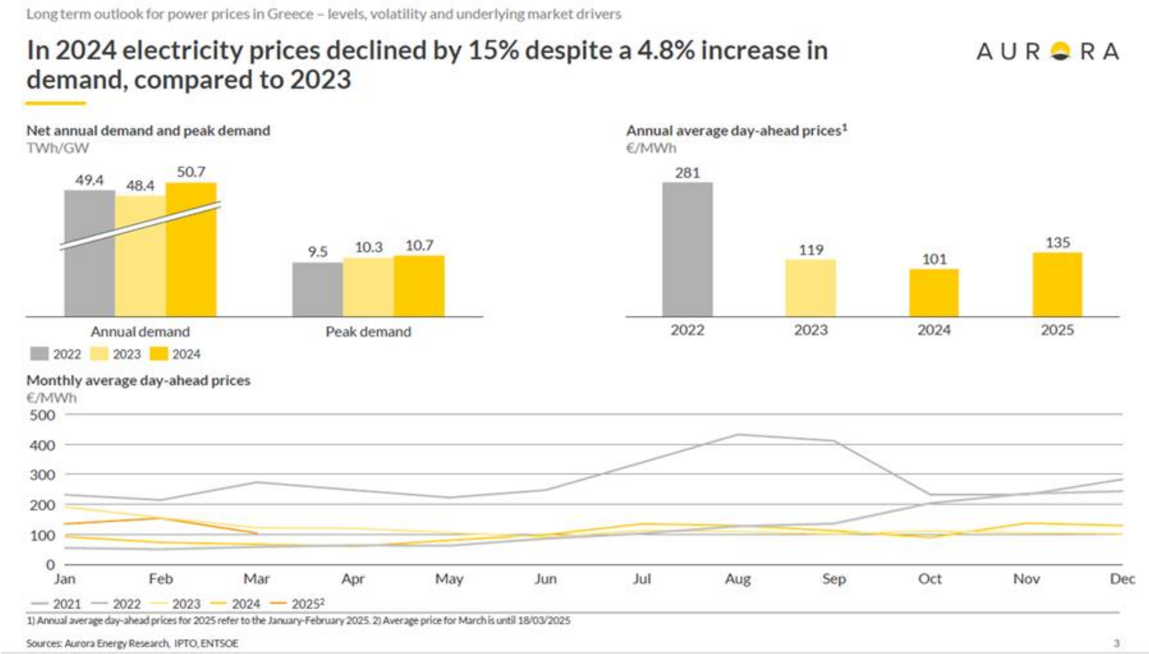


Figure 10: Electricity prices and energy demand

3. National Renewable Energy Legislation

In the past few years, we have witnessed a growing interest in investments in photovoltaics and the revival of the market. This is a consequence of the fact that the investment cost of photovoltaics has fallen drastically in comparison with the previous decade (a fall that reaches an average of 80%). At the same time, the institutional regime is constantly being adjusted to show the new reality.
Today, the options that someone has vary depending on the type and size of the investment they wish to make. These options are summarized as follows:

• Selling the generated energy to the grid
- With fixed prices per kilowatt-hour (for power systems up to 500 kWp or 1 MWp specifically for energy communities).
- By participating in competitive procedures for power systems greater than 500 kWp or 1 MWp specifically for energy communities).
- By direct participation in the wholesale markets of the energy exchange.
- By concluding private sales contracts with interested consumers.

• Self-consumption of produced energy
- Self-production with energy netting (net-metering/net-billing).
- Self-production with sale of up to 20% of the produced energy (concerning businesses)

3.1. Licensing

In case of a utility scale PV (>1MW) project, the following licenses and signed contracts are prerequisite:
- Producer License
- Environmental Terms Approval (ETA) or Inclusion of Intervention Approval (ITT)
- Grid Connection Agreement (GCA)
- Installation License
- Power Purchase Agreement (PPA)
- Operation License

With Law 4685/2020 the process of issuing a production license was simplified and accelerated. The basic criteria for the issuance of a production license is related to the installation location (overlap with previous licenses, saturated electric grid, exclusion zones, etc.) and the issuance of the license is evaluated through an automated process of the new electronic register of electricity generation from RES. (HELAPCO, 2020)
The simplification of the licensing process was combined with the setting of reasonable milestones for the implementation of the projects to avoid the non-utilization of national resources in the long run.
Till 2022 there was no robust and specific legal framework regarding battery energy storage systems (BESS). With paragraphs 11A and 11B of Law 4685/2020 after the

amendment of 4951/2022, two new types of co-located storage systems with renewable energy sources were added. A distinction is made according to whether or not they have the ability to store electrical energy absorbed by the grid.
The main feature of the Greek legal framework regarding energy storage systems has to do with the distinction between stand-alone storage systems and storage systems co-located with RES units.
In summary the different storage entities in Greece are:

- Stand-alone storage systems (BESS), with an independent connection point to the grid, using a storage technology (batteries, pumped storage, etc.).
- Hybrid plants (RES with BESS), which are eligible to be installed only in non-interconnected Islands that: a) combines RES & BESS units, b) on an annual basis, cannot absorb, from the grid, over 30% of the total RES produced energy used to charge the storage units and c) the installed capacity of the RES units cannot exceed the installed capacity of the storage units, increased by a percentage of up to 20%.
- BESS co-located with RES with the obligation to charge the energy storage system only from the RES unit (obligation not to absorb electricity from the grid)
- BESS co-located with RES, which can charge the energy storage system either from the grid or the RES unit

3.2. Support Scheme

It should be clarified that there are two (2) types of power purchase agreement contracts with DAPEEP S.A.:

- Photovoltaic parks with a capacity of up to 400 kW have a fixed operating support contract with a fixed tariff (FiT). While these parks participate in the markets, they are represented by DAPEEP. Thus, projects with FiT are paid exclusively by DAPEEP, at the end of each month, at a price equal to their reference price. These contracts have a fixed selling price for the energy produced for the entire duration of the contract, which is 20 years.
- Photovoltaic parks with a capacity of over 400 kW are represented in the market, usually by a cumulative representation body (aggregator), which has the appropriate mechanisms to participate in the energy markets. For these parks, there is a operating support contract named feed in premium (FiP) that is signed with DAPEEP. Producers of projects with FiP contracts are paid from two sources, the energy markets (through the aggregator that represents them) and DAPEEP. From the market (aggregator) they are paid for each MWh they produce, at a price equal to the price that the day-ahead market had at that time. From DAPEEP, they are paid at the end of the month, at a price equal to the difference between their reference price and the special market price. The special market price is calculated based on the reduced monthly weighted average value of electricity of each RES technology, which is obtained based on the sum per hour of the month of the system marginal price and the wholesale market mechanisms as they apply during the examined monthly period. In essence, these parks are paid with the price determined by the market and subsequently their price is corrected so that the final amount is close to

the amount they would receive if they had a fixed price. Essentially, more or less, the price they have is fixed and close to their reference price that is secured through competitive bidding procedure.

The reference prices are as follows:

- Photovoltaic parks with a capacity of < 500 kWp have a reference price: 63 €/MWh.
- Especially for energy communities (for projects ≤1MW) and professional farmers (for projects <500 kW) the reference price is 65 €/MWh.

The Greek electricity market as a whole has been experiencing continuous changes in recent years, which aim to improve the conditions under which both conventional electricity generation units and renewable energy sources operate. (Papachristou, 2019)

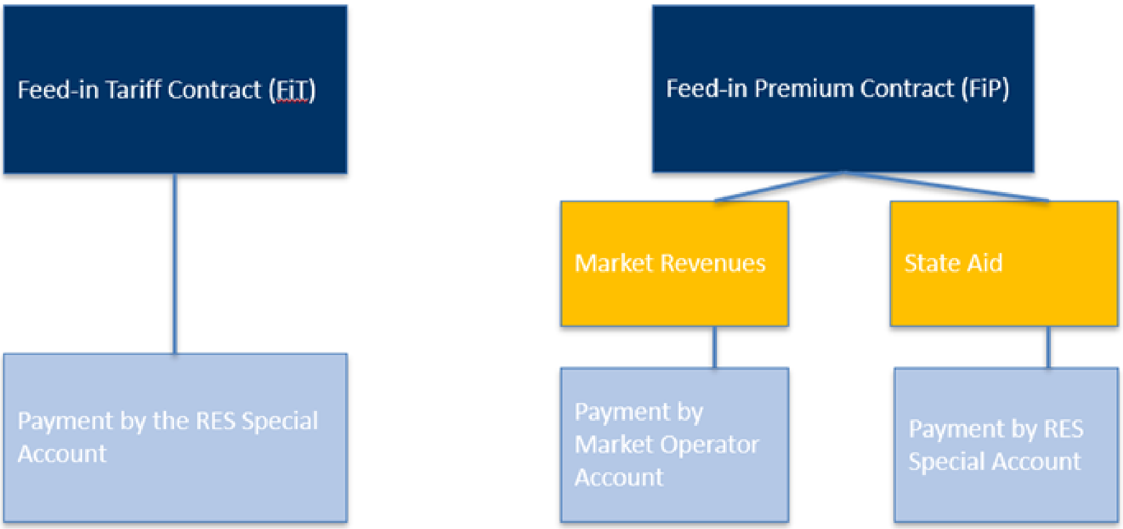


Figure 11: Types of power purchase agreement contracts with DAPEEP S.A.

3.3. Energy Curtailments

In recent years, the European energy debate has revolved around one key question on how to deal with high electricity prices, which have burdened households, businesses and government budgets. The post-2021 energy crisis, soaring gas prices and inflation made the cost of electricity a symbol of economic insecurity. Yet, just a few years later, Europe faced a paradoxical phenomenon, negative electricity prices. 2025 was a milestone year. Negative prices, for example the hours during which producers pay to feed electricity into the system, have gone from being a rare market anomaly to a systemic phenomenon. In several EU countries, consumers were paid to consume electricity for hundreds of hours during the year. During the period January-September 2025 in Greece, we had 280 hours with zero/negative values (4,3% of total hours) of which 89 hours (1,4%) with negative values, mainly during the months of August and September.

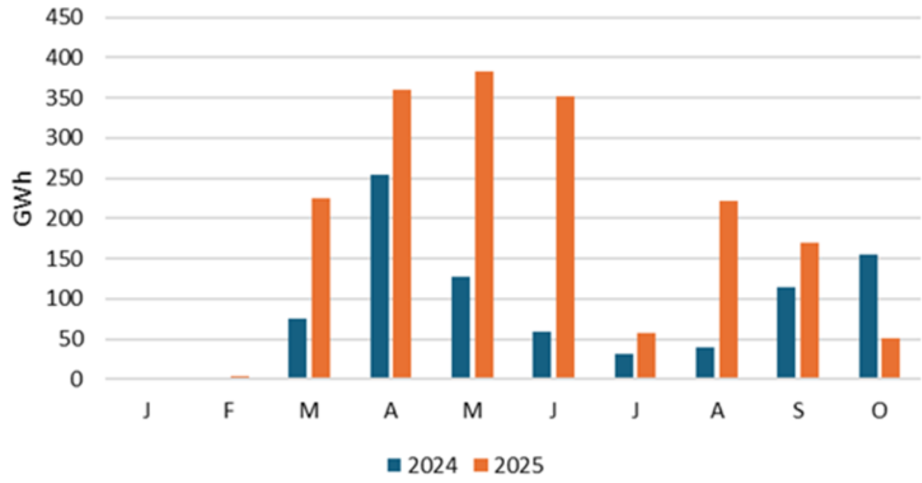


Figure 12: Renewable energy system curtailments in Greece

One of the issues that has dominated the Greek renewable energy market over the past year is energy curtailments – and in particular their percentage impact on grid availability. A number of PV parks owned by non-institutional investors and built or electrified in the period 2021–2022, present similar financial characteristics. Negative prices are a symptom of a deeper transition. Europe has invested massively in renewable energy sources (RES), mainly in solar and wind power. In many countries, the installed capacity of photovoltaic and wind parks has grown exponentially in less than a decade. However, renewable energy production does not always keep up with demand. The sun shines brightest during the midday hours of spring and summer, when consumption is relatively low, and the wind can blow with force regardless of the system's needs. When supply exceeds demand and there is insufficient flexibility or storage capacity, prices collapse – and in extreme cases become negative.

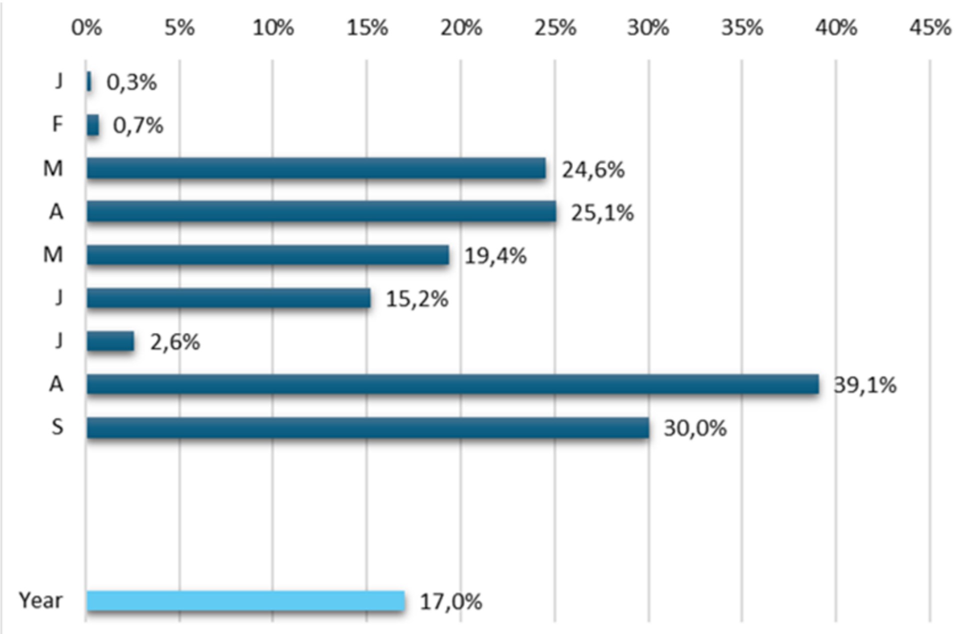


Figure 13: Average revenue loss due to zero/negative prices and curtailments for Greek PV projects with feed-in-premium in 2025

The official PV target of 13,5 GW for 2030 will be met by 2026 and in case that the pace of development remains the same, then it seems that there will be about 21,5 GW PV connected to the grid by the year of 2030.

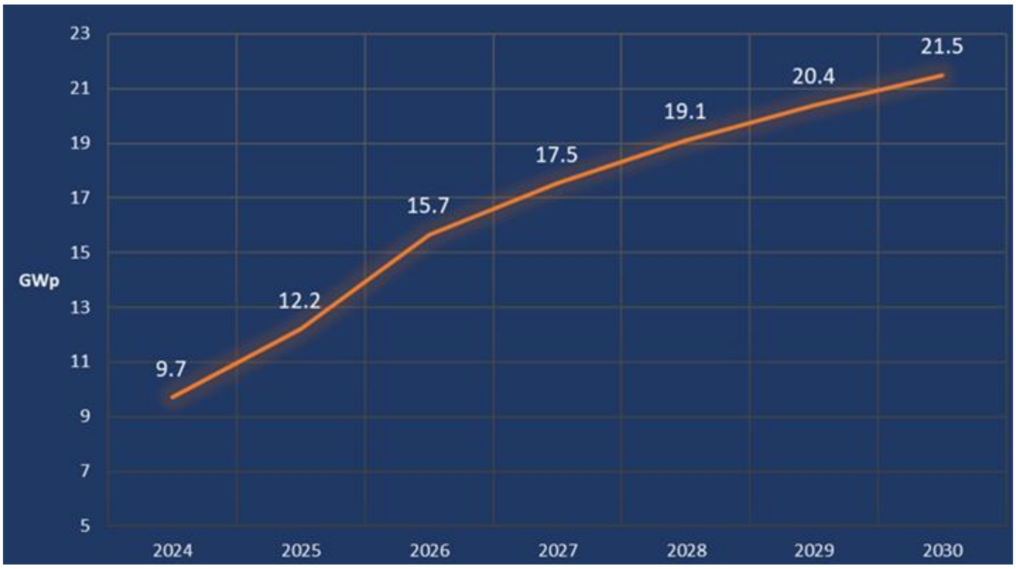


Figure 14: Outlook of Greek photovoltaic market

The main conclusions from all the above mentioned are:
Firstly, negative prices are not an indication of a failure of the energy transition, but a sign of the immaturity of the system. Greece has succeeded in installing huge amounts of clean energy, but without upgrading the networks, storage and flexibility mechanisms at the same pace.
Secondly, it has been shown that the existing subsidy and pricing regimes often send conflicting signals to the market. When producers are paid regardless of the conditions of the system, the market loses its ability to self-regulate.
Third, negative prices have highlighted the need for an active role for demand. Consumption remains largely inflexible, while it could act as a “sponge” to absorb excess energy through flexible tariffs, electric vehicles, heat pumps and industrial loads. (HELAPCO, 2025)

4. Theoretical Overview

4.1. The Photovoltaic Phenomenon

In 1839 French physicist Edmund Becquerel found that some materials could generate sparks of electricity when they were exposed to sunlight. This is a phenomenon called the photoelectric effect and was used for the first time in solar cells in the late 18th century. In the 1950s, scientists at Bell Labs adapted the technology and using silicon as a base created solar cells that could convert about 4% of energy directly from the sun into electricity. The most important elements of a solar cell are two layers of semiconductor material, which is generally made up from silicon crystals. Crystalline silicon, on its own, is not a very good conductor of electricity, but when impurities are added to it, the conditions for the production of electricity are created. Boron, on the other hand, is typically incorporated in the bottom layer of the solar cell, which bonds with the silicon, and this leads to the creation of a positive charge (p). Phosphorus, typically, is added to the top layer of the solar cell which bonds with the silicon and causes the formation of a negative charge (n). The surface between the p-type and the n-type semiconductors created is called a p-n junction. (TEE, 2018)

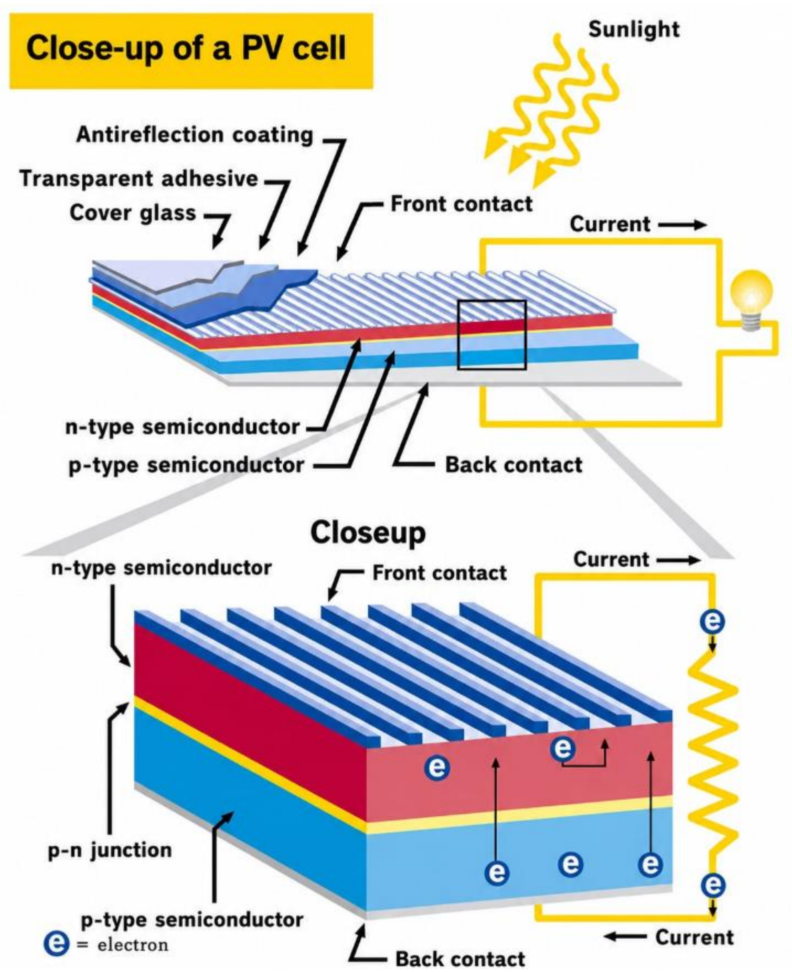


Figure 15: Basic structure of solar cell

When the cell is exposed to sunlight (see Figure 15) the energy from the sunlight releases electrons on both layers. These electrons, also referred to as free electrons, attempt, because of the assorted charges of the two layers, to pass from the n-type layer to the p-type layer, however electrons are prevented by the electrical field at the p-n junction. The presence of an external circuit offers the required path for the transfer of electrons from the n-type layer to the p-type layer. Extremely thin wires that are present along the n-type layer enable the flow of electrons and this flow of electrons leads to the development of current. Solar cells are typically square in shape about 10 cm. A solar cell produces very little power (usually less than 2W), and are therefore electrically connected in series or parallel, as will be discussed below, to create photovoltaic panels. The efficiency of solar cells is measured as the percent of solar energy converted to electricity and it depends on the technology of the materials that are used. At a research level, efficiencies up to 44% have been reported. However, most solar cells and photovoltaic panels currently offered on the market have a maximum efficiency of 20-15%. (Andrew, 2012)

4.2. PV Modules

Photovoltaic cells are electrically connected in series and/or parallel circuits to provide higher voltages, currents and power levels. Photovoltaic modules are made up of solar cell circuits encapsulated in a protective polymer and are the most important building blocks of photovoltaic (PV) systems. Photovoltaic panels consist of one or more photovoltaic cells assembled in a pre-wired field-installable unit. A photovoltaic array is a complete power generating unit and consists of any number of photovoltaic modules.

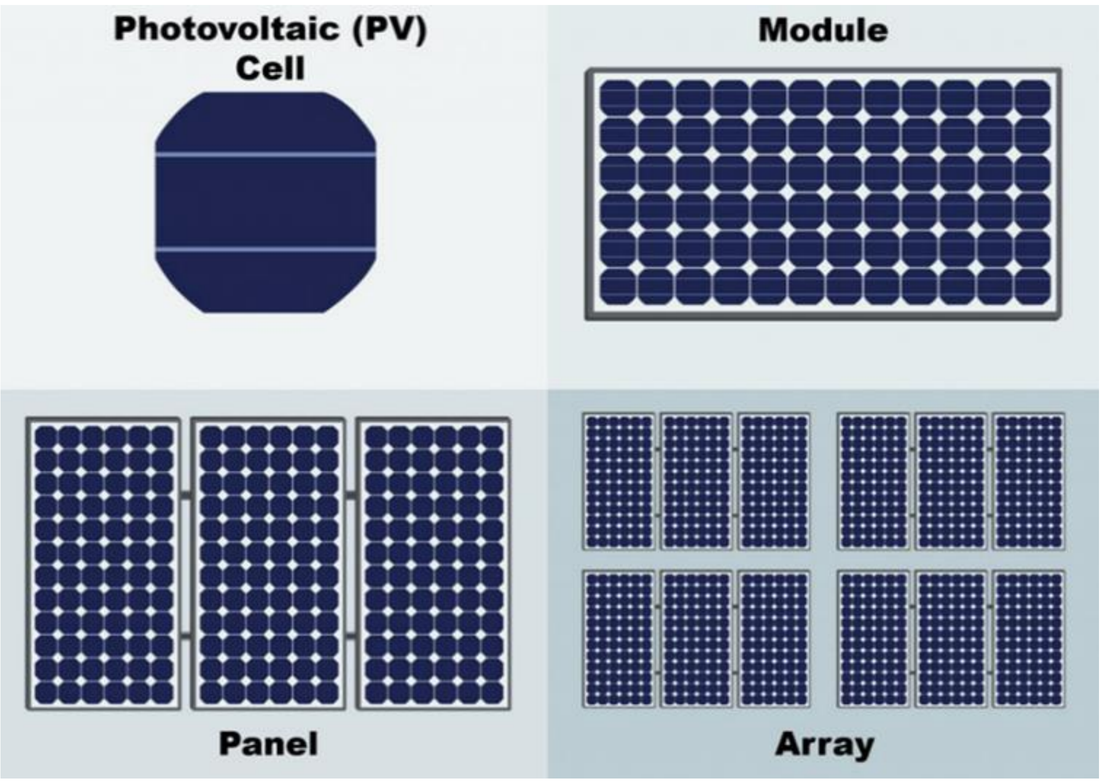


Figure 16: Solar cell, PV module, PV panel, PV array

N-type and P-type photovoltaic panels

Most N-type and P-type photovoltaic cells are nearly identical with some variations in the way they are built.

Photovoltaic panels with P-type cells are doped with atoms that have one less electron than silicon such as boron and hence have a positive charge (p). N-type, on the other hand, are doped with a different set of atoms that have one extra electron that will make them negative (n). While N-type cells offer a higher efficiency potential than P-type cells, they are more expensive. P-type photovoltaic panels are the most common and popular type of modules on the market. A P-type photovoltaic cell is manufactured using a (P-type) positive bulk region of c-Si, with a density of 10^{16} cm^{-3} and a thickness of 200μm. The N-type photovoltaic cell features a negative (N-type) bulk region of c-Si with a thickness of 200μm and a doping density of 10^{16} cm^{-3}.

In summary, N-type photovoltaic panels have several advantages over the P-type photovoltaic panel and the main element that differentiates N-type photovoltaic cells from their P-type counterparts is the technique used for the bulk region and for the emitter. When phosphorus is used to negatively bias the bulk region, this creates an N-type photovoltaic cell, while when boron is used to positively bias the crystalline silicon in the bulk region, this makes the panel P-type. (TEE, 2018)

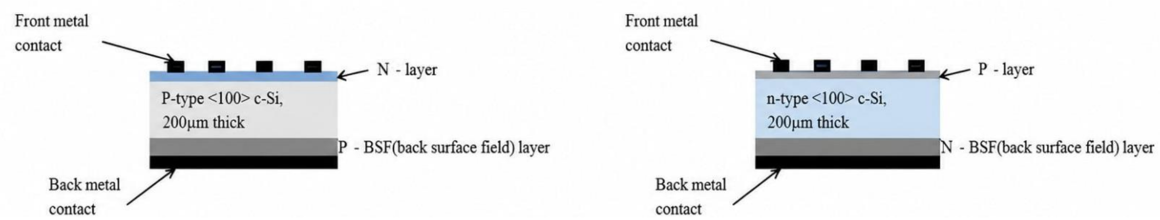


Figure 17: Structure of P-type (left) and N-type (right) photovoltaic cell

Bifacial photovoltaic panels

Until recently, most crystalline silicon photovoltaic cells were made of P-type silicon with a back electrical contact made of aluminum that is nontransparent to light. More advanced cell designs, such as the passivated emitter back cell (PERC), the fully diffused passivated emitter back (PERT), the locally diffused passivated emitter back (PERL), and the 15-layer silicon "heterostructure" (HJT), can use a local back contact that requires metallization of portions of only the back side of the cell. These advanced cells are double-sided, capable of accepting light from both the back and front sides, as shown below:

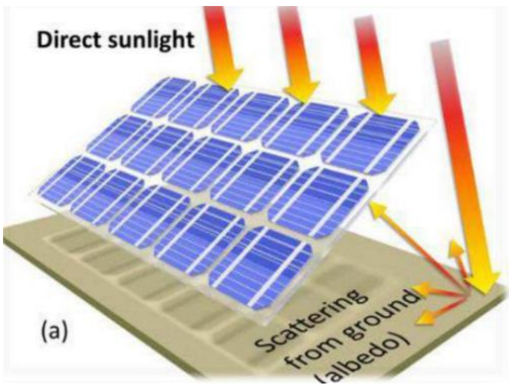


Figure 18: Bifacial photovoltaic panel

4.3. Inverters

The main role of grid-interactive or synchronous inverters or simply grid-tied inverters is to synchronize the phase, voltage and frequency of the power line with the grid. Grid tied inverters can be quickly disconnected from the grid in the event of a grid malfunction (e.g. undervoltage). This is a required measure which ensures that in the case of a power outage, the grid inverter will be shut down so that the energy it generates does not harm anyone who comes into contact with the power grid (anti-islanding).
Grid-tied inverters include conventional low-frequency types with transformer coupling, newer high-frequency types, also with transformer coupling and transformerless types.
Transformerless inverters, which are widespread in Europe, are lighter, smaller and more efficient than transformer coupled inverters. These inverters are mostly used in the connection of low voltage (400V-800V).
They are surely the most widespread class of inverters for small to medium power plants. The basic operating principle of them is based on the parallel connection of a number of strings to the corresponding inverter inputs.
Inverters of this type are available with or without a transformer, as well as in single-phase or three-phase connection (usually above 10kW). They offer considerable flexibility regarding the number of panels that can be connected to their inputs, as long as their maximum safety settings are not violated. Furthermore, it is advisable to connect the same type and number of panels to their inputs. (TEE, 2018)
The figure below shows an example of transformerless (string) inverter of this type:

Figure 19: String inverter (SUN2000-330KTL-H1)

4.4. Cables

The photovoltaic system electrical installation requires the use of DC and AC cables. DC cables are used in interconnecting the panels and connecting the strings to the inverter inputs, while the conventional AC power cables are used in connecting the inverters to a three-phase system and the final connection to the grid. The cables that are used to connect the PV panels in series are typically made to be used in outdoor applications. Their cross-section is generally 4-6mm^2 for crystalline silicon panels. These cables are usually single-core and double-insulated, in order to avoid faults in between the positive and negative poles of the PV panels or ground faults. They are also manufactured in multi strands to provide their connection with the required flexibility.

Figure 20: Types of cable

The frequently used cable with rubber insulation and neoprene jacket type H07RN-F, in its standard version, is allowed at temperatures up to 60 °C and thus they are suitable for use in photovoltaic systems in a limited range. For this purpose, manufacturers have proceeded to create special cables for photovoltaic applications (solar cables). Their main characteristics are that they are resistant to weather conditions and ultraviolet (UV) radiation with a wider temperature range (from -55 °C to 125 °C). In addition, some manufacturers offer cables with a metal mesh for greater protection against rodents and better protection against surges. (TEE, 2018)

4.5. Medium Voltage Substations

Medium voltage substations are necessary in cases of PV connection to the grid with an installed capacity of more than 100 kWp. In this case, the electricity producer must install a substation to connect the station directly to the medium voltage (MV) 20-33kV network of the IPTO. In general, a substation of a PV system consists of the following sections:
− The medium voltage electrical panel section.
− The power transformer.
− The low voltage electrical panel section.
When designing a substation, calculations should be made to determine:
− Size and number of power transformers.
− Size and type of medium voltage cables.
− Size and type of medium and low voltage busbars.
− Size and type of medium and low voltage protection devices.
The power of a substation's transformer is calculated based on the maximum active power of the station, which is determined in the design phase. The selection of one or more transformers is determined by the power size and location of the PV station and its impact on the station's losses, as well as for redundancy reasons. When selecting a transformer, its short-circuit voltage, its connection group and its insulation type should also be determined. In ordinary cases, a short-circuit voltage of 4-6% is preferred to keep the voltage drop low. The most common connection groups for 20/0,4 kV transformers are Dy and Yz. In private substations, the most common connection type is Dy. (TEE, 2018)

Figure 21: Medium voltage substation (JUPITER-9000K-H0)

4.6. Mounting Structures

<u>Ground based fix-mounted structures</u>

Fixed structures are the simplest and most economical way of mounting PV panels. Their design principle is simple, the sun's rays should fall perpendicularly on the surface of the panels at noon. Thus, the bases are constructed to allow the panels to be positioned at a fixed angle, around 25 degrees. This angle is considered a satisfactory average value for Greek data. It is typically stated that the ideal angle is considerably smaller during the summer months and considerably larger during the winter months. Fixed structures are usually made of aluminum or stainless steel (hot-dip galvanized steel). They are usually constructed after a technical study to determine their static adequacy and their resistance to wind pressure or snow loads. The bases are placed on the ground either by concreting or directly by driving them into the ground. The concreting of the bases is usually carried out on a beam (i.e. throughout the row of bases) made of reinforced concrete or on concrete footings, placed appropriately to allow the screwing of the base sockets. The ground driving is usually carried out at depths of typically 0,5-1,5 meters, where piles are placed, on which the base is then supported. The concreting of the bases increases the installation cost in relation to simple ground driving. However, it is recommended to carry out an inspection and a geotechnical study to determine whether the type of soil allows ground driving without creating issues of static adequacy of the structures. In addition, the engineer should be careful in the use of accessory materials such as screws or PV panel connectors, as care should be taken to avoid oxidation or electrolysis. Care should also be taken to ensure the possibility of cable routing as well as the support of panels or inverters, in the event that this is technically determined to be the best solution. Fixed structures usually consist of pieces that are assembled on site. Each piece is characterized by the maximum mounting surface, which is usually calculated by taking some average panel dimensions. The panels can be installed in a single row or (more commonly) in a double row or even in a triple or quadruple row. It is also possible to place them either in the small dimension (portrait) or in the large dimension (landscape). The exact placement depends on the morphology of the available installation space and its dimensions. The following picture shows a fixed structure.

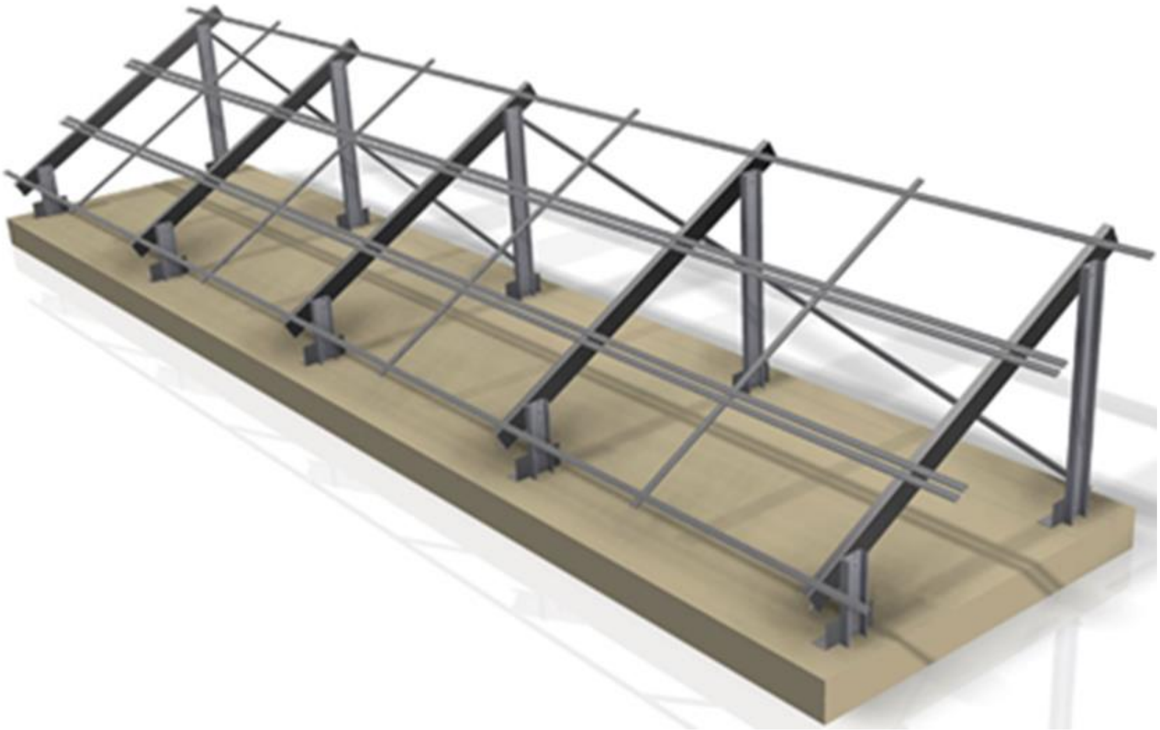


Figure 22: Fixed structure

PV power production profiles, shown below, are calculated as an average of all the hourly data for each month. The profiles give an indication of changing power production patterns for a PV project with 25 degree fixed-tilt structures in the course of a day. It should be noted that the "average daily profile" is a theoretical concept, since in the majority of cases a profile is specific for each individual day of the year due to the variability of the weather.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1	-	-	-	-	-	-	-	-	-	-	-	-
1 - 2	-	-	-	-	-	-	-	-	-	-	-	-
2 - 3	-	-	-	-	-	-	-	-	-	-	-	-
3 - 4	-	-	-	-	-	-	-	-	-	-	-	-
4 - 5	-	-	-	-	0.0	0.0	0.0	-	-	-	-	-
5 - 6	-	-	-	0.2	5.1	11.2	5.4	0.6	0.0	-	-	-
6 - 7	-	0.0	1.2	24.5	62.1	73.6	60.2	33.6	10.5	0.8	0.0	-
7 - 8	0.0	3.8	64.0	146.0	197.6	219.7	202.1	172.9	134.2	67.7	4.8	0.3
8 - 9	63.4	135.7	231.4	308.3	358.0	397.0	383.9	359.6	311.2	252.6	162.4	83.1
9 - 10	251.9	310.1	390.5	450.4	495.3	544.8	543.0	526.0	467.0	393.8	305.0	242.9
10 - 11	365.0	425.2	503.3	551.9	589.2	639.4	654.2	638.8	572.4	486.6	397.2	339.8
11 - 12	431.1	493.3	561.7	587.5	627.0	677.9	705.7	685.4	605.0	523.8	437.2	386.7
12 - 13	451.1	521.9	578.6	591.3	613.3	656.7	694.1	680.4	606.3	534.0	450.5	404.4
13 - 14	437.3	503.5	557.9	565.2	576.9	621.5	647.6	631.7	563.7	513.1	421.7	382.1
14 - 15	382.3	450.0	503.7	494.1	503.0	553.3	575.2	561.9	489.1	433.0	353.6	323.6
15 - 16	234.3	345.7	393.8	394.7	405.9	448.5	472.8	458.8	382.4	308.0	161.7	100.8
16 - 17	30.0	189.9	262.4	275.4	296.3	329.2	353.6	326.7	249.0	121.0	21.4	16.8
17 - 18	1.2	15.0	73.1	135.1	169.5	198.9	218.1	183.5	67.2	6.3	0.0	0.0
18 - 19	-	0.0	4.2	21.6	44.1	65.6	67.3	30.1	2.4	0.0	-	-
19 - 20	-	-	0.0	0.0	3.7	12.7	9.4	0.4	0.0	-	-	-
20 - 21	-	-	-	-	-	0.0	0.0	-	-	-	-	-
21 - 22	-	-	-	-	-	-	-	-	-	-	-	-
22 - 23	-	-	-	-	-	-	-	-	-	-	-	-
23 - 24	-	-	-	-	-	-	-	-	-	-	-	-
Sum	2647.5	3394.1	4125.9	4546.3	4946.9	5449.9	5592.6	5290.4	4460.5	3640.9	2715.5	2280.6

Table 2: Specific PV power output – hourly average of 25° degree fixed-tilt structures (Wh/kWp)

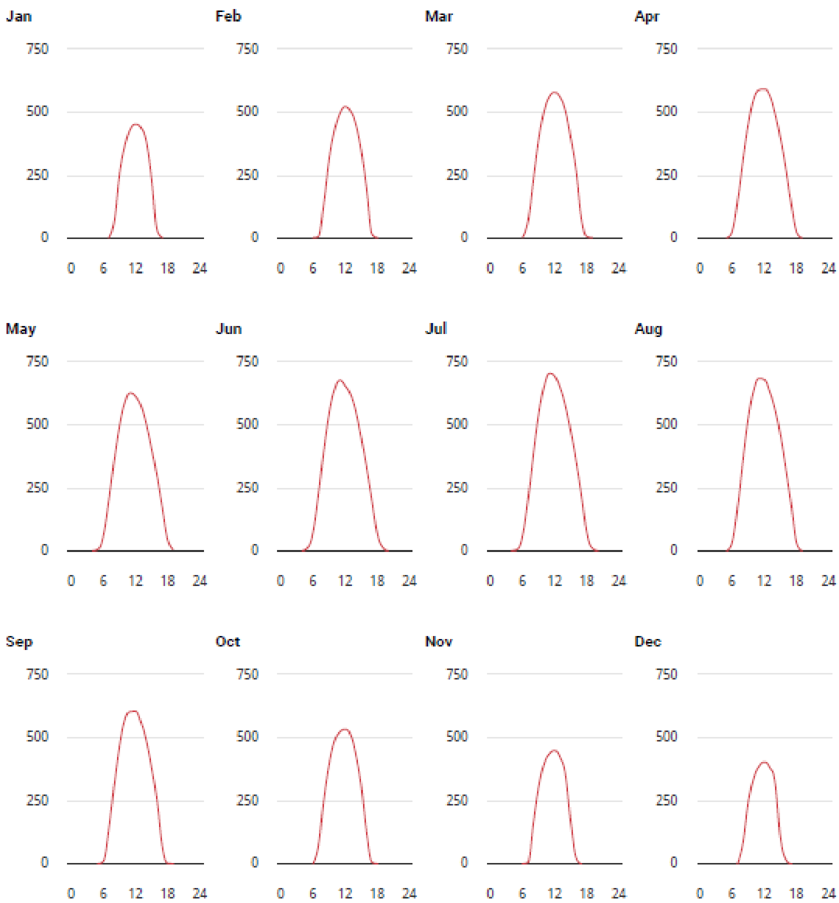


Figure 23: Specific PV power output – hourly average of 25° degree fixed-tilt structures (Wh/kWp)

Tracker structures with one horizontal axis

Sun tracking is a technique that aims to maximize the electrical energy produced by attempting to move the panel bases during the day to continuously achieve vertical incidence of solar radiation.

Sun tracking systems or sun trackers, are characterized by greater complexity in relation to base systems, but provide increased efficiency, on average around 30%. They are divided into two main categories:

- Single axis systems: these are systems in which the panels move along one axis, the north-south axis, during the day. Typically, these systems achieve an increase in production by 20-25% compared to fixed base systems.
- Dual axis systems: these are systems in which it is also possible to adjust the tilt of the panels towards the horizontal. This additional capability provides increased efficiency by typically 25-40% compared to fixed base systems.

The movement in these systems is usually achieved by electro-mechanical or electro-hydraulic means. Consequently, all tracking systems are characterized by self-consumption, which is small since the movement is not continuous but periodic, typically one movement every 10 minutes.

The detection of the sun's path is usually done in two ways. The first way is with solar sensors, which perceive the sun's position. The second way is through software from astronomical data, based on which the sun's position and path are calculated for each day of the year, depending on the geographical coordinates of the area. Due to the need to move a significant number of panels, tracking systems are characterized by flat surfaces placed on a support base perpendicular to the ground. The inverter is usually placed on the support base or, if this is not possible, cables are routed to a central collection point where the inverters are also located.

This leads to structures of considerable height, ranging from 2,5 to 10-12 meters, depending on the structure. The height of the structure usually increases with the increase in the surface area of the panels. Today, tracking systems are manufactured to carry a panel power ranging from 2-3kWp to approximately 33kWp. The significant size of the structure also makes the foundation more complex. Usually, the support bases are based on reinforced concrete of considerable volume (from 2-3 to approximately 20-30 cubic meters) in order to ensure their static adequacy. In addition, installation costs increase compared to fixed structure systems.

The significant size of these systems (and especially their height) increases the space requirements compared to a fixed base system, usually by 1,5-2 times, due to the greater distances between them to avoid shading. In addition, the size of their trackers makes them more vulnerable (compared to fixed structure systems) to wind pressures. The most common technique used is to use an anemometer and when the wind speed exceeds a certain limit for a certain period of time, the movement system is commanded to place the surface of the panels almost parallel to the ground, a process known as stow position, for protection reasons. This speed varies depending on the manufacturer but can be as low as 5-6 Bf wind. Consequently, every engineer should assess the wind data of the installation area before proceeding to select a specific type of such system.

In addition to the above, every engineer and potential owner of a PV park should take into account the following practical issues regarding the installation of tracking systems:

1. All tracking systems require maintenance due to the existence of electro-mechanical or electro-hydraulic drive means. In some cases, it may become necessary to re-program the software of the drive system due to data loss.
2. Due to the significant height, the execution of various tasks becomes more difficult compared to fixed structure systems. Examples of such tasks include the replacement of a damaged panel or the cleaning of the panels. Below are some examples of single axis tracking structures. (Kamrul, 2017)

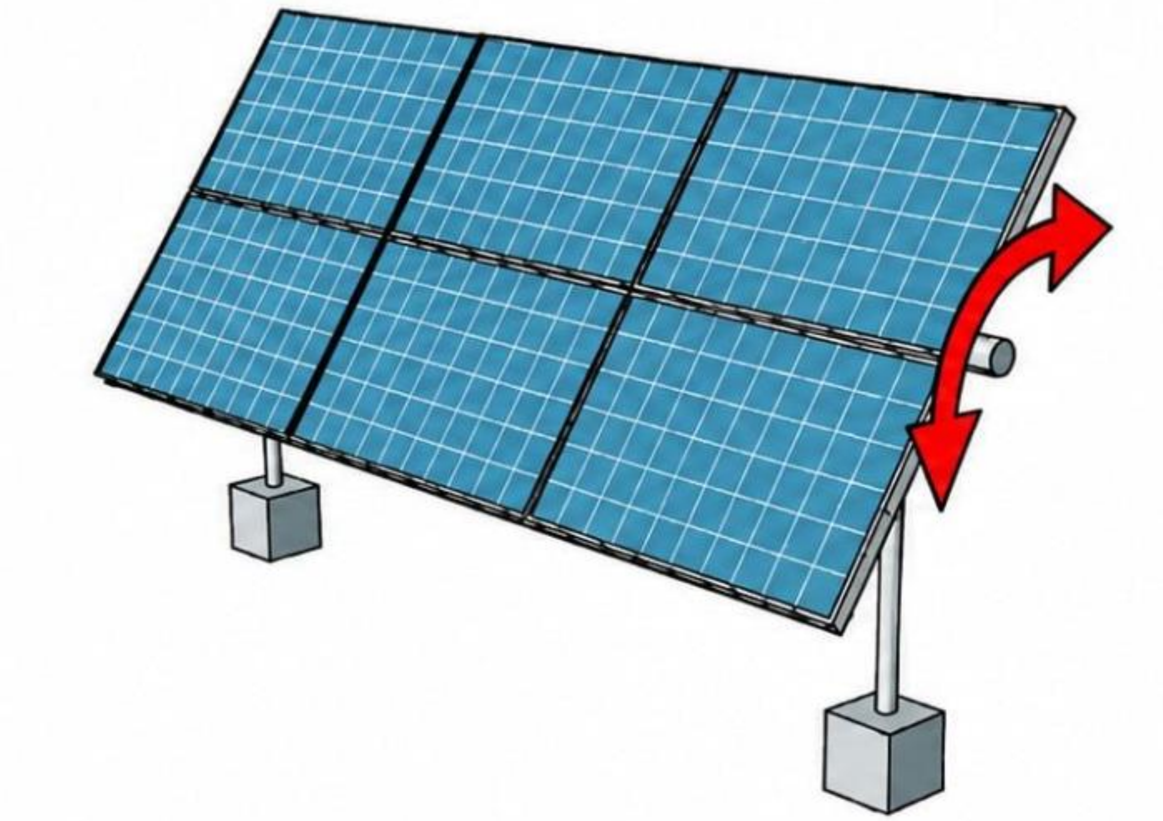


Figure 24: Single axis tracking structure

PV power production profiles, shown below, are calculated as an average of all the hourly data for each month. The profiles give an indication of changing power production patterns for a PV project with Single Axis Tracking structures (North - South) in the course of a day. It should be noted that the "average daily profile" is a theoretical concept, since in the majority of cases a profile is specific for each individual day of the year due to the variability of the weather.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1	-	-	-	-	-	-	-	-	-	-	-	-
1 - 2	-	-	-	-	-	-	-	-	-	-	-	-
2 - 3	-	-	-	-	-	-	-	-	-	-	-	-
3 - 4	-	-	-	-	-	-	-	-	-	-	-	-
4 - 5	-	-	-	-	0.0	0.0	0.0	-	-	-	-	-
5 - 6	-	-	-	0.2	5.1	11.2	5.4	0.6	0.0	-	-	-
6 - 7	-	0.0	1.2	24.5	62.1	73.6	60.2	33.6	10.5	0.8	0.0	-
7 - 8	0.0	3.8	64.0	146.0	197.6	219.7	202.1	172.9	134.2	67.7	4.8	0.3
8 - 9	63.4	135.7	231.4	308.3	358.0	397.0	383.9	359.6	311.2	252.6	162.4	83.1
9 - 10	251.9	310.1	390.5	450.4	495.3	544.8	543.0	526.0	467.0	393.8	305.0	242.9
10 - 11	365.0	425.2	503.3	551.9	589.2	639.4	654.2	638.8	572.4	486.6	397.2	339.8
11 - 12	431.1	493.3	561.7	587.5	627.0	677.9	705.7	685.4	605.0	523.8	437.2	386.7
12 - 13	451.1	521.9	578.6	591.3	613.3	656.7	694.1	680.4	606.3	534.0	450.5	404.4
13 - 14	437.3	503.5	557.9	565.2	576.9	621.5	647.6	631.7	563.7	513.1	421.7	382.1
14 - 15	382.3	450.0	503.7	494.1	503.0	553.3	575.2	561.9	489.1	433.0	353.6	323.6
15 - 16	234.3	345.7	393.8	394.7	405.9	448.5	472.8	458.8	382.4	308.0	161.7	100.8
16 - 17	30.0	189.9	262.4	275.4	296.3	329.2	353.6	326.7	249.0	121.0	21.4	16.8
17 - 18	1.2	15.0	73.1	135.1	169.5	198.9	218.1	183.5	67.2	6.3	0.0	0.0
18 - 19	-	0.0	4.2	21.6	44.1	65.6	67.3	30.1	2.4	0.0	-	-
19 - 20	-	-	0.0	0.0	3.7	12.7	9.4	0.4	0.0	-	-	-
20 - 21	-	-	-	-	-	0.0	0.0	-	-	-	-	-
21 - 22	-	-	-	-	-	-	-	-	-	-	-	-
22 - 23	-	-	-	-	-	-	-	-	-	-	-	-
23 - 24	-	-	-	-	-	-	-	-	-	-	-	-
Sum	2647.5	3394.1	4125.9	4546.3	4946.9	5449.9	5592.6	5290.4	4460.5	3640.9	2715.5	2280.6

Table 3: Specific PV power output – hourly average of tracking structure with one horizontal axis (Wh/kWp)

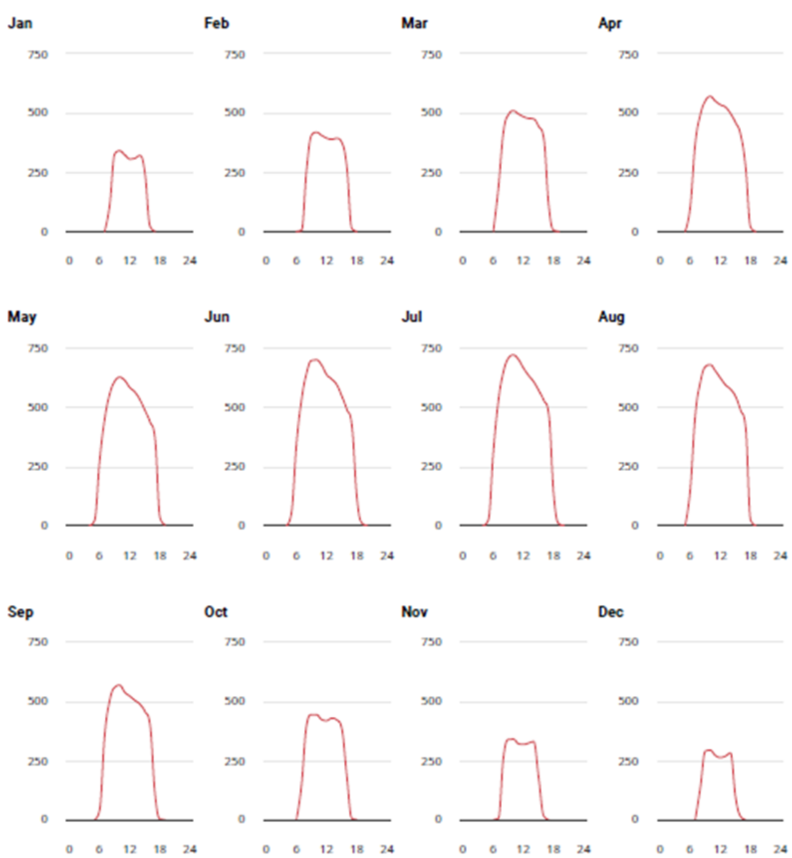


Figure 25: Specific PV power output – hourly average of tracking structure with one horizontal axis (Wh/kWp)

5. Solar Power Plant with Installed Capacity of 40MW in Greece

For the purpose of the thesis, we are going to use a hypothetical solar power plant (the "project") with an installed capacity of 40MW, located at the municipality unit of Kozani, municipality of Servion, regional unit of western Macedonia, in Greece.
The energy study and the yield assessment is based on SolarGIS meteorological data imported to PVsyst 8.1.0. software.

5.1. Technical Description of the Project

The project is connected to the 150kV national energy grid via its own medium voltage (MV) interconnection network through an existing 33/150kV high voltage (HV) substation. The access to the project can be performed through existing asphalt and dirt roads that will need some improvements. The project is located on public owned forest land. The project has obtained the production license, the environmental terms approval (ETA) and the final connection terms, however all licenses are required to be amended according to the final design parameters.

Figure 26: Project location and detailed map view

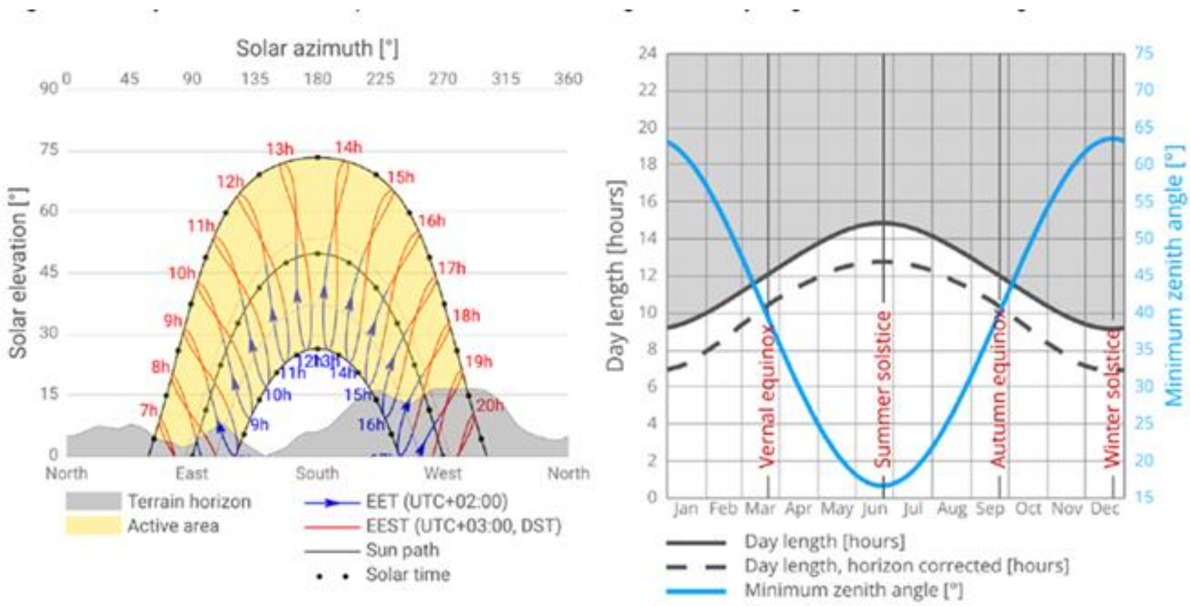


Figure 27: Project horizon–sun path and day length–solar zenith angle

5.2. PV Station Infrastructure

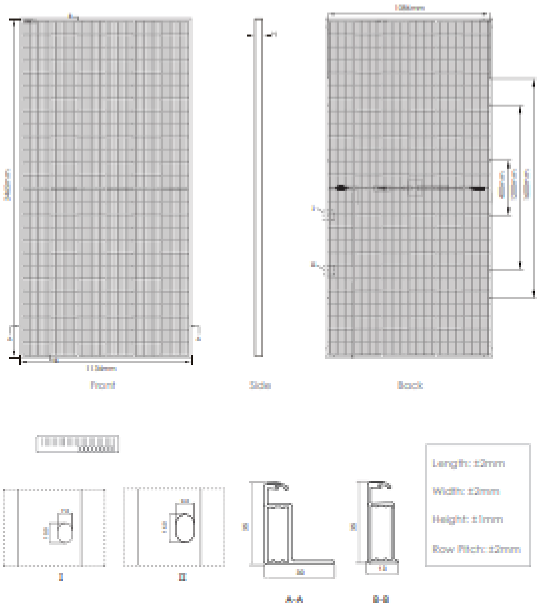
<u>Main equipment of PV Station</u>

Equipment	Type	Total
PV Modules	JKM-600N-78HL4-BDV	66.672
Fixed Structures	POWERWAY	400
Single Axis Tracking Structures	ARCTECH SOLAR SKYLINE II	999
Inverters	HUAWEI SUN2000-330KTL-H1	103
Power Transformers	HUAWEI JUPITER-9000K-H1	5
Installed Capacity of PV Station		40 MWp

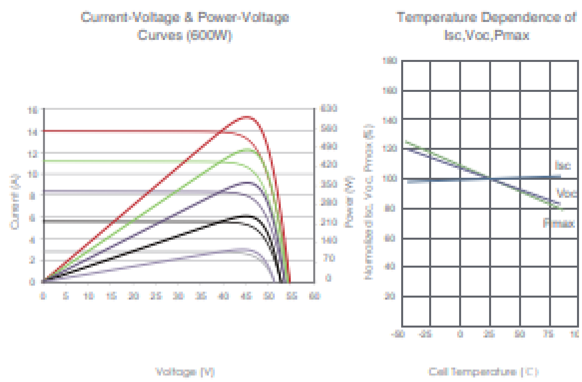
Table 4: Main equipment

For the production of electricity, bifacial PV modules of the Chinese company Jinko, type JKM-600N-78HL4-BDV with a power of 600 Wp, monocrystalline silicon will be used. The number of installed PV modules will be 66.672 pieces and will be connected in 2.778 parallel strings (PV strings) of 24 in-line PV modules and correspond to an installed capacity of 40 MWp.
The following image shows the electrical characteristics of the PV modules.

Engineering Drawings



Electrical Performance & Temperature Dependence



Packaging Configuration

(Two pallets = One stack)

31pcs/pallets, 62pcs/stack, 496pcs/ 40'HQ Container

Mechanical Characteristics

Cell Type	N type Mono-crystalline
No. of cells	156 (2×78)
Dimensions	2465×1134×35mm (97.05×44.65×1.38 inch)
Weight	34.6kg (76.28 lbs)
Front Glass	2.0mm, Anti-Reflection Coating
Back Glass	2.0mm, Heat Strengthened Glass
Frame	Anodized Aluminium Alloy
Junction Box	IP68 Rated
Output Cables	TUV 1×4.0mm² (+): 400mm , (-): 200mm or Customized Length

SPECIFICATIONS

Module Type	JKM590N-78HL4-BDV		JKM595N-78HL4-BDV		JKM600N-78HL4-BDV		JKM605N-78HL4-BDV		JKM610N-78HL4-BDV	
	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT
Maximum Power (Pmax)	590Wp	444Wp	595Wp	447Wp	600Wp	451Wp	605Wp	455Wp	610Wp	459Wp
Maximum Power Voltage (Vmp)	44.91V	41.89V	45.08V	42.00V	45.25V	42.12V	45.42V	42.23V	45.60V	42.35V
Maximum Power Current (Imp)	13.14A	10.59A	13.20A	10.65A	13.26A	10.71A	13.32A	10.77A	13.38A	10.83A
Open-circuit Voltage (Voc)	54.76V	52.02V	54.90V	52.15V	55.03V	52.27V	55.17V	52.41V	55.31V	52.54V
Short-circuit Current (Isc)	13.71A	11.07A	13.79A	11.13A	13.87A	11.20A	13.95A	11.26A	14.03A	11.33A
Module Efficiency STC (%)	21.11%		21.29%		21.46%		21.64%		21.82%	
Operating Temperature(℃)	-40℃~+85℃									
Maximum system voltage	1500VDC (IEC)									
Maximum series fuse rating	30A									
Power tolerance	0~+3%									
Temperature coefficients of Pmax	-0.30%/℃									
Temperature coefficients of Voc	-0.25%/℃									
Temperature coefficients of Isc	0.046%/℃									
Nominal operating cell temperature (NOCT)	45±2℃									
Refer. Bifacial Factor	80±5%									

Figure 28: PV module characteristics

The 2.778 PV strings will be connected in parallel rows to 104 power converters (string Inverters) of the Chinese company Huawei, type SUN2000-330KTL-H1 (Figure 19) with a nominal operating power of 330kW.

The string inverters of the company Huawei comply with all the requirements of the Greek electricity network, including those of the VDE 0126-1-1 standard for protecting the network from the islanding phenomenon and Regulation (EU) 2016/631 RFG for the

establishment of a network code regarding the requirements for the connection of power generators to the network.
The image below shows the electrical characteristics of power converters.

Efficiency	
Max. Efficiency	≥99.0%
European Efficiency	≥98.8%
Input	
Max. Input Voltage	1,500 V
Number of MPP Trackers	6
Max. Current per MPPT	65 A
Max. Short Circuit Current per MPPT	115 A
Max. PV Inputs per MPPT	4/5/5/4/5/5
Start Voltage	550 V
MPPT Operating Voltage Range	500 V ~ 1,500 V
Nominal Input Voltage	1,080 V
Output	
Nominal AC Active Power	300,000 W
Max. AC Apparent Power	330,000 VA
Max. AC Active Power (cosϕ=1)	330,000 W
Nominal Output Voltage	800 V, 3W + PE
Rated AC Grid Frequency	50 Hz / 60 Hz
Nominal Output Current	216.6 A
Max. Output Current	238.2 A
Adjustable Power Factor Range	0.8 LG ... 0.8 LD
Total Harmonic Distortion	< 1%
Protection	
Smart String-Level Disconnector(SSLD)	Yes
Anti-islanding Protection	Yes
AC Overcurrent Protection	Yes
DC Reverse-polarity Protection	Yes
PV-array String Fault Monitoring	Yes
DC Surge Arrester	Type II
AC Surge Arrester	Type II
DC Insulation Resistance Detection	Yes
AC Grounding Fault Protection	Yes
Residual Current Monitoring Unit	Yes
Communication	
Display	LED Indicators, WLAN + APP
USB	Yes
MBUS	Yes
RS485	Yes
General	
Dimensions (W x H x D)	1,048 x 732 x 395 mm
Weight (with mounting plate)	≤112 kg
Operating Temperature Range	-30 °C ~ 60 °C
Cooling Method	Smart Air Cooling
Max. Operating Altitude without Derating	4,000 m (13,123 ft.)
Relative Humidity	0 ~ 100%
AC Connector	Waterproof Connector + OT/DT Terminal
Protection Degree	IP 66

Figure 29: Inverter characteristics

The installation will include five (5) cabins of the Chinese company Huawei, type JUPITER-9000K-H1, which will concentrate the power from 103 string inverters respectively, before transforming and transferring it to the central control room of the park and then to the nation grid. The following image shows the electrical characteristics JUPITER-9000K-H1.

Input		
Available Inverters	SUN2000-330KTL-H1/ SUN2000-330KTL-H2	
Max. LV AC Inputs	30	
AC Power	9,000 kVA @40℃ / 8,250 kVA @50℃ [1]	
Rated Input Voltage	800 V	
LV Main Inputs	ACB (4,000 A / 800 V / 3P, 2 x 1 pcs), MCCB (400 A / 800 V / 3P, 2 x 15 pcs)	
Output		
Rated Output Voltage	22 kV, 30 kV, 33 kV, 35 kV [2]	34.5 kV [2]
Frequency	50 Hz	60 Hz
Transformer Type	Oil-immersed, Conservator Type	
Transformer Cooling Type	ONAN	
Transformer Tappings	± 2 x 2.5%	
Transformer Oil Type	Mineral Oil (PCB Free)	
Transformer Vector Group	Dy11-y11	
Transformer Min. Peak Efficiency Index	Tier 1 or Tier 2 In Accordance with EN 50588-1	
RMU Type	SF_6 Gas Insulated	
RMU Transformer Protection Unit	MV Vacuum Circuit Breaker Unit	
RMU Cable Incoming / Outgoing Unit	Direct Cable Unit or Cable Load Break Switch Unit	
Auxiliary Transformer	Dry Type Transformer, 5 kVA	
Protection		
Transformer Monitoring & Protection	Oil Level, Oil Temperature, Oil Pressure and Buchholz	
Protection Degree of MV & LV Room	IP 54	
Internal Arcing Fault of STS	IAC A 20 kA 1s	
MV Relay Protection	50/51, 50N/51N	
LV Overvoltage Protection	Type I+II	
Anti-rodent Protection	C5 in accordance with ISO 12944	
Features		
2 kVA UPS	Optional [3]	
MV Surge Arrester for MV VCB	Optional [3]	
General		
Dimensions (W x H x D)	6,058 x 2,896 x 2,438 mm (20' HC Container)	
Weight	< 28 t	
Operating Temperature Range	-25℃ ~ 60℃ [4] (-13°F ~ 140°F)	
Relative Humidity	0% ~ 95%	
Max. Operating Altitude	1,000 m [5]	
MV-LV AC Connections	Prewired and Pretested, No Internal Cabling Onsite	
LV & MV Room Cooling	Smart Cooling without Air-across for Higher Availability	
Communication	Modbus TCP, Preconfigured with SmartACU2000D	
Applicable Standards	IEC 62271-202, EN 50588-1, IEC 60076, IEC 62271-200, IEC 61439-1	

Figure 30: MV transformer characteristics

The cabins consist of three (3) areas. The low voltage area, where the LV panel and the low voltage protection elements of the installation to which the string inverters are connected. The power transformer area, where the LV of the Inverters (800 Vac) is transformed into medium voltage (33kV). The MV area where the MV (SF6 insulating) switchgears of the Spanish company Ormazabal Velatia type GIS CGM.3-RBVL input/output and transformers with their switching elements will be located.

The basic cables that will be used for connecting the basic equipment are the following:

- PV panels – String inverters: H1Z2Z2-K 1x6mm² 1500VDC, from the Greek company CABLEL
- String inverters – Jupiter9000KH1: AL/XLPE/PVC/STA/PVC 1x400 mm², 1.8/3.0kV, from the Greek company CABLEL.
- Jupiter9000KH1 – Central control room: AL/XLPE/AL-PE/PE 3x1x240/630 mm², 18/30(36) kV, from the Greek company CABLEL.

Regarding the support of the PV panels, two basic scenarios will be examined, fixed structures and single axis tracking structures. For the analysis of fixed structures, equipment from the Chinese company Powerway will be used. For the analysis of single axis tracking structures, equipment from the Chinese company Artech Solar, type Skyline II with a rotation capacity of ±60 will be used. There will also be two types of structures that could hold 72 PV panels (3 PV Strings) and 48 PV panels (2 PV Strings).

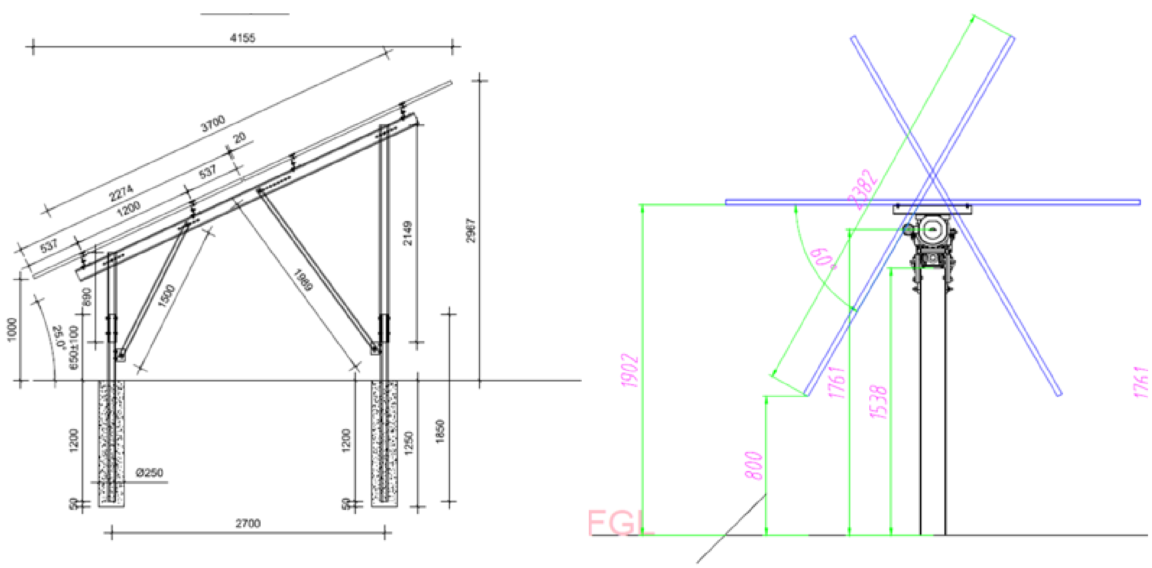


Figure 31: Types of mounting structures

5.3. Interconnection Network

The generated electricity of the project will be led through one (1) exclusive line consisting of 2 circuits, three-pole underground cables (XLPE-Al), cross-section 3x1x800mm^2 medium voltage to the existing HV network of the area. The underground line will have a total length of approximately 2 km and will run parallel to the existing road network.

The interconnection of the station will be done through appropriate automatic interconnection switches and the corresponding accompanying measurement and protection devices provided.

5.4. Battery Energy Storage System Infrastructure (BESS)

A battery energy storage system (BESS) is a type of storage power station that uses a battery bank to generate electrical energy. Battery storage is the fastest-responding energy source in electrical grids and it is used to stabilize electrical grids as battery storage can go from stand by power to full power in less than a second to deal with surges in the grid. Battery storage power stations are generally designed to be able to output their full power for several hours. Battery storage can be used to provide short-term alternative power and utility services such as backup and frequency control to minimize the possibility of power outages. They are often sited close to other power stations and may be attached to the same grid connection to lower the cost.
Energy storage systems include the key elements, such as battery systems or battery modules - consist of low-voltage cells arranged in racks in a module, pack or container. Batteries supply electrical energy produced through chemical energy and are connected in series or parallel to accomplish the need for capacity. They are placed in a container, as an outdoor unit or as a large-scale solution (multiple containers connected).

Figure 32: Battery energy storage system (Huawei LUNA2000-4.5MWH-2H1)

A battery management system (BMS) is a system that ensures the safe operation of the battery, ensuring that it operates within the correct charging and discharging limits. Thus, the management system monitors the current, voltage and temperature of the battery and estimate the state of charge (SoC) and state of health (SoH) of the cells, to prevent safety risks and ensure reliable operation and performance of the system. The battery generates direct current (DC) which is converted by the inverter (PCS) into a current of alternating directions (AC) that is used for the power grid and commercial or industrial use. Inverters enable the battery to be charged and discharged. Energy management system (EMS) controls and monitors the energy flow of the storage system (BESS) and the rest of the systems. The energy management system (EMS) coordinates the battery management system (BMS), inverters and other battery system components collecting and analyzing data used to manage and optimize the overall performance of the system.

Depending on the functionality and operating conditions, a battery energy storage system (BESS) may include a fire suppression system, smoke detection system, temperature control system, cooling, heating and air conditioning systems. A specialized monitoring and control system ensures the safe operation of the energy storage system and the prevention of fires and dangerous incidents. The battery energy storage system (BESS) is housed in a secure area, with limited access and may include closed-circuit television (CCTV) monitoring.

Systems consisting of photovoltaics (PV) coupled with a battery storage system (usually lithium), are the subject of increasing interest due to recent improvements in the cost and performance of the technology, as well as due to the policies that are implemented (EU, etc.).The Figure 33 below presents the basic architectures for PV projects combined with energy storage.

- AC coupled, co-located: The photovoltaic panels and energy storage (batteries) are located at the same location and either share a single connection point to the grid or have two separate connections. However, the solar and energy storage systems are connected to separate inverters, and the energy storage is located next to the solar generation. They can be dispatched together or independently.
- DC coupled, co-located: The photovoltaic panels and energy storage are located at the same location and share the same connection. Additionally, they are connected to the same DC bus and use the same inverter. They can be shipped together as a single installation

The benefits of combining solar and storage can be achieved even if they are located in different geographic areas. Wherever located, a stand-alone energy storage facility can provide services to the grid and shift “blocks” of renewable energy during the afternoon peak. If solar resources are located far from congested centers, the optimal physical layout may be to place stand-alone storage close to load centers. Utilities and decision makers should focus on installing storage systems where they have the greatest net benefits, which may or may not be in the same area as solar. (Sklavounos, 2024)

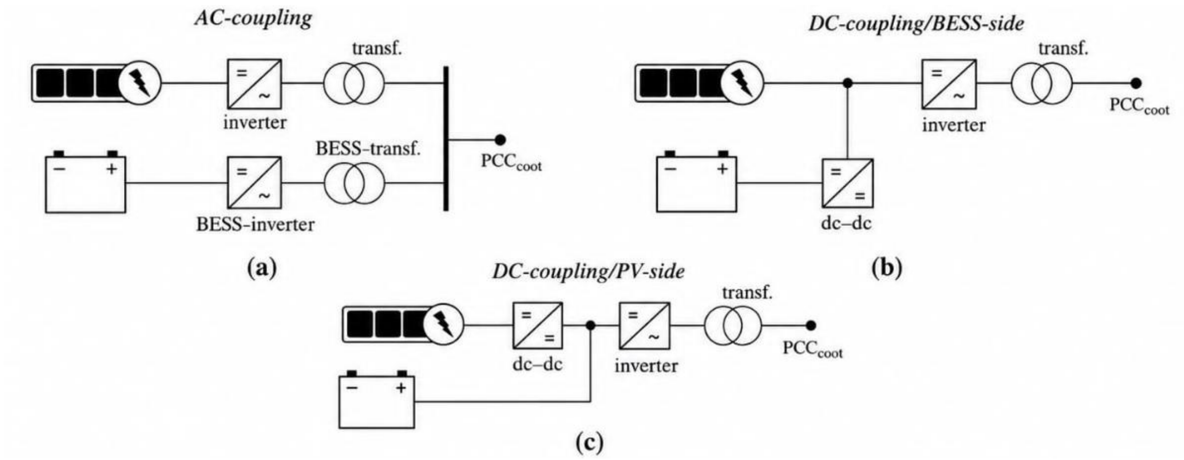


Figure 33: Basic architecture for PV plus storage

For the analysis, a hypothetical example of energy storage that has the capability to deliver 40MW of power to the grid and also has the capability to store energy only from PV curtailments will be examined. The installed capacity of the BESS will be 104 MWh, which will be the result from the installation of containers of the lithium iron phosphate battery type LUNA2000-4.5MWH-2H1 of the company Huawei.

Each storage unit has autonomous and independent elements, which are equipped with DC-DC converters, in order to achieve the best possible performance in each of their operating conditions. At the same time, each unit has an independent and integrated cooling system that ensures its smooth operation in all weather conditions, while all of the specific units are constructed, specifically for outdoor environments, without the need for any additions and/or building structures. At this point it is important to mention that the electric battery storage units have the ability to respond quickly (instant charge/discharge) in terms of their power flow to all possible grid disturbances, making the system ideal for primary regulation (frequency regulation), voltage control and generally ancillary services (ancillary services). The electrical energy produced by the photovoltaic station will be concentrated via underground medium voltage cables at the PV station's control room, where there will be discrete metering and switching devices.

The station's storage system will be co-located with the PV infrastructure and will be interconnected with the grid through two hundred seventy six (276) bidirectional inverters and through twenty four (24) battery containers along with eight (8) MV/LV transformers, and it will be controlled by a monitoring and control software (EMS & BMS) according to the applicable specifications. The BESS project will be oversized, since no battery replacement strategy has been considered for the analysis and the minimum guaranteed capacity of the BESS will be 65MWh for a 20-year life spam.

6. Evaluation Methods of Investment Proposals

6.1. Basic Theory and Case Study

Investment decisions play an important role in the well-being and development of economic units, due to their long term effects on the whole organization as well as the capital requirement required for its implementation. These decisions are typically made based on an evaluation of the relevant alternatives. Each investment plan is therefore a proposal of an evaluation of specific alternatives in respect of fixed assets (or their functional units), from the perspective of a relevant investment decision.
The widely used investment evaluation methods are:

- Levelized Cost of Energy (LCOE)
- Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Payback Period (PP)
- Return on Investment (ROI)

6.1.1. Levelized Cost of Energy (LCOE)

Many analyses of new generation technologies focus on costs and cost minimization. Levelized cost of energy (LCOE) is probably the most widely used metric for discussing the costs of electricity generation, owing to its simplicity, historical use, and clear definition. (J. Herna´ndez-Moro, 2013)

$$LCOE = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{t,el}}{(1+i)^t}}$$

LCOE	Levelized Cost of Electricity in EUR/kWh
I_0	Investment expenditure in EUR
A_t	Annual total cost in EUR per year t
$M_{t,el}$	Produced amount of electricity in kWh per year
i	Real interest rate in %
n	Economic lifetime in years
t	Year of lifetime (1, 2, ...n)

Figure 34: Calculation formula of levelized cost of energy

6.1.2. Net Present Value (NPV)

With the "net present value" (NPV) method, the initial cost (CF0) of the investment is subtracted from the present value (PV) of all expected net cash inflows (CFn), discounted based on the cost of capital (r).

$$PV = Cn^*[1/(1+r)^n] \Rightarrow NPV = -CF_0 + \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \frac{CF_3}{(1+r)^3} + \frac{CF_n}{(1+r)^n}$$

Figure 35: Calculation formula of net present value

If the NPV is positive, the investment is acceptable, (and vice versa). In the case of mutually exclusive investments, the one with the highest NPV is chosen.

6.1.3. Internal Rate of Return (IRR)

The internal rate of return (IRR) is the interest rate that equates the present value of all expected cash flows, with the initial outlay.

$$NPV = -CF_0 + \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \frac{CF_3}{(1+r)^3} + \frac{CF_n}{(1+r)^n}$$

$$0 = -CF_0 + \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \frac{CF_3}{(1+r)^3} + \frac{CF_n}{(1+r)^n}$$

Figure 36: Calculation of internal rate of return

In practice, the equation NPV is used but now the discount rate (r) is not specified, but requested, as IRR. IRR will therefore be the value of discount rate (r) that will equal the sum of the discounted receipts with the initial cost of the investment.
Therefore, IRR is the interest rate for which the sum of all discounted cash flows is zero. Each investment option is considered viable if the IRR is greater than the current market interest rate. (Makrigiannis, 2024)

6.1.4. Payback Period (PP)

The “payback period” refers to the time required for the accumulated profits to equal the cost of the respective investment. (How soon?)
Knowing the time that each candidate investment will “return” the required amount, we choose the one with the shortest time.

$$\text{Payback period} = \text{Years before full recovery} + \frac{\text{Unrecovered cost at start of the year}}{\text{Cash flow during the year}}$$

Figure 37: Calculation formula of payback period

6.1.5. Return on Investment (ROI)

Ratio of NPV against the initial investment measures the return on investment (ROI). A negative ROI indicates that the system is not profitable. (Wind and solar energy system, 2024)

$$\mathrm{ROI} = \left(\frac{\text{Net Present Value}}{\text{Initial Investment}}\right) \times 100$$

Figure 38: Calculation of return on investment

6.2. Project Investment Analysis

6.2.1. Main Data and Assumptions

As already mentioned, utility scale PV projects suffer from energy curtailments due to low grid availability. This fact has a major impact on the debt service coverage ratio (DSCR) and on the cash flow available for debt service (CFADS) in case of a term loan.
The blow is particularly severe in projects implemented in the last four years, the period when construction costs skyrocketed due to the pandemic, the problems in the supply chain and the increased price of materials and transportation. Many of these projects were financed with high bank borrowing, which makes them unsustainable today, as the income from production is not sufficient even for their loan obligations.
Recently, the first tender for RES units with integrated batteries was announced, with a total capacity of 250 MW. It should be noted that a special regulation in the bill that has been introduced to parliament for approval includes provisions describing the new tender format. An obligation to install batteries and/or the imposition of significant injection restrictions is introduced for RES stations that will be selected after participating in a competitive bidding process for receiving operating aid.
For this purpose, investment proposals regarding PV project that is co-located with BESS, which is not allowed to inject more than 40% (16 MW) of the installed PV capacity into the grid will also be examined.
According to Ministry of Energy and Natural Resources reports, two types of tenders will be announced from now on. One will concern RES units with batteries and the second without batteries but with greater restrictions on energy injection.

6.2.2. Technical Inputs and Financial Assumptions

The basic parameters that are considered as technical inputs on the simulations can be found below:

PVSyst Input Parameters	Fixed Structures	Single Axis Tracking Structures
PV Syst software version	V8.1.0	V8.1.0
Horizon	PVGIS	PVGIS
Near Shadings module strings	Mutual shadings of sheds	No shadings
DC wire losses @STC	0,7% per array	0,7% per array
AC wire losses @STC	0,7% per system	0,7% per system
MV line losses @STC	1,00%	1,00%
MV Transformer Iron /Copper Losses @ STC	0,1% / 1,00%	0,1% / 1,00%
Array Soiling Losses	1,5%	1,5%
Thermal Loss factor Uc / Uw	29,0 / 0.0	29,0 / 0.0
Module Mismatch Losses	0,6% at MPP	0,6% at MPP
String Mismatch Losses	0,1% at MPP	0,1% at MPP
Module Quality Losses	0,0%	0,0%
LID-Light Induced Degradation	2,00%	2,00%
IAM Factor	SHRAE MODEL (bo=0,05)	SHRAE MODEL (bo=0,05)
Phi min/max	-	-/+ 60°
Modules per string	24	24
Model	Unlimited sheds 2D simulation	Unlimited sheds 2D simulation
Sheds spacing	9,5 m	6,6 m
Sensitive width	4,53 m	2,38 m
Ground albedo	0,15	0,15
Axis Height above ground	1 m	1 m
Azimuth	0^0	0^0
Number of Modules	66.672 pcs	66.672 pcs
Number of Sheds	400 pcs	999 pcs
Number of Inverters	103 pcs	103 pcs
Number of Batteries	24 pcs	24 pcs
Charging period (Fixed charging power before exporting)	8:00 - 19:00 (40MW) / 8:00 - 19:00 (16MW)	8:00 - 19:00 (40MW) / 8:00 - 19:00 (16MW)
Discharging period (Specified hours)	20:00 - 7:00 (40MW) / 20:00 - 7:00 (16MW)	20:00 - 7:00 (40MW) / 20:00 - 7:00 (16MW)
Active Power Limitation	40 MW (No Limitation) / 16 MW (40% Setpoint)	40 MW (No Limitation) / 16 MW (40% Setpoint)

Table 5: PVsyst parameters

The project will be financed by 50% private equity and 50% bank loan of CAPEX for 10 years with a fixed amortization, a tax rate (Tc) of 22% and an interest rate (Rd) of 5%. The baseline scenario will be a PV tariff of 47,98 €/MWh and a BESS tariff of 116,82 €/MWh. Moreover, the weighted average cost of capital (WACC) will be used as discount rate for cost of equity (Re) of 9%, as follows:

$$WACC = (\frac{E}{V} * Re) + ((\frac{D}{V} * Rd) *(1\text{-}Tc)) = (50\%*9\%) + (50\%*5\%*(1\text{-}22\%)) = 6,45\%$$

As sensitivity analysis, variations in PV tariff will be examined for a 20-year feed-In-premium (FiP) agreement according to the results from the competitive bidding procedure for RES (RAAEY, 2022). Also, for the sensitivity analysis of the project, the impact of power setpoint (40% - 16 MW), as energy curtailments, will be assessed. According to the below table, the income for a project that participates in the day-ahead market will be calculated. (Mpiskas, 2025)

Year	Market Clearing Price Day-Ahead Market (€/MWh)	Average Market Clearing Price 12:00-15:00 (€/MWh)	Average Market Clearing Price 18:00-21:00 (€/MWh)	Difference on Market Clearing Price (€/MWh)
2027	77,79	39,46	113,60	74,14
2028	85,72	42,00	123,74	81,74
2029	91,85	41,98	130,05	88,07
2030	93,28	42,30	129,77	87,48
2031	81,94	35,15	114,35	79,21
2032	82,40	34,20	116,04	81,84
2033	81,73	32,87	114,62	81,75
2034	81,07	35,24	112,40	77,16
2035	80,66	38,71	115,00	76,29
2036	81,22	38,78	116,38	77,60
2037	81,22	37,38	115,63	78,25
2038	81,09	39,98	115,09	75,11
2039	80,89	39,85	115,18	75,33
2040	81,66	40,21	115,99	75,78
2041	81,03	37,38	114,09	76,71
2042	81,43	40,95	115,27	74,33
2043	81,30	40,41	114,79	74,38
2044	81,55	40,22	116,09	75,87
2045	81,04	37,93	114,12	76,19
2046	81,05	37,95	114,14	76,19
Average	82,49	36,75	116,82	78,17

Table 6: Estimations of market clearing price (€/MWh)

6.2.3. Case Study Scenarios

For the analysis of the project, we are going to examine the following four (4) Investment Proposals for a utility scale PV project:
- Investment proposal 1: Construction of PV project with fixed structures.
- Investment proposal 2: Construction of PV project with tracking structures.
- Investment proposal 3: Construction of PV project with fixed structures in combination with Battery Energy Storage System (BESS).
- Investment proposal 4: Construction of PV project with tracking structures in combination with Battery Energy Storage System (BESS).

6.2.4. Evaluation of Investment Proposals

<u>Investment Proposal 1: Construction of PV project with fixed structures</u>

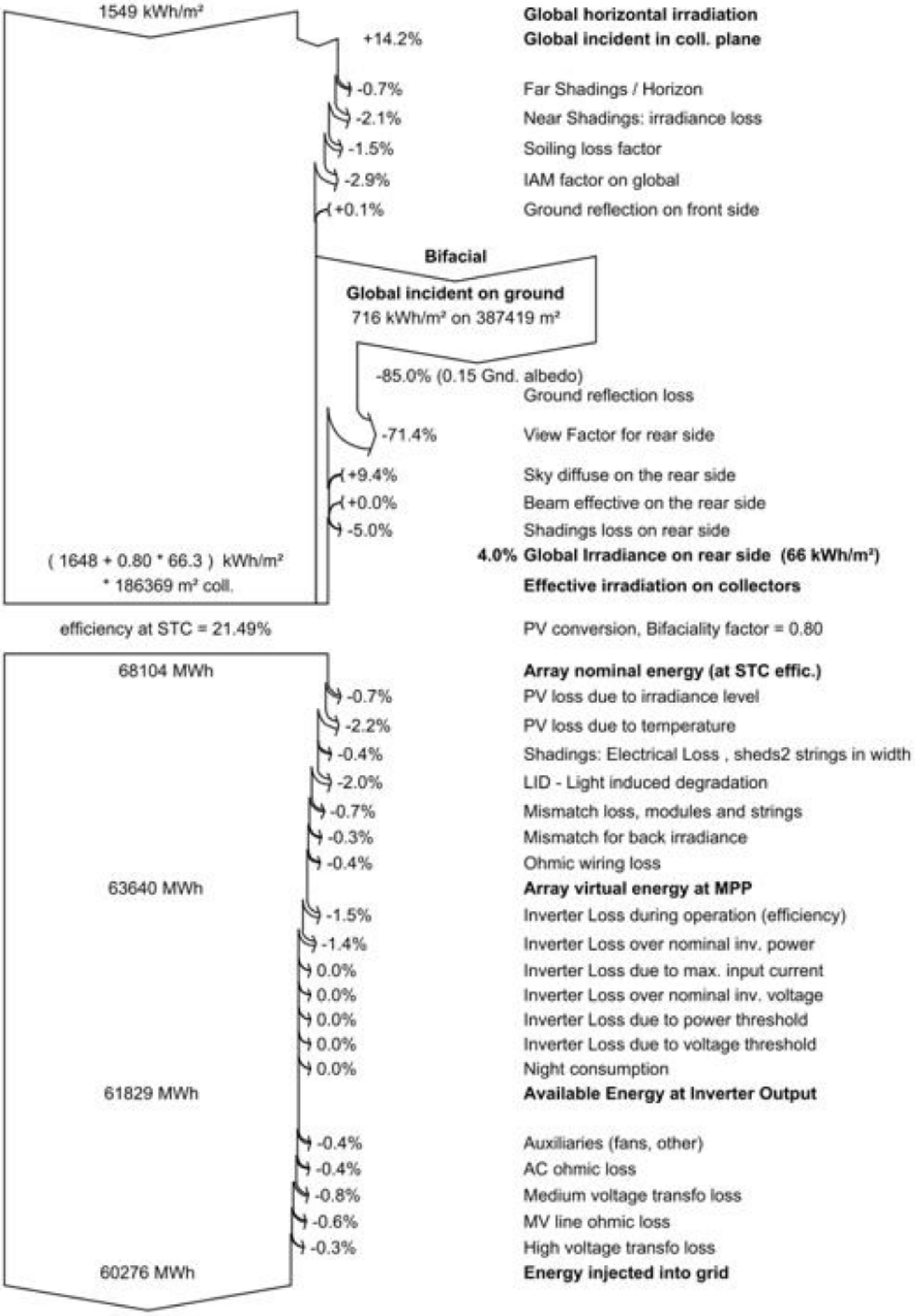


Figure 39: Investment proposal 1 estimated energy yield (Baseline)

Capex	24.000.000 €	PV energy	60.276 MWh	BESS energy	-
Opex	200.000 €	PV tariff	47,98 €/MWh	BESS tariff	-
Taxes	22 %				
Inflation	2 %	Interest rate		5,00 %	
Initial asset value	19.200.000 €	Discount rate		6,45 %	
Salvage value	2.880.000 €	LCOE		39,90 €/MWh	
Total depreciable cost	16.320.000 €	NPV		1.522.290 €	
Annual depreciation	816.000 €	IRR		7,62 %	
Annual performance degradation	0,40 %	PP		12,01 years	
Total energy injected into grid	60.276 MWh	ROI		6,34 %	

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	2.892.042	12.000.000	0	0		0	-24.000.000	0	0	-12.000.000	-12.000.000	-12.000.000	-12.000.000
1	2.892.042		1.200.000	600.000	200.000	816.000	2.692.042	1.276.042	280.729	611.313	-11.388.687	574.273	-11.425.727
2	2.880.474		1.200.000	540.000	204.000	816.000	2.676.474	1.320.474	290.504	645.970	-10.742.717	570.061	-10.855.667
3	2.868.952		1.200.000	480.000	208.080	816.000	2.660.872	1.364.872	300.272	680.600	-10.062.116	564.229	-10.291.438
4	2.857.477		1.200.000	420.000	212.242	816.000	2.645.235	1.409.235	310.032	715.203	-9.346.913	556.989	-9.734.449
5	2.846.047		1.200.000	360.000	216.486	816.000	2.629.560	1.453.560	319.783	749.777	-8.597.136	548.534	-9.185.914
6	2.834.663		1.200.000	300.000	220.816	816.000	2.613.846	1.497.846	329.526	784.320	-7.812.816	539.038	-8.646.876
7	2.823.324		1.200.000	240.000	225.232	816.000	2.598.091	1.542.091	339.260	818.831	-6.993.985	528.658	-8.118.219
8	2.812.031		1.200.000	180.000	229.737	816.000	2.582.293	1.586.293	348.985	853.309	-6.140.676	517.536	-7.600.682
9	2.800.782		1.200.000	120.000	234.332	816.000	2.566.451	1.630.451	358.699	887.751	-5.252.924	505.802	-7.094.880
10	2.789.579		1.200.000	60.000	239.019	816.000	2.550.561	1.674.561	368.403	922.157	-4.330.767	493.570	-6.601.311
11	2.778.421				243.799	816.000	2.534.622	1.718.622	378.097	2.156.525	-2.174.242	1.084.307	-5.517.004
12	2.767.307				248.675	816.000	2.518.632	1.702.632	374.579	2.144.053	-30.188	1.012.716	-4.504.288
13	2.756.238				253.648	816.000	2.502.590	1.686.590	371.050	2.131.540	2.101.352	945.801	-3.558.487
14	2.745.213				258.721	816.000	2.486.492	1.670.492	367.508	2.118.984	4.220.335	883.259	-2.675.227
15	2.734.232				263.896	816.000	2.470.337	1.654.337	363.954	2.106.382	6.326.718	824.807	-1.850.421
16	2.723.295				269.174	816.000	2.454.122	1.638.122	360.387	2.093.735	8.420.453	770.178	-1.080.243
17	2.712.402				274.557	816.000	2.437.845	1.621.845	356.806	2.081.039	10.501.492	719.124	-361.118
18	2.701.553				280.048	816.000	2.421.504	1.605.504	353.211	2.068.293	12.569.785	671.414	310.295
19	2.690.746				285.649	816.000	2.405.097	1.589.097	349.601	2.055.496	14.625.281	626.829	937.124
20	2.679.983				291.362	816.000	2.388.621	1.572.621	345.977	2.042.644	16.667.925	585.167	1.522.290
Total	58.586.805	12.000.000	12.000.000	3.300.000	4.859.474	16.320.000		31.215.289	6.867.364	28.667.925		1.522.290	

Table 7: Financial analysis on investment proposal 1 (Baseline)

Investment Proposal 2: Construction of PV project with single axis tracking structures

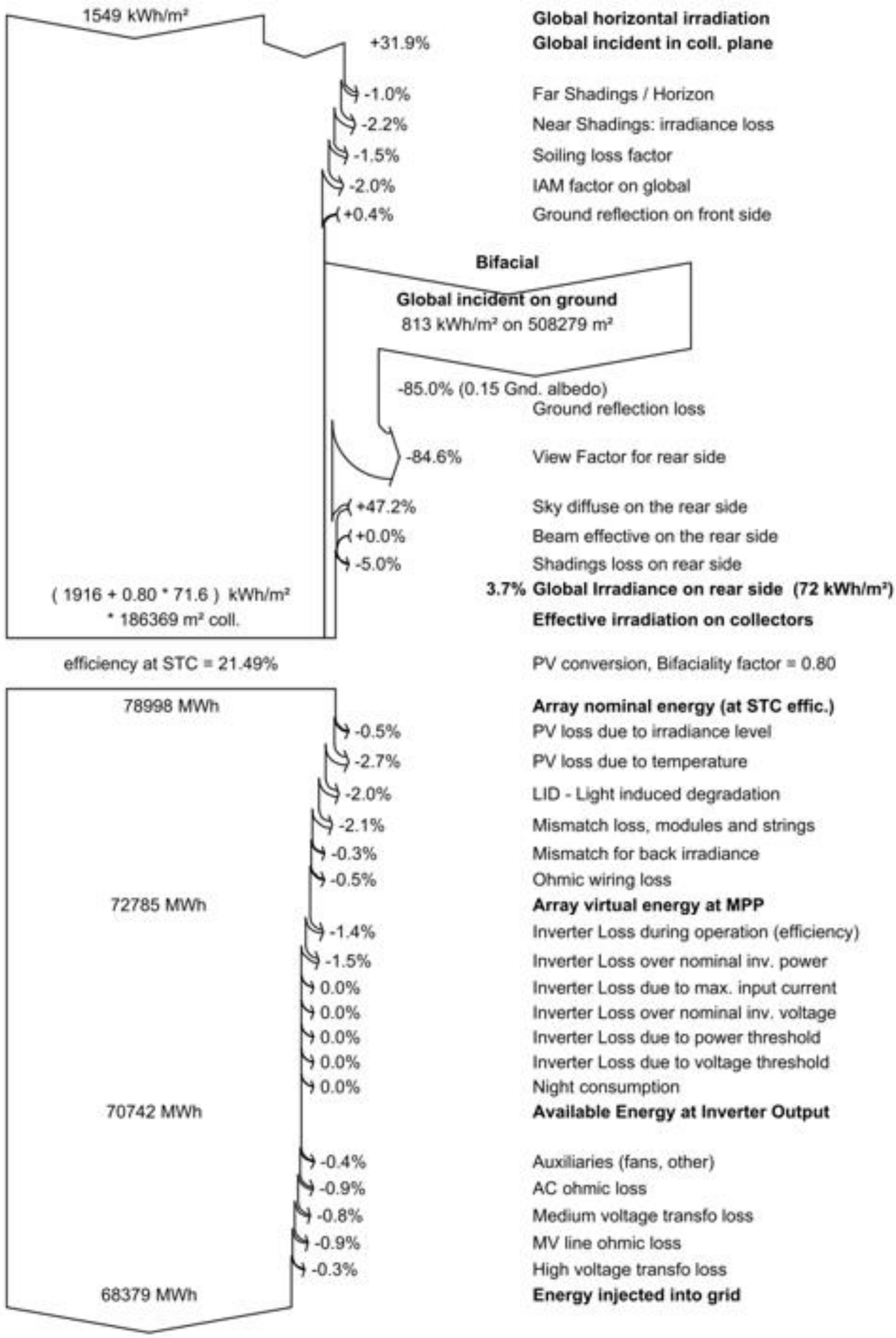


Figure 40: Investment proposal 2 estimated energy yield (Baseline)

Capex	28.000.000 €	PV energy	68.379 MWh	BESS energy	-
Opex	250.000 €	PV tariff	47,98 €/MWh	BESS tariff	-
Taxes	22 %				
Inflation	2 %	Interest rate		5,00 %	
Initial asset value	22.400.000 €	Discount rate		6,45 %	
Salvage value	3.360.000 €	LCOE		41,33 €/MWh	
Total depreciable cost	19.040.000 €	NPV		827.366 €	
Annual depreciation	952.000 €	IRR		7,00 %	
Annual performance degradation	0,40 %	PP		12,44 years	
Total energy injected into grid	68.379 MWh	ROI		2,95 %	

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	3.280.824	14.000.000	0	0		0	-28.000.000	0	0	-14.000.000	-14.000.000	-14.000.000	-14.000.000
1	3.280.824		1.400.000	700.000	250.000	952.000	3.030.824	1.378.824	303.341	627.483	-13.372.517	589.463	-13.410.537
2	3.267.701		1.400.000	630.000	255.000	952.000	3.012.701	1.430.701	314.754	667.947	-12.704.570	589.455	-12.821.082
3	3.254.630		1.400.000	560.000	260.100	952.000	2.994.530	1.482.530	326.157	708.374	-11.996.196	587.253	-12.233.829
4	3.241.612		1.400.000	490.000	265.302	952.000	2.976.310	1.534.310	337.548	748.762	-11.247.435	583.124	-11.650.705
5	3.228.645		1.400.000	420.000	270.608	952.000	2.958.037	1.586.037	348.928	789.109	-10.458.326	577.310	-11.073.396
6	3.215.731		1.400.000	350.000	276.020	952.000	2.939.711	1.637.711	360.296	829.414	-9.628.911	570.030	-10.503.366
7	3.202.868		1.400.000	280.000	281.541	952.000	2.921.327	1.689.327	371.652	869.675	-8.759.236	561.484	-9.941.882
8	3.190.056		1.400.000	210.000	287.171	952.000	2.902.885	1.740.885	382.995	909.890	-7.849.346	551.853	-9.390.028
9	3.177.296		1.400.000	140.000	292.915	952.000	2.884.381	1.792.381	394.324	950.057	-6.899.289	541.301	-8.848.727
10	3.164.587		1.400.000	70.000	298.773	952.000	2.865.814	1.843.814	405.639	990.175	-5.909.114	529.975	-8.318.753
11	3.151.929				304.749	952.000	2.847.180	1.895.180	416.940	2.430.240	-3.478.873	1.221.932	-7.096.821
12	3.139.321				310.844	952.000	2.828.477	1.876.477	412.825	2.415.652	-1.063.221	1.141.002	-5.955.819
13	3.126.764				317.060	952.000	2.809.703	1.857.703	408.695	2.401.008	1.337.787	1.065.369	-4.890.450
14	3.114.257				323.402	952.000	2.790.855	1.838.855	404.548	2.386.307	3.724.094	994.688	-3.895.762
15	3.101.800				329.870	952.000	2.771.930	1.819.930	400.385	2.371.545	6.095.640	928.638	-2.967.124
16	3.089.392				336.467	952.000	2.752.925	1.800.925	396.204	2.356.722	8.452.361	866.917	-2.100.207
17	3.077.035				343.196	952.000	2.733.838	1.781.838	392.004	2.341.834	10.794.195	809.245	-1.290.962
18	3.064.727				350.060	952.000	2.714.666	1.762.666	387.787	2.326.880	13.121.075	755.356	-535.606
19	3.052.468				357.062	952.000	2.695.406	1.743.406	383.549	2.311.857	15.432.932	705.007	169.401
20	3.040.258				364.203	952.000	2.676.055	1.724.055	379.292	2.296.763	17.729.695	657.965	827.366
Total	66.462.724	14.000.000	14.000.000	3.850.000	6.074.342	19.040.000		34.217.557	7.527.863	31.729.695		827.366	

Table 8: Financial analysis on investment proposal 2 (Baseline)

<u>Investment Proposal 3: Construction of PV project with fixed structures in combination with Battery Energy Storage System (BESS)</u>

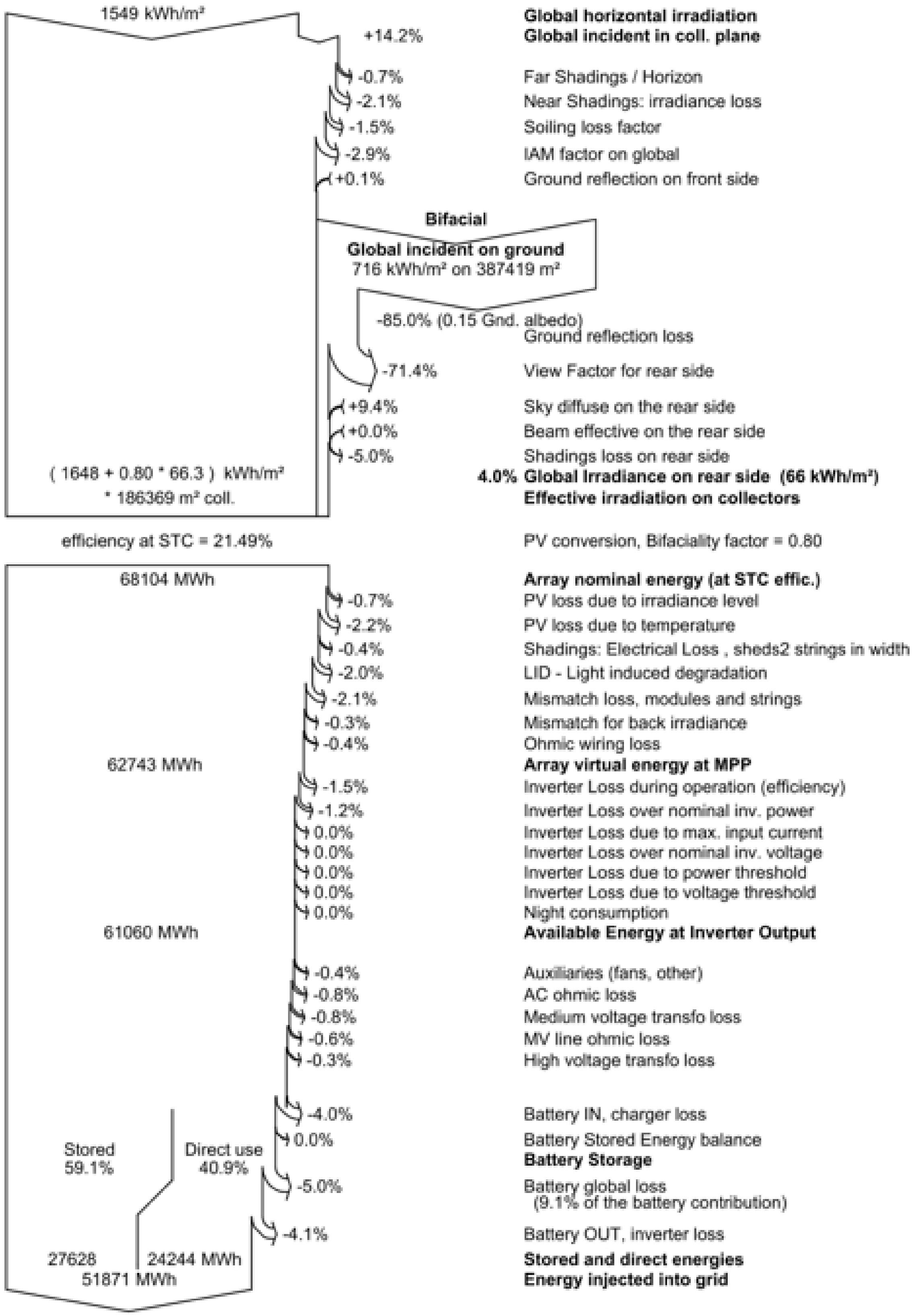


Figure 41: Investment proposal 3 estimated energy yield (Baseline)

Capex	37.000.000 €	PV energy	24.244 MWh	BESS energy	27.628 MWh
Opex	400.000 €	PV tariff	47,98 €/MWh	BESS tariff	116,82 €/MWh
Taxes	22 %				
Inflation	2 %	Interest rate		5,00 %	
Initial asset value	29.600.000 €	Discount rate		6,45 %	
Salvage value	4.440.000 €	LCOE		73,61 €/MWh	
Total depreciable cost	25.160.000 €	NPV		855.896 €	
Annual depreciation	1.258.500 €	IRR		6,88 %	
Annual performance degradation	0,40 %	PP		12,52 years	
Total energy injected into grid	51.871 MWh	ROI		2,31 %	

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	4.390.730	18.500.000	0	0		0	-37.000.000	0	0	-18.500.000	-18.500.000	-18.500.000	-18.500.000
1	4.390.730		1.850.000	925.000	400.000	1.258.000	3.990.730	1.807.730	397.701	818.029	-17.681.971	768.464	-17.731.536
2	4.373.167		1.850.000	832.500	408.000	1.258.000	3.965.167	1.874.667	412.427	870.240	-16.811.730	767.976	-16.963.560
3	4.355.674		1.850.000	740.000	416.160	1.258.000	3.939.514	1.941.514	427.133	922.381	-15.889.349	764.669	-16.198.891
4	4.338.252		1.850.000	647.500	424.483	1.258.000	3.913.769	2.008.269	441.819	974.450	-14.914.899	758.886	-15.440.005
5	4.320.899		1.850.000	555.000	432.973	1.258.000	3.887.926	2.074.926	456.484	1.026.442	-13.888.457	750.942	-14.689.063
6	4.303.615		1.850.000	462.500	441.632	1.258.000	3.861.983	2.141.483	471.126	1.078.357	-12.810.100	741.120	-13.947.943
7	4.286.401		1.850.000	370.000	450.465	1.258.000	3.835.936	2.207.936	485.746	1.130.190	-11.679.911	729.679	-13.218.264
8	4.269.255		1.850.000	277.500	459.474	1.258.000	3.809.781	2.274.281	500.342	1.181.939	-10.497.972	716.852	-12.501.412
9	4.252.178		1.850.000	185.000	468.664	1.258.000	3.783.514	2.340.514	514.913	1.233.601	-9.264.370	702.852	-11.798.560
10	4.235.169		1.850.000	92.500	478.037	1.258.000	3.757.132	2.406.632	529.459	1.285.173	-7.979.197	687.868	-11.110.692
11	4.218.229				487.598	1.258.000	3.730.631	2.472.631	543.979	3.186.652	-4.792.545	1.602.258	-9.508.435
12	4.201.356				497.350	1.258.000	3.704.006	2.446.006	538.121	3.165.885	-1.626.660	1.495.365	-8.013.070
13	4.184.550				507.297	1.258.000	3.677.254	2.419.254	532.236	3.145.018	1.518.358	1.395.499	-6.617.571
14	4.167.812				517.443	1.258.000	3.650.370	2.392.370	526.321	3.124.048	4.642.406	1.302.202	-5.315.369
15	4.151.141				527.792	1.258.000	3.623.349	2.365.349	520.377	3.102.973	7.745.378	1.215.047	-4.100.323
16	4.134.536				538.347	1.258.000	3.596.189	2.338.189	514.402	3.081.787	10.827.166	1.133.632	-2.966.691
17	4.117.998				549.114	1.258.000	3.568.884	2.310.884	508.394	3.060.489	13.887.655	1.057.583	-1.909.107
18	4.101.526				560.097	1.258.000	3.541.430	2.283.430	502.355	3.039.075	16.926.730	986.551	-922.557
19	4.085.120				571.298	1.258.000	3.513.822	2.255.822	496.281	3.017.541	19.944.271	920.207	-2.350
20	4.068.780				582.724	1.258.000	3.486.055	2.228.055	490.172	2.995.883	22.940.154	858.246	855.896
Total	88.947.120	18.500.000	18.500.000	5.087.500	9.718.948	25.160.000		44.589.942	9.809.787	41.440.154		855.896	

Table 9: Financial analysis on investment proposal 3 (Baseline)

<u>Investment proposal 4: Construction of PV project with single axis tracking structures in combination with Battery Energy Storage System (BESS)</u>

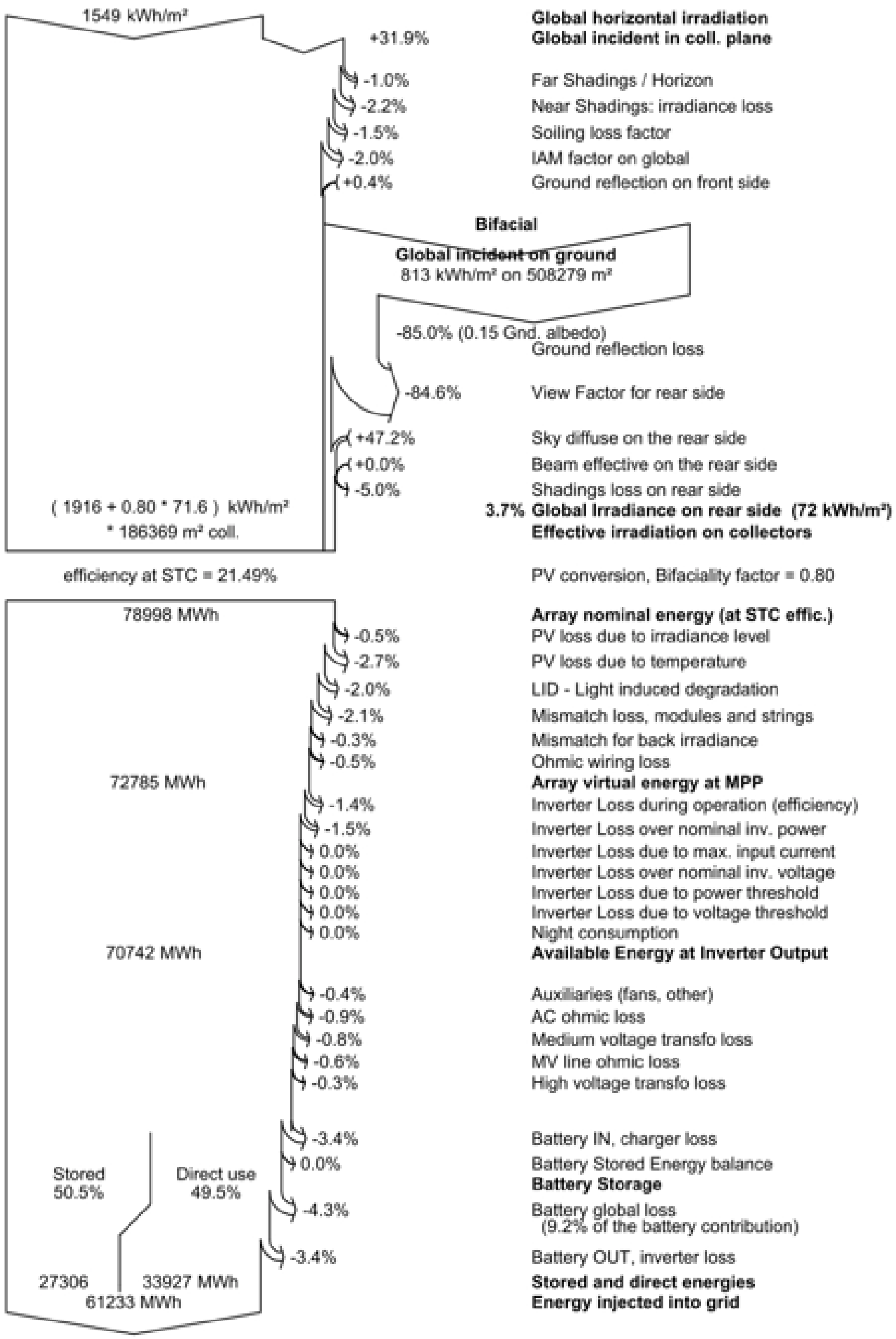


Figure 42: Investment proposal 4 estimated energy yield (Baseline)

Capex Opex Taxes	41.000.000 € 450.000 € 22 %	PV energy PV tariff	33.927 MWh 47,98 €/MWh	BESS energy BESS tariff	27.306 MWh 116,82 €/MWh
Inflation	2 %	Interest rate		5,00 %	
Initial asset value	32.800.000 €	Discount rate		6,45 %	
Salvage value	4.920.000 €	LCOE		69,23 €/MWh	
Total depreciable cost	27.880.000 €	NPV		480.874 €	
Annual depreciation	1.394.000 €	IRR		6,67 %	
Annual performance degradation	0,40 %	PP		12,67 years	
Total energy injected into grid	61.233 MWh	ROI		1,17 %	

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	4.817.704	20.500.000	0	0		0	-41.000.000	0	0	-20.500.000	-20.500.000	-20.500.000	-20.500.000
1	4.817.704		2.050.000	1.025.000	450.000	1.394.000	4.367.704	1.948.704	428.715	863.989	-19.636.011	811.639	-19.688.361
2	4.798.434		2.050.000	922.500	459.000	1.394.000	4.339.434	2.022.934	445.045	921.888	-18.714.122	813.555	-18.874.806
3	4.779.240		2.050.000	820.000	468.180	1.394.000	4.311.060	2.097.060	461.353	979.707	-17.734.416	812.193	-18.062.614
4	4.760.123		2.050.000	717.500	477.544	1.394.000	4.282.579	2.171.079	477.637	1.037.442	-16.696.974	807.944	-17.254.670
5	4.741.082		2.050.000	615.000	487.094	1.394.000	4.253.988	2.244.988	493.897	1.095.091	-15.601.883	801.165	-16.453.505
6	4.722.118		2.050.000	512.500	496.836	1.394.000	4.225.282	2.318.782	510.132	1.152.650	-14.449.234	792.179	-15.661.326
7	4.703.230		2.050.000	410.000	506.773	1.394.000	4.196.456	2.392.456	526.340	1.210.116	-13.239.118	781.281	-14.880.045
8	4.684.417		2.050.000	307.500	516.909	1.394.000	4.167.508	2.466.008	542.522	1.267.486	-11.971.631	768.737	-14.111.308
9	4.665.679		2.050.000	205.000	527.247	1.394.000	4.138.432	2.539.432	558.675	1.324.757	-10.646.874	754.789	-13.356.519
10	4.647.016		2.050.000	102.500	537.792	1.394.000	4.109.225	2.612.725	574.799	1.381.925	-9.264.949	739.653	-12.616.867
11	4.628.428				548.547	1.394.000	4.079.881	2.685.881	590.894	3.488.987	-5.775.962	1.754.272	-10.862.594
12	4.609.914				559.518	1.394.000	4.050.396	2.656.396	584.407	3.465.989	-2.309.973	1.637.115	-9.225.479
13	4.591.475				570.709	1.394.000	4.020.766	2.626.766	577.889	3.442.878	1.132.905	1.527.664	-7.697.815
14	4.573.109				582.123	1.394.000	3.990.986	2.596.986	571.337	3.419.649	4.552.554	1.425.418	-6.272.397
15	4.554.817				593.765	1.394.000	3.961.051	2.567.051	564.751	3.396.300	7.948.853	1.329.906	-4.942.491
16	4.536.597				605.641	1.394.000	3.930.956	2.536.956	558.130	3.372.826	11.321.679	1.240.690	-3.701.801
17	4.518.451				617.754	1.394.000	3.900.697	2.506.697	551.473	3.349.224	14.670.903	1.157.358	-2.544.442
18	4.500.377				630.109	1.394.000	3.870.268	2.476.268	544.779	3.325.489	17.996.393	1.079.527	-1.464.915
19	4.482.376				642.711	1.394.000	3.839.665	2.445.665	538.046	3.301.618	21.298.011	1.006.837	-458.078
20	4.464.446				655.565	1.394.000	3.808.881	2.414.881	531.274	3.277.607	24.575.618	938.952	480.874
Total	97.596.737	20.500.000	20.500.000	5.637.500	10.933.816	27.880.000		48.327.716	10.632.097	45.075.618		480.874	

Table 10: Financial analysis on investment proposal 4 (Baseline)

6.2.5. Comparative Analysis and Sensitivity Analysis Results

<u>Comparative Analysis</u>

Investment proposal 1 - Investment proposal 3 key points:
-Lower capital expenditures (CAPEX)
-Lower operational expenditures (OPEX)
-Better availability on the operation of the equipment

Investment proposal 2 - Investment proposal 4 Key points:
-Improved energy yield
-More complex projects

The above-mentioned investment proposals are summarized in the table below:

	Energy from PV (MWh)	Energy from BESS (MWh)	Tariff for Energy from PV (€/MWh)	Tariff for Energy from BESS (€/MWh)	LCOE (€/MWh)	IRR (%)	NPV (€)	PP (years)	ROI (%)	Ranking
Investment Proposal 1	60.276	-	47,98	-	39,90	7,62	1.522.290	12,01	6,3	1
Investment Proposal 2	68.379	-	47,98	-	41,33	7,00	827.366	12,44	3,0	3
Investment Proposal 3	24.244	27.628	47,98	116,82	73,61	6,88	855.896	12,52	2,3	2
Investment Proposal 4	33.927	27.306	47,98	116,82	69,23	6,67	480.874	12,67	1,2	4

Table 11: Summary table of all investment proposals (Baseline)

<u>Sensitivity Analysis</u>

In the following part, a sensitivity analysis is conducted in case of the lowest (46 €/MWh) and the highest (53,90 €/MWh) PV tariff, according to the results from the competitive bidding procedure of RAE Announcement No. 2/2022. Additionally, a sensitivity analysis is performed in case of curtailed energy (40% setpoint of installed capacity) on the power injected into the grid.

Investment proposal 1 - PV tariff = 46 € (Low)

Capex	24.000.000 €	PV energy	60.276 MWh	BESS energy	-
Opex	200.000 €	PV tariff	46 €/MWh	BESS tariff	-
Taxes	22 %				
Inflation	2 %	Interest rate		5,00 %	
Initial asset value	19.200.000 €	Discount rate		6,45 %	
Salvage value	2.880.000 €	LCOE		39,90 €/MWh	
Total depreciable cost	16.320.000 €	NPV		522.633 €	
Annual depreciation	816.000 €	IRR		6,85 %	
Annual performance degradation	0,40 %	PP		12,55 years	
Total energy injected into grid	60.276 MWh	ROI		2,18 %	

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	2.772.696	12.000.000	0	0		0	-24.000.000	0	0	-12.000.000	-12.000.000	-12.000.000	-12.000.000
1	2.772.696		1.200.000	600.000	200.000	816.000	2.572.696	1.156.696	254.473	518.223	-11.481.777	486.823	-11.513.177
2	2.761.605		1.200.000	540.000	204.000	816.000	2.557.605	1.201.605	264.353	553.252	-10.928.525	488.238	-11.024.939
3	2.750.559		1.200.000	480.000	208.080	816.000	2.542.479	1.246.479	274.225	588.253	-10.340.272	487.672	-10.537.267
4	2.739.557		1.200.000	420.000	212.242	816.000	2.527.315	1.291.315	284.089	623.226	-9.717.046	485.359	-10.051.909
5	2.728.598		1.200.000	360.000	216.486	816.000	2.512.112	1.336.112	293.945	658.167	-9.058.879	481.513	-9.570.396
6	2.717.684		1.200.000	300.000	220.816	816.000	2.496.868	1.380.868	303.791	693.077	-8.365.802	476.329	-9.094.067
7	2.706.813		1.200.000	240.000	225.232	816.000	2.481.581	1.425.581	313.628	727.953	-7.637.849	469.985	-8.624.082
8	2.695.986		1.200.000	180.000	229.737	816.000	2.466.249	1.470.249	323.455	762.794	-6.875.055	462.639	-8.161.443
9	2.685.202		1.200.000	120.000	234.332	816.000	2.450.870	1.514.870	333.271	797.599	-6.077.456	454.437	-7.707.006
10	2.674.461		1.200.000	60.000	239.019	816.000	2.435.443	1.559.443	343.077	832.365	-5.245.091	445.510	-7.261.497
11	2.663.763				243.799	816.000	2.419.964	1.603.964	352.872	2.067.092	-3.177.998	1.039.340	-6.222.157
12	2.653.108				248.675	816.000	2.404.433	1.588.433	349.455	2.054.978	-1.123.020	970.642	-5.251.515
13	2.642.496				253.648	816.000	2.388.848	1.572.848	346.026	2.042.821	919.801	906.435	-4.345.079
14	2.631.926				258.721	816.000	2.373.205	1.557.205	342.585	2.030.620	2.950.420	846.426	-3.498.653
15	2.621.398				263.896	816.000	2.357.502	1.541.502	339.131	2.018.372	4.968.792	790.344	-2.708.309
16	2.610.913				269.174	816.000	2.341.739	1.525.739	335.663	2.006.076	6.974.869	737.933	-1.970.376
17	2.600.469				274.557	816.000	2.325.912	1.509.912	332.181	1.993.731	8.968.600	688.954	-1.281.422
18	2.590.067				280.048	816.000	2.310.019	1.494.019	328.684	1.981.335	10.949.934	643.185	-638.237
19	2.579.707				285.649	816.000	2.294.058	1.478.058	325.173	1.968.885	12.918.819	600.417	-37.821
20	2.569.388				291.362	816.000	2.278.026	1.462.026	321.646	1.956.380	14.875.199	560.454	522.633
Total	56.169.092	12.000.000	12.000.000	3.300.000	4.859.474	16.320.000		28.916.922	6.361.723	26.875.199		522.633	

Table 12: Financial analysis of sensitivity on investment proposal 1 - PV tariff = 46 € (Low)

Investment proposal 2 - PV tariff = 46 € (Low)

Capex	28.000.000 €	PV energy	68.379 MWh	BESS energy	-
Opex	250.000 €	PV tariff	46 €/MWh	BESS tariff	-
Taxes	22 %				
Inflation	2 %	Interest rate		5,00 %	
Initial asset value	22.400.000 €	Discount rate		6,45 %	
Salvage value	3.360.000 €	LCOE		41,33 €/MWh	
Total depreciable cost	19.040.000 €	NPV		-306.676 €	
Annual depreciation	952.000 €	IRR		6,25 %	
Annual performance degradation	0,40 %	PP		13,00 years	
Total energy injected into grid	68.379 MWh	ROI		-1,10 %	

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	3.145.434	14.000.000	0	0		0	-28.000.000	0	0	-14.000.000	-14.000.000	-14.000.000	-14.000.000
1	3.145.434		1.400.000	700.000	250.000	952.000	2.895.434	1.243.434	273.555	521.879	-13.478.121	490.257	-13.509.743
2	3.132.852		1.400.000	630.000	255.000	952.000	2.877.852	1.295.852	285.087	562.765	-12.915.357	496.633	-13.013.110
3	3.120.321		1.400.000	560.000	260.100	952.000	2.860.221	1.348.221	296.609	603.612	-12.311.744	500.404	-12.512.706
4	3.107.840		1.400.000	490.000	265.302	952.000	2.842.538	1.400.538	308.118	644.419	-11.667.325	501.864	-12.010.842
5	3.095.408		1.400.000	420.000	270.608	952.000	2.824.800	1.452.800	319.616	685.184	-10.982.141	501.278	-11.509.564
6	3.083.027		1.400.000	350.000	276.020	952.000	2.807.006	1.505.006	331.101	725.905	-10.256.236	498.891	-11.010.672
7	3.070.694		1.400.000	280.000	281.541	952.000	2.789.154	1.557.154	342.574	766.580	-9.489.656	494.923	-10.515.749
8	3.058.412		1.400.000	210.000	287.171	952.000	2.771.240	1.609.240	354.033	807.207	-8.682.449	489.576	-10.026.174
9	3.046.178		1.400.000	140.000	292.915	952.000	2.753.263	1.661.263	365.478	847.785	-7.834.663	483.031	-9.543.143
10	3.033.993		1.400.000	70.000	298.773	952.000	2.735.220	1.713.220	376.908	888.312	-6.946.352	475.454	-9.067.688
11	3.021.857				304.749	952.000	2.717.109	1.765.109	388.324	2.328.785	-4.617.567	1.170.920	-7.896.769
12	3.009.770				310.844	952.000	2.698.926	1.746.926	384.324	2.314.603	-2.302.964	1.093.273	-6.803.496
13	2.997.731				317.060	952.000	2.680.670	1.728.670	380.307	2.300.363	-2.601	1.020.711	-5.782.786
14	2.985.740				323.402	952.000	2.662.338	1.710.338	376.274	2.286.064	2.283.463	952.904	-4.829.882
15	2.973.797				329.870	952.000	2.643.927	1.691.927	372.224	2.271.703	4.555.166	889.542	-3.940.339
16	2.961.902				336.467	952.000	2.625.435	1.673.435	368.156	2.257.279	6.812.445	830.337	-3.110.002
17	2.950.054				343.196	952.000	2.606.858	1.654.858	364.069	2.242.789	9.055.234	775.019	-2.334.984
18	2.938.254				350.060	952.000	2.588.194	1.636.194	359.963	2.228.231	11.283.465	723.333	-1.611.651
19	2.926.501				357.062	952.000	2.569.439	1.617.439	355.837	2.213.603	13.497.068	675.044	-936.607
20	2.914.795				364.203	952.000	2.550.592	1.598.592	351.690	2.198.902	15.695.970	629.930	-306.676
Total	63.719.994	14.000.000	14.000.000	3.850.000	6.074.342	19.040.000		31.610.217	6.954.248	29.695.970		-306.676	

Table 13: Financial analysis of sensitivity on investment proposal 2 - PV tariff = 46 € (Low)

Investment proposal 3 - PV tariff = 46 € (Low)

Capex	37.000.000 €	PV energy	24.244 MWh	BESS energy	27.628 MWh
Opex	400.000 €	PV tariff	46 €/MWh	BESS tariff	116,82 €/MWh
Taxes	22 %				
Inflation	2 %	Interest rate		5,00 %	
Initial asset value	29.600.000 €	Discount rate		6,45 %	
Salvage value	4.440.000 €	LCOE		73,61 €/MWh	
Total depreciable cost	25.160.000 €	NPV		453.817 €	
Annual depreciation	1.258.000 €	IRR		6,68 %	
Annual performance degradation	0,40 %	PP		12,66 years	
Total energy injected into grid	51.871 MWh	ROI		1,23 %	

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	4.342.727	18.500.000	0	0		0	-37.000.000	0	0	-18.500.000	-18.500.000	-18.500.000	-18.500.000
1	4.342.727		1.850.000	925.000	400.000	1.258.000	3.942.727	1.759.727	387.140	780.587	-17.719.413	733.290	-17.766.710
2	4.325.356		1.850.000	832.500	408.000	1.258.000	3.917.356	1.826.856	401.908	832.948	-16.886.465	735.066	-17.031.644
3	4.308.055		1.850.000	740.000	416.160	1.258.000	3.891.895	1.893.895	416.657	885.238	-16.001.227	733.876	-16.297.768
4	4.290.822		1.850.000	647.500	424.483	1.258.000	3.866.339	1.960.839	431.385	937.455	-15.063.773	730.075	-15.567.692
5	4.273.659		1.850.000	555.000	432.973	1.258.000	3.840.686	2.027.686	446.091	989.595	-14.074.178	723.985	-14.843.708
6	4.256.564		1.850.000	462.500	441.632	1.258.000	3.814.932	2.094.432	460.775	1.041.657	-13.032.520	715.897	-14.127.810
7	4.239.538		1.850.000	370.000	450.465	1.258.000	3.789.073	2.161.073	475.436	1.093.637	-11.938.883	706.079	-13.421.731
8	4.222.580		1.850.000	277.500	459.474	1.258.000	3.763.106	2.227.606	490.073	1.145.533	-10.793.351	694.772	-12.726.959
9	4.205.690		1.850.000	185.000	468.664	1.258.000	3.737.026	2.294.026	504.686	1.197.340	-9.596.011	682.192	-12.044.767
10	4.188.867		1.850.000	92.500	478.037	1.258.000	3.710.830	2.360.330	519.273	1.249.057	-8.346.953	668.537	-11.376.230
11	4.172.112				487.598	1.258.000	3.684.514	2.426.514	533.833	3.150.681	-5.196.272	1.584.171	-9.792.059
12	4.155.423				497.350	1.258.000	3.658.073	2.400.073	528.016	3.130.057	-2.066.215	1.478.442	-8.313.617
13	4.138.801				507.297	1.258.000	3.631.505	2.373.505	522.171	3.109.334	1.043.118	1.379.665	-6.933.952
14	4.122.246				517.443	1.258.000	3.604.804	2.346.804	516.297	3.088.507	4.131.625	1.287.387	-5.646.564
15	4.105.757				527.792	1.258.000	3.577.966	2.319.966	510.392	3.067.573	7.199.198	1.201.185	-4.445.379
16	4.089.334				538.347	1.258.000	3.550.987	2.292.987	504.457	3.046.530	10.245.728	1.120.662	-3.324.717
17	4.072.977				549.114	1.258.000	3.523.863	2.265.863	498.490	3.025.373	13.271.101	1.045.448	-2.279.269
18	4.056.685				560.097	1.258.000	3.496.588	2.238.588	492.489	3.004.099	16.275.200	975.197	-1.304.072
19	4.040.458				571.298	1.258.000	3.469.160	2.211.160	486.455	2.982.705	19.257.904	909.584	-394.488
20	4.024.296				582.724	1.258.000	3.441.572	2.183.572	480.386	2.961.186	22.219.090	848.306	453.817
Total	87.974.675	18.500.000	18.500.000	5.087.500	9.718.948	25.160.000		43.665.501	9.606.410	40.719.090		453.817	

Table 14: Financial analysis of sensitivity on investment proposal 3 - PV tariff = 46 € (Low)

Investment proposal 4 - PV tariff = 46 € (Low)

Capex	41.000.000 €	PV energy	33.927 MWh	BESS energy	27.306 MWh
Opex	450.000 €	PV tariff	46 €/MWh	BESS tariff	116,82 €/MWh
Taxes	22 %				

Inflation	2 %	Interest rate	5,00 %
Initial asset value	32.800.000 €	Discount rate	6,45 %
Salvage value	4.920.000 €	LCOE	69,23 €/MWh
Total depreciable cost	27.880.000 €	NPV	-81.793 €
Annual depreciation	1.394.000 €	IRR	6,41 %
Annual performance degradation	0,40 %	PP	12,86 years
Total energy injected into grid	61.233 MWh	ROI	-0,20 %

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	4.750.529	20.500.000	0	0		0	-41.000.000	0	0	-20.500.000	-20.500.000	-20.500.000	-20.500.000
1	4.750.529		2.050.000	1.025.000	450.000	1.394.000	4.300.529	1.881.529	413.936	811.593	-19.688.407	762.417	-19.737.583
2	4.731.527		2.050.000	922.500	459.000	1.394.000	4.272.527	1.956.027	430.326	869.701	-18.818.707	767.500	-18.970.083
3	4.712.601		2.050.000	820.000	468.180	1.394.000	4.244.421	2.030.421	446.693	927.728	-17.890.978	769.102	-18.200.981
4	4.693.750		2.050.000	717.500	477.544	1.394.000	4.216.207	2.104.707	463.035	985.671	-16.905.307	767.626	-17.433.356
5	4.674.975		2.050.000	615.000	487.094	1.394.000	4.187.881	2.178.881	479.354	1.043.527	-15.861.780	763.441	-16.669.915
6	4.656.275		2.050.000	512.500	496.836	1.394.000	4.159.439	2.252.939	495.647	1.101.292	-14.760.488	756.883	-15.913.032
7	4.637.650		2.050.000	410.000	506.773	1.394.000	4.130.877	2.326.877	511.913	1.158.964	-13.601.523	748.256	-15.164.776
8	4.619.100		2.050.000	307.500	516.909	1.394.000	4.102.191	2.400.691	528.152	1.216.539	-12.384.984	737.838	-14.426.938
9	4.600.623		2.050.000	205.000	527.247	1.394.000	4.073.377	2.474.377	544.363	1.274.014	-11.110.971	725.877	-13.701.061
10	4.582.221		2.050.000	102.500	537.792	1.394.000	4.044.429	2.547.929	560.544	1.331.385	-9.779.586	712.602	-12.988.459
11	4.563.892				548.547	1.394.000	4.015.344	2.621.344	576.696	3.438.649	-6.340.937	1.728.962	-11.259.497
12	4.545.636				559.518	1.394.000	3.986.118	2.592.118	570.266	3.415.852	-2.925.085	1.613.433	-9.646.064
13	4.527.454				570.709	1.394.000	3.956.745	2.562.745	563.804	3.392.941	467.856	1.505.507	-8.140.557
14	4.509.344				582.123	1.394.000	3.927.221	2.533.221	557.309	3.369.912	3.837.768	1.404.686	-6.735.871
15	4.491.307				593.765	1.394.000	3.897.541	2.503.541	550.779	3.346.762	7.184.530	1.310.509	-5.425.363
16	4.473.341				605.641	1.394.000	3.867.701	2.473.701	544.214	3.323.486	10.508.017	1.222.541	-4.202.822
17	4.455.448				617.754	1.394.000	3.837.694	2.443.694	537.613	3.300.082	13.808.098	1.140.377	-3.062.445
18	4.437.626				630.109	1.394.000	3.807.518	2.413.518	530.974	3.276.544	17.084.642	1.063.638	-1.998.807
19	4.419.876				642.711	1.394.000	3.777.165	2.383.165	524.296	3.252.869	20.337.511	991.971	-1.006.836
20	4.402.196				655.565	1.394.000	3.746.631	2.352.631	517.579	3.229.052	23.566.563	925.043	-81.793
Total	96.235.901	20.500.000	20.500.000	5.637.500	10.933.816	27.880.000		47.034.055	10.347.492	44.066.563		-81.793	

Table 15: Financial analysis of sensitivity on investment proposal 4 - PV tariff = 46 € (Low)

Investment proposal 1 - PV tariff = 53,90 € (High)

Capex	24.000.000 €	PV energy	60.276 MWh	BESS energy	-
Opex	200.000 €	PV tariff	53,90 €/MWh	BESS tariff	-
Taxes	22 %				
Inflation	2 %	Interest rate		5,00 %	
Initial asset value	19.200.000 €	Discount rate		6,45 %	
Salvage value	2.880.000 €	LCOE		39,90 €/MWh	
Total depreciable cost	16.320.000 €	NPV		4.511.164 €	
Annual depreciation	816.000 €	IRR		9,86 %	
Annual performance degradation	0,40 %	PP		10,66 years	
Total energy injected into grid	60.276 MWh	ROI		18,80 %	

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	3.248.876	12.000.000	0	0		0	-24.000.000	0	0	-12.000.000	-12.000.000	-12.000.000	-12.000.000
1	3.248.876		1.200.000	600.000	200.000	816.000	3.048.876	1.632.876	359.233	889.644	-11.110.356	835.738	-11.164.262
2	3.235.881		1.200.000	540.000	204.000	816.000	3.031.881	1.675.881	368.694	923.187	-10.187.169	814.701	-10.349.560
3	3.222.937		1.200.000	480.000	208.080	816.000	3.014.857	1.718.857	378.149	956.709	-9.230.461	793.127	-9.556.433
4	3.210.046		1.200.000	420.000	212.242	816.000	2.997.804	1.761.804	387.597	990.207	-8.240.253	771.158	-8.785.275
5	3.197.205		1.200.000	360.000	216.486	816.000	2.980.719	1.804.719	397.038	1.023.681	-7.216.573	748.921	-8.036.354
6	3.184.417		1.200.000	300.000	220.816	816.000	2.963.600	1.847.600	406.472	1.057.128	-6.159.444	726.530	-7.309.824
7	3.171.679		1.200.000	240.000	225.232	816.000	2.946.446	1.890.446	415.898	1.090.548	-5.068.896	704.085	-6.605.738
8	3.158.992		1.200.000	180.000	229.737	816.000	2.929.255	1.933.255	425.316	1.123.939	-3.944.957	681.675	-5.924.063
9	3.146.356		1.200.000	120.000	234.332	816.000	2.912.024	1.976.024	434.725	1.157.299	-2.787.658	659.378	-5.264.685
10	3.133.771		1.200.000	60.000	239.019	816.000	2.894.752	2.018.752	444.126	1.190.627	-1.597.031	637.263	-4.627.422
11	3.121.236				243.799	816.000	2.877.437	2.061.437	453.516	2.423.921	826.890	1.218.754	-3.408.667
12	3.108.751				248.675	816.000	2.860.076	2.044.076	449.697	2.410.379	3.237.269	1.138.511	-2.270.156
13	3.096.316				253.648	816.000	2.842.667	2.026.667	445.867	2.396.801	5.634.069	1.063.502	-1.206.654
14	3.083.931				258.721	816.000	2.825.209	2.009.209	442.026	2.383.183	8.017.253	993.386	-213.268
15	3.071.595				263.896	816.000	2.807.699	1.991.699	438.174	2.369.525	10.386.778	927.847	714.579
16	3.059.308				269.174	816.000	2.790.135	1.974.135	434.310	2.355.825	12.742.603	866.587	1.581.166
17	3.047.071				274.557	816.000	2.772.514	1.956.514	430.433	2.342.081	15.084.684	809.330	2.390.496
18	3.034.883				280.048	816.000	2.754.835	1.938.835	426.544	2.328.291	17.412.975	755.815	3.146.311
19	3.022.743				285.649	816.000	2.737.094	1.921.094	422.641	2.314.453	19.727.428	705.799	3.852.110
20	3.010.652				291.362	816.000	2.719.290	1.903.290	418.724	2.300.566	22.027.995	659.055	4.511.164
Total	65.815.523	12.000.000	12.000.000	3.300.000	4.859.474	16.320.000		38.087.173	8.379.178	34.027.995		4.511.164	

Table 16: Financial analysis of sensitivity on investment proposal 1 - PV tariff = 53,90 € (High)

Investment proposal 2 - PV tariff = 53,90 € (High)

Capex	28.000.000 €	PV energy	68.379 MWh	BESS energy	-
Opex	250.000 €	PV tariff	53,90 €/MWh	BESS tariff	-
Taxes	22 %				
Inflation	2 %	Interest rate		5,00 %	
Initial asset value	22.400.000 €	Discount rate		6,45 %	
Salvage value	3.360.000 €	LCOE		41,33 €/MWh	
Total depreciable cost	19.040.000 €	NPV		4.218.039 €	
Annual depreciation	952.000 €	IRR		9,20 %	
Annual performance degradation	0,40 %	PP		11,03 years	
Total energy injected into grid	68.379 MWh	ROI		15,06 %	

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	3.685.628	14.000.000	0	0		0	-28.000.000	0	0	-14.000.000	-14.000.000	-14.000.000	-14.000.000
1	3.685.628		1.400.000	700.000	250.000	952.000	3.435.628	1.783.628	392.398	943.230	-13.056.770	886.078	-13.113.922
2	3.670.886		1.400.000	630.000	255.000	952.000	3.415.886	1.833.886	403.455	982.431	-12.074.339	866.983	-12.246.939
3	3.656.202		1.400.000	560.000	260.100	952.000	3.396.102	1.884.102	414.502	1.021.600	-11.052.740	846.923	-11.400.016
4	3.641.577		1.400.000	490.000	265.302	952.000	3.376.275	1.934.275	425.541	1.060.735	-9.992.005	826.084	-10.573.933
5	3.627.011		1.400.000	420.000	270.608	952.000	3.356.403	1.984.403	436.569	1.099.834	-8.892.171	804.635	-9.769.298
6	3.612.503		1.400.000	350.000	276.020	952.000	3.336.483	2.034.483	447.586	1.138.896	-7.753.274	782.727	-8.986.571
7	3.598.053		1.400.000	280.000	281.541	952.000	3.316.512	2.084.512	458.593	1.177.920	-6.575.355	760.494	-8.226.076
8	3.583.661		1.400.000	210.000	287.171	952.000	3.296.489	2.134.489	469.588	1.216.902	-5.358.453	738.057	-7.488.019
9	3.569.326		1.400.000	140.000	292.915	952.000	3.276.411	2.184.411	480.570	1.255.841	-4.102.612	715.523	-6.772.496
10	3.555.049		1.400.000	70.000	298.773	952.000	3.256.276	2.234.276	491.541	1.294.735	-2.807.877	692.986	-6.079.510
11	3.540.829				304.749	952.000	3.236.080	2.284.080	502.498	2.733.582	-74.295	1.374.453	-4.705.058
12	3.526.665				310.844	952.000	3.215.822	2.263.822	498.041	2.717.781	2.643.486	1.283.709	-3.421.349
13	3.512.559				317.060	952.000	3.195.498	2.243.498	493.570	2.701.929	5.345.414	1.198.892	-2.222.457
14	3.498.508				323.402	952.000	3.175.107	2.223.107	489.083	2.686.023	8.031.437	1.119.619	-1.102.837
15	3.484.514				329.870	952.000	3.154.645	2.202.645	484.582	2.670.063	10.701.500	1.045.530	-57.307
16	3.470.576				336.467	952.000	3.134.109	2.182.109	480.064	2.654.045	13.355.545	976.287	918.980
17	3.456.694				343.196	952.000	3.113.497	2.161.497	475.529	2.637.968	15.993.513	911.577	1.830.557
18	3.442.867				350.060	952.000	3.092.807	2.140.807	470.977	2.621.829	18.615.343	851.104	2.681.660
19	3.429.096				357.062	952.000	3.072.034	2.120.034	466.408	2.605.627	21.220.969	794.593	3.476.253
20	3.415.379				364.203	952.000	3.051.176	2.099.176	461.819	2.589.358	23.810.327	741.786	4.218.039
Total	74.663.210	14.000.000	14.000.000	3.850.000	6.074.342	19.040.000		42.013.240	9.242.913	37.810.327		4.218.039	

Table 17: Financial analysis of sensitivity on investment proposal 2 - PV tariff = 53,90 € (High)

Investment proposal 3 - PV tariff = 53,90 € (High)

Capex	37.000.000 €	PV energy	24.244 MWh	BESS energy	27.628 MWh
Opex	400.000 €	PV tariff	53,90 €/MWh	BESS tariff	116,82 €/MWh
Taxes	22 %				
Inflation	2 %	Interest rate		5,00 %	
Initial asset value	29.600.000 €	Discount rate		6,45 %	
Salvage value	4.440.000 €	LCOE		73,61 €/MWh	
Total depreciable cost	25.160.000 €	NPV		2.058.070 €	
Annual depreciation	1.258.000 €	IRR		7,48 %	
Annual performance degradation	0,40 %	PP		12,10 years	
Total energy injected into grid	51.871 MWh	ROI		5,56 %	

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	4.534.255	18.500.000	0	0		0	-37.000.000	0	0	-18.500.000	-18.500.000	-18.500.000	-18.500.000
1	4.534.255		1.850.000	925.000	400.000	1.258.000	4.134.255	1.951.255	429.276	929.979	-17.570.021	873.629	-17.626.371
2	4.516.118		1.850.000	832.500	408.000	1.258.000	4.108.118	2.017.618	443.876	981.742	-16.588.280	866.375	-16.759.996
3	4.498.053		1.850.000	740.000	416.160	1.258.000	4.081.893	2.083.893	458.456	1.033.437	-15.554.843	856.736	-15.903.260
4	4.480.061		1.850.000	647.500	424.483	1.258.000	4.055.578	2.150.078	473.017	1.085.061	-14.469.783	845.028	-15.058.231
5	4.462.141		1.850.000	555.000	432.973	1.258.000	4.029.168	2.216.168	487.557	1.136.611	-13.333.172	831.541	-14.226.691
6	4.444.292		1.850.000	462.500	441.632	1.258.000	4.002.660	2.282.160	502.075	1.188.085	-12.145.087	816.532	-13.410.159
7	4.426.515		1.850.000	370.000	450.465	1.258.000	3.976.050	2.348.050	516.571	1.239.479	-10.905.608	800.239	-12.609.920
8	4.408.809		1.850.000	277.500	459.474	1.258.000	3.949.335	2.413.835	531.044	1.290.791	-9.614.817	782.872	-11.827.048
9	4.391.174		1.850.000	185.000	468.664	1.258.000	3.922.510	2.479.510	545.492	1.342.018	-8.272.800	764.623	-11.062.425
10	4.373.609		1.850.000	92.500	478.037	1.258.000	3.895.572	2.545.072	559.916	1.393.156	-6.879.644	745.664	-10.316.762
11	4.356.114				487.598	1.258.000	3.868.517	2.610.517	574.314	3.294.203	-3.585.441	1.656.334	-8.660.427
12	4.338.690				497.350	1.258.000	3.841.340	2.583.340	568.335	3.273.005	-312.435	1.545.962	-7.114.465
13	4.321.335				507.297	1.258.000	3.814.039	2.556.039	562.328	3.251.710	2.939.275	1.442.840	-5.671.625
14	4.304.050				517.443	1.258.000	3.786.607	2.528.607	556.294	3.230.314	6.169.589	1.346.497	-4.325.129
15	4.286.834				527.792	1.258.000	3.759.042	2.501.042	550.229	3.208.813	9.378.402	1.256.491	-3.068.637
16	4.269.686				538.347	1.258.000	3.731.339	2.473.339	544.135	3.187.204	12.565.606	1.172.409	-1.896.228
17	4.252.608				549.114	1.258.000	3.703.493	2.445.493	538.009	3.165.485	15.731.091	1.093.865	-802.363
18	4.235.597				560.097	1.258.000	3.675.501	2.417.501	531.850	3.143.650	18.874.741	1.020.498	218.136
19	4.218.655				571.298	1.258.000	3.647.356	2.389.356	525.658	3.121.698	21.996.439	951.970	1.170.106
20	4.201.780				582.724	1.258.000	3.619.056	2.361.056	519.432	3.099.623	25.096.063	887.965	2.058.070
Total	91.854.629	18.500.000	18.500.000	5.087.500	9.718.948	25.160.000		47.353.926	10.417.864	43.596.063		2.058.070	

Table 18: Financial analysis of sensitivity on investment proposal 3 - PV tariff = 53,90 € (High)

Investment proposal 4 - PV tariff = 53,90 € (High)

Capex	41.000.000 €	PV energy	33.927 MWh	BESS energy	27.306 MWh
Opex	450.000 €	PV tariff	53,90 €/MWh	BESS tariff	116,82 €/MWh
Taxes	22 %				
Inflation	2 %	Interest rate		5,00 %	
Initial asset value	32.800.000 €	Discount rate		6,45 %	
Salvage value	4.920.000 €	LCOE		69,23 €/MWh	
Total depreciable cost	27.880.000 €	NPV		2.163.194 €	
Annual depreciation	1.394.000 €	IRR		7,43 %	
Annual performance degradation	0,40 %	PP		12,13 years	
Total energy injected into grid	61.233 MWh	ROI		5,28 %	

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	5.018.552	20.500.000	0	0		0	-41.000.000	0	0	-20.500.000	-20.500.000	-20.500.000	-20.500.000
1	5.018.552		2.050.000	1.025.000	450.000	1.394.000	4.568.552	2.149.552	472.901	1.020.651	-19.479.349	958.808	-19.541.192
2	4.998.478		2.050.000	922.500	459.000	1.394.000	4.539.478	2.222.978	489.055	1.077.923	-18.401.426	951.254	-18.589.939
3	4.978.484		2.050.000	820.000	468.180	1.394.000	4.510.304	2.296.304	505.187	1.135.117	-17.266.309	941.031	-17.648.908
4	4.958.570		2.050.000	717.500	477.544	1.394.000	4.481.027	2.369.527	521.296	1.192.231	-16.074.079	928.491	-16.720.417
5	4.938.736		2.050.000	615.000	487.094	1.394.000	4.451.641	2.442.641	537.381	1.249.260	-14.824.818	913.955	-15.806.463
6	4.918.981		2.050.000	512.500	496.836	1.394.000	4.422.145	2.515.645	553.442	1.306.203	-13.518.615	897.711	-14.908.752
7	4.899.305		2.050.000	410.000	506.773	1.394.000	4.392.532	2.588.532	569.477	1.363.055	-12.155.561	880.022	-14.028.729
8	4.879.708		2.050.000	307.500	516.909	1.394.000	4.362.799	2.661.299	585.486	1.419.813	-10.735.747	861.125	-13.167.605
9	4.860.189		2.050.000	205.000	527.247	1.394.000	4.332.942	2.733.942	601.467	1.476.475	-9.259.272	841.231	-12.326.374
10	4.840.748		2.050.000	102.500	537.792	1.394.000	4.302.957	2.806.457	617.420	1.533.036	-7.726.236	820.532	-11.505.842
11	4.821.385				548.547	1.394.000	4.272.838	2.878.838	633.344	3.639.493	-4.086.743	1.829.947	-9.675.894
12	4.802.100				559.518	1.394.000	4.242.581	2.848.581	626.688	3.615.893	-470.849	1.707.920	-7.967.974
13	4.782.891				570.709	1.394.000	4.212.182	2.818.182	620.000	3.592.182	3.121.333	1.593.913	-6.374.061
14	4.763.760				582.123	1.394.000	4.181.637	2.787.637	613.280	3.568.357	6.689.690	1.487.404	-4.886.657
15	4.744.705				593.765	1.394.000	4.150.939	2.756.939	606.527	3.544.413	10.234.102	1.387.904	-3.498.753
16	4.725.726				605.641	1.394.000	4.120.085	2.726.085	599.739	3.520.346	13.754.449	1.294.955	-2.203.798
17	4.706.823				617.754	1.394.000	4.089.069	2.695.069	592.915	3.496.154	17.250.603	1.208.132	-995.666
18	4.687.996				630.109	1.394.000	4.057.887	2.663.887	586.055	3.471.832	20.722.435	1.127.033	131.367
19	4.669.244				642.711	1.394.000	4.026.533	2.632.533	579.157	3.447.376	24.169.810	1.051.286	1.182.653
20	4.650.567				655.565	1.394.000	3.995.002	2.601.002	572.220	3.422.781	27.592.592	980.541	2.163.194
Total	101.665.499	20.500.000	20.500.000	5.637.500	10.933.816	27.880.000		52.195.630	11.483.039	48.092.592		2.163.194	

Table 19: Financial analysis of sensitivity on investment proposal 4 - PV tariff = 53,90 € (High)

Investment Proposal 1 - Setpoint 40% (16 MW)

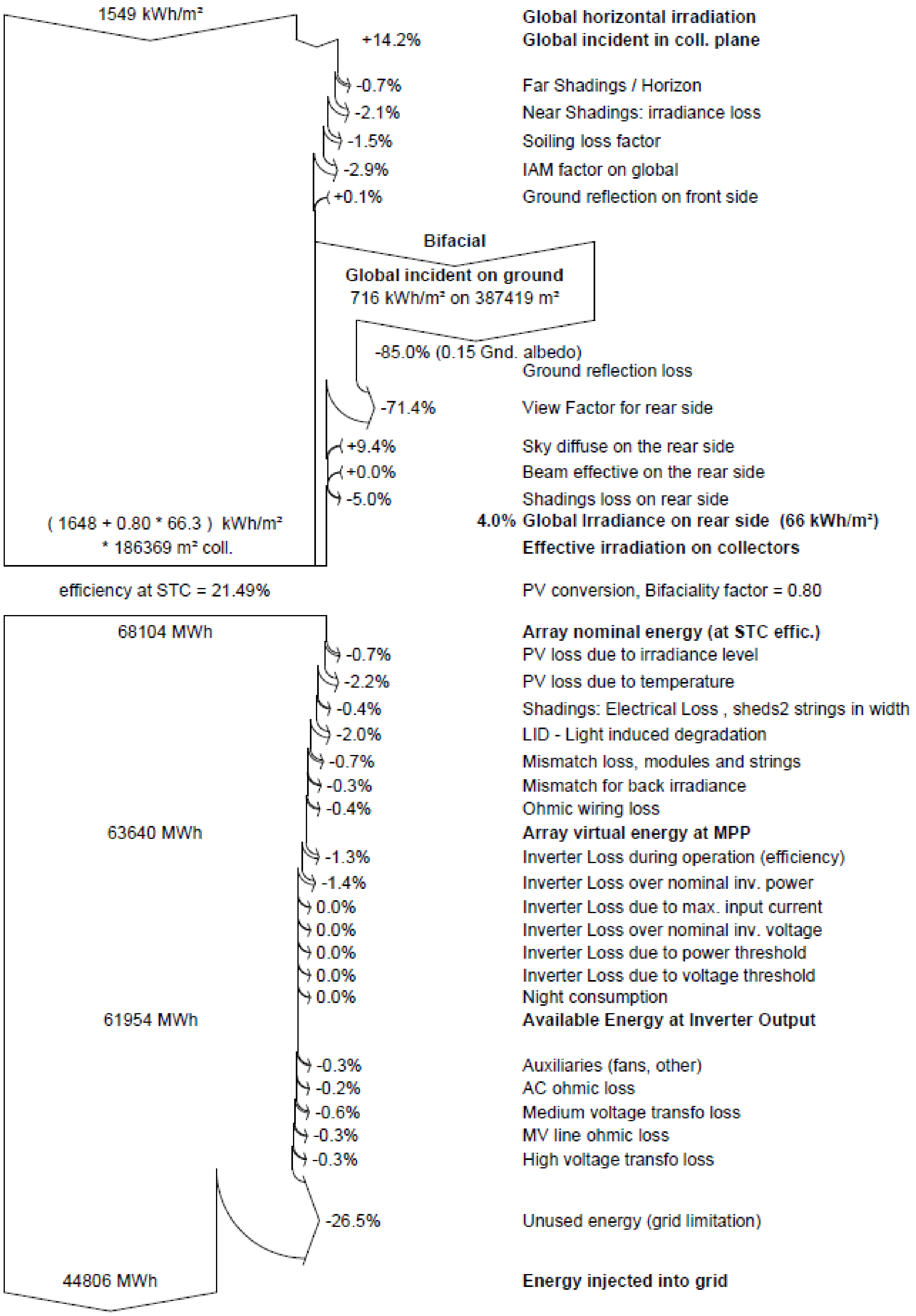


Figure 43: Sensitivity analysis on investment proposal 1 estimated energy yield – Power Setpoint = 16 MW € (40%) (Baseline)

Capex	24.000.000 €	PV energy	44.806 MWh	BESS energy (MWh)	-
Opex	200.000 €	PV tariff	47,98 €/MWh	BESS tariff (€/MWh)	-
Taxes	22 %				
Inflation	2 %	Interest rate	5,00 %		
Initial asset value	19.200.000 €	Discount rate	6,45 %		
Salvage value	2.880.000 €	LCOE	53,68 €/MWh		
Total depreciable cost	16.320.000 €	NPV	-4.494.869 €		
Annual depreciation	816.000 €	IRR	2,68 %		
Annual performance degradation	0,40 %	PP	16,37 years		
Total energy injected into grid	44.806 MWh	ROI	-19,56 %		

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	2.149.792	12.000.000	0	0		0	-24.000.000	0	0	-12.000.000	-12.000.000	-12.000.000	-12.000.000
1	2.149.792		1.200.000	600.000	200.000	816.000	1.949.792	533.792	117.434	32.358	-11.967.642	30.397	-11.969.603
2	2.141.193		1.200.000	540.000	204.000	816.000	1.937.193	581.193	127.862	69.330	-11.898.312	61.183	-11.908.420
3	2.132.628		1.200.000	480.000	208.080	816.000	1.924.548	628.548	138.281	106.267	-11.792.045	88.097	-11.820.322
4	2.124.097		1.200.000	420.000	212.242	816.000	1.911.856	675.856	148.688	143.168	-11.648.877	111.497	-11.708.826
5	2.115.601		1.200.000	360.000	216.486	816.000	1.899.115	723.115	159.085	180.029	-11.468.848	131.709	-11.577.117
6	2.107.139		1.200.000	300.000	220.816	816.000	1.886.322	770.322	169.471	216.852	-11.251.996	149.035	-11.428.082
7	2.098.710		1.200.000	240.000	225.232	816.000	1.873.478	817.478	179.845	253.633	-10.998.364	163.751	-11.264.330
8	2.090.315		1.200.000	180.000	229.737	816.000	1.860.578	864.578	190.207	290.371	-10.707.993	176.112	-11.088.219
9	2.081.954		1.200.000	120.000	234.332	816.000	1.847.622	911.622	200.557	327.065	-10.380.927	186.347	-10.901.871
10	2.073.626		1.200.000	60.000	239.019	816.000	1.834.608	958.608	210.894	363.714	-10.017.213	194.672	-10.707.199
11	2.065.332				243.799	816.000	1.821.533	1.005.533	221.217	1.600.316	-8.416.898	804.643	-9.902.556
12	2.057.070				248.675	816.000	1.808.395	992.395	218.327	1.590.068	-6.826.829	751.048	-9.151.508
13	2.048.842				253.648	816.000	1.795.194	979.194	215.423	1.579.771	-5.247.058	700.972	-8.450.536
14	2.040.647				258.721	816.000	1.781.925	965.925	212.504	1.569.422	-3.677.637	654.185	-7.796.352
15	2.032.484				263.896	816.000	1.768.588	952.588	209.569	1.559.019	-2.118.618	610.473	-7.185.879
16	2.024.354				269.174	816.000	1.755.180	939.180	206.620	1.548.561	-570.057	569.636	-6.616.242
17	2.016.257				274.557	816.000	1.741.700	925.700	203.654	1.538.046	967.989	531.487	-6.084.755
18	2.008.192				280.048	816.000	1.728.143	912.143	200.672	1.527.472	2.495.461	495.851	-5.588.904
19	2.000.159				285.649	816.000	1.714.510	898.510	197.672	1.516.838	4.012.298	462.564	-5.126.341
20	1.992.158				291.362	816.000	1.700.796	884.796	194.655	1.506.141	5.518.439	431.472	-4.694.869
Total	43.550.342	12.000.000	12.000.000	3.300.000	4.859.474	16.320.000		16.921.076	3.722.637	17.518.439		-4.694.869	

Table 20: Financial analysis of sensitivity on investment proposal 1 – Power Setpoint = 16 MW € (40%) (Baseline)

Investment Proposal 2 - Setpoint 40% (16 MW)

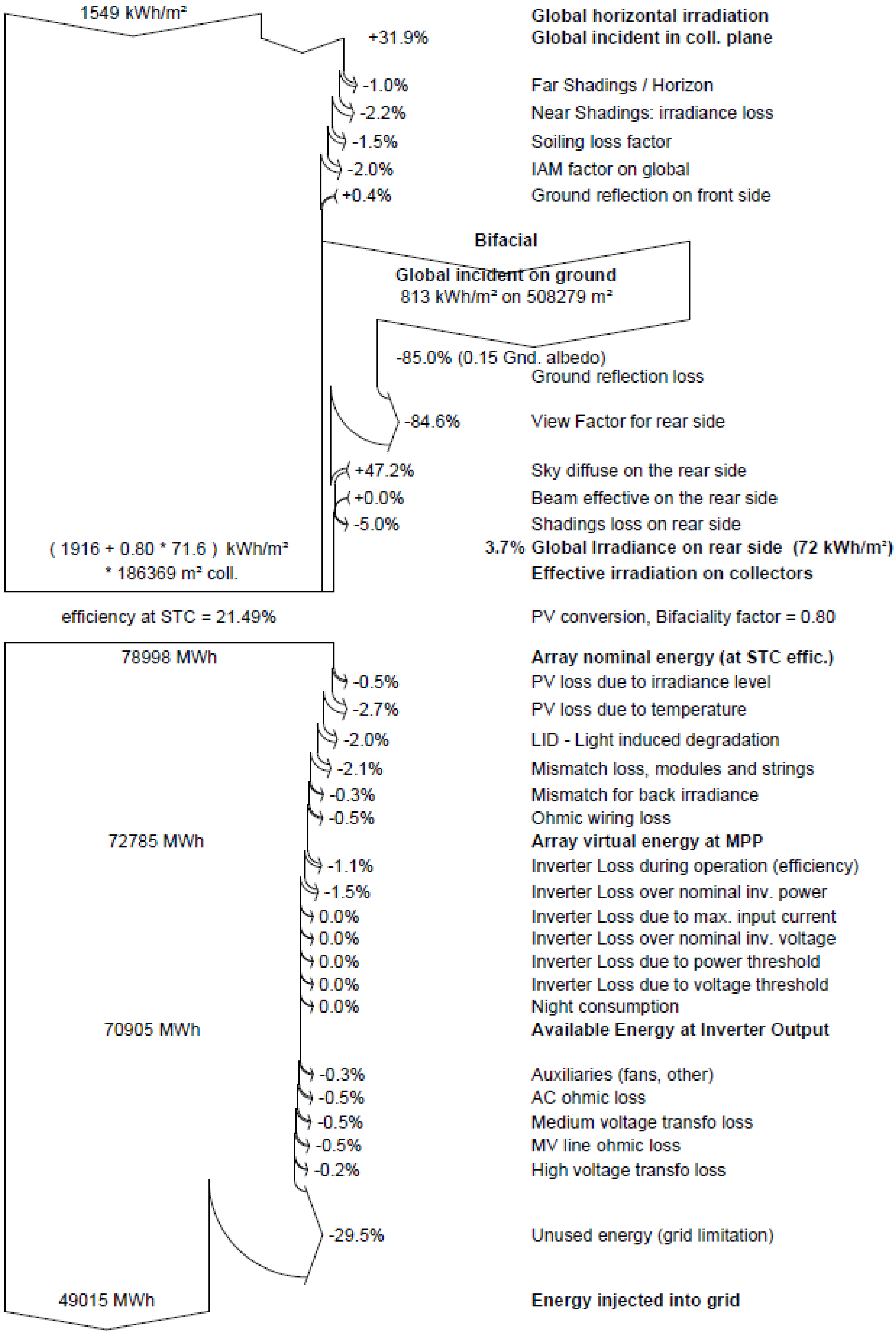


Figure 44: Sensitivity analysis on investment proposal 2 estimated energy yield – Power Setpoint = 16 MW € (40%) (Baseline)

Capex Opex Taxes	28.000.000 € 250.000 € 22 %	PV energy PV tariff	49.015 MWh 47,98 €/MWh	BESS energy (MWh) BESS tariff (€/MWh)	- -
Inflation	2 %	Interest rate		5,00 %	
Initial asset value	22.400.000 €	Discount rate		6,45 %	
Salvage value	3.360.000 €	LCOE		57,66 €/MWh	
Total depreciable cost	19.040.000 €	NPV		-6.954.733 €	
Annual depreciation	952.000 €	IRR		1,60 %	
Annual performance degradation	0,40 %	PP		17,69 years	
Total energy injected into grid	49.015 MWh	ROI		-24,84 %	

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	2.351.740	14.000.000	0	0		0	-28.000.000	0	0	-14.000.000	-14.000.000	-14.000.000	-14.000.000
1	2.351.740		1.400.000	700.000	250.000	952.000	2.101.740	449.740	98.943	-97.203	-14.097.203	-91.313	-14.091.313
2	2.342.333		1.400.000	630.000	255.000	952.000	2.087.333	505.333	111.173	-53.840	-14.151.043	-47.514	-14.138.827
3	2.332.963		1.400.000	560.000	260.100	952.000	2.072.863	560.863	123.390	-10.527	-14.161.570	-8.727	-14.147.554
4	2.323.632		1.400.000	490.000	265.302	952.000	2.058.330	616.330	135.593	32.737	-14.128.833	25.495	-14.122.058
5	2.314.337		1.400.000	420.000	270.608	952.000	2.043.729	671.729	147.780	75.949	-14.052.884	55.564	-14.066.495
6	2.305.080		1.400.000	350.000	276.020	952.000	2.029.059	727.059	159.953	119.106	-13.933.778	81.858	-13.984.637
7	2.295.859		1.400.000	280.000	281.541	952.000	2.014.319	782.319	172.110	162.209	-13.771.569	104.726	-13.879.911
8	2.286.676		1.400.000	210.000	287.171	952.000	1.999.505	837.505	184.251	205.254	-13.566.316	124.487	-13.755.423
9	2.277.529		1.400.000	140.000	292.915	952.000	1.984.614	892.614	196.375	248.239	-13.318.077	141.436	-13.613.988
10	2.268.419		1.400.000	70.000	298.773	952.000	1.969.646	947.646	208.482	291.164	-13.026.913	155.841	-13.458.147
11	2.259.345				304.749	952.000	1.954.597	1.002.597	220.571	1.734.026	-11.292.887	871.873	-12.586.274
12	2.250.308				310.844	952.000	1.939.464	987.464	217.242	1.722.222	-9.570.665	813.469	-11.772.805
13	2.241.307				317.060	952.000	1.924.246	972.246	213.894	1.710.352	-7.860.313	758.913	-11.013.892
14	2.232.342				323.402	952.000	1.908.940	956.940	210.527	1.698.413	-6.161.900	707.952	-10.305.939
15	2.223.412				329.870	952.000	1.893.543	941.543	207.139	1.686.403	-4.475.496	660.353	-9.645.586
16	2.214.519				336.467	952.000	1.878.051	926.051	203.731	1.674.320	-2.801.176	615.897	-9.029.689
17	2.205.660				343.196	952.000	1.862.464	910.464	200.302	1.662.162	-1.139.014	574.377	-8.455.312
18	2.196.838				350.060	952.000	1.846.778	894.778	196.851	1.649.926	510.912	535.603	-7.919.710
19	2.188.051				357.062	952.000	1.830.989	878.989	193.378	1.637.611	2.148.523	499.394	-7.420.316
20	2.179.298				364.203	952.000	1.815.096	863.096	189.881	1.625.214	3.773.738	465.583	-6.954.733
Total	47.641.387	14.000.000	14.000.000	3.850.000	6.074.342	19.040.000		16.325.305	3.591.567	17.773.738		-6.954.733	

Table 21: Financial analysis of sensitivity on investment proposal 2 – Power Setpoint = 16 MW € (40%) (Baseline)

Investment Proposal 3 - Setpoint 40% (16 MW)

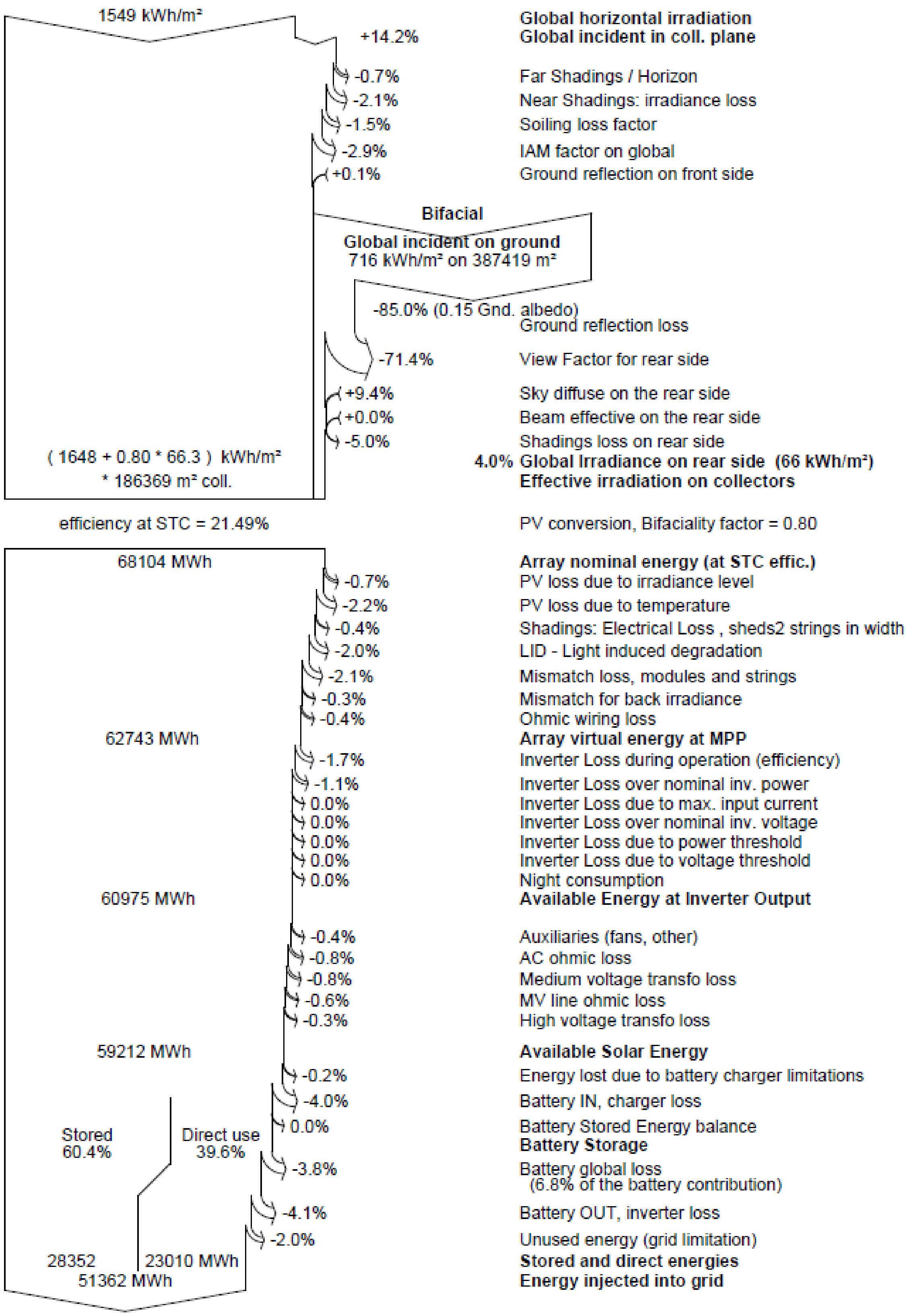


Figure 45: Sensitivity analysis on investment proposal 3 estimated energy yield – Power Setpoint = 16 MW € (40%) (Baseline)

Capex	37.000.000 €	PV energy	23.010 MWh	BESS energy	28.352 MWh
Opex	400.000 €	PV tariff	47,98 €/MWh	BESS tariff	116,82 €/MWh
Taxes	22%				
Inflation	2%	Interest rate	5,00 %		
Initial asset value	29.600.000 €	Discount rate	6,45 %		
Salvage value	4.440.000 €	LCOE	74,34 €/MWh		
Total depreciable cost	25.160.000 €	NPV	1.068.400 €		
Annual depreciation	1.258.000 €	IRR	6,99 %		
Annual performance degradation	0,40%	PP	12,44 years		
Total energy injected into grid	51.362 MWh	ROI	2,89 %		

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	4.416.100	18.500.000	0	0		0	-37.000.000	0	0	-18.500.000	-18.500.000	-18.500.000	-18.500.000
1	4.416.100		1.850.000	925.000	400.000	1.258.000	4.016.100	1.833.100	403.282	837.818	-17.662.182	787.053	-17.712.947
2	4.398.436		1.850.000	832.500	408.000	1.258.000	3.990.436	1.899.936	417.986	889.950	-16.772.232	785.370	-16.927.577
3	4.380.842		1.850.000	740.000	416.160	1.258.000	3.964.682	1.966.682	432.670	942.012	-15.830.219	780.943	-16.146.633
4	4.363.319		1.850.000	647.500	424.483	1.258.000	3.938.836	2.033.336	447.334	994.002	-14.836.217	774.113	-15.372.520
5	4.345.866		1.850.000	555.000	432.973	1.258.000	3.912.893	2.099.893	461.976	1.045.916	-13.790.301	765.189	-14.607.331
6	4.328.482		1.850.000	462.500	441.632	1.258.000	3.886.850	2.166.350	476.597	1.097.753	-12.692.548	754.450	-13.852.881
7	4.311.168		1.850.000	370.000	450.465	1.258.000	3.860.703	2.232.703	491.195	1.149.509	-11.543.040	742.151	-13.110.729
8	4.293.924		1.850.000	277.500	459.474	1.258.000	3.834.449	2.298.949	505.769	1.201.180	-10.341.859	728.522	-12.382.207
9	4.276.748		1.850.000	185.000	468.664	1.258.000	3.808.084	2.365.084	520.319	1.252.766	-9.089.094	713.771	-11.668.436
10	4.259.641		1.850.000	92.500	478.037	1.258.000	3.781.604	2.431.104	534.843	1.304.261	-7.784.833	698.084	-10.970.352
11	4.242.602				487.598	1.258.000	3.755.005	2.497.005	549.341	3.205.664	-4.579.169	1.611.817	-9.358.535
12	4.225.632				497.350	1.258.000	3.728.282	2.470.282	543.462	3.184.820	-1.394.349	1.504.309	-7.854.227
13	4.208.729				507.297	1.258.000	3.701.433	2.443.433	537.555	3.163.877	1.769.529	1.403.867	-6.450.360
14	4.191.894				517.443	1.258.000	3.674.452	2.416.452	531.619	3.142.832	4.912.361	1.310.032	-5.140.328
15	4.175.127				527.792	1.258.000	3.647.335	2.389.335	525.654	3.121.682	8.034.043	1.222.373	-3.917.955
16	4.158.426				538.347	1.258.000	3.620.079	2.362.079	519.657	3.100.422	11.134.464	1.140.486	-2.777.468
17	4.141.793				549.114	1.258.000	3.592.678	2.334.678	513.629	3.079.049	14.213.513	1.063.997	-1.713.472
18	4.125.226				560.097	1.258.000	3.565.129	2.307.129	507.568	3.057.561	17.271.074	992.552	-720.920
19	4.108.725				571.298	1.258.000	3.537.426	2.279.426	501.474	3.035.952	20.307.026	925.822	204.901
20	4.092.290				582.724	1.258.000	3.509.565	2.251.565	495.344	3.014.221	23.321.247	863.499	1.068.400
Total	89.461.071	18.500.000	18.500.000	5.087.500	9.718.948	25.160.000		45.078.522	9.917.275	41.821.247		1.068.400	

Table 22: Financial analysis of sensitivity on investment proposal 3 – Power Setpoint = 16 MW € (40%) (Baseline)

Investment Proposal 4 - Setpoint 40% (16 MW)

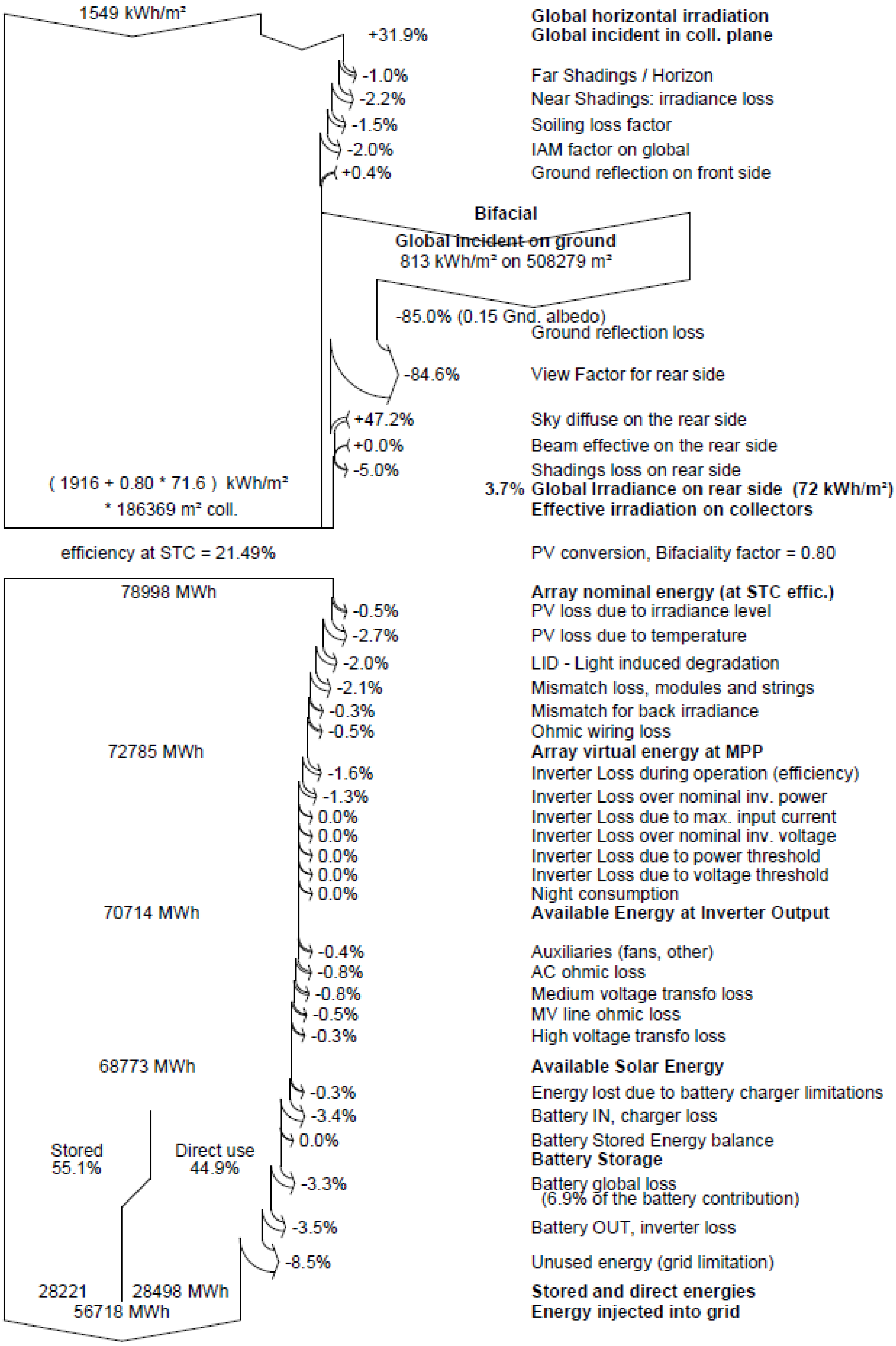


Figure 46: Sensitivity analysis on investment proposal 4 estimated energy yield – Power Setpoint = 16 MW € (40%) (Baseline)

Capex	41.000.000 €	PV energy	28.498 MWh	BESS energy	28.221 MWh
Opex	450.000 €	PV tariff	47,98 €/MWh	BESS tariff	116,82 €/MWh
Taxes	22 %				
Inflation	2 %	Interest rate		5,00 %	
Initial asset value	32.800.000 €	Discount rate		6,45 %	
Salvage value	4.920.000 €	LCOE		74,74 €/MWh	
Total depreciable cost	27.880.000 €	NPV		-805.636 €	
Annual depreciation	1.394.500 €	IRR		6,08 %	
Annual performance degradation	0,40 %	PP		13,12 years	
Total energy injected into grid	56.718 MWh	ROI		-1,96 %	

Year	Electricity sale (€)	Own funds (€)	Loan principal (€)	Loan interest (€)	Run costs (€)	Deprec. Allow. (€)	EBITDA (€)	Taxable income (€)	Taxes (€)	After-tax profit (€)	Cumul. Profit (€)	Discounted Taxable Income (€)	Discounted Cumul. Profit (€)
0	4.664.111	20.500.000	0	0		0	-41.000.000	0	0	-20.500.000	-20.500.000	-20.500.000	-20.500.000
1	4.664.111		2.050.000	1.025.000	450.000	1.394.000	4.214.111	1.795.111	394.924	744.187	-19.755.813	699.095	-19.800.905
2	4.645.455		2.050.000	922.500	459.000	1.394.000	4.186.455	1.869.955	411.390	802.565	-18.953.248	708.254	-19.092.651
3	4.626.873		2.050.000	820.000	468.180	1.394.000	4.158.693	1.944.693	427.832	860.861	-18.092.388	713.667	-18.378.984
4	4.608.366		2.050.000	717.500	477.544	1.394.000	4.130.822	2.019.322	444.251	919.071	-17.173.317	715.758	-17.663.226
5	4.589.932		2.050.000	615.000	487.094	1.394.000	4.102.838	2.093.838	460.644	977.193	-16.196.124	714.911	-16.948.314
6	4.571.572		2.050.000	512.500	496.836	1.394.000	4.074.736	2.168.236	477.012	1.035.224	-15.160.899	711.476	-16.236.838
7	4.553.286		2.050.000	410.000	506.773	1.394.000	4.046.513	2.242.513	493.353	1.093.160	-14.067.739	705.771	-15.531.067
8	4.535.073		2.050.000	307.500	516.909	1.394.000	4.018.164	2.316.664	509.666	1.150.998	-12.916.741	698.087	-14.832.980
9	4.516.933		2.050.000	205.000	527.247	1.394.000	3.989.686	2.390.686	525.951	1.208.735	-11.708.006	688.684	-14.144.296
10	4.498.865		2.050.000	102.500	537.792	1.394.000	3.961.073	2.464.573	542.206	1.266.367	-10.441.639	677.802	-13.466.494
11	4.480.869				548.547	1.394.000	3.932.322	2.538.322	558.431	3.373.891	-7.067.748	1.696.402	-11.770.092
12	4.462.946				559.518	1.394.000	3.903.427	2.509.427	552.074	3.351.353	-3.716.395	1.582.968	-10.187.124
13	4.445.094				570.709	1.394.000	3.874.385	2.480.385	545.685	3.328.701	-387.694	1.477.002	-8.710.122
14	4.427.314				582.123	1.394.000	3.845.191	2.451.191	539.262	3.305.929	2.918.235	1.378.016	-7.332.106
15	4.409.605				593.765	1.394.000	3.815.839	2.421.839	532.805	3.283.034	6.201.269	1.285.554	-6.046.551
16	4.391.966				605.641	1.394.000	3.786.325	2.392.325	526.312	3.260.014	9.461.283	1.199.192	-4.847.359
17	4.374.398				617.754	1.394.000	3.756.645	2.362.645	519.782	3.236.863	12.698.146	1.118.531	-3.728.828
18	4.356.901				630.109	1.394.000	3.726.792	2.332.792	513.214	3.213.578	15.911.724	1.043.198	-2.685.630
19	4.339.473				642.711	1.394.000	3.696.762	2.302.762	506.608	3.190.155	19.101.878	972.846	-1.712.784
20	4.322.115				655.565	1.394.000	3.666.550	2.272.550	499.961	3.166.589	22.268.467	907.149	-805.636
Total	94.485.257	20.500.000	20.500.000	5.637.500	10.933.816	27.880.000		45.369.830	9.981.363	42.768.467		-805.636	

Table 23: Financial analysis of sensitivity on investment proposal 4 – Power Setpoint = 16 MW € (40%) (Baseline)

The abovementioned sensitivity analysis is summarized in the tables below:

PV Tariff = 46 €/MWh (Low) & BESS Tariff = 116,82 €/MWh			
No Setpoint (40 MW)	IRR	NPV	Ranking
Investment Proposal 1	6,85 %	522.633 €	1
Investment Proposal 2	6,25 %	-306.676 €	4
Investment Proposal 3	6,68 %	453.817 €	2
Investment Proposal 4	6,41 %	-81.793 €	3

Table 24: Sensitivity analysis on IRR and on NPV of all investment proposals – PV tariff = 46 €/MWh (Low)

PV Tariff = 53,90 €/MWh (High) & BESS Tariff = 116,82 €/MWh			
No Setpoint (40 MW)	IRR	NPV	Ranking
Investment Proposal 1	9,86 %	4.511.164 €	1
Investment Proposal 2	9,20 %	4.218.039 €	2
Investment Proposal 3	7,48 %	2.058.070 €	4
Investment Proposal 4	7,43 %	2.163.194 €	3

Table 25: Sensitivity analysis on IRR and on NPV of all investment proposals – PV tariff = 53,90 €/MWh (High)

PV Tariff = 47,98 €/MWh (Baseline) & BESS Tariff = 116,82 €/MWh			
40% Setpoint (16 MW)	IRR	NPV	Ranking
Investment Proposal 1	2,68 %	-4.694.869 €	3
Investment Proposal 2	1,60 %	-6.954.733 €	4
Investment Proposal 3	6,99 %	1.068.400 €	1
Investment Proposal 4	6,08 %	-805.636 €	2

Table 26: Sensitivity analysis on IRR and on NPV of all investment proposals – 40% Setpoint (16 MW) (Baseline)

7. Conclusions

For the implementation of any business investment, the preparation of a business plan is necessary. It is the only study that presents the business investment in its entirety, therefore it must be realistic, feasible, complete, and understandable. The importance of a correct and complete business plan is crucial because the final decision of a company is often based on it.

In terms of profitability, Investment Proposal 1 (PV project with fixed structures) and Investment Proposal 3 (PV project with fixed structures in combination with BESS) are the best choices, since these investments offer the highest NPV in most cases. Considering the latest challenges of energy curtailments, if an investor wants to mitigate risks on the expected income due to energy curtailments, then it is crucial to combine a BESS with the PV project. On the one hand, if energy curtailment increases it seems that PV projects without BESS may become even unprofitable. On the other hand, PV projects combined with BESS could become even more profitable by participating in more energy markets (i.e. balancing market, etc.). Nevertheless, overcontribution of the BESS means a reduction in the lifespan of the battery equipment and it is a major factor that should be also examined.

Investments in PV power plants in Greece face a substantial number of problems (e.g. bureaucracy, inadequate transmission network, negative prices in the electricity market). The major risk on PV market now is energy curtailments, both the duration and the size of these cuts remain uncertain. This phenomenon will be temporary until other solutions and incentives (such as the installation of storage units) are introduced to the market. Our country has begun to move in the direction of smoothing out the problem by passing the Law 5261/2025 and by announcing the first tender that will concern PV projects combined with storage.

A critical question that arises from the analysis and from the creation of the new market in electricity storage is whether the tariff should be increased to cover the additional cost of installing a battery. To answer this question, let's look at the critical details of the Law 5261/2025 and the recent tender that took place on the 19th of March 2026.

In case a BESS that charges only from the PV system is installed, a permanent setpoint of the maximum production power of the station of forty percent (40%) is applied in relation to the installed power of the PV during the hours from 7:00 to 19:00 of each allocation day. This means that any energy injected into the grid directly from the PV continues to be compensated with the operational support, while the energy stored in the battery (presumably at noon) and injected later in the evening hours is sold at stock exchange prices (which are significantly higher).

The general idea is that a new landscape is being created in the RES market for investors, requiring much more study and of course the assumption of much greater risk. On the other hand, there are still opportunities and estimates that the market will continue to grow in the coming years, but with different data and conditions. The entry of energy storage is now changing the data and requires careful decisions, planning and choices daily by participants in the RES market. New investments now face a significant risk, as the current period is a transitional one for Greece. We are going from a system where demand and price were guaranteed to a system where neither demand nor price will be guaranteed.

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Appendix A: "Baseline Analysis Scenarios"

<u>Investment Proposal 1:</u>

PVsyst V8.1.0
VCH, Simulation date:
03/05/26 00:11
with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures

Nikos Vasilopoulos

Project summary

Geographical Site		**Situation**		**Project settings**	
Láva		Latitude	40.1114 °(N)	Albedo	0.15
Greece		Longitude	22.0409 °(E)		
		Altitude	790 m		
		Time zone	UTC+2		
Weather data					
Láva					
SolarGIS - Synthetic					

System summary

Grid-Connected System		**Unlimited sheds**			
Orientation #1		**Near Shadings**		**User's needs**	
Sheds		Mutual shadings of sheds		Unlimited load (grid)	
Tilt	25 °	Electrical effect			
Azimuth	0 °				

System information

PV Array		**Inverters**	
Nb. of modules	66672 units	Nb. of units	102.7 units
Pnom total	40.00 MWp	Total power	30800 kWac
		Pnom ratio	1.30

Results summary

Simulation step	Hourly				
Produced Energy	60276 MWh/year	Specific production	1507 kWh/kWp/year	Perf. Ratio PR	85.22 %
				Bifacial perf. ratio	82.61 %

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures

Nikos Vasilopoulos

PVsyst V8.1.0
VCH, Simulation date:
03/05/26 00:11
with V8.1.0

General parameters

Grid-Connected System | **Unlimited sheds**

Simulation step
Hourly

Orientation #1

Sheds		Sheds configuration		Sizes	
Tilt	25 °	Nb. of sheds	400 units	Sheds spacing	9.50 m
Azimuth	0 °	Unlimited sheds		Sensitive width	4.53 m
		Shading limit angle		GCR Shading	47.9 %
		Limit profile angle	19.7 °	Top inactive band	0.02 m
		Shadings electrical effect		Bottom inactive band	0.02 m
		Cell size	15.6 cm		
		Strings in width	2 units		

Models used		Horizon		Near Shadings
Transposition	Perez	Average Height	2.1 °	Mutual shadings of sheds
Diffuse	Perez, Meteonorm			Electrical effect
Circumsolar	with diffuse			

Bifacial system definition
Orientation #1
Bifacial system

Model	Unlimited Sheds 2D Model
Bifacial model geometry	
Sheds spacing	9.50 m
Sheds width	4.57 m
Limit profile angle	19.7 °
GCR Bifacial	48.1 %
Height above ground	1.00 m
Nb. of sheds	400 units
Bifacial model definitions	
Ground albedo	0.15
Bifaciality factor	80 %
Rear shading factor	5.0 %
Rear mismatch loss	10.0 %
Shed transparent fraction	0.0 %

User's needs
Unlimited load (grid)

PV Array Characteristics

PV module		Inverter	
Manufacturer	Jinkosolar	Manufacturer	Huawei Technologies
Model	JKM-600N-78HL4-BDV	Model	SUN2000-300KTL-H0
(Original PVsyst database)		(Original PVsyst database)	
Unit Nom. Power	600 Wp	Unit Nom. Power	300 kWac
Number of PV modules	66672 units	Number of inverters	616 * MPPT 17% 102.7 units
Nominal (STC)	40.00 MWp	Total power	30800 kWac
Modules	2778 string x 24 In series	Operating voltage	550-1500 V
At operating cond. (50°C)		Max. power (=>30°C)	330 kWac
Pmpp	37.03 MWp	Pnom ratio (DC:AC)	1.30
U mpp	1009 V	No power sharing between MPPTs	
I mpp	36696 A		

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PV Array Characteristics

Total PV power		**Total inverter power**	
Nominal (STC)	40003 kWp	Total power	30800 kWac
Total	66672 modules	Nb. of inverters	103 units
Module area	186369 m²		0.3 unused
Cell area	172259 m²	Pnom ratio	1.30

Array losses

Array Soiling Losses
Loss Fraction 1.5 %

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. 0.21 mΩ
Loss Fraction 0.70 % at STC

LID - Light Induced Degradation
Loss Fraction 2.00 %

Module Quality Loss
Loss Fraction 0.00 %

Module mismatch losses
Loss Fraction 0.60 % at MPP

Strings Mismatch loss
Loss Fraction 0.10 %

IAM loss factor
ASHRAE Param.: IAM = 1 - bo (1/cosi -1)
bo Param. 0.05

System losses

Auxiliary losses
Proportional to Power 4.0 W/kW
0.0 kW from Power thresh.

AC wiring losses

Inv. output line up to MV transfo

Inverter voltage	800 Vac tri
Loss Fraction	0.70 % at STC
Global System	
Wire section	Alu 3 x 30000 mm²
Wires length	108 m

MV line up to HV Transfo

MV Voltage	33 kV
Average each transformer	
Wires	Alu 3 x 1000 mm²
Length	43710 m
Loss Fraction	1.00 % at STC

AC losses in transformers

MV transfo

Medium voltage	33 kV		
One transfo parameters		**Operating losses at STC (full system)**	
Nominal power at STC	7.92 MVA	Nb. identical MV transfos	5
Iron Loss (night disconnect)	7.95 kVA	Nominal power at STC	39.59 MVA
Iron loss fraction	0.10 % at STC	Iron loss (night disconnect)	39.73 kVA
Copper loss	79.17 kVA	Copper loss	395.86 kVA
Copper loss fraction	1.00 % at STC		
Coils equivalent resistance	3 x 0.81 mΩ		

AC losses in transformers

HV transfo

Grid voltage	150 kV
Transformer from Datasheets	
Nominal power	50000 kVA
Iron Loss (night disconnect)	23.80 kVA
Iron loss fraction	0.05 % of PNom
Copper loss	184.20 kVA
Copper loss fraction	0.37 % at PNom
Coils equivalent resistance	3 x 80.24 mΩ

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures

PVsyst V8.1.0
VCH, Simulation date:
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with V8.1.0

Nikos Vasilopoulos

Horizon definition

Horizon from PVGIS website API, Lat=-13°39'59", Long=167°42'41", Alt=24m

Average Height	2.1 °	Albedo Factor	0.94
Diffuse Factor	0.99	Albedo Fraction	100 %

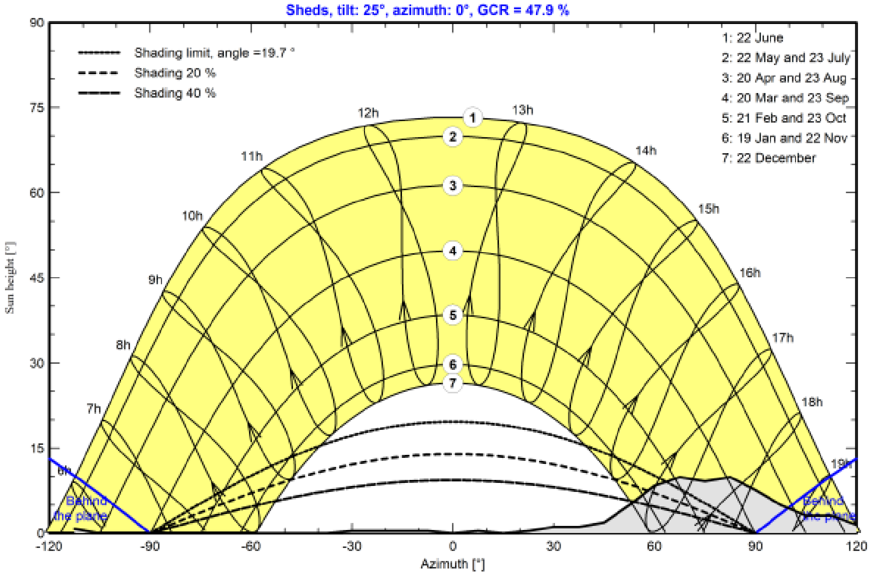
Horizon profile

Azimuth [°]	-113	-105	-38	-30	-8	0	8	15	23	30	38	45	53	60
Height [°]	0.8	0.0	0.0	0.4	0.4	0.0	0.4	0.0	0.4	1.1	1.1	1.9	5.0	8.4
Azimuth [°]	68	75	83	90	98	105	113	120	128	135	143	158	165	
Height [°]	9.9	9.2	9.9	7.6	5.0	3.1	3.1	1.5	1.1	1.5	1.1	1.1	0.8	

Sun Paths (Height / Azimuth diagram)

Orientation #1

Sheds, tilt: 25°, azimuth: 0°, GCR = 47.9 %



Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures

Nikos Vasilopoulos

PVsyst V8.1.0
VCH, Simulation date:
03/05/26 00:11
with V8.1.0

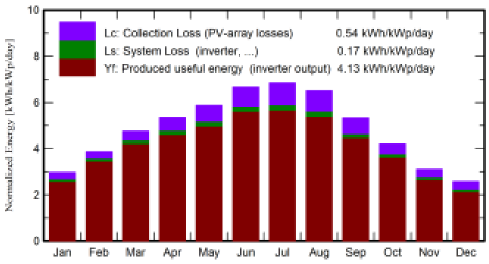
Main results

Simulation step
Hourly

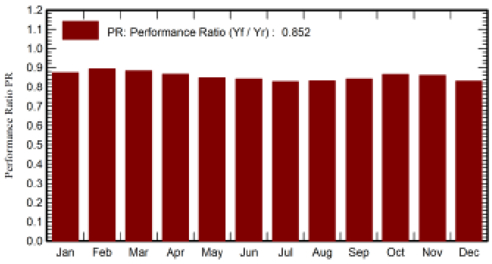
System Production

Produced Energy	60276 MWh/year	Specific production	1507 kWh/kWp/year
		Perf. Ratio PR	85.22 %
		Bifacial perf. ratio	82.61 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio	PRBifi ratio
January	59.3	25.40	2.10	92.3	84.9	3358	3223	0.873	0.854
February	77.4	31.50	3.60	108.4	101.2	4033	3874	0.893	0.870
March	120.6	47.70	6.50	147.8	138.3	5432	5223	0.883	0.859
April	147.2	64.50	10.90	160.4	149.8	5783	5555	0.866	0.839
May	182.5	77.90	16.10	182.2	169.9	6440	6181	0.848	0.818
June	205.2	77.00	20.70	199.9	186.8	7012	6731	0.842	0.810
July	216.4	75.30	23.40	212.3	198.7	7324	7033	0.828	0.798
August	190.3	71.30	23.00	201.3	188.7	6970	6698	0.832	0.805
September	137.7	54.60	18.30	159.8	149.7	5601	5378	0.841	0.818
October	99.7	40.10	13.10	130.5	121.7	4703	4517	0.865	0.842
November	62.9	27.90	8.00	93.1	85.5	3342	3205	0.861	0.840
December	49.6	22.50	3.50	80.1	72.6	2783	2661	0.830	0.814
Year	1548.8	615.70	12.48	1768.1	1647.7	62781	60276	0.852	0.826

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane	PRBifi	Bifacial Performance Ratio
GlobEff	Effective Global, corr. for IAM and shadings		

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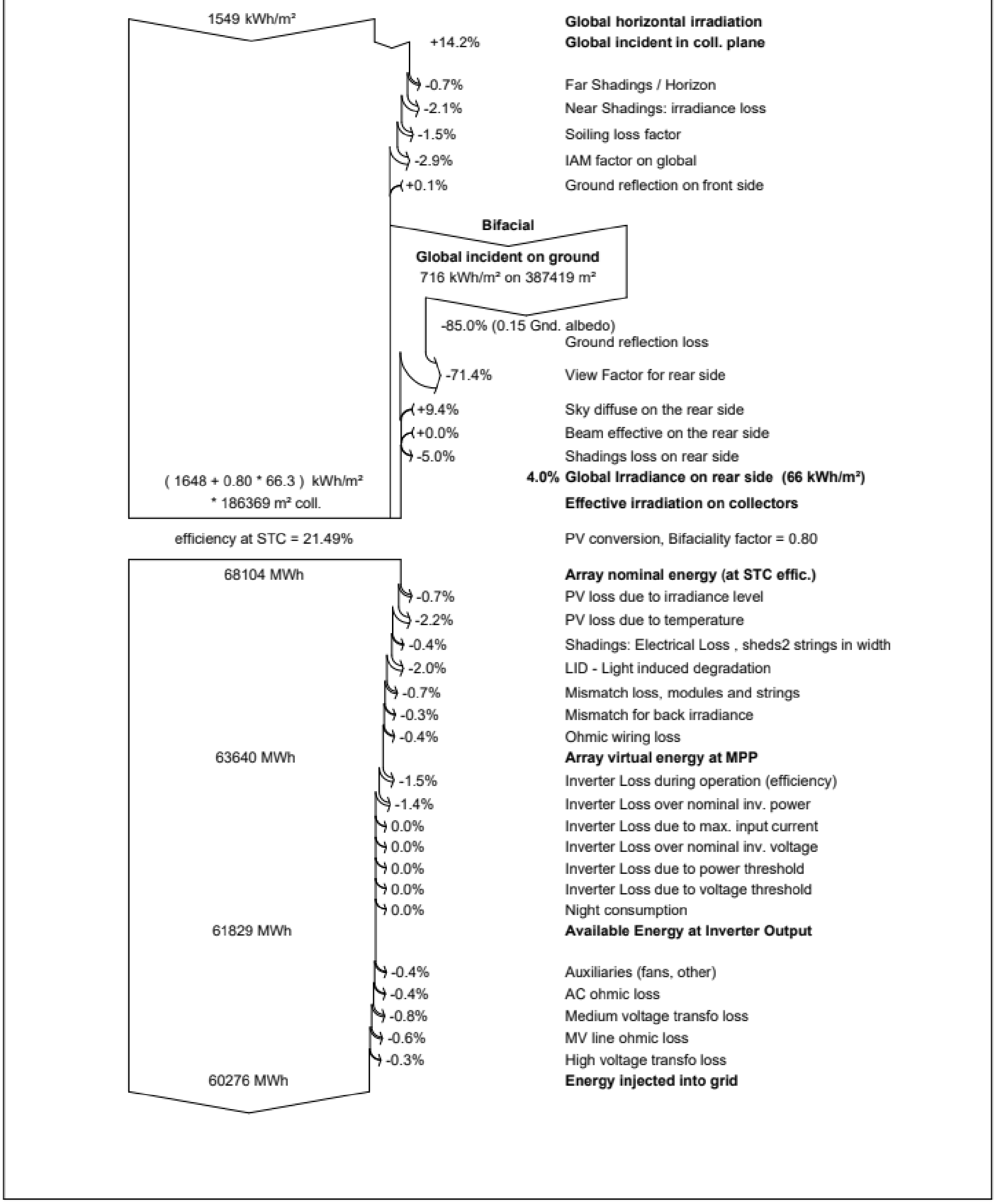
Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures

PVsyst V8.1.0
VCH, Simulation date:
03/05/26 00:11
with V8.1.0

Nikos Vasilopoulos

Loss diagram



Investment Proposal 2

PVsyst V8.1.0
VEP, Simulation date:
03/05/26 00:15
with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures

Nikos Vasilopoulos

Project summary

Geographical Site
Láva
Greece

Situation

Latitude	40.1114 °(N)
Longitude	22.0409 °(E)
Altitude	790 m
Time zone	UTC+2

Project settings
Albedo 0.15

Weather data
Láva
SolarGIS - Synthetic

System summary

Grid-Connected System

Unlimited Trackers with backtracking

Orientation #1
Tracking horizontal axis
Axis azimuth 0 °
Phi min / max. -/+ 60 °
Tracking algorithm
Astronomic calculation
Backtracking activated

Near Shadings
no Shadings

User's needs
Unlimited load (grid)

System information

PV Array		**Inverters**	
Nb. of modules	66672 units	Nb. of units	102.7 units
Pnom total	40.00 MWp	Total power	30800 kWac
		Pnom ratio	1.30

Results summary

Simulation step	Hourly				
Produced Energy	68379 MWh/year	Specific production	1709 kWh/kWp/year	Perf. Ratio PR	83.70 %
				Bifacial perf. ratio	81.30 %

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures

PVsyst V8.1.0
VEP, Simulation date:
03/05/26 00:15
with V8.1.0

Nikos Vasilopoulos

General parameters

Grid-Connected System — **Unlimited Trackers with backtracking**

Simulation step
Hourly

Orientation #1

Tracking horizontal axis

Axis azimuth	0 °
Phi min / max.	-/+ 60 °

Tracking algorithm
Astronomic calculation
Backtracking activated

Field properties

Nb. of trackers	999 units
Unlimited trackers	

Sizes

Tracker Spacing	6.60 m
Sensitive width	2.38 m
GCR Shading	36.4 %
Left inactive band	0.02 m
Right inactive band	0.02 m

Backtracking limit angle

Phi limits	+/- 68.5 °

Backtracking parameters

Backtracking pitch	6.60 m
Backtracking width	2.40 m
Left inactive band	0.02 m
Right inactive band	0.02 m
GCR Backtracking	36.4 %
Parameters choice	Automatic

Models used

Transposition	Perez
Diffuse	Perez, Meteonorm
Circumsolar	with diffuse

Horizon
Average Height 2.1 °

Near Shadings
no Shadings

User's needs
Unlimited load (grid)

Bifacial system definition

Orientation #1

Bifacial system

Model	Unlimited Trackers 2D model

Bifacial model geometry

Tracker Spacing	6.60 m
Tracker width	2.42 m
Axis height above ground	1.00 m
Nb. of sheds	999 units

Bifacial model definitions

Ground albedo	0.15
Bifaciality factor	80 %
Rear shading factor	5.0 %
Rear mismatch loss	10.0 %
Shed transparent fraction	0.0 %

PV Array Characteristics

PV module

Manufacturer	Jinkosolar
Model	JKM-600N-78HL4-BDV
(Original PVsyst database)	
Unit Nom. Power	600 Wp
Number of PV modules	66672 units
Nominal (STC)	40.00 MWp
Modules	2778 string x 24 In series

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures

PVsyst V8.1.0
VEP, Simulation date:
03/05/26 00:15
with V8.1.0

Nikos Vasilopoulos

PV Array Characteristics

PV module		**Inverter**	
At operating cond. (50°C)		Manufacturer	Huawei Technologies
Pmpp	37.03 MWp	Model	SUN2000-300KTL-H0
U mpp	1009 V	(Original PVsyst database)	
I mpp	36696 A	Unit Nom. Power	300 kWac
		Number of inverters	616 * MPPT 17% 102.7 units
		Total power	30800 kWac
		Operating voltage	550-1500 V
		Max. power (=>30°C)	330 kWac
		Pnom ratio (DC:AC)	1.30
		No power sharing between MPPTs	
Total PV power		**Total inverter power**	
Nominal (STC)	40003 kWp	Total power	30800 kWac
Total	66672 modules	Nb. of inverters	103 units
Module area	186369 m²		0.3 unused
Cell area	172259 m²	Pnom ratio	1.30

Array losses

Array Soiling Losses		**Thermal Loss factor**		**DC wiring losses**	
Loss Fraction	1.5 %	Module temperature according to irradiance		Global array res.	0.21 mΩ
		Uc (const)	29.0 W/m²K	Loss Fraction	0.70 % at STC
		Uv (wind)	0.0 W/m²K/m/s		
LID - Light Induced Degradation		**Module Quality Loss**		**Module mismatch losses**	
Loss Fraction	2.00 %	Loss Fraction	0.00 %	Loss Fraction	2.00 % at MPP
Strings Mismatch loss		**IAM loss factor**			
Loss Fraction	0.10 %	ASHRAE Param.: IAM = 1 - bo (1/cosi -1)			
		bo Param.	0.05		

System losses

Auxiliary losses

Proportional to Power	4.0 W/kW
0.0 kW from Power thresh.	

AC wiring losses

Inv. output line up to MV transfo	
Inverter voltage	800 Vac tri
Loss Fraction	1.50 % at STC
Global System	
Wire section	Alu 3 x 30000 mm²
Wires length	231 m
MV line up to HV Transfo	
MV Voltage	33 kV
Average each transformer	
Wires	Alu 3 x 1000 mm²
Length	65510 m
Loss Fraction	1.50 % at STC

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures

PVsyst V8.1.0
VEP, Simulation date:
03/05/26 00:15
with V8.1.0

Nikos Vasilopoulos

AC losses in transformers

MV transfo

Medium voltage	33 kV		
One transfo parameters		**Operating losses at STC (full system)**	
Nominal power at STC	7.92 MVA	Nb. identical MV transfos	5
Iron Loss (night disconnect)	7.95 kVA	Nominal power at STC	39.59 MVA
Iron loss fraction	0.10 % at STC	Iron loss (night disconnect)	39.73 kVA
Copper loss	79.17 kVA	Copper loss	395.86 kVA
Copper loss fraction	1.00 % at STC		
Coils equivalent resistance	3 x 0.81 mΩ		

HV transfo

Grid voltage	150 kV
Transformer from Datasheets	
Nominal power	50000 kVA
Iron Loss (night disconnect)	23.80 kVA
Iron loss fraction	0.05 % of PNom
Copper loss	184.20 kVA
Copper loss fraction	0.37 % at PNom
Coils equivalent resistance	3 x 80.24 mΩ

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PVsyst V8.1.0
VEP, Simulation date:
03/05/26 00:15
with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures

Nikos Vasilopoulos

Horizon definition

Horizon from PVGIS website API, Lat=-13°39'59", Long=167°42'41", Alt=24m

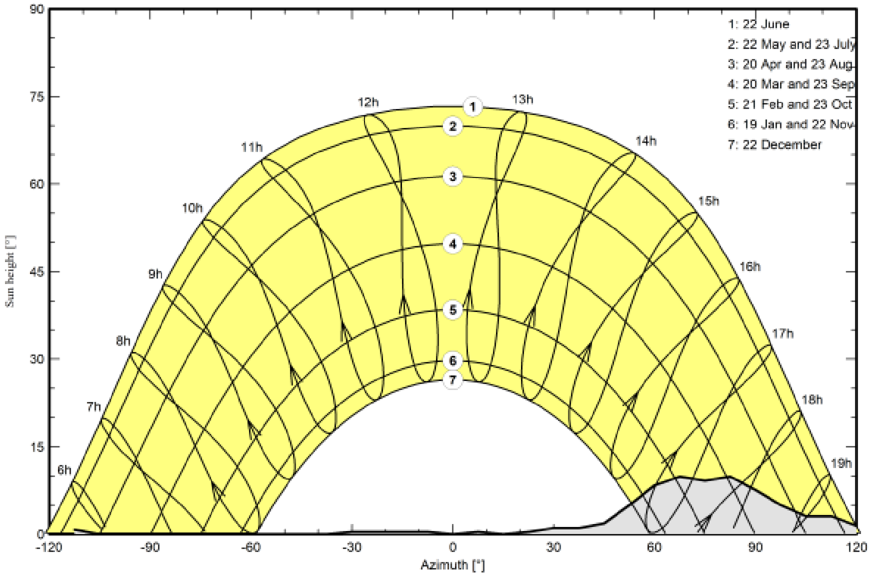
Average Height	2.1 °	Albedo Factor	0.00
Diffuse Factor	1.00	Albedo Fraction	100 %

Horizon profile

Azimuth [°]	-113	-105	-38	-30	-8	0	8	15	23	30	38	45	53	60
Height [°]	0.8	0.0	0.0	0.4	0.4	0.0	0.4	0.0	0.4	1.1	1.1	1.9	5.0	8.4
Azimuth [°]	68	75	83	90	98	105	113	120	128	135	143	158	165	
Height [°]	9.9	9.2	9.9	7.6	5.0	3.1	3.1	1.5	1.1	1.5	1.1	1.1	0.8	

Sun Paths (Height / Azimuth diagram)

Orientation #1



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PVsyst V8.1.0
VEP, Simulation date:
03/05/26 00:15
with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures

Nikos Vasilopoulos

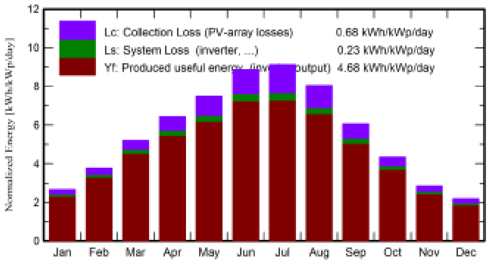
Main results

Simulation step
Hourly

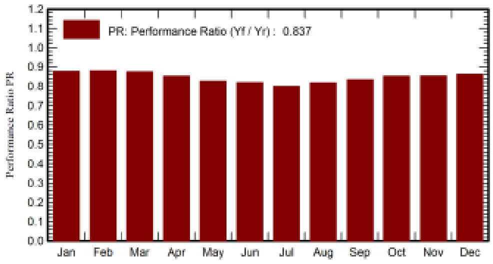
System Production

Produced Energy	68379 MWh/year	Specific production	1709 kWh/kWp/year
		Perf. Ratio PR	83.70 %
		Bifacial perf. ratio	81.30 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio	PRBifi ratio
January	59.3	25.40	2.10	82.2	75.1	3017	2884	0.877	0.850
February	77.4	31.50	3.60	105.3	97.3	3876	3706	0.880	0.854
March	120.6	47.70	6.50	161.1	150.2	5897	5635	0.875	0.849
April	147.2	64.50	10.90	192.7	181.2	6898	6577	0.853	0.828
May	182.5	77.90	16.10	232.1	219.4	8068	7682	0.827	0.802
June	205.2	77.00	20.70	265.9	252.4	9156	8716	0.820	0.797
July	216.4	75.30	23.40	282.7	268.9	9511	9051	0.800	0.779
August	190.3	71.30	23.00	249.6	236.1	8574	8173	0.819	0.796
September	137.7	54.60	18.30	181.9	170.7	6374	6073	0.835	0.811
October	99.7	40.10	13.10	135.0	125.0	4821	4602	0.852	0.828
November	62.9	27.90	8.00	86.0	78.0	3075	2935	0.854	0.828
December	49.6	22.50	3.50	67.8	61.4	2460	2342	0.863	0.836
Year	1548.8	615.70	12.48	2042.1	1915.5	71728	68379	0.837	0.813

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane	PRBifi	Bifacial Performance Ratio
GlobEff	Effective Global, corr. for IAM and shadings		

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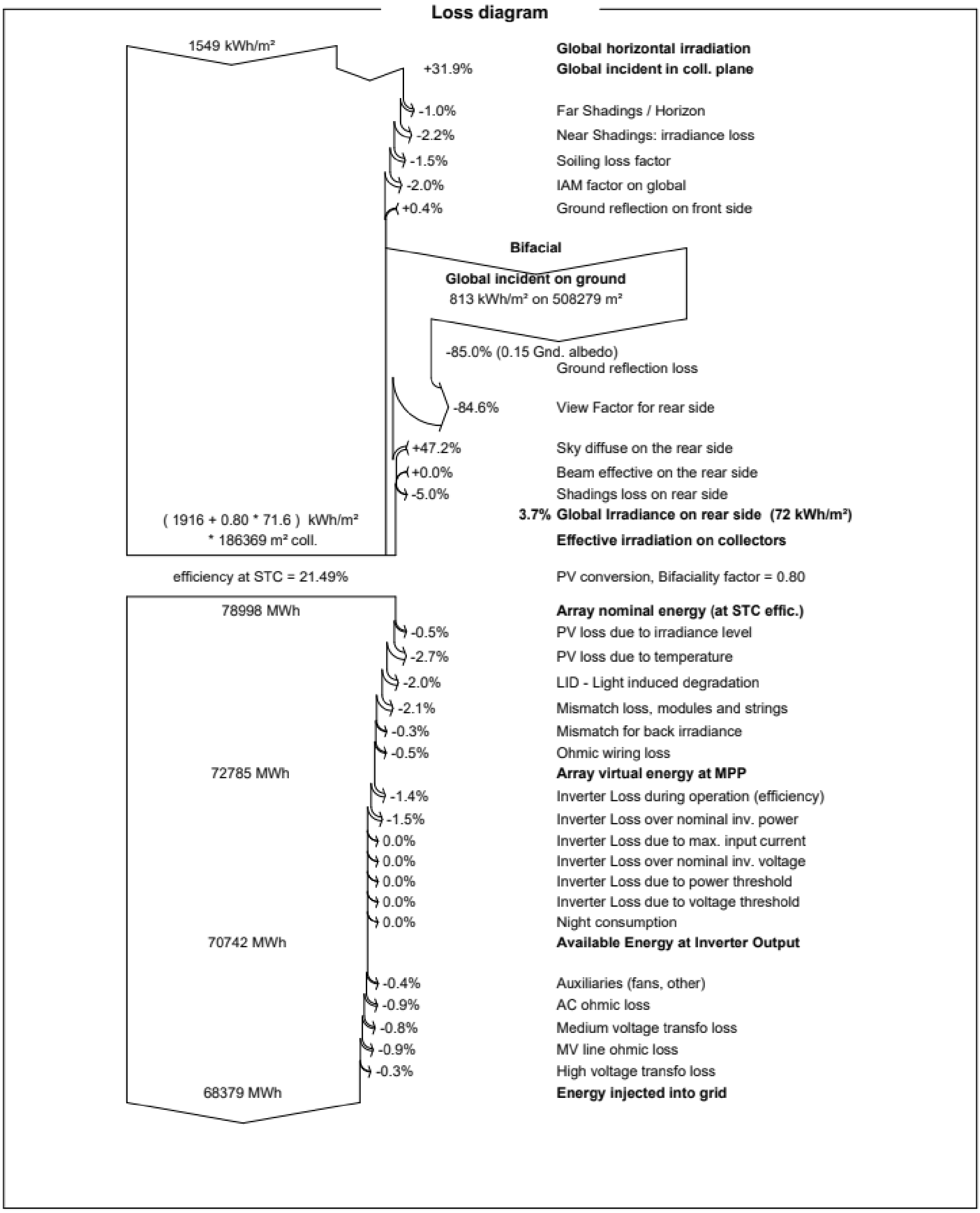
Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures

PVsyst V8.1.0
VEP, Simulation date:
03/05/26 00:15
with V8.1.0

Nikos Vasilopoulos



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Investment Proposal 3:

PVsyst V8.1.0
VEK, Simulation date:
29/05/26 13:57
with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures in combination with 40MW/102MWh BESS (12h charging/discharging)

Nikos Vasilopoulos

Project summary

Geographical Site	Situation		Project settings	
Láva	Latitude	40.1114 °(N)	Albedo	0.15
Greece	Longitude	22.0409 °(E)		
	Altitude	790 m		
	Time zone	UTC+2		

Weather data
Láva
SolarGIS - Synthetic

System summary

Grid-Connected System — **Unlimited sheds**

Orientation #1		Near Shadings	User's needs
Sheds		Mutual shadings of sheds	Unlimited load (grid)
Tilt	25 °	Electrical effect	
Azimuth	0 °		

System information

PV Array		**Inverters**		**Battery pack**	
Nb. of modules	66672 units	Nb. of units	102.7 units	Storage strategy: Power shifting	
Pnom total	40.00 MWp	Total power	30800 kWac	Nb. of units	24 units
		Pnom ratio	1.30	Voltage	1325 V
				Capacity	80640 Ah

Results summary

Simulation step	Hourly				
Produced Energy	51871 MWh/year	Specific production	1297 kWh/kWp/year	Perf. Ratio PR	73.34 %
				Bifacial perf. ratio	71.09 %

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures in combination with 40MW/102MWh BESS (12h charging/discharging)

Nikos Vasilopoulos

General parameters

Grid-Connected System | **Unlimited sheds**

Simulation step
Hourly

Orientation #1

Sheds		**Sheds configuration**		**Sizes**	
Tilt	25 °	Nb. of sheds	400 units	Sheds spacing	9.50 m
Azimuth	0 °	Unlimited sheds		Sensitive width	4.53 m
		Shading limit angle		GCR Shading	47.9 %
		Limit profile angle	19.7 °	Top inactive band	0.02 m
		Shadings electrical effect		Bottom inactive band	0.02 m
		Cell size	15.6 cm		
		Strings in width	2 units		

Models used		**Horizon**		**Near Shadings**
Transposition	Perez	Average Height	2.1 °	Mutual shadings of sheds
Diffuse	Perez, Meteonorm			Electrical effect
Circumsolar	with diffuse			

Bifacial system definition
Orientation #1
Bifacial system

Model	Unlimited Sheds 2D Model
Bifacial model geometry	
Sheds spacing	9.50 m
Sheds width	4.57 m
Limit profile angle	19.7 °
GCR Bifacial	48.1 %
Height above ground	1.00 m
Nb. of sheds	400 units
Bifacial model definitions	
Ground albedo	0.15
Bifaciality factor	80 %
Rear shading factor	5.0 %
Rear mismatch loss	10.0 %
Shed transparent fraction	0.0 %

User's needs
Unlimited load (grid)

Storage
Kind: Power shifting

PV Array Characteristics

PV module		**Inverter**	
Manufacturer	Jinkosolar	Manufacturer	Huawei Technologies
Model	JKM-600N-78HL4-BDV	Model	SUN2000-300KTL-H0
(Original PVsyst database)		(Original PVsyst database)	
Unit Nom. Power	600 Wp	Unit Nom. Power	300 kWac
Number of PV modules	66672 units	Number of inverters	616 * MPPT 17% 102.7 units
Nominal (STC)	40.00 MWp	Total power	30800 kWac
Modules	2778 string x 24 In series	Operating voltage	550-1500 V
At operating cond. (50°C)		Max. power (=>30°C)	330 kWac
Pmpp	37.03 MWp	Pnom ratio (DC:AC)	1.30
U mpp	1009 V	No power sharing between MPPTs	
I mpp	36696 A		

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PVsyst V8.1.0
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with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures in combination with 40MW/102MWh BESS (12h charging/discharging)

Nikos Vasilopoulos

PV Array Characteristics

Total PV power		**Total inverter power**	
Nominal (STC)	40003 kWp	Total power	30800 kWac
Total	66672 modules	Nb. of inverters	103 units
Module area	186369 m²		0.3 unused
Cell area	172259 m²	Pnom ratio	1.30

Grid storage - Power shifting

Battery		**Battery input charger**	
Manufacturer	Huawei	Model	Generic
Model	Luna2000 - 4.5 MWh - 2H1	Max. charging power	40.00 MWdc
Battery pack		Max./Euro effic.	95.0 / 93.0 %
Nb. of units	24 in parallel	**Battery to Grid inverter**	
Voltage	1325 V	Model	Generic
Nominal Capacity (C10)	80640 Ah	Max. discharging power	40.00 MWac
Nominal energy	106.8 MWh	Max./Euro effic.	94.0 / 92.0 %
Operating SOC limits	98.0 / 2.0 %		
Useable energy	102.6 MWh		
Operating temperature	Fixed 20 °C		
Charging strategy		**Discharging strategy**	
Charging strategy	Fixed charging power before exporting	Discharging strategy	Specified hours
Fixed charging power	144000.00 MW	Discharging power	40.00 MW
Charging hours	8:00 to 20:00 (12 hours)	Discharging hours	8:00 to 12:00 (4 hours)
=> Daily stored energy for a clear day	275.3 MWh	=> possible discharging per day	480.0 MWh

Array losses

Array Soiling Losses		**Thermal Loss factor**		**DC wiring losses**	
Loss Fraction	1.5 %	Module temperature according to irradiance		Global array res.	0.21 mΩ
		Uc (const)	29.0 W/m²K	Loss Fraction	0.70 % at STC
		Uv (wind)	0.0 W/m²K/m/s		
LID - Light Induced Degradation		**Module Quality Loss**		**Module mismatch losses**	
Loss Fraction	2.00 %	Loss Fraction	0.00 %	Loss Fraction	2.00 % at MPP
Strings Mismatch loss		**IAM loss factor**			
Loss Fraction	0.10 %	ASHRAE Param.: IAM = 1 - bo (1/cosi -1)			
		bo Param.	0.05		

System losses

Auxiliary losses
Proportional to Power 4.0 W/kW
0.0 kW from Power thresh.

AC wiring losses

Inv. output line up to MV transfo	
Inverter voltage	800 Vac tri
Loss Fraction	1.50 % at STC
Global System	
Wire section	Alu 3 x 30000 mm²
Wires length	231 m

PVsyst V8.1.0
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with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures in combination with 40MW/102MWh BESS (12h charging/discharging)

Nikos Vasilopoulos

AC wiring losses

MV line up to HV Transfo

MV Voltage	33 kV
Average each transformer	
Wires	Alu 3 x 1000 mm²
Length	43710 m
Loss Fraction	1.00 % at STC

AC losses in transformers

MV transfo

Medium voltage	33 kV		
One transfo parameters		**Operating losses at STC (full system)**	
Nominal power at STC	7.92 MVA	Nb. identical MV transfos	5
Iron Loss (night disconnect)	7.95 kVA	Nominal power at STC	39.59 MVA
Iron loss fraction	0.10 % at STC	Iron loss (night disconnect)	39.73 kVA
Copper loss	79.17 kVA	Copper loss	395.86 kVA
Copper loss fraction	1.00 % at STC		
Coils equivalent resistance	3 x 0.81 mΩ		

HV transfo

Grid voltage	150 kV
Transformer from Datasheets	
Nominal power	50000 kVA
Iron Loss (night disconnect)	23.80 kVA
Iron loss fraction	0.05 % of PNom
Copper loss	184.20 kVA
Copper loss fraction	0.37 % at PNom
Coils equivalent resistance	3 x 80.24 mΩ

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures in combination with 40MW/102MWh BESS (12h charging/discharging)

Nikos Vasilopoulos

Horizon definition

Horizon from PVGIS website API, Lat=-13°39'59", Long=167°42'41", Alt=24m

Average Height	2.1 °	Albedo Factor	0.94
Diffuse Factor	0.99	Albedo Fraction	100 %

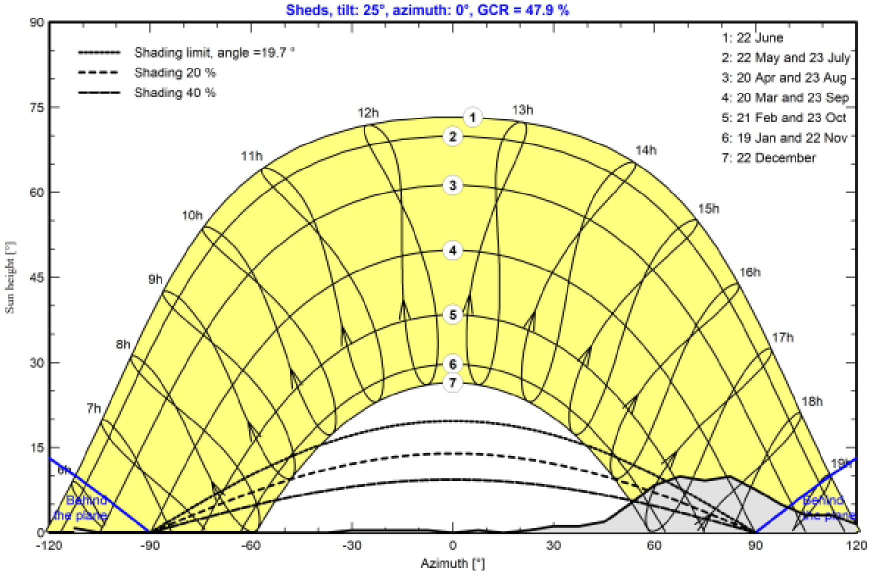
Horizon profile

Azimuth [°]	-113	-105	-38	-30	-8	0	8	15	23	30	38	45	53	60
Height [°]	0.8	0.0	0.0	0.4	0.4	0.0	0.4	0.0	0.4	1.1	1.1	1.9	5.0	8.4
Azimuth [°]	68	75	83	90	98	105	113	120	128	135	143	158	165	
Height [°]	9.9	9.2	9.9	7.6	5.0	3.1	3.1	1.5	1.1	1.5	1.1	1.1	0.8	

Sun Paths (Height / Azimuth diagram)

Orientation #1

Sheds, tilt: 25°, azimuth: 0°, GCR = 47.9 %



Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures in combination with 40MW/102MWh BESS (12h charging/discharging)

PVsyst V8.1.0
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with V8.1.0

Nikos Vasilopoulos

Main results

Simulation step
Hourly

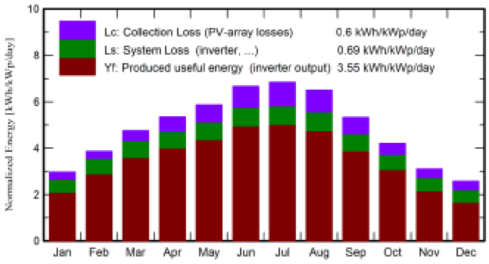
System Production

Produced Energy	51871 MWh/year	Specific production	1297 kWh/kWp/year
		Perf. Ratio PR	73.34 %
		Bifacial perf. ratio	71.09 %

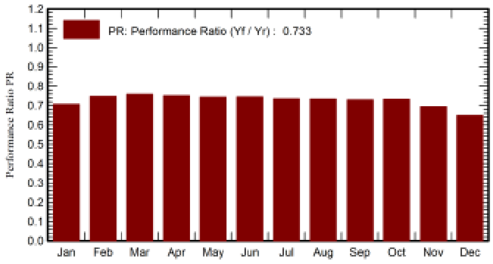
Battery ageing (State of Wear)

Cycles SOW	92.2 %
Static SOW	90.0 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio	PRBifi ratio
January	59.3	25.40	2.10	92.3	84.9	3311	2613	0.708	0.692
February	77.4	31.50	3.60	108.4	101.2	3979	3246	0.748	0.729
March	120.6	47.70	6.50	147.8	138.3	5364	4486	0.759	0.738
April	147.2	64.50	10.90	160.4	149.8	5713	4821	0.751	0.728
May	182.5	77.90	16.10	182.2	169.9	6364	5419	0.744	0.717
June	205.2	77.00	20.70	199.9	186.8	6928	5962	0.746	0.718
July	216.4	75.30	23.40	212.3	198.7	7241	6244	0.735	0.708
August	190.3	71.30	23.00	201.3	188.7	6889	5913	0.734	0.711
September	137.7	54.60	18.30	159.8	149.7	5534	4670	0.731	0.710
October	99.7	40.10	13.10	130.5	121.7	4643	3827	0.733	0.713
November	62.9	27.90	8.00	93.1	85.5	3297	2587	0.695	0.678
December	49.6	22.50	3.50	80.1	72.6	2744	2081	0.649	0.637
Year	1548.8	615.70	12.48	1768.1	1647.7	62007	51871	0.733	0.711

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane	PRBifi	Bifacial Performance Ratio
GlobEff	Effective Global, corr. for IAM and shadings		

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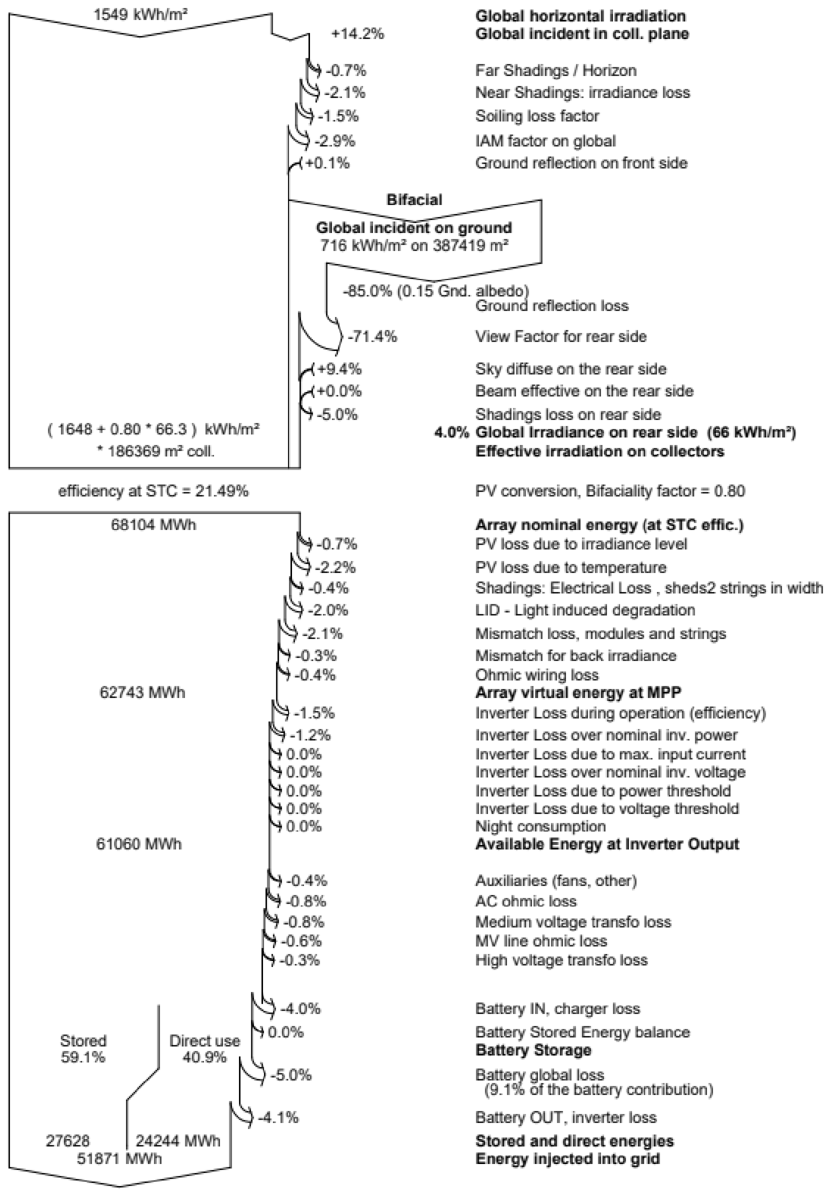
Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures in combination with 40MW/102MWh BESS (12h charging/discharging)

Nikos Vasilopoulos

Loss diagram



Investment Proposal 4:

PVsyst V8.1.0
VET, Simulation date:
29/05/26 14:06
with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures in combination with 40MW/102MWh BESS (12h charging/discharging)

Nikos Vasilopoulos

Project summary

Geographical Site	Situation		Project settings	
Láva	Latitude	40.1114 °(N)	Albedo	0.15
Greece	Longitude	22.0409 °(E)		
	Altitude	790 m		
	Time zone	UTC+2		

Weather data
Láva
SolarGIS - Synthetic

System summary

Grid-Connected System — **Unlimited Trackers with backtracking**

Orientation #1		Near Shadings	User's needs
Tracking horizontal axis		no Shadings	Unlimited load (grid)
Axis azimuth	0 °		
Phi min / max.	-/+ 60 °		
Tracking algorithm			
Astronomic calculation			
Backtracking activated			

System information

PV Array		Inverters		Battery pack	
Nb. of modules	66672 units	Nb. of units	102.7 units	Storage strategy: Power shifting	
Pnom total	40.00 MWp	Total power	30800 kWac	Nb. of units	24 units
		Pnom ratio	1.30	Voltage	1325 V
				Capacity	80640 Ah

Results summary

Simulation step	Hourly				
Produced Energy	61233 MWh/year	Specific production	1531 kWh/kWp/year	Perf. Ratio PR	74.96 %
				Bifacial perf. ratio	72.81 %

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures in combination with 40MW/102MWh BESS (12h charging/discharging)

Nikos Vasilopoulos

General parameters

Grid-Connected System — **Unlimited Trackers with backtracking**

Simulation step
Hourly

Orientation #1

Tracking horizontal axis		**Field properties**		**Models used**	
Axis azimuth	0 °	Nb. of trackers	999 units	Transposition	Perez
Phi min / max.	-/+ 60 °	Unlimited trackers		Diffuse	Perez, Meteonorm
Tracking algorithm		**Sizes**		Circumsolar	with diffuse
Astronomic calculation		Tracker Spacing	6.60 m		
Backtracking activated		Sensitive width	2.38 m		
		GCR Shading	36.4 %		
		Left inactive band	0.02 m		
		Right inactive band	0.02 m		
		Backtracking limit angle			
		Phi limits	+/- 68.5 °		
		Backtracking parameters			
		Backtracking pitch	6.60 m		
		Backtracking width	2.40 m		
		Left inactive band	0.02 m		
		Right inactive band	0.02 m		
		GCR Backtracking	36.4 %		
		Parameters choice	Automatic		

Horizon		**Near Shadings**		**User's needs**	
Average Height	2.1 °	no Shadings		Unlimited load (grid)	

Bifacial system definition
Orientation #1
Bifacial system

Model	Unlimited Trackers 2D model
Bifacial model geometry	
Tracker Spacing	6.60 m
Tracker width	2.42 m
Axis height above ground	1.00 m
Nb. of sheds	999 units
Bifacial model definitions	
Ground albedo	0.15
Bifaciality factor	80 %
Rear shading factor	5.0 %
Rear mismatch loss	10.0 %
Shed transparent fraction	0.0 %

Storage

Kind	Power shifting

PV Array Characteristics

PV module

Manufacturer	Jinkosolar
Model	JKM-600N-78HL4-BDV
(Original PVsyst database)	
Unit Nom. Power	600 Wp
Number of PV modules	66672 units
Nominal (STC)	40.00 MWp
Modules	2778 string x 24 In series

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures in combination with 40MW/102MWh BESS (12h charging/discharging)

Nikos Vasilopoulos

PV Array Characteristics

PV module

At operating cond. (50°C)

Pmpp	37.03 MWp
U mpp	1009 V
I mpp	36696 A

Inverter

Manufacturer	Huawei Technologies
Model	SUN2000-300KTL-H0
(Original PVsyst database)	
Unit Nom. Power	300 kWac
Number of inverters	616 * MPPT 17% 102.7 units
Total power	30800 kWac
Operating voltage	550-1500 V
Max. power (=>30°C)	330 kWac
Pnom ratio (DC:AC)	1.30
No power sharing between MPPTs	

Total PV power

Nominal (STC)	40003 kWp
Total	66672 modules
Module area	186369 m²
Cell area	172259 m²

Total inverter power

Total power	30800 kWac
Nb. of inverters	103 units
	0.3 unused
Pnom ratio	1.30

Grid storage - Power shifting

Battery

Manufacturer	Huawei
Model	Luna2000 - 4.5 MWh - 2H1

Battery pack

Nb. of units	24 in parallel
Voltage	1325 V
Nominal Capacity (C10)	80640 Ah
Nominal energy	106.8 MWh
Operating SOC limits	98.0 / 2.0 %
Useable energy	102.6 MWh
Operating temperature	Fixed 20 °C

Battery input charger

Model	Generic
Max. charging power	40.00 MWdc
Max./Euro effic.	95.0 / 93.0 %

Battery to Grid inverter

Model	Generic
Max. discharging power	40.00 MWac
Max./Euro effic.	94.0 / 92.0 %

Charging strategy

Charging strategy	Fixed charging power before exporting
Fixed charging power	144000.00 MW
Charging hours	8:00 to 20:00 (12 hours)
=> Daily stored energy for a clear day	371.2 MWh

Discharging strategy

Discharging strategy	Specified hours
Discharging power	40.00 MW
Discharging hours	8:00 to 12:00 (4 hours)
=> possible discharging per day	480.0 MWh

Array losses

Array Soiling Losses

Loss Fraction 1.5 %

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.	0.21 mΩ
Loss Fraction	0.70 % at STC

LID - Light Induced Degradation

Loss Fraction 2.00 %

Module Quality Loss

Loss Fraction 0.00 %

Module mismatch losses

Loss Fraction 2.00 % at MPP

Strings Mismatch loss

Loss Fraction 0.10 %

IAM loss factor

ASHRAE Param.: IAM = 1 - bo (1/cosi -1)

bo Param. 0.05

System losses

Auxiliary losses

Proportional to Power 4.0 W/kW

0.0 kW from Power thresh.

AC wiring losses

Inv. output line up to MV transfo

Inverter voltage	800 Vac tri
Loss Fraction	1.50 % at STC
Global System	
Wire section	Copper 3 x 30000 mm²
Wires length	387 m

MV line up to HV Transfo

MV Voltage	33 kV
Average each transformer	
Wires	Alu 3 x 1000 mm²
Length	43710 m
Loss Fraction	1.00 % at STC

AC losses in transformers

MV transfo

Medium voltage	33 kV
One transfo parameters	
Nominal power at STC	7.92 MVA
Iron Loss (night disconnect)	7.95 kVA
Iron loss fraction	0.10 % at STC
Copper loss	79.17 kVA
Copper loss fraction	1.00 % at STC
Coils equivalent resistance	3 x 0.81 mΩ

Operating losses at STC (full system)

Nb. identical MV transfos	5
Nominal power at STC	39.59 MVA
Iron loss (night disconnect)	39.73 kVA
Copper loss	395.86 kVA

HV transfo

Grid voltage	150 kV
Transformer from Datasheets	
Nominal power	50000 kVA
Iron Loss (night disconnect)	23.80 kVA
Iron loss fraction	0.05 % of PNom
Copper loss	184.20 kVA
Copper loss fraction	0.37 % at PNom
Coils equivalent resistance	3 x 80.24 mΩ

PVsyst V8.1.0
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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures in combination with 40MW/102MWh BESS (12h charging/discharging)

Nikos Vasilopoulos

Horizon definition

Horizon from PVGIS website API, Lat=-13°39'59", Long=167°42'41", Alt=24m

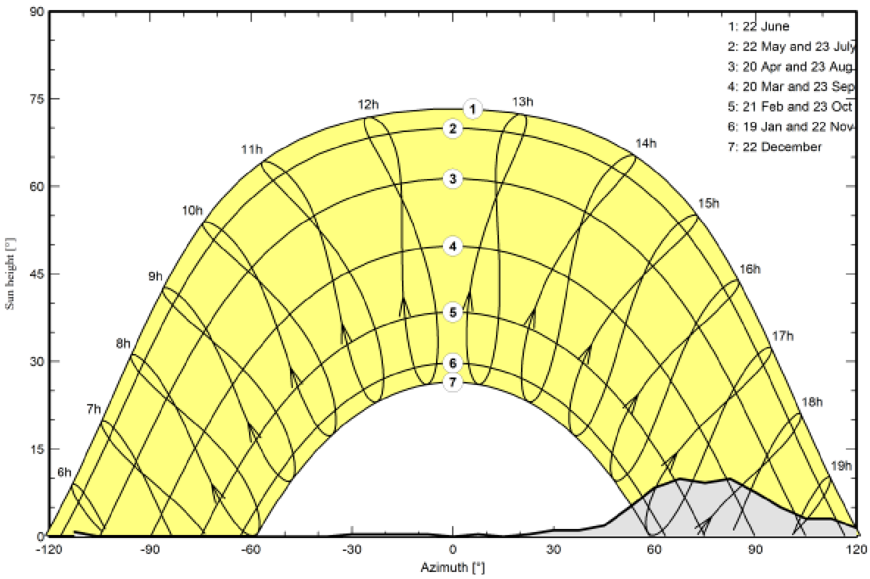
Average Height	2.1 °	Albedo Factor	0.00
Diffuse Factor	1.00	Albedo Fraction	100 %

Horizon profile

Azimuth [°]	-113	-105	-38	-30	-8	0	8	15	23	30	38	45	53	60
Height [°]	0.8	0.0	0.0	0.4	0.4	0.0	0.4	0.0	0.4	1.1	1.1	1.9	5.0	8.4
Azimuth [°]	68	75	83	90	98	105	113	120	128	135	143	158	165	
Height [°]	9.9	9.2	9.9	7.6	5.0	3.1	3.1	1.5	1.1	1.5	1.1	1.1	0.8	

Sun Paths (Height / Azimuth diagram)

Orientation #1



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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures in combination with 40MW/102MWh BESS (12h charging/discharging)

Nikos Vasilopoulos

Main results

Simulation step
Hourly

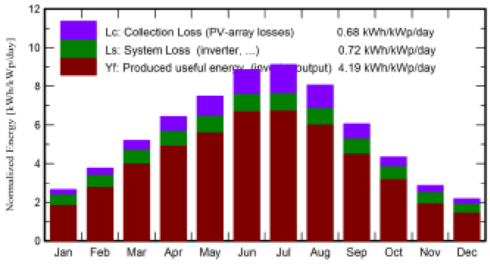
System Production

Produced Energy	61233 MWh/year	Specific production	1531 kWh/kWp/year
		Perf. Ratio PR	74.96 %
		Bifacial perf. ratio	72.81 %

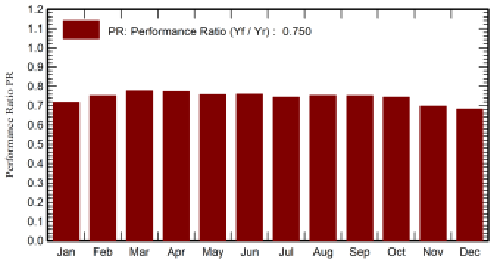
Battery ageing (State of Wear)

Cycles SOW	92.3 %
Static SOW	90.0 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio	PRBifi ratio
January	59.3	25.40	2.10	82.2	75.1	3017	2361	0.718	0.696
February	77.4	31.50	3.60	105.3	97.3	3876	3165	0.752	0.730
March	120.6	47.70	6.50	161.1	150.2	5897	5003	0.776	0.754
April	147.2	64.50	10.90	192.7	181.2	6898	5949	0.772	0.749
May	182.5	77.90	16.10	232.1	219.4	8068	7037	0.758	0.735
June	205.2	77.00	20.70	265.9	252.4	9156	8077	0.760	0.738
July	216.4	75.30	23.40	282.7	268.9	9511	8394	0.742	0.722
August	190.3	71.30	23.00	249.6	236.1	8574	7516	0.753	0.732
September	137.7	54.60	18.30	181.9	170.7	6374	5470	0.752	0.730
October	99.7	40.10	13.10	135.0	125.0	4821	4012	0.743	0.722
November	62.9	27.90	8.00	86.0	78.0	3075	2399	0.698	0.677
December	49.6	22.50	3.50	67.8	61.4	2460	1851	0.682	0.661
Year	1548.8	615.70	12.48	2042.1	1915.5	71728	61233	0.750	0.728

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane	PRBifi	Bifacial Performance Ratio
GlobEff	Effective Global, corr. for IAM and shadings		

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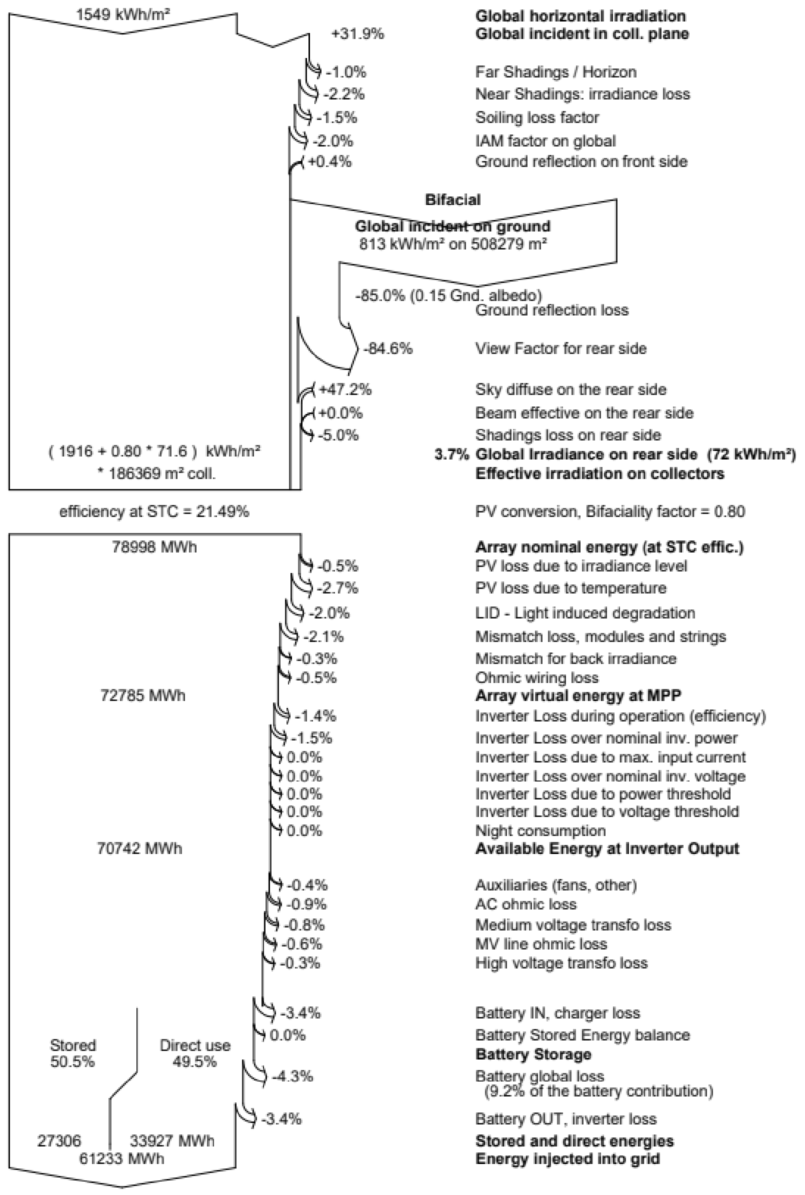
PVsyst V8.1.0
VET, Simulation date:
29/05/26 14:06
with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures in combination with 40MW/102MWh BESS (12h charging/discharging)

Nikos Vasilopoulos

Loss diagram



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Appendix B: “Sensitivity Analysis Scenarios”

Investment Proposal 1

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures_16MW Setpoint

Nikos Vasilopoulos

PVsyst V8.1.0
VEF, Simulation date:
26/05/26 15:18
with V8.1.0

Project summary

Geographical Site		**Situation**		**Project settings**	
Láva		Latitude	40.1114 °(N)	Albedo	0.15
Greece		Longitude	22.0409 °(E)		
		Altitude	790 m		
		Time zone	UTC+2		

Weather data
Láva
SolarGIS - Synthetic

System summary

Grid-Connected System		**Unlimited sheds**		
Orientation #1		**Near Shadings**	**User's needs**	
Sheds		Mutual shadings of sheds	Unlimited load (grid)	
Tilt	25 °	Electrical effect		
Azimuth	0 °			

System information

PV Array		**Inverters**	
Nb. of modules	66672 units	Nb. of units	102.7 units
Pnom total	40.00 MWp	Total power	30800 kWac
		Grid power limit	16.00 MWac
		Grid lim. Pnom ratio	2.500

Results summary

Simulation step	Hourly				
Produced Energy	44806 MWh/year	Specific production	1120 kWh/kWp/year	Perf. Ratio PR	63.35 %
				Bifacial perf. ratio	61.41 %

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PVsyst V8.1.0
VEF, Simulation date:
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with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures_16MW Setpoint

Nikos Vasilopoulos

General parameters

Grid-Connected System — **Unlimited sheds**

Simulation step
Hourly

Orientation #1

Sheds		**Sheds configuration**		**Sizes**	
Tilt	25 °	Nb. of sheds	400 units	Sheds spacing	9.50 m
Azimuth	0 °	Unlimited sheds		Sensitive width	4.53 m
		Shading limit angle		GCR Shading	47.9 %
		Limit profile angle	19.7 °	Top inactive band	0.02 m
		Shadings electrical effect		Bottom inactive band	0.02 m
		Cell size	15.6 cm		
		Strings in width	2 units		

Models used		**Horizon**		**Near Shadings**
Transposition	Perez	Average Height	2.1 °	Mutual shadings of sheds
Diffuse	Perez, Meteonorm			Electrical effect
Circumsolar	with diffuse			

Bifacial system definition
Orientation #1
Bifacial system

Model	Unlimited Sheds 2D Model
Bifacial model geometry	
Sheds spacing	9.50 m
Sheds width	4.57 m
Limit profile angle	19.7 °
GCR Bifacial	48.1 %
Height above ground	1.00 m
Nb. of sheds	400 units
Bifacial model definitions	
Ground albedo	0.15
Bifaciality factor	80 %
Rear shading factor	5.0 %
Rear mismatch loss	10.0 %
Shed transparent fraction	0.0 %

User's needs
Unlimited load (grid)

Grid power limitation

Active power	16.00 MWac
Pnom ratio	2.500

Limit applied at the injection point

PV Array Characteristics

PV module		**Inverter**	
Manufacturer	Jinkosolar	Manufacturer	Huawei Technologies
Model	JKM-600N-78HL4-BDV	Model	SUN2000-300KTL-H0
(Original PVsyst database)		(Original PVsyst database)	
Unit Nom. Power	600 Wp	Unit Nom. Power	300 kWac
Number of PV modules	66672 units	Number of inverters	616 * MPPT 17% 102.7 units
Nominal (STC)	40.00 MWp	Total power	30800 kWac
Modules	2778 string x 24 In series	Operating voltage	550-1500 V
At operating cond. (50°C)		Max. power (=>30°C)	330 kWac
Pmpp	37.03 MWp	Pnom ratio (DC:AC)	1.30
U mpp	1009 V	No power sharing between MPPTs	
I mpp	36696 A		

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures_16MW Setpoint

PVsyst V8.1.0
VEF, Simulation date:
26/05/26 15:18
with V8.1.0

Nikos Vasilopoulos

PV Array Characteristics

Total PV power		**Total inverter power**	
Nominal (STC)	40003 kWp	Total power	30800 kWac
Total	66672 modules	Nb. of inverters	103 units
Module area	186369 m²		0.3 unused
Cell area	172259 m²	Pnom ratio	1.30

Array losses

Array Soiling Losses
Loss Fraction 1.5 %

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. 0.21 mΩ
Loss Fraction 0.70 % at STC

LID - Light Induced Degradation
Loss Fraction 2.00 %

Module Quality Loss
Loss Fraction 0.00 %

Module mismatch losses
Loss Fraction 0.60 % at MPP

Strings Mismatch loss
Loss Fraction 0.10 %

IAM loss factor
ASHRAE Param.: IAM = 1 - bo (1/cosi -1)
bo Param. 0.05

System losses

Auxiliary losses
Proportional to Power 4.0 W/kW
0.0 kW from Power thresh.

AC wiring losses

Inv. output line up to MV transfo	
Inverter voltage	800 Vac tri
Loss Fraction	0.70 % at STC
Global System	
Wire section	Alu 3 x 30000 mm²
Wires length	108 m
MV line up to HV Transfo	
MV Voltage	33 kV
Average each transformer	
Wires	Alu 3 x 1000 mm²
Length	43710 m
Loss Fraction	1.00 % at STC

AC losses in transformers

MV transfo			
Medium voltage	33 kV		
One transfo parameters		**Operating losses at STC (full system)**	
Nominal power at STC	7.92 MVA	Nb. identical MV transfos	5
Iron Loss (night disconnect)	7.95 kVA	Nominal power at STC	39.59 MVA
Iron loss fraction	0.10 % at STC	Iron loss (night disconnect)	39.73 kVA
Copper loss	79.17 kVA	Copper loss	395.86 kVA
Copper loss fraction	1.00 % at STC		
Coils equivalent resistance	3 x 0.81 mΩ		

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AC losses in transformers

HV transfo

Grid voltage	150 kV
Transformer from Datasheets	
Nominal power	50000 kVA
Iron Loss (night disconnect)	23.80 kVA
Iron loss fraction	0.05 % of PNom
Copper loss	184.20 kVA
Copper loss fraction	0.37 % at PNom
Coils equivalent resistance	3 x 80.24 mΩ

PVsyst V8.1.0
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with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures_16MW Setpoint

Nikos Vasilopoulos

Horizon definition

Horizon from PVGIS website API, Lat=-13°39'59", Long=167°42'41", Alt=24m

Average Height	2.1 °	Albedo Factor	0.94
Diffuse Factor	0.99	Albedo Fraction	100 %

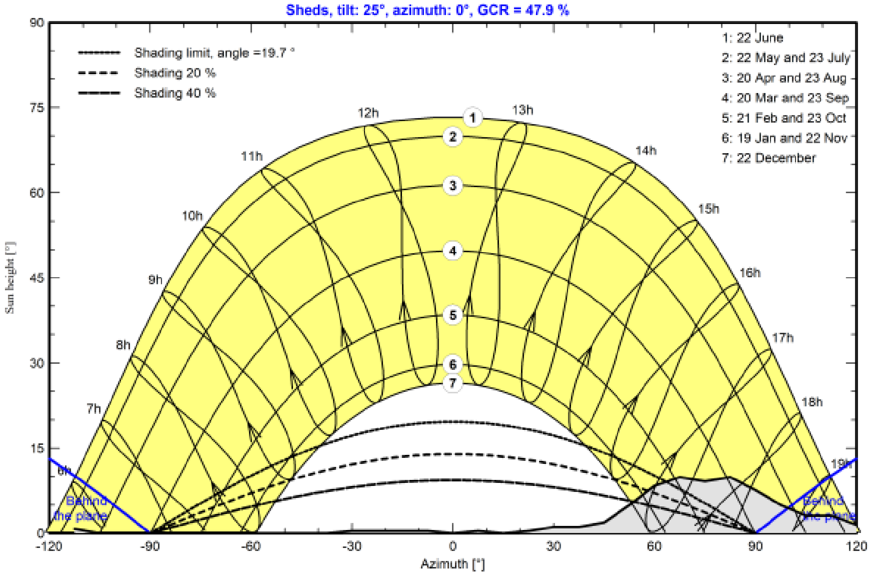
Horizon profile

Azimuth [°]	-113	-105	-38	-30	-8	0	8	15	23	30	38	45	53	60
Height [°]	0.8	0.0	0.0	0.4	0.4	0.0	0.4	0.0	0.4	1.1	1.1	1.9	5.0	8.4
Azimuth [°]	68	75	83	90	98	105	113	120	128	135	143	158	165	
Height [°]	9.9	9.2	9.9	7.6	5.0	3.1	3.1	1.5	1.1	1.5	1.1	1.1	0.8	

Sun Paths (Height / Azimuth diagram)

Orientation #1

Sheds, tilt: 25°, azimuth: 0°, GCR = 47.9 %



PVsyst V8.1.0
VEF, Simulation date:
26/05/26 15:18
with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures_16MW Setpoint

Nikos Vasilopoulos

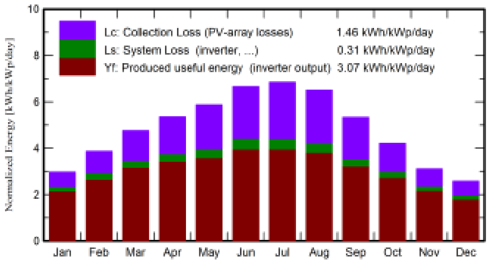
Main results

Simulation step
Hourly

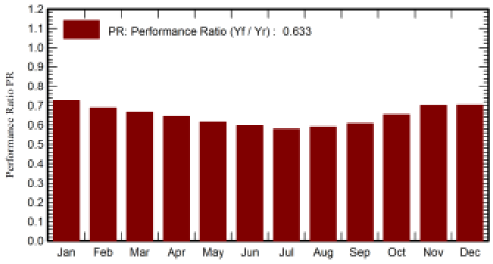
System Production

Produced Energy	44806 MWh/year	Specific production	1120 kWh/kWp/year
		Perf. Ratio PR	63.35 %
		Bifacial perf. ratio	61.41 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio	PRBifi ratio
January	59.3	25.40	2.10	92.3	84.9	2919	2677	0.725	0.709
February	77.4	31.50	3.60	108.4	101.2	3298	2988	0.689	0.671
March	120.6	47.70	6.50	147.8	138.3	4322	3940	0.666	0.648
April	147.2	64.50	10.90	160.4	149.8	4552	4124	0.643	0.623
May	182.5	77.90	16.10	182.2	169.9	4941	4477	0.614	0.592
June	205.2	77.00	20.70	199.9	186.8	5291	4772	0.597	0.574
July	216.4	75.30	23.40	212.3	198.7	5462	4922	0.579	0.558
August	190.3	71.30	23.00	201.3	188.7	5259	4749	0.590	0.571
September	137.7	54.60	18.30	159.8	149.7	4277	3879	0.607	0.590
October	99.7	40.10	13.10	130.5	121.7	3746	3407	0.653	0.635
November	62.9	27.90	8.00	93.1	85.5	2849	2615	0.702	0.685
December	49.6	22.50	3.50	80.1	72.6	2457	2256	0.704	0.690
Year	1548.8	615.70	12.48	1768.1	1647.7	49374	44806	0.633	0.614

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane	PRBifi	Bifacial Performance Ratio
GlobEff	Effective Global, corr. for IAM and shadings		

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures_16MW Setpoint

PVsyst V8.1.0
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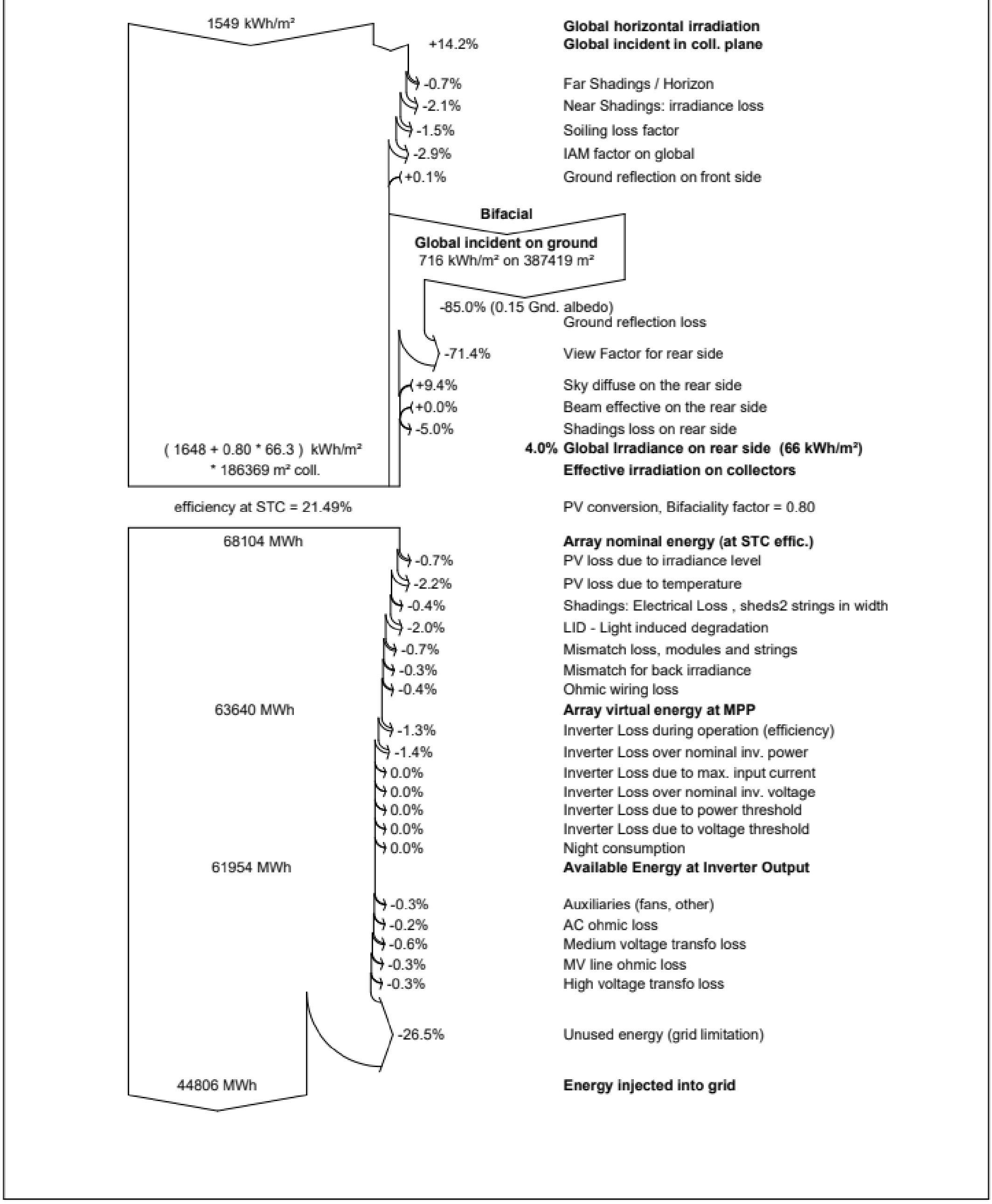
26/05/26 15:18
with V8.1.0

Nikos Vasilopoulos

Loss diagram



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Investment Proposal 2:

PVsyst V8.1.0
VES, Simulation date:
26/05/26 15:19
with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures_16MW Setpoint

Nikos Vasilopoulos

Project summary

Geographical Site		**Situation**		**Project settings**	
Láva		Latitude	40.1114 °(N)	Albedo	0.15
Greece		Longitude	22.0409 °(E)		
		Altitude	790 m		
		Time zone	UTC+2		

Weather data
Láva
SolarGIS - Synthetic

System summary

Grid-Connected System

Unlimited Trackers with backtracking

Orientation #1		**Near Shadings**	**User's needs**
Tracking horizontal axis		no Shadings	Unlimited load (grid)
Axis azimuth	0 °		
Phi min / max.	-/+ 60 °		
Tracking algorithm			
Astronomic calculation			
Backtracking activated			

System information

PV Array		**Inverters**	
Nb. of modules	66672 units	Nb. of units	102.7 units
Pnom total	40.00 MWp	Total power	30800 kWac
		Grid power limit	16.00 MWac
		Grid lim. Pnom ratio	2.500

Results summary

Simulation step	Hourly				
Produced Energy	49015 MWh/year	Specific production	1225 kWh/kWp/year	Perf. Ratio PR	60.00 %
				Bifacial perf. ratio	58.28 %

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VES, Simulation date:
26/05/26 15:19
with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures_16MW Setpoint

Nikos Vasilopoulos

General parameters

Grid-Connected System — **Unlimited Trackers with backtracking**

Simulation step
Hourly

Orientation #1

Tracking horizontal axis

Axis azimuth	0 °
Phi min / max.	-/+ 60 °

Tracking algorithm
Astronomic calculation
Backtracking activated

Field properties

Nb. of trackers	999 units
Unlimited trackers	

Sizes

Tracker Spacing	6.60 m
Sensitive width	2.38 m
GCR Shading	36.4 %
Left inactive band	0.02 m
Right inactive band	0.02 m

Backtracking limit angle

Phi limits	+/- 68.5 °

Backtracking parameters

Backtracking pitch	6.60 m
Backtracking width	2.40 m
Left inactive band	0.02 m
Right inactive band	0.02 m
GCR Backtracking	36.4 %
Parameters choice	Automatic

Models used

Transposition	Perez
Diffuse	Perez, Meteonorm
Circumsolar	with diffuse

Horizon
Average Height 2.1 °

Near Shadings
no Shadings

User's needs
Unlimited load (grid)

Bifacial system definition

Orientation #1

Bifacial system
Model Unlimited Trackers 2D model

Bifacial model geometry

Tracker Spacing	6.60 m
Tracker width	2.42 m
Axis height above ground	1.00 m
Nb. of sheds	999 units

Bifacial model definitions

Ground albedo	0.15
Bifaciality factor	80 %
Rear shading factor	5.0 %
Rear mismatch loss	10.0 %
Shed transparent fraction	0.0 %

Grid power limitation

Active power	16.00 MWac
Pnom ratio	2.500

Limit applied at the injection point

PV Array Characteristics

PV module

Manufacturer	Jinkosolar
Model	JKM-600N-78HL4-BDV
(Original PVsyst database)	
Unit Nom. Power	600 Wp
Number of PV modules	66672 units
Nominal (STC)	40.00 MWp
Modules	2778 string x 24 In series

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures_16MW Setpoint

Nikos Vasilopoulos

PVsyst V8.1.0
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with V8.1.0

PV Array Characteristics

PV module		**Inverter**	
At operating cond. (50°C)		Manufacturer	Huawei Technologies
Pmpp	37.03 MWp	Model	SUN2000-300KTL-H0
U mpp	1009 V	(Original PVsyst database)	
I mpp	36696 A	Unit Nom. Power	300 kWac
		Number of inverters	616 * MPPT 17% 102.7 units
		Total power	30800 kWac
		Operating voltage	550-1500 V
		Max. power (=>30°C)	330 kWac
		Pnom ratio (DC:AC)	1.30
		No power sharing between MPPTs	
Total PV power		**Total inverter power**	
Nominal (STC)	40003 kWp	Total power	30800 kWac
Total	66672 modules	Nb. of inverters	103 units
Module area	186369 m²		0.3 unused
Cell area	172259 m²	Pnom ratio	1.30

Array losses

Array Soiling Losses		**Thermal Loss factor**		**DC wiring losses**	
Loss Fraction	1.5 %	Module temperature according to irradiance		Global array res.	0.21 mΩ
		Uc (const)	29.0 W/m²K	Loss Fraction	0.70 % at STC
		Uv (wind)	0.0 W/m²K/m/s		
LID - Light Induced Degradation		**Module Quality Loss**		**Module mismatch losses**	
Loss Fraction	2.00 %	Loss Fraction	0.00 %	Loss Fraction	2.00 % at MPP
Strings Mismatch loss		**IAM loss factor**			
Loss Fraction	0.10 %	ASHRAE Param.: IAM = 1 - bo (1/cosi -1)			
		bo Param.	0.05		

System losses

Auxiliary losses	
Proportional to Power	4.0 W/kW
0.0 kW from Power thresh.	

AC wiring losses

Inv. output line up to MV transfo	
Inverter voltage	800 Vac tri
Loss Fraction	1.50 % at STC
Global System	
Wire section	Alu 3 x 30000 mm²
Wires length	231 m
MV line up to HV Transfo	
MV Voltage	33 kV
Average each transformer	
Wires	Alu 3 x 1000 mm²
Length	65510 m
Loss Fraction	1.50 % at STC

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PVsyst V8.1.0
VES, Simulation date:
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with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures_16MW Setpoint

Nikos Vasilopoulos

AC losses in transformers

MV transfo

Medium voltage	33 kV
One transfo parameters	
Nominal power at STC	7.92 MVA
Iron Loss (night disconnect)	7.95 kVA
Iron loss fraction	0.10 % at STC
Copper loss	79.17 kVA
Copper loss fraction	1.00 % at STC
Coils equivalent resistance	3 x 0.81 mΩ

Operating losses at STC (full system)

Nb. identical MV transfos	5
Nominal power at STC	39.59 MVA
Iron loss (night disconnect)	39.73 kVA
Copper loss	395.86 kVA

HV transfo

Grid voltage	150 kV
Transformer from Datasheets	
Nominal power	50000 kVA
Iron Loss (night disconnect)	23.80 kVA
Iron loss fraction	0.05 % of PNom
Copper loss	184.20 kVA
Copper loss fraction	0.37 % at PNom
Coils equivalent resistance	3 x 80.24 mΩ

PVsyst V8.1.0
VES, Simulation date:
26/05/26 15:19
with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures_16MW Setpoint

Nikos Vasilopoulos

Horizon definition

Horizon from PVGIS website API, Lat=-13°39'59", Long=167°42'41", Alt=24m

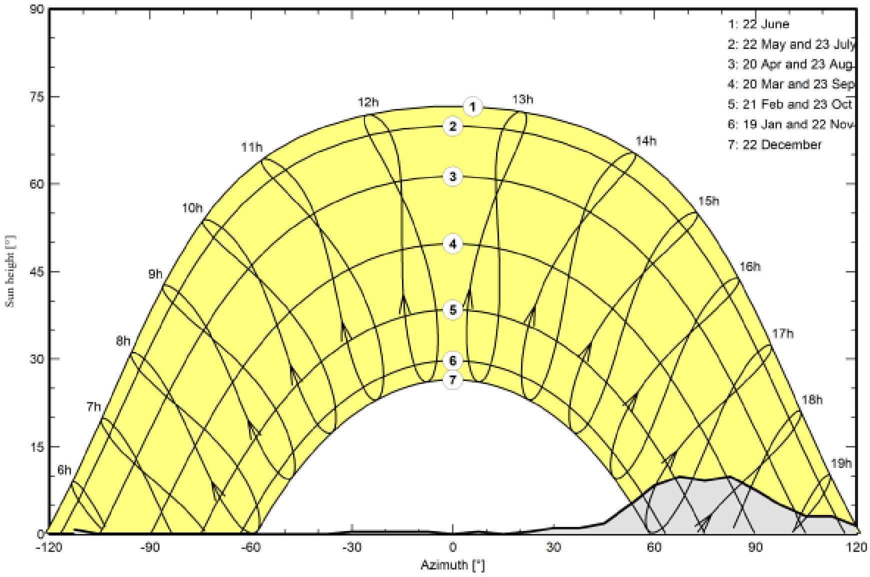
Average Height	2.1 °	Albedo Factor	0.00
Diffuse Factor	1.00	Albedo Fraction	100 %

Horizon profile

Azimuth [°]	-113	-105	-38	-30	-8	0	8	15	23	30	38	45	53	60
Height [°]	0.8	0.0	0.0	0.4	0.4	0.0	0.4	0.0	0.4	1.1	1.1	1.9	5.0	8.4
Azimuth [°]	68	75	83	90	98	105	113	120	128	135	143	158	165	
Height [°]	9.9	9.2	9.9	7.6	5.0	3.1	3.1	1.5	1.1	1.5	1.1	1.1	0.8	

Sun Paths (Height / Azimuth diagram)

Orientation #1



PVsyst V8.1.0
VES, Simulation date:
26/05/26 15:19
with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures_16MW Setpoint

Nikos Vasilopoulos

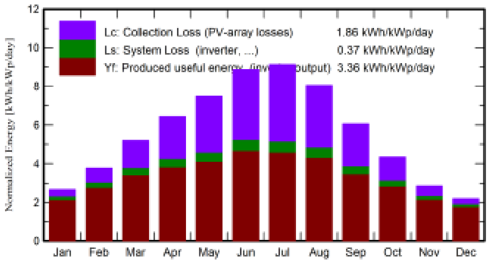
Main results

Simulation step
Hourly

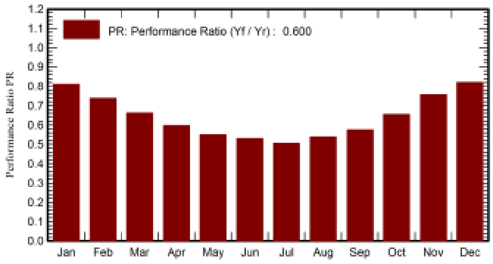
System Production

Produced Energy	49015 MWh/year	Specific production	1225 kWh/kWp/year
		Perf. Ratio PR	60.00 %
		Bifacial perf. ratio	58.28 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio	PRBifi ratio
January	59.3	25.40	2.10	82.2	75.1	2893	2667	0.811	0.786
February	77.4	31.50	3.60	105.3	97.3	3434	3106	0.738	0.716
March	120.6	47.70	6.50	161.1	150.2	4710	4263	0.662	0.642
April	147.2	64.50	10.90	192.7	181.2	5154	4610	0.598	0.581
May	182.5	77.90	16.10	232.1	219.4	5708	5115	0.551	0.534
June	205.2	77.00	20.70	265.9	252.4	6311	5626	0.529	0.514
July	216.4	75.30	23.40	282.7	268.9	6411	5709	0.505	0.491
August	190.3	71.30	23.00	249.6	236.1	6028	5374	0.538	0.523
September	137.7	54.60	18.30	181.9	170.7	4672	4184	0.575	0.559
October	99.7	40.10	13.10	135.0	125.0	3928	3532	0.654	0.635
November	62.9	27.90	8.00	86.0	78.0	2827	2602	0.757	0.734
December	49.6	22.50	3.50	67.8	61.4	2405	2228	0.821	0.795
Year	1548.8	615.70	12.48	2042.1	1915.5	54480	49015	0.600	0.583

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane	PRBifi	Bifacial Performance Ratio
GlobEff	Effective Global, corr. for IAM and shadings		

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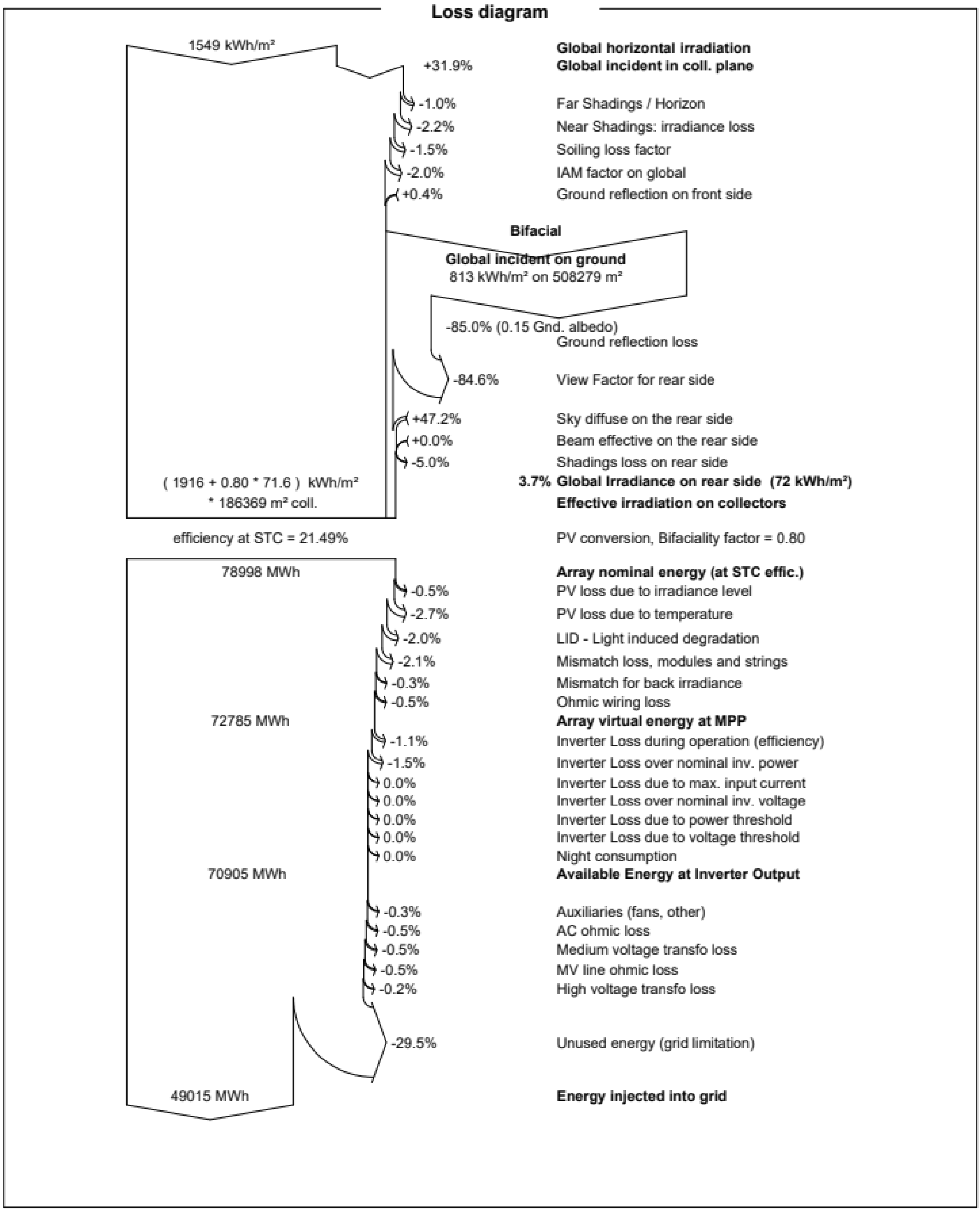
Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures_16MW Setpoint

Nikos Vasilopoulos

Loss diagram



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Investment Proposal 3:

PVsyst V8.1.0
VEN, Simulation date:
29/05/26 14:25
with V8.1.0

Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures in combination with 16MW/102MWh BESS (12h charging/discharging)_16MW Setpoint

Nikos Vasilopoulos

Project summary

Geographical Site	**Situation**		**Project settings**	
Láva	Latitude	40.1114 °(N)	Albedo	0.15
Greece	Longitude	22.0409 °(E)		
	Altitude	790 m		
	Time zone	UTC+2		

Weather data
Láva
SolarGIS - Synthetic

System summary

Grid-Connected System — **Unlimited sheds**

Orientation #1		**Near Shadings**	**User's needs**
Sheds		Mutual shadings of sheds	Unlimited load (grid)
Tilt	25 °	Electrical effect	
Azimuth	0 °		

System information

PV Array		**Inverters**		**Battery pack**	
Nb. of modules	66672 units	Nb. of units	102.7 units	Storage strategy: Power shifting	
Pnom total	40.00 MWp	Total power	30800 kWac	Nb. of units	24 units
		Grid power limit	16.00 MWac	Voltage	1325 V
		Grid lim. Pnom ratio	2.500	Capacity	80640 Ah

Results summary

Simulation step	Hourly				
Produced Energy	51362 MWh/year	Specific production	1284 kWh/kWp/year	Perf. Ratio PR	72.62 %
				Bifacial perf. ratio	70.39 %

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures in combination with 16MW/102MWh BESS (12h charging/discharging)_16MW Setpoint

Nikos Vasilopoulos

General parameters

Grid-Connected System | **Unlimited sheds**

Simulation step
Hourly

Orientation #1

Sheds		**Sheds configuration**		**Sizes**	
Tilt	25 °	Nb. of sheds	400 units	Sheds spacing	9.50 m
Azimuth	0 °	Unlimited sheds		Sensitive width	4.53 m
		Shading limit angle		GCR Shading	47.9 %
		Limit profile angle	19.7 °	Top inactive band	0.02 m
		Shadings electrical effect		Bottom inactive band	0.02 m
		Cell size	15.6 cm		
		Strings in width	2 units		

Models used		**Horizon**		**Near Shadings**
Transposition	Perez	Average Height	2.1 °	Mutual shadings of sheds
Diffuse	Perez, Meteonorm			Electrical effect
Circumsolar	with diffuse			

Bifacial system definition
Orientation #1
Bifacial system

Model	Unlimited Sheds 2D Model
Bifacial model geometry	
Sheds spacing	9.50 m
Sheds width	4.57 m
Limit profile angle	19.7 °
GCR Bifacial	48.1 %
Height above ground	1.00 m
Nb. of sheds	400 units
Bifacial model definitions	
Ground albedo	0.15
Bifaciality factor	80 %
Rear shading factor	5.0 %
Rear mismatch loss	10.0 %
Shed transparent fraction	0.0 %

User's needs
Unlimited load (grid)

Storage
Kind: Power shifting

Grid power limitation

Active power	16.00 MWac
Pnom ratio	2.500

Limit applied at the injection point

PV Array Characteristics

PV module		**Inverter**	
Manufacturer	Jinkosolar	Manufacturer	Huawei Technologies
Model	JKM-600N-78HL4-BDV	Model	SUN2000-300KTL-H0
(Original PVsyst database)		(Original PVsyst database)	
Unit Nom. Power	600 Wp	Unit Nom. Power	300 kWac
Number of PV modules	66672 units	Number of inverters	616 * MPPT 17% 102.7 units
Nominal (STC)	40.00 MWp	Total power	30800 kWac
Modules	2778 string x 24 In series	Operating voltage	550-1500 V
At operating cond. (50°C)		Max. power (=>30°C)	330 kWac
Pmpp	37.03 MWp	Pnom ratio (DC:AC)	1.30
U mpp	1009 V	No power sharing between MPPTs	
I mpp	36696 A		

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PV Array Characteristics

Total PV power		**Total inverter power**	
Nominal (STC)	40003 kWp	Total power	30800 kWac
Total	66672 modules	Nb. of inverters	103 units
Module area	186369 m²		0.3 unused
Cell area	172259 m²	Pnom ratio	1.30

Grid storage - Power shifting

Battery		**Battery input charger**	
Manufacturer	Huawei	Model	Generic
Model	Luna2000 - 4.5 MWh - 2H1	Max. charging power	16.00 MWdc
Battery pack		Max./Euro effic.	95.0 / 93.0 %
Nb. of units	24 in parallel	**Battery to Grid inverter**	
Voltage	1325 V	Model	Generic
Nominal Capacity (C10)	80640 Ah	Max. discharging power	16.00 MWac
Nominal energy	106.8 MWh	Max./Euro effic.	94.0 / 92.0 %
Operating SOC limits	98.0 / 2.0 %		
Useable energy	102.6 MWh		
Operating temperature	Fixed 20 °C		
Charging strategy		**Discharging strategy**	
Charging strategy	Fixed charging power before exporting	Discharging strategy	Specified hours
Fixed charging power	57600.00 MW	Discharging power	16.00 MW
Charging hours	8:00 to 20:00 (12 hours)	Discharging hours	8:00 to 12:00 (4 hours)
=> Daily stored energy for a clear day	160.5 MWh	=> possible discharging per day	192.0 MWh

Array losses

Array Soiling Losses		**Thermal Loss factor**		**DC wiring losses**	
Loss Fraction	1.5 %	Module temperature according to irradiance		Global array res.	0.21 mΩ
		Uc (const)	29.0 W/m²K	Loss Fraction	0.70 % at STC
		Uv (wind)	0.0 W/m²K/m/s		
LID - Light Induced Degradation		**Module Quality Loss**		**Module mismatch losses**	
Loss Fraction	2.00 %	Loss Fraction	0.00 %	Loss Fraction	2.00 % at MPP
Strings Mismatch loss		**IAM loss factor**			
Loss Fraction	0.10 %	ASHRAE Param.: IAM = 1 - bo (1/cosi -1)			
		bo Param.	0.05		

System losses

Auxiliary losses
Proportional to Power 4.0 W/kW
0.0 kW from Power thresh.

AC wiring losses

Inv. output line up to MV transfo	
Inverter voltage	800 Vac tri
Loss Fraction	1.50 % at STC
Global System	
Wire section	Alu 3 x 30000 mm²
Wires length	231 m

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures in combination with 16MW/102MWh BESS (12h charging/discharging)_16MW Setpoint

Nikos Vasilopoulos

AC wiring losses

MV line up to HV Transfo

MV Voltage	33 kV
Average each transformer	
Wires	Alu 3 x 1000 mm²
Length	43710 m
Loss Fraction	1.00 % at STC

AC losses in transformers

MV transfo

Medium voltage	33 kV		
One transfo parameters		**Operating losses at STC (full system)**	
Nominal power at STC	7.92 MVA	Nb. identical MV transfos	5
Iron Loss (night disconnect)	7.95 kVA	Nominal power at STC	39.59 MVA
Iron loss fraction	0.10 % at STC	Iron loss (night disconnect)	39.73 kVA
Copper loss	79.17 kVA	Copper loss	395.86 kVA
Copper loss fraction	1.00 % at STC		
Coils equivalent resistance	3 x 0.81 mΩ		

HV transfo

Grid voltage	150 kV
Transformer from Datasheets	
Nominal power	50000 kVA
Iron Loss (night disconnect)	23.80 kVA
Iron loss fraction	0.05 % of PNom
Copper loss	184.20 kVA
Copper loss fraction	0.37 % at PNom
Coils equivalent resistance	3 x 80.24 mΩ

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures in combination with 16MW/102MWh BESS (12h charging/discharging)_16MW Setpoint

Nikos Vasilopoulos

Horizon definition

Horizon from PVGIS website API, Lat=-13°39'59", Long=167°42'41", Alt=24m

Average Height	2.1 °	Albedo Factor	0.94
Diffuse Factor	0.99	Albedo Fraction	100 %

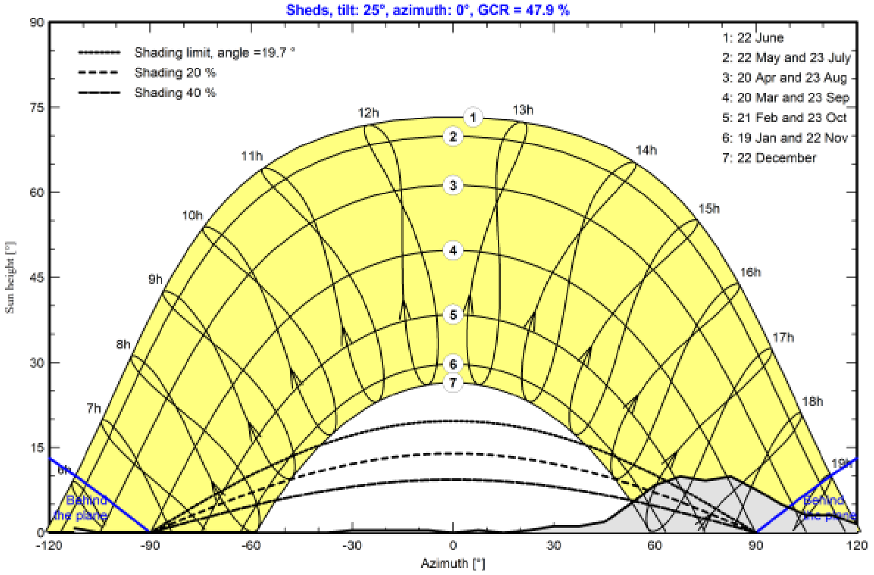
Horizon profile

Azimuth [°]	-113	-105	-38	-30	-8	0	8	15	23	30	38	45	53	60
Height [°]	0.8	0.0	0.0	0.4	0.4	0.0	0.4	0.0	0.4	1.1	1.1	1.9	5.0	8.4
Azimuth [°]	68	75	83	90	98	105	113	120	128	135	143	158	165	
Height [°]	9.9	9.2	9.9	7.6	5.0	3.1	3.1	1.5	1.1	1.5	1.1	1.1	0.8	

Sun Paths (Height / Azimuth diagram)

Orientation #1

Sheds, tilt: 25°, azimuth: 0°, GCR = 47.9 %



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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures in combination with 16MW/102MWh BESS (12h charging/discharging)_16MW Setpoint

Nikos Vasilopoulos

Main results

Simulation step
Hourly

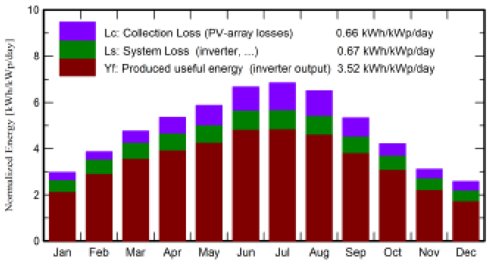
System Production

Produced Energy	51362 MWh/year	Specific production	1284 kWh/kWp/year
		Perf. Ratio PR	72.62 %
		Bifacial perf. ratio	70.39 %

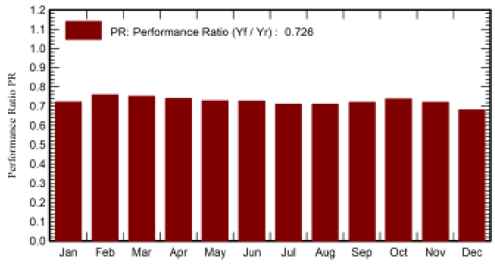
Battery ageing (State of Wear)

Cycles SOW	91.6 %
Static SOW	90.0 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio	PRBifi ratio
January	59.3	25.40	2.10	92.3	84.9	3311	2664	0.722	0.706
February	77.4	31.50	3.60	108.4	101.2	3971	3291	0.759	0.739
March	120.6	47.70	6.50	147.8	138.3	5300	4444	0.751	0.731
April	147.2	64.50	10.90	160.4	149.8	5622	4748	0.740	0.717
May	182.5	77.90	16.10	182.2	169.9	6249	5311	0.729	0.703
June	205.2	77.00	20.70	199.9	186.8	6795	5814	0.727	0.700
July	216.4	75.30	23.40	212.3	198.7	7041	6040	0.711	0.685
August	190.3	71.30	23.00	201.3	188.7	6740	5729	0.711	0.689
September	137.7	54.60	18.30	159.8	149.7	5452	4608	0.721	0.701
October	99.7	40.10	13.10	130.5	121.7	4624	3853	0.738	0.718
November	62.9	27.90	8.00	93.1	85.5	3296	2683	0.720	0.703
December	49.6	22.50	3.50	80.1	72.6	2744	2179	0.680	0.667
Year	1548.8	615.70	12.48	1768.1	1647.7	61145	51362	0.726	0.704

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane	PRBifi	Bifacial Performance Ratio
GlobEff	Effective Global, corr. for IAM and shadings		

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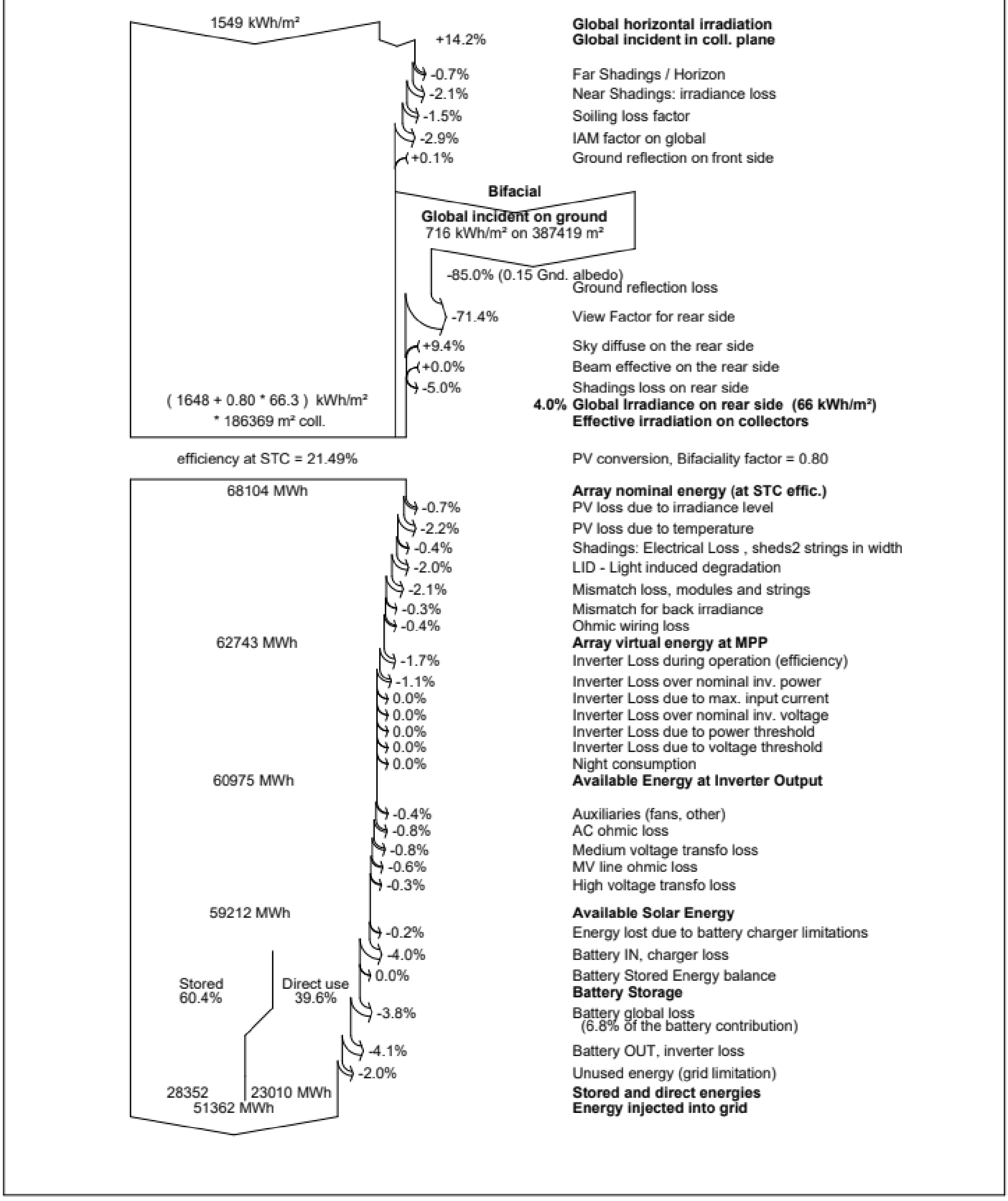
Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Fixed Structures in combination with 16MW/102MWh BESS (12h charging/discharging)_16MW Setpoint

Nikos Vasilopoulos

Loss diagram



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Investment Proposal 4:

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures in combination with 16MW/102MWh BESS (12h charging/discharging)_16MW Setpoint

Nikos Vasilopoulos

Project summary

Geographical Site		**Situation**		**Project settings**	
Láva		Latitude	40.1114 °(N)	Albedo	0.15
Greece		Longitude	22.0409 °(E)		
		Altitude	790 m		
		Time zone	UTC+2		

Weather data
Láva
SolarGIS - Synthetic

System summary

Grid-Connected System — **Unlimited Trackers with backtracking**

Orientation #1		**Near Shadings**		**User's needs**	
Tracking horizontal axis		no Shadings		Unlimited load (grid)	
Axis azimuth	0 °				
Phi min / max.	-/+ 60 °				
Tracking algorithm					
Astronomic calculation					
Backtracking activated					

System information

PV Array		**Inverters**		**Battery pack**	
Nb. of modules	66672 units	Nb. of units	102.7 units	Storage strategy: Power shifting	
Pnom total	40.00 MWp	Total power	30800 kWac	Nb. of units	24 units
		Grid power limit	16.00 MWac	Voltage	1325 V
		Grid lim. Pnom ratio	2.500	Capacity	80640 Ah

Results summary

Simulation step	Hourly				
Produced Energy	56718 MWh/year	Specific production	1418 kWh/kWp/year	Perf. Ratio PR	69.43 %
				Bifacial perf. ratio	67.44 %

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures in combination with 16MW/102MWh BESS (12h charging/discharging)_16MW Setpoint

Nikos Vasilopoulos

General parameters

Grid-Connected System — **Unlimited Trackers with backtracking**

Simulation step
Hourly

Orientation #1

Tracking horizontal axis

Axis azimuth	0 °
Phi min / max.	-/+ 60 °

Tracking algorithm
Astronomic calculation
Backtracking activated

Field properties

Nb. of trackers	999 units
Unlimited trackers	

Sizes

Tracker Spacing	6.60 m
Sensitive width	2.38 m
GCR Shading	36.4 %
Left inactive band	0.02 m
Right inactive band	0.02 m

Backtracking limit angle

Phi limits	+/- 68.5 °

Backtracking parameters

Backtracking pitch	6.60 m
Backtracking width	2.40 m
Left inactive band	0.02 m
Right inactive band	0.02 m
GCR Backtracking	36.4 %
Parameters choice	Automatic

Models used

Transposition	Perez
Diffuse	Perez, Meteonorm
Circumsolar	with diffuse

Horizon

Average Height	2.1 °

Near Shadings
no Shadings

User's needs
Unlimited load (grid)

Bifacial system definition

Orientation #1

Bifacial system

Model	Unlimited Trackers 2D model

Bifacial model geometry

Tracker Spacing	6.60 m
Tracker width	2.42 m
Axis height above ground	1.00 m
Nb. of sheds	999 units

Bifacial model definitions

Ground albedo	0.15
Bifaciality factor	80 %
Rear shading factor	5.0 %
Rear mismatch loss	10.0 %
Shed transparent fraction	0.0 %

Grid power limitation

Active power	16.00 MWac
Pnom ratio	2.500

Limit applied at the injection point

Storage

Kind	Power shifting

PV Array Characteristics

PV module

Manufacturer	Jinkosolar
Model	JKM-600N-78HL4-BDV
(Original PVsyst database)	
Unit Nom. Power	600 Wp
Number of PV modules	66672 units
Nominal (STC)	40.00 MWp
Modules	2778 string x 24 In series

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures in combination with 16MW/102MWh BESS (12h charging/discharging)_16MW Setpoint

Nikos Vasilopoulos

PV Array Characteristics

PV module		**Inverter**	
At operating cond. (50°C)		Manufacturer	Huawei Technologies
Pmpp	37.03 MWp	Model	SUN2000-300KTL-H0
U mpp	1009 V	(Original PVsyst database)	
I mpp	36696 A	Unit Nom. Power	300 kWac
		Number of inverters	616 * MPPT 17% 102.7 units
		Total power	30800 kWac
		Operating voltage	550-1500 V
		Max. power (=>30°C)	330 kWac
		Pnom ratio (DC:AC)	1.30
		No power sharing between MPPTs	
Total PV power		**Total inverter power**	
Nominal (STC)	40003 kWp	Total power	30800 kWac
Total	66672 modules	Nb. of inverters	103 units
Module area	186369 m²		0.3 unused
Cell area	172259 m²	Pnom ratio	1.30

Grid storage - Power shifting

Battery		**Battery input charger**	
Manufacturer	Huawei	Model	Generic
Model	Luna2000 - 4.5 MWh - 2H1	Max. charging power	16.00 MWdc
Battery pack		Max./Euro effic.	95.0 / 93.0 %
Nb. of units	24 in parallel	**Battery to Grid inverter**	
Voltage	1325 V	Model	Generic
Nominal Capacity (C10)	80640 Ah	Max. discharging power	16.00 MWac
Nominal energy	106.8 MWh	Max./Euro effic.	94.0 / 92.0 %
Operating SOC limits	98.0 / 2.0 %		
Useable energy	102.6 MWh		
Operating temperature	Fixed 20 °C		
Charging strategy		**Discharging strategy**	
Charging strategy	Fixed charging power before exporting	Discharging strategy	Specified hours
Fixed charging power	57600.00 MW	Discharging power	16.00 MW
Charging hours	8:00 to 20:00 (12 hours)	Discharging hours	8:00 to 12:00 (4 hours)
=> Daily stored energy for a clear day	180.1 MWh	=> possible discharging per day	192.0 MWh

Array losses

Array Soiling Losses		**Thermal Loss factor**		**DC wiring losses**	
Loss Fraction	1.5 %	Module temperature according to irradiance		Global array res.	0.21 mΩ
		Uc (const)	29.0 W/m²K	Loss Fraction	0.70 % at STC
		Uv (wind)	0.0 W/m²K/m/s		
LID - Light Induced Degradation		**Module Quality Loss**		**Module mismatch losses**	
Loss Fraction	2.00 %	Loss Fraction	0.00 %	Loss Fraction	2.00 % at MPP
Strings Mismatch loss		**IAM loss factor**			
Loss Fraction	0.10 %	ASHRAE Param.: IAM = 1 - bo (1/cosi -1)			
		bo Param.	0.05		

System losses

Auxiliary losses
Proportional to Power 4.0 W/kW
0.0 kW from Power thresh.

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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures in combination with 16MW/102MWh BESS (12h charging/discharging)_16MW Setpoint

Nikos Vasilopoulos

AC wiring losses

Inv. output line up to MV transfo

Inverter voltage	800 Vac tri
Loss Fraction	1.50 % at STC
Global System	
Wire section	Copper 3 x 30000 mm²
Wires length	387 m

MV line up to HV Transfo

MV Voltage	33 kV
Average each transformer	
Wires	Alu 3 x 1000 mm²
Length	43710 m
Loss Fraction	1.00 % at STC

AC losses in transformers

MV transfo

Medium voltage	33 kV		
One transfo parameters		**Operating losses at STC (full system)**	
Nominal power at STC	7.92 MVA	Nb. identical MV transfos	5
Iron Loss (night disconnect)	7.95 kVA	Nominal power at STC	39.59 MVA
Iron loss fraction	0.10 % at STC	Iron loss (night disconnect)	39.73 kVA
Copper loss	79.17 kVA	Copper loss	395.86 kVA
Copper loss fraction	1.00 % at STC		
Coils equivalent resistance	3 x 0.81 mΩ		

HV transfo

Grid voltage	150 kV
Transformer from Datasheets	
Nominal power	50000 kVA
Iron Loss (night disconnect)	23.80 kVA
Iron loss fraction	0.05 % of PNom
Copper loss	184.20 kVA
Copper loss fraction	0.37 % at PNom
Coils equivalent resistance	3 x 80.24 mΩ

Horizon definition

Horizon from PVGIS website API, Lat=-13°39'59", Long=167°42'41", Alt=24m

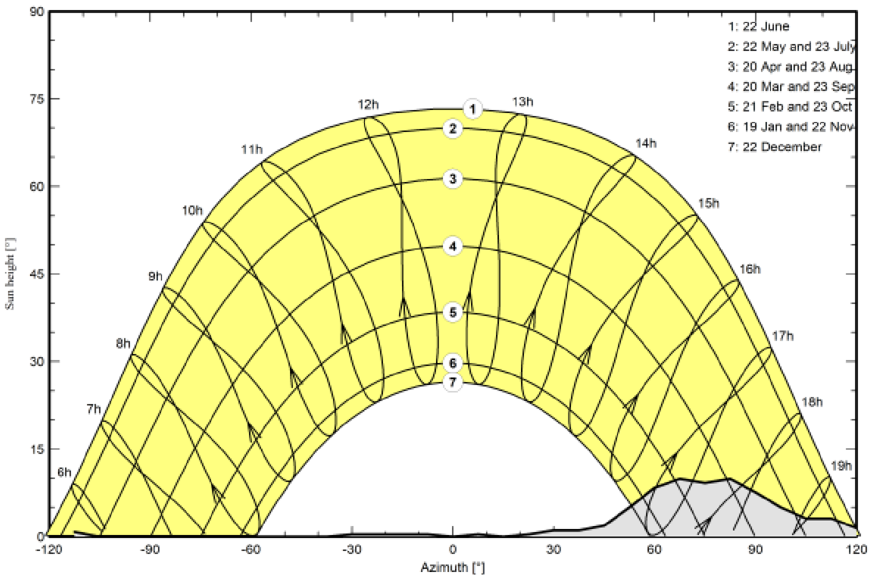
Average Height	2.1 °	Albedo Factor	0.00
Diffuse Factor	1.00	Albedo Fraction	100 %

Horizon profile

Azimuth [°]	-113	-105	-38	-30	-8	0	8	15	23	30	38	45	53	60
Height [°]	0.8	0.0	0.0	0.4	0.4	0.0	0.4	0.0	0.4	1.1	1.1	1.9	5.0	8.4
Azimuth [°]	68	75	83	90	98	105	113	120	128	135	143	158	165	
Height [°]	9.9	9.2	9.9	7.6	5.0	3.1	3.1	1.5	1.1	1.5	1.1	1.1	0.8	

Sun Paths (Height / Azimuth diagram)

Orientation #1



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Project: Evaluation of Investment Proposals for a Utility Scale Solar Project in Greece

Variant: Single Axis Tracking Structures in combination with 16MW/102MWh BESS (12h charging/discharging)_16MW Setpoint

Nikos Vasilopoulos

Main results

Simulation step
Hourly

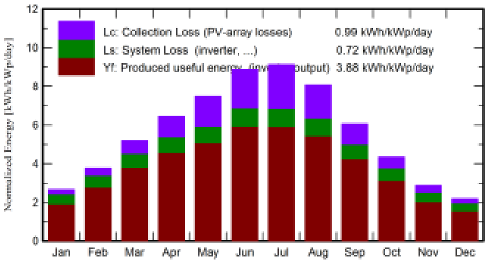
System Production

Produced Energy	56718 MWh/year	Specific production	1418 kWh/kWp/year
		Perf. Ratio PR	69.43 %
		Bifacial perf. ratio	67.44 %

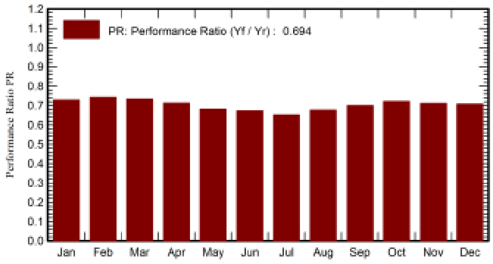
Battery ageing (State of Wear)

Cycles SOW	91.7 %
Static SOW	90.0 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio	PRBifi ratio
January	59.3	25.40	2.10	82.2	75.1	3015	2401	0.730	0.708
February	77.4	31.50	3.60	105.3	97.3	3814	3129	0.743	0.721
March	120.6	47.70	6.50	161.1	150.2	5634	4734	0.735	0.713
April	147.2	64.50	10.90	192.7	181.2	6474	5502	0.714	0.693
May	182.5	77.90	16.10	232.1	219.4	7376	6319	0.681	0.660
June	205.2	77.00	20.70	265.9	252.4	8288	7148	0.672	0.654
July	216.4	75.30	23.40	282.7	268.9	8513	7359	0.651	0.633
August	190.3	71.30	23.00	249.6	236.1	7878	6746	0.676	0.657
September	137.7	54.60	18.30	181.9	170.7	6014	5105	0.702	0.682
October	99.7	40.10	13.10	135.0	125.0	4680	3902	0.723	0.702
November	62.9	27.90	8.00	86.0	78.0	3043	2450	0.713	0.691
December	49.6	22.50	3.50	67.8	61.4	2460	1924	0.709	0.687
Year	1548.8	615.70	12.48	2042.1	1915.5	67189	56718	0.694	0.674

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane	PRBifi	Bifacial Performance Ratio
GlobEff	Effective Global, corr. for IAM and shadings		

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PVsyst V8.1.0
VEW, Simulation date:
29/05/26 14:33
with V8.1.0

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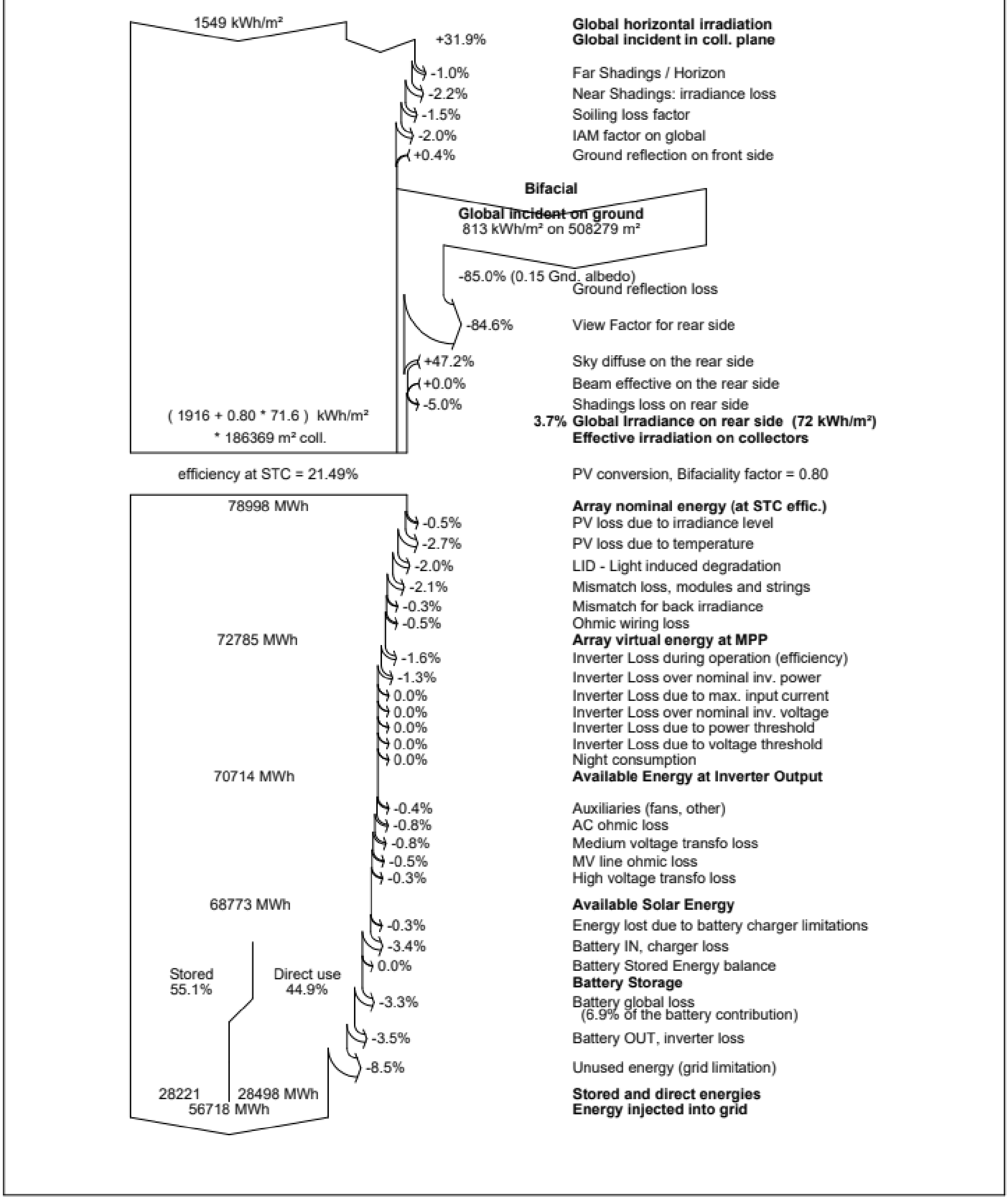
Loss diagram



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