UNIVERSITAT POLITÈCNICA DE VALÈNCIA

School of Industrial Engineering

Photovoltaic installation project for self-consumption on industrial roof

Master's Thesis

Master's Degree in Energy Technologies for Sustainable Development

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TRABAJO FIN DE MÁSTER

TECNOLOGÍA ENERGÉTICA PARA DESARROLLO SOSTENIBLE

"PHOTOVOLTAIC INSTALLATION FOR SELF-CONSUMPTION ON INDUSTRIAL ROOF"

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RESUMEN

El proyecto se inicia con un análisis del contexto nacional referente al uso de la energía fotovoltaica y la evolución de los precios de la energía durante este último año, con el afán de reducir el gasto de la factura eléctrica de una compañía local en concreto, debido al aumento del coste de la en este último periodo de tiempo. Con esto en mente se inicia un proceso de investigación de todas las diferentes opciones y la selección de la más adecuada con el fin de rebajar el coste de la facturación eléctrica, así como avanzar hacia el uso de energías renovables menos contaminantes con el medio ambiente. Se conforma así un proyecto de autoconsumo vía placas solares sin excedentes.

Por lo tanto, el grueso del proyecto se compone con el estudio de la situación actual de la nave industrial, comenzando por la localización del emplazamiento donde se encuentra situada y por lo tanto la cantidad de luz solar recibida a lo largo de las épocas del año y la sombra generada por las diferentes edificaciones colindantes, debido a sus formas y alturas. Como punto base, se analiza el coste de la factura eléctrica actual.

Con el estudio inicial realizado, se investigan varias opciones para todos los elementos que componen una instalación fotovoltaica de este tipo de aplicación, con el objetivo de sondear todas las opciones disponibles actuales y obtener un resultado final lo más optimizado posible.

Las diferentes propuestas se generan tanto para la ubicación de las placas sobre la cubierta, observando la incidencia del sol sobre ellas y la generación de las mismas dependiendo tanto de la inclinación como de la orientación, para continuar, se realiza una comparativa de varios tipos de inversores observando tanto las principales ventajas como inconvenientes asociados a su uso de los diversos tipos y tecnologías que se pueden encontrar actualmente, así como para las diferentes tecnologías de paneles solares existentes. Debido a las infinitas posibilidades de ubicación, se procede a hacer un análisis de la estructura necesaria para sustentar las placas solares en su posición óptima de funcionamiento para este caso, teniendo en cuenta el peso y según la orientación la carga que pueda ocasionar sobre ellas la acción del viento.

Una vez seleccionada la mejor propuesta, se procede a desarrollar todos los cálculos definitivos para el sistema seleccionado con un nivel de detalle mayor y teniendo en cuenta parámetros más técnicos, enfocados ahora sí, a realizar un presupuesto y dimensionamiento de toda la instalación requerida con la mayor precisión posible y valorando todas las necesidades del sistema, como puedan ser, el dimensionamiento del cableado, diseño y configuración del generador fotovoltaico, cálculo de la carga estructural sobre la nave. Con todos estos análisis realizados se genera un estudio sobre la viabilidad económica del sistema elegido finalmente, haciendo un cálculo sobre el gasto de inversión total, los gastos derivados, la previsión de ahorros, así como la evolución económica de la inversión a lo largo de la vida útil del sistema y un breve resumen del ahorro que supone esta propuesta.

Se incluye un pliego de condiciones y un estudio básico de seguridad y salud referente al proyecto.

ABSTRACT

The project begins with an analysis of the national context regarding the use of photovoltaic energy and the evolution of energy prices over the last year, with the aim of reducing the cost of the electricity bill of a specific local company, due to the increase in the cost of electricity in this last period of time. With this in mind, a process of investigating all the different options and selecting the most suitable one in order to reduce the cost of the electricity bill, as well as moving towards the use of renewable energies that are less polluting to the environment, was started. In this way, a self-consumption project via solar panels without surpluses is set up.

Therefore, the bulk of the project consists of the study of the current situation of the industrial building, starting with the location of the site where it is located and therefore the amount of sunlight received throughout the year and the shade generated by the different adjacent buildings, due to their shapes and heights. As a base point, the cost of the current electricity bill is analyzed.

With the initial study carried out, various options are investigated for all the elements that make up a photovoltaic installation of this type of application, with the aim of sounding out all the current options available and obtaining a final result that is as optimised as possible.

The different proposals are generated both for the location of the panels on the roof, observing the incidence of the sun on them and the generation of the same depending on both the inclination and orientation, to continue, a comparison of various types of inverters is made observing both the main advantages and disadvantages associated with its use of the various types and technologies that can be found today, as well as for the different technologies of existing solar panels. Due to the infinite possibilities of location, an analysis is made of the structure necessary to support the solar panels in their optimum operating position for this case, taking into account the weight and, depending on the orientation, the load that the wind may place on them.

Once the best proposal has been selected, we proceed to develop all the definitive calculations for the selected system with a greater level of detail and taking into account more technical parameters, focused now on making a budget and sizing of the entire installation required with the greatest possible precision and assessing all the needs of the system, such as the sizing of the wiring, design and configuration of the photovoltaic generator, calculation of the structural load on the building. With all these analyses carried out, a study is generated on the economic viability of the system finally chosen, making a calculation of the total investment cost, the derived costs, the savings forecast, as well as the economic evolution of the investment throughout the useful life of the system and a brief summary of the savings that this proposal entails.

A set of specifications and a basic health and safety study for the project are included.

CONTENTS

1 - INTRODUCTION

1.1 - PURPOSE AND SCOPE OF THE PROJECT

This project as a whole represents the completion of the Final Master Degree Project in MUTED at the Polytechnical university of Valencia

As a technical project, the general aim is to collect and explain as a whole the information relating to the design, dimensioning, projection, viability and execution of a photovoltaic installation of 96 kW nominal power on the roof of an industrial plant, for the purpose of self-consumption. Therefore, the connection of the generator system to the internal electrical grid of the plant will be carried out. To this end, the technical and economic characteristics for its achievement and execution will be presented, selecting the different elements that make up this installation.

In this way, the general objectives of this PV installation include:

- Reduction of the developer's electricity bill, since the electricity generated by the projected system is intended to self-supply the industrial plant.
- Reduction of pollutant emissions, as a result of reducing the demand on the electricity grid, whose energy supply is based on non-renewable sources and which emit large quantities of pollutants and greenhouse gases.
- Improvement of the developer's reputation and image, showing interest and sensitivity to environmental care.
- Favoring the energy transition towards a more ecological, sustainable, distributed, self-generation and decarbonization model.

The specific objectives for the achievement of this PV installation are:

- Study of the solar resource available on the site, as well as shadows or other impediments or obstacles.
- To carry out a study of the load curve of the industrial plant to obtain information on its consumption and demand.
- Determine the ideal orientation and inclination, as well as the number of panels and optimal distribution for maximum use of the roof.
- The design of a reliable and safe installation that does not alter the operating conditions and activities of the industrial plant where it is installed.
- Economic study to determine the feasibility and profitability of the project.

2 - BACKGROUND

This section aims to contextualise the situation of the photovoltaic sector, from the principle of operation of the use of solar energy by means of photovoltaic technology, passing through the most important concepts that encompass it; ending with the current regulatory framework at state level in Spain, describing the recent legal provisions and their situation with a view to the approach of a photovoltaic installation such as the one that is intended to be planned in this document.

It should be noted that there will be numerous technical-theoretical information related to a photovoltaic installation (such as the detailed description of the elements that compose it as well as its typologies) that will not be presented in this section. This is because it will be included in sections later in the document, in which the analysis of the technological alternatives is presented, as well as the subsequent projection, design and description of the photovoltaic installation that is the object of this project, based on the final solution of configuration, elements and technology chosen.

2.1 - SOLAR PHOTOVOLTAIC ENERGY AND TECHNOLOGY

Photovoltaic solar energy is energy that produces electricity from the energy available from solar radiation by means of a semiconductor device (photovoltaic cell) incorporated in solar panels.

A photovoltaic installation does not pollute in its operation, as it is a sustainable and renewable source, which generates energy without producing agents or emissions that damage the environment.

Broadly speaking, photovoltaic panels are made up of a set of cells, which are made of semiconductor devices made from pure silicon (Si) with the addition of impurities (boron, B and phosphorus, P) forming two layers between which a potential difference is formed when the photons of light strike, due to the accumulation of electrons in the upper layer and the absence of them in the lower layer. In this way, there are two points at different potentials, generating voltage and, when the two terminals are joined by connecting a charge, a continuous electric current will circulate.

2.1.1 - Principle of operation: photovoltaic effect.

The operating principle, based on the physical phenomenon of the photovoltaic effect, is introduced and explained in more detail below.

In 1940, it was discovered that if a small number of impurities were added to certain crystals, their electrical conductivity varied when the material was exposed to a light source. Elements such as silicon (Si), germanium (Ge) and selenium (Se) are elements that possess these intermediate characteristics between conducting and insulating bodies, the so-called semiconductors. Under certain conditions, these elements allow the free flow of electric current in one direction, but not in the opposite direction. This property is the basis for diodes, transistors, electronic devices that rectify alternating current, etc., as well as photovoltaic panels. One of the methods to increase the conductivity of a semiconductor element is to introduce impurities (doping) into its crystalline structure.

Returning to the application to the photovoltaic panel, made of Si crystals, these atoms have an atomic valence of 4 (i.e. 4 electrons in their last shell), so a covalent bond is formed with each of the adjacent Si atoms. They do not give up or accept electrons as they have a full valence shell, so they do not allow electric current to flow, functioning as an insulator. When doped with an atom with 5 valence electrons, such as phosphorus (P), it is incorporated into the crystal lattice replacing a Si atom, so that atom will have four covalent bonds and an unbonded free electron. This forms an N-type semiconductor material, in which there is an excess of free electrons and therefore a negative charge. In the same way, but doping with elements such as boron (B), whose atoms have 3 valence electrons, then you will have a lattice with atoms linked by three covalent bonds and a hole which will be in a position to accept a free electron. This is summarised graphically in figure 1.

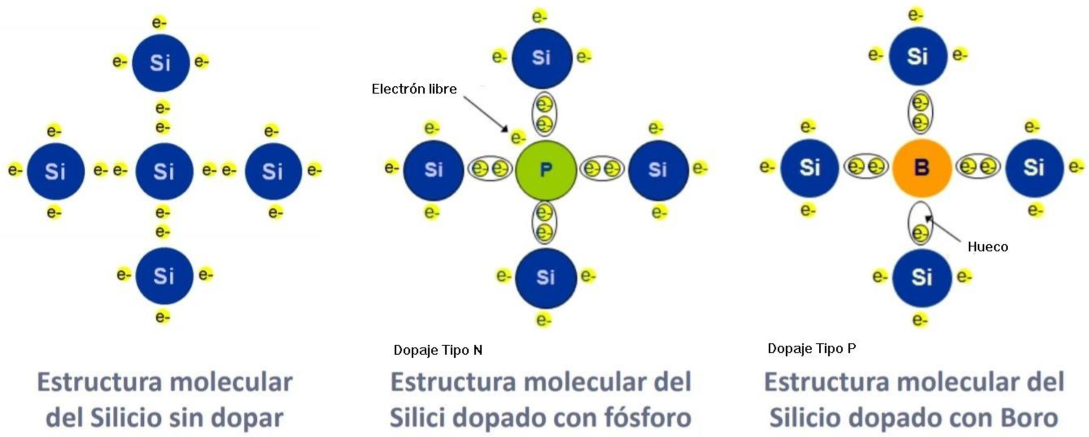


Figure 1. Doping of the crystalline molecular structure of silicon (Si) to form P-type and N-type semiconductors, the P-N junction of which forms the material used in photovoltaic panels for their photoelectric effect. Source: [1].

Therefore, in a sheet of silicon crystals alone, the electrons are not free to move because their covalent bonds keep them in a fixed structure. If you add impurities such as phosphorus (with 5 valence electrons), you get a structure where when the free electrons get enough energy they move freely. If light (photons) hits them, the electrons gain energy by becoming excited and can move freely. However, this movement is random and would not cause current if a charge were connected to its ends.

Therefore, a driving force is required to direct the movement of these electrons, which can be achieved with a p-n junction. In a solar cell, both p-type and n-type semiconductor materials are joined together to form a p-n junction, which acts like a diode. When junctioned, some of the electrons from the N-side will migrate to the P-region and fill the 'holes' (absence of electrons) available there.

In this area, a 'depletion region' is formed, where there are no free electrons and no holes. Due to the electron migration, the N-side boundary becomes slightly positively charged and the P-side becomes negatively charged. An electric field will definitely form between these charges, which produces the necessary 'driving' force discussed above. In detail, the following will occur when light strikes: photons of light strike the N-zone of the photovoltaic cell, penetrate and reach the depletion region, generating an excitation, which causes a movement of the electrons and the generation of electron-hole pairs in this region.

The electric field here electrostatically drives the holes and electrons out of this region, increasing the concentration of electrons in the n-zone and holes in the p-zone to such a level that a potential difference is generated between the two sides. As soon as any charge is connected between the two regions, electrons will flow through the charge recombining with the holes in the p-region after completing their path. In this way a PV cell continuously delivers dc current. Below are several pictures that graphically represent the above explanation.

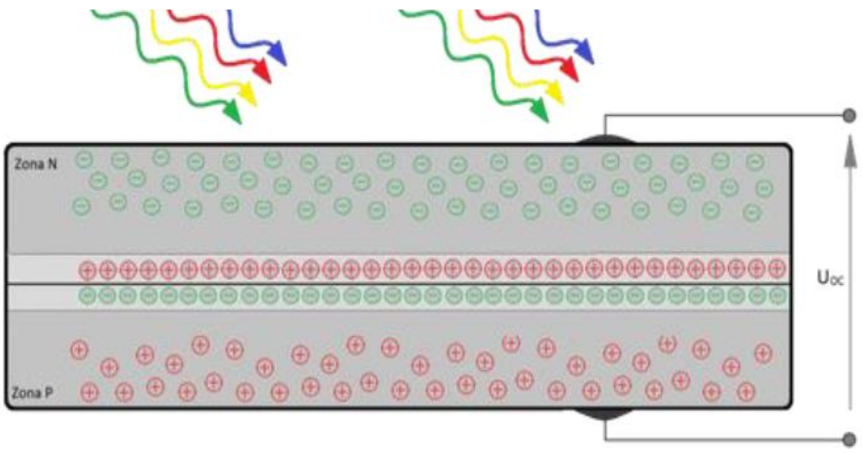


Figure 2. Photovoltaic effect, in vacuum. Source: Areatecnologia.com/electricidad

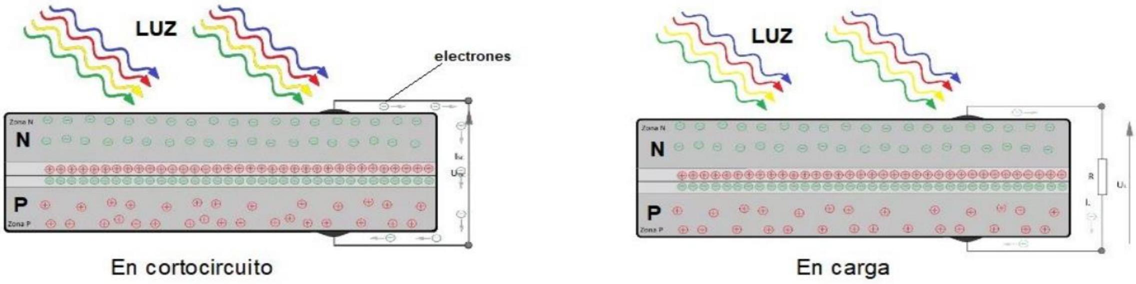


Figure 3. Photovoltaic effect, short-circuit (left) and load (right). Source: Areatecnologia.com/electricidad

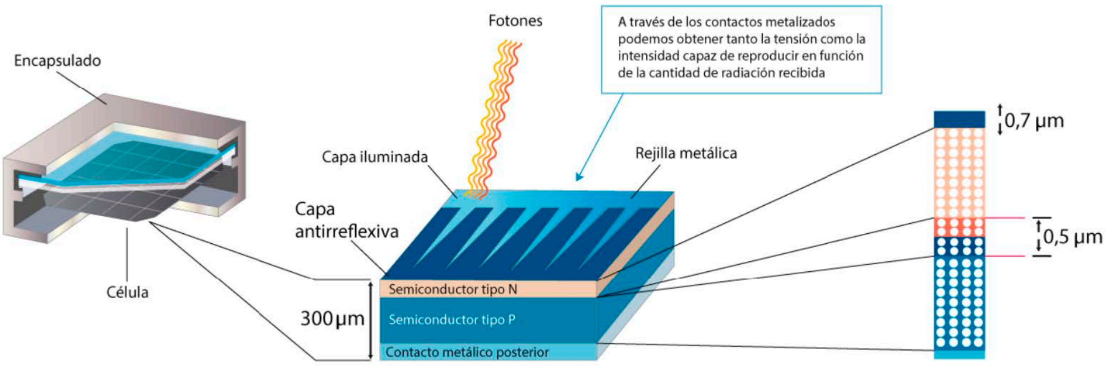


Figure 4. Section of a photovoltaic cell. N-P junction. Source: LEDSBeSolar

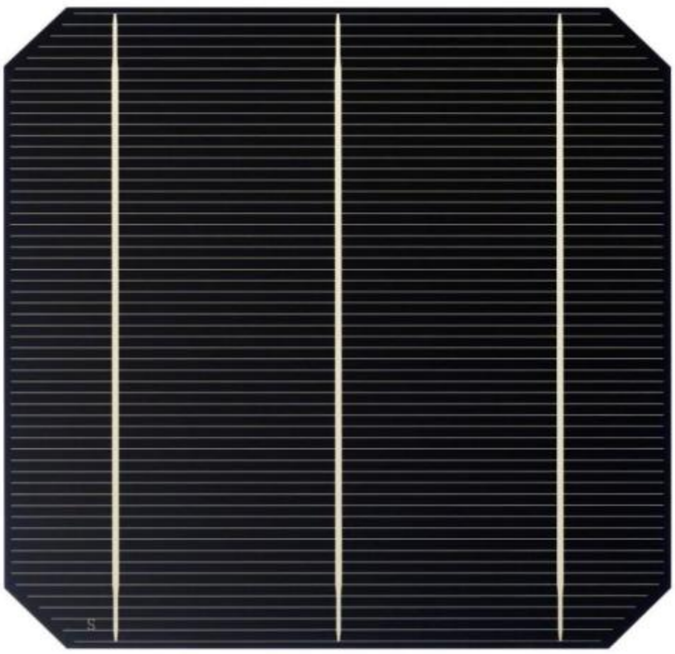


Figure 5. Image of a photovoltaic cell. Source: Google Images

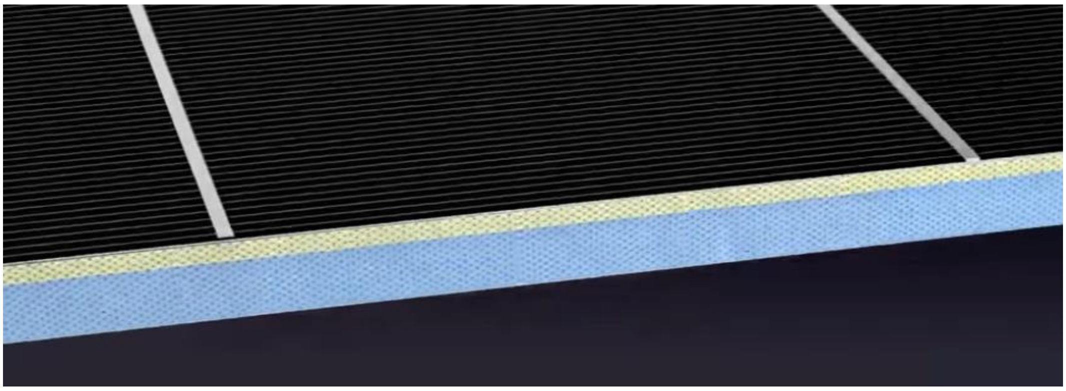


Figure 6. Represents the section of a cell with the n-p junction. Source: Learn Engineering

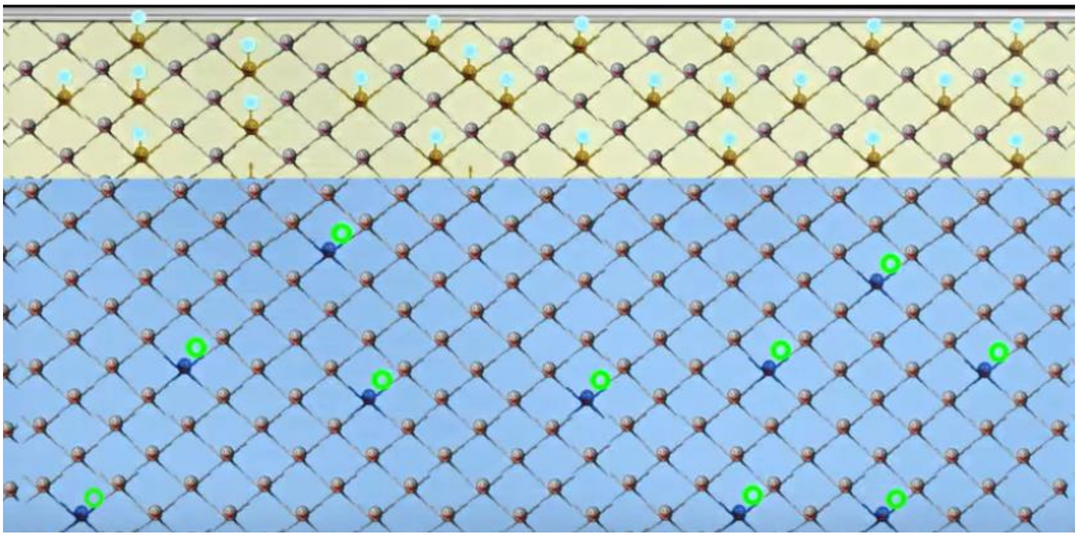


Figure 7. Representation, at molecular lattice scale, of the section of a cell showing the upper n-layer lighter and more doped than the lower p-layer, which is thicker and less doped. Source: Learn Engineering.

In a solar cell in practice, currently, you have a top layer n which is much thinner and doped than the bottom layer p, which is thick and slightly doped, as can be seen in figures 6 and 7. This is to increase the performance of the cell. The formation of the depletion region here is much wider. Therefore, with the incidence of light, more electron-hole pairs are excited, resulting in higher electrical generation. In addition, having a thinner top n-layer means that more of the light energy contained in the photons can reach the depletion region.

Silicon PV cells are typically metallised with thin strips printed on the front and back. There are thinner strips (called fingers) that lead to thick strips perpendicular to the front, called bus bars, bus bars or bus rails, see figure 8. The fingers are needed for the excess electrons on the n-side to be brought to a conduction terminal. After passing through the fingers, the electrons accumulate/concentrate on the main bus bars, and will flow through them as an electric current when a load is connected. The top negative side of the cell is connected to the back side of the next cell via copper strips, as shown in Figure 9. Typically, cells have 2 or 3 bus bars (2BB or 3 BB), although to achieve higher efficiencies 4 and even 5 bus bars are incorporated. This is because the internal resistance losses are reduced due to the smaller distance between the bus bars.

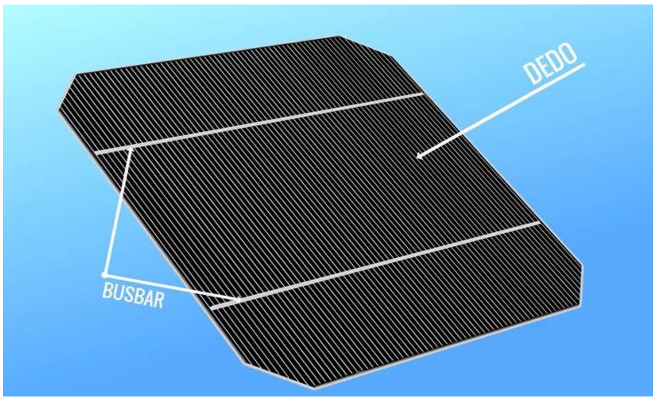


Figure 8. 2BB PV cell, showing the fingers and both bus bars. Source: Learn Engineering

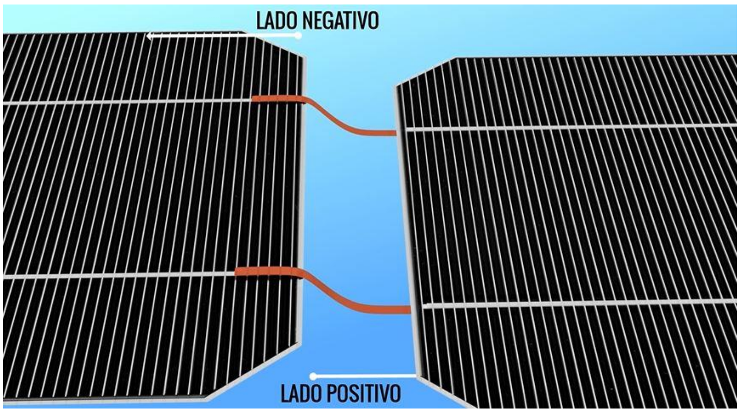


Figure 9. Serial connection of the top side of one cell to the back side of the next, positive to negative connection. Source: Learn Engineering.

Through the above explanation, it is possible to generate a voltage difference between two different points, the two terminals of each cell. By having the various cells interconnected in a series circuit, the voltage is increased; by having various strips of cells connected in parallel, the current is increased. This set of cells is what makes up the so-called photovoltaic panel, whose combination of cells in series and parallel increases the current and voltage values to a usable range. It has two terminals (positive and negative) between which there will be a potential difference (voltage) when solar radiation strikes. In the same way, several panels can be joined in series to increase the voltage generated, having the same circulating electric current, or several panels can be joined in parallel, increasing the intensity generated (this being the sum of the contribution of each panel) and maintaining the voltage between the terminals fixed. The type of electric current it provides, when a load is connected between its terminals, is direct current (dc), so if alternating current (ac) is required, an inverter must be added. If the energy generated needs to be stored for later use and not immediately, a storage system, such as a battery with its regulator, can be added.

2.1.2 - Concepts of solar radiation

As explained in the previous section, photovoltaics uses precise technology to harness the energy present in solar radiation and convert it into electricity. The concept of solar radiation refers to the electromagnetic radiation emitted by the sun, which can be distinguished according to different wavelengths. The spectrum of visible light has the precise wavelength that photovoltaic cells take advantage of, triggering the photovoltaic effect when photons strike, as explained above. This is why a PV panel is not yet able to harness 100% of the vast amount of energy available in the solar radiation received by the Earth.

Despite its abundance, the use of solar energy in general, and in this case photovoltaic energy in particular, is mainly conditioned by three aspects: the intensity of solar radiation received on Earth, the daily and annual cycles to which it is subjected in its spatial trajectory, and the climatic conditions of each terrestrial region. The profitable use of solar radiation as a source of energy is directly linked to the geographical location of the place chosen to make use of it and the time variations, parameters that must be taken into account in photovoltaic installation projects, as is the case here.

Two relevant concepts can be distinguished in relation to the sun's rays:

- Solar irradiance (represented as E): refers to the incident radiant power or intensity per unit of land area on a plane at a particular terrestrial location. It is measured in [W/m2].
    - If the irradiance value is plotted for each instant in a day, the irradiance curve is obtained, as shown in figure 10.

- Solar irradiance (represented as G or H): also referred to as solar radiation, global radiation or insolation. It refers to the amount of energy received per unit of land area at a particular land location at a particular time. It is measured in [Wh/m2].
    - It can be obtained by integration of the irradiance curve; if this is done for the time interval of a specific day, the diurnal insolation measurement is obtained, and if it is done for a whole year, the annual insolation is measured.

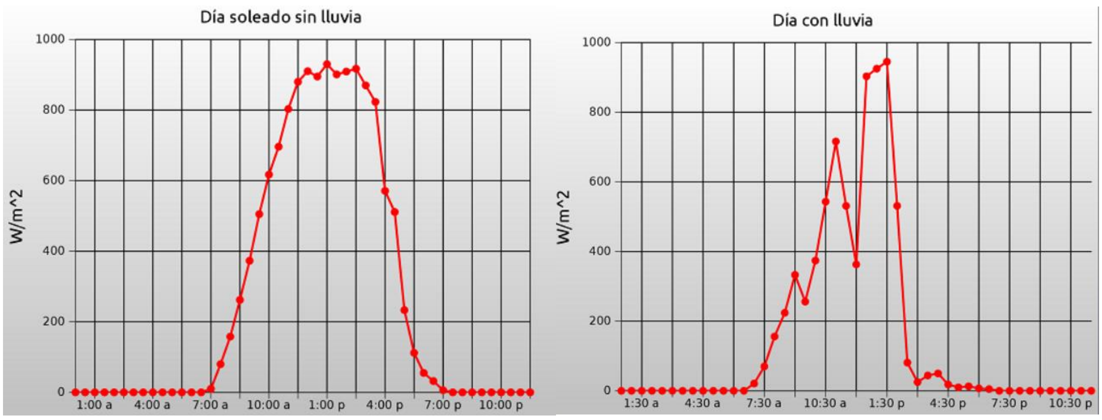


Figure 10. Irradiance curve of a typical day: left) a clear and sunny day; right) a cloudy or rainy day. Source: SesLab

It can be seen in the left graph of figure 10 that a day mostly clear of clouds, i.e. quite sunny, forms a bell-shaped irradiance curve: when the day begins it starts to increase its value up to a maximum of solar intensity at midday and then starts to decrease until nightfall. This bell-shaped curve is altered on cloudy or rainy days (right graph, fig. 10) where the sun's rays do not maintain their incidence and a variability of the curve is obtained.

The intensity or solar irradiance that the Earth receives outside the atmosphere is a fixed amount called solar constant, around 1353 W/m2 according to NASA, although it oscillates between approximately 1,300 and 1,400 W/m2 during the year. Losses to the atmosphere through reflection, absorption and scattering reduce this value by about 30%, giving a maximum achievable terrestrial irradiance of about 1,000 W/m2, after deducting the aforementioned losses. These values vary according to weather conditions.

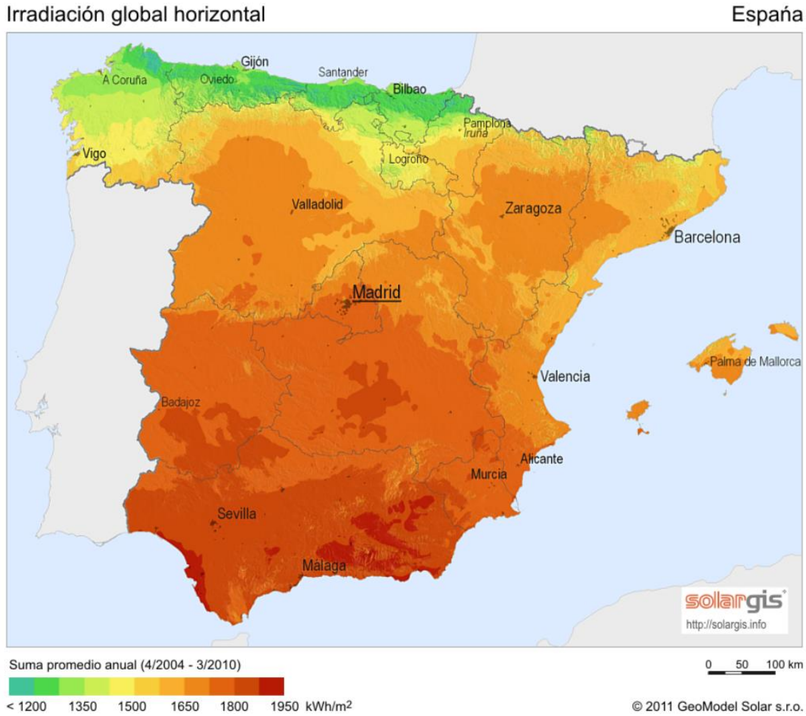


Figure 11. Annual average of horizontal solar irradiation (GHI) in the Spanish territory. Source: Solargis

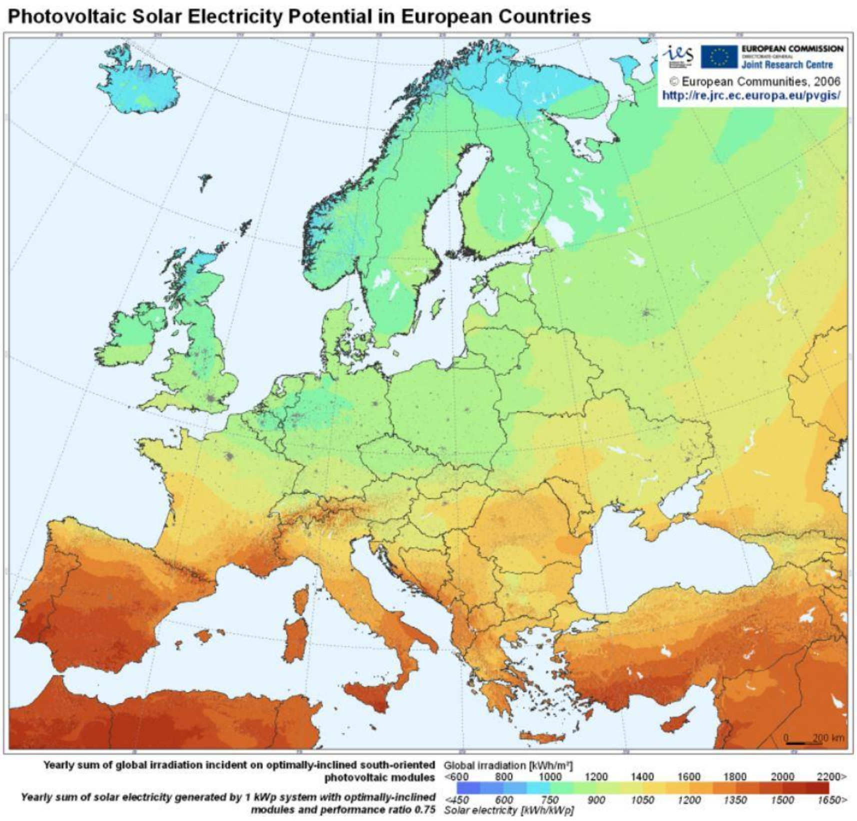


Figure 12. Average annual solar irradiation in the European framework. Source: The European Commission's Joint Research Centre, Institute for Environment and Sustainability.

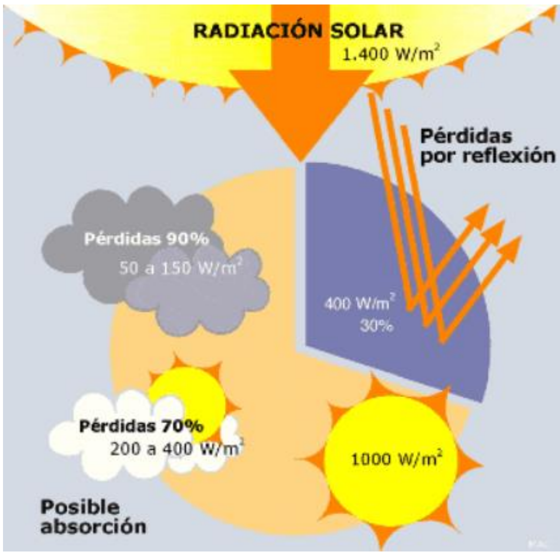


Figure 13.Graph showing the solar intensity (irradiance) that the Earth receives after the reflection losses portion (blue), being 1000W/m2 for a sunny day, or after cloudy day losses (70%) or rainfall losses (90%), remaining between 400 and 50 W/m2 respectively.

Both concepts (solar irradiance and solar irradiance) include the energy/power coming from direct radiation plus the diffuse radiation that, scattered by the atmosphere, comes from the rest of the sky. There is also the component of reflected solar radiation (also called albedo), which comes from the reflection of solar radiation on different objects before it hits the surface. However, this is not taken into account in the calculations covered by this framework; although it is worth mentioning that there is research aimed at developing photovoltaic technology to also take advantage of this third component of radiation, for example bifacial panels, an interesting emerging technology but outside the scope of this project.

2.1.2.1 - Concept of Peak Solar Time (PSH)

This concept becomes relevant when referring to or calculating the production or available energy of a PV system; it is also useful for comparing the solar potential of two sites. Peak solar hours' can be defined as the number of hours per day with a hypothetical irradiance of 1,000 W/m2 that together add up to the same amount of total irradiance as the actual irradiance of that day, i.e. they are equivalent. When represented in the solar irradiance curve graph (see figure 14), it would be a rectangle whose height is the value of 1,000 W/m2 and its base is the number of peak solar hours (HSP), therefore, the area of this rectangle is the same value as the area under the curve (its integral).

In other words, the HSP refers to the number of hours during which a panel could be generating its peak power, which occurs when the maximum terrestrial irradiance of 1000 W/m2 is incident on it.

One peak solar hour is equivalent to 1 kWh/m2. It is used as a way of counting the energy received from the sun by grouping it into packages, each package being 'one hour receiving 1000W/m2.

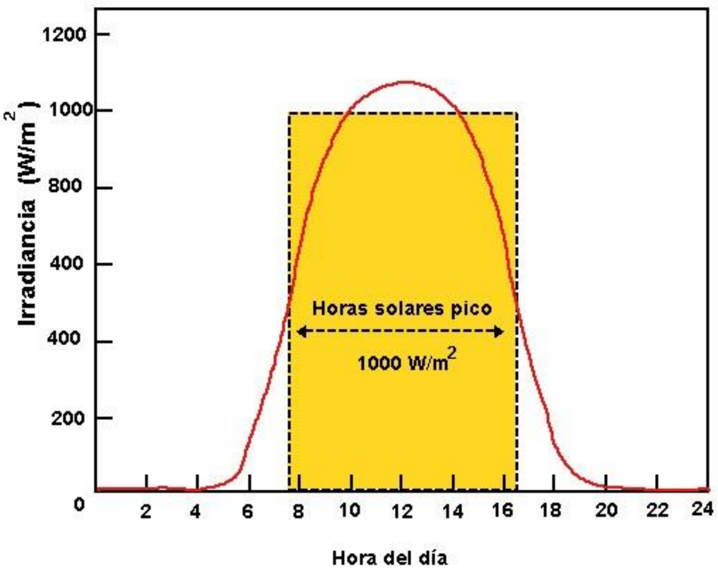


Figure 14.Schematic of HSPs in a 'type' irradiance curve. Source: CalculationsSolar.

To calculate the HSP value, the value of the incident irradiance (integral of the irradiance curve) is divided by the value of the irradiance power under standard measurement conditions (STC), since it is under these conditions that the electrical characteristics of the photovoltaic modules are fulfilled. This irradiance value at STC is the aforementioned 1000 W/m2. In other words, if you have the solar irradiance data for a given day and divide it by 1000, you obtain the HSP.

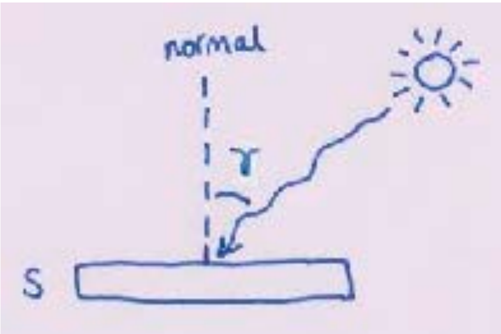
Establishing the HSP is also a way of defining the total incident energy (irradiance, G) over the course of the day at a location. It is worth mentioning that if G is measured in kWh/m2day, then HSP≡G.

2.1.2.2 - Solar Geometry

In order to be able to determine the optimum orientation and inclination of the panels of photovoltaic installations in any given case, it is essential to have knowledge of solar geometry.

First of all, it must be taken into account that in order to obtain the maximum photovoltaic energy production, it will always be of interest that the sun's rays are incident perpendicular to the panel. Based on the concepts presented in the previous point, we have the following.

The intensity of radiation on a plane decreases proportionally to the cosine of the angle of solar incidence in relation to the normal of a surface, in accordance with the following expression:



where:

G: irradiance (Wh/m2)

E: irradiance (W/m2)

S: surface (m2)

t: time (s)

γ: angle between solar ray and normal (º)

Figure 15. Visual representation of the angle between the solar ray and the normal to the surface on which it strikes. Source: Own freehand creation

Therefore, it follows from the above that the surface of interest S (in this case the photovoltaic panel) will receive the most energy (in irradiance G) from sunlight by maximising cos(γ), i.e. when it is 1, and for this purpose γ=0º, i.e. when the sun's ray is incident perpendicular to the surface, in the direction of the normal.

The position of the Sun varies with the daily cycle as well as with the annual seasonal cycle as a result of the rotational movement of the Earth around it and also around its own axis, therefore, one way of making the most of the irradiation is to have a surface with built-in tracking on two axes, so that it follows the East-West path of the solar trajectory, in order to constantly maintain γ=0º ; In turn, another axis rotates it as the sun changes its height in its annual trajectory, being more incorporated (greater inclination) in winter when the sun is lower and being more horizontal in summer when the sun is higher, in order to also maintain γ=0º at all times and therefore the maximum incidence of solar irradiation, obtaining the maximum energy production.

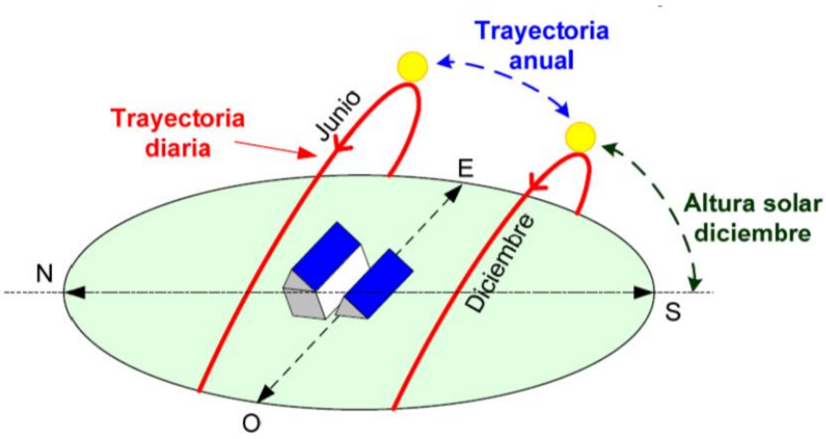


Figure 16.Daily (in red) and annual (in blue) solar paths in the northern hemisphere. Source: Own creation.

Without monitoring, in order to optimise the design of the fixed PV installation, the incident irradiance is critically dependent on two angles that need to be decided and fixed:

- The orientation (α): angle between the normal to the (projected) surface and the line marking the geographical south. Also called the azimuthal angle of the panel. See figure 17.

In installations in the northern hemisphere, the panels obtain their maximum irradiation with an orientation towards the south (α=0º); and in the southern hemisphere it is the opposite, i.e. with an orientation towards the north. The power losses for each degree of deviation from the optimum orientation are in the order of 0.2% for each degree. However, the optimum orientation will depend on the situation of each particular case, the characteristics of the existing roofs, the space available, among other variables.

- The tilt (ß): angle of the surface of interest (the panel) with respect to the horizontal. See figure 17. In winter a large angle of inclination is of interest because the Sun is at a higher altitude and in summer a smaller angle of inclination is of interest because the Sun is at a lower altitude.
    - In practice, a fixed tilt is usually adopted, taking as a general rule the latitude of the site minus 10º (dimensioned to be used equally all year round).
    - In the case of dimensioning the installation for priority use in winter, an inclination equal to the latitude of the site plus 10º is usually adopted. For example, in cases where the most critical months of consumption are the winter months.
    - In the case of an installation for preferential use in spring/summer, an inclination equal to the latitude would be adopted.

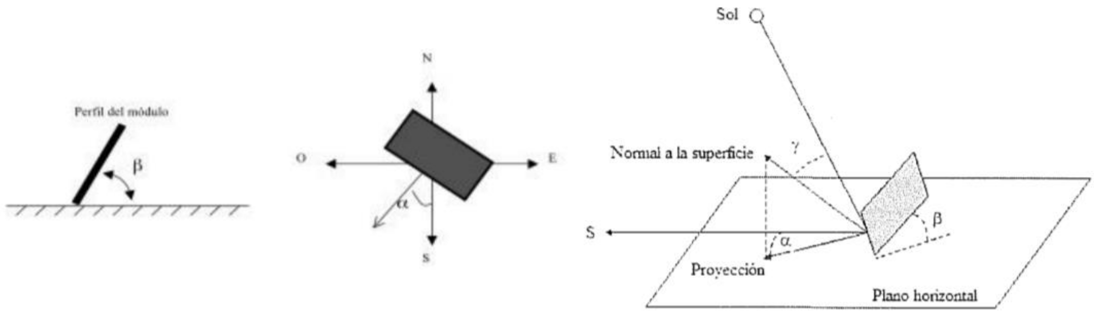


Figure 17. Diagrams of the inclination and orientation. Source: Own creation.

Regarding the selection of the inclination, this depends mainly on the location of the PV installation, which is defined by the geographical latitude. This magnitude is the distance in degrees from the equator at which the parallel passing through the location under consideration is located. The maximum height of the sun, and therefore the inclination of the sun over the surface of the panels, varies throughout the annual seasons, being higher in summer and lower in winter, as mentioned above. It can be seen how the maximum height of the sun presents an angle complementary to the latitude of the location considered during the equinoxes. Thus, for a location on the equator, whose latitude is 0º, the sun's rays form an angle of 90º with the earth's horizontal, it is convenient to place the panels with an inclination of 0º; in the same way, in a location with a latitude of 40º, the sun's rays form an angle of 50º with the earth's horizontal, it is convenient to place the panels with an inclination of 40º. See figure 18. The guidelines most commonly used in practice have been described above.

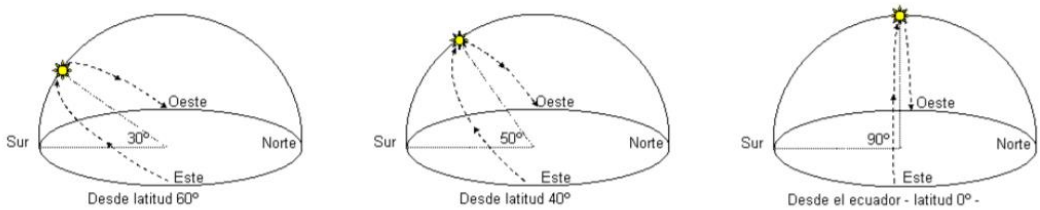


Figure 18. Complementary convenient latitude-inclination relationship. Source: Own creation.

2.2 - TYPES OF PV SYSTEMS

PV installations are classified into two different groups depending on whether or not they are connected to the grid:

- Isolated installation: also called off-grid, it allows energy supply in a house, building or other installation where there is no connection to the electricity grid, i.e. there is no previous electricity installation or contract with an electricity company. They are carried out in places where without the PV installation there would be no electricity supply, either by the owner's own decision or due to the complexity of the grid supply, the distance or the terrain in which it is located.

- Grid-connected installation: an installation that is installed in houses, warehouses or other infrastructure where there is already a previous energy supply from the electricity company.

    - Energy sales installation: an installation in which energy is generated not for direct use, but rather is dumped into the electricity grid as a sales action, for subsequent use by other consumers also connected to the grid; after such dumping, it is taken care of by the relevant body that manages energy in that territory, in this case REE (Spanish Electricity Grid).

    - Self-consumption installation: grid-connected installation in which, for example, the aim is to reduce the consumption of the electricity bill by means of the contribution provided by the PV panels, which will serve to self-supply electricity consumption. This typology is the one that concerns the present project and the modalities that can be used to process the installation, as defined in the current regulations in force, will be explained later on.

Sometimes the above classification is understood as 3 different groups, in which there is the isolated, the grid-connected (which implicitly refers to the sale of energy to the grid) and finally the self-consumption, which in turn can be divided into self-consumption installations connected to the grid, or isolated self-consumption installations. An additional group can even be included, the shared self-consumption installation, which is beginning to be implemented to supply a housing complex. However, for this project, it has been presented in this way to avoid confusion, since, as will be seen in the modalities, the concept of "self-consumption installation" is used in the understanding that it already has a grid connection and the PV installation complements it.

Further information, such as examples and diagrams on the above classification are included in the following subsections.

2.2.1. Isolated installation

These can range from simply lighting a road sign to powering an entire neighbourhood at the microgrid level. PV systems for off-grid self-consumption are not exclusive to households, but can be used in a wide range of different situations and applications. The following are examples of applications:

- Lighting: advertising signs, street lighting, bus stops, garden lights...
- Signalling: road signs, weather buoys, level crossings...
- Telecommunications: signal repeaters, roadside SOS posts...
- Rural electrification: dwellings far from urban areas where the public electricity grid supply does not reach; villages; mountain refuges; isolated or periodically occupied dwellings; or for those communities living in regions in underdeveloped countries; etc.
- Agricultural and livestock use: solar pumping; irrigation; electrification of fences...
- Others: environmental measuring stations, motorhomes, toys, various electronic devices...

Figure 19 below shows the usual diagram of the elements and their interconnection in an isolated PV installation in a home. In these installations, it is essential to have an energy storage system, usually batteries, to guarantee autonomy. They are also usually accompanied by an additional support system, such as a fuel generator, in the event that the PV installation is unable to generate, there is little radiation or a high demand for prolonged periods of time. It is worth noting that the battery charge regulator is often nowadays incorporated in the inverter itself (called inverter-charger). You can see the blue part being DC and the red part AC. In addition, these inverters usually have an AC input to be supplied by the external fuel generator mentioned above to guarantee autonomy; through this AC terminal, an interconnection can also be made with a network that connects a community of neighbours, or microgrids at various scales. These inverters, in applications that include pumping or irrigation, usually incorporate a frequency inverter for precise and automatic control of the electric pumps.

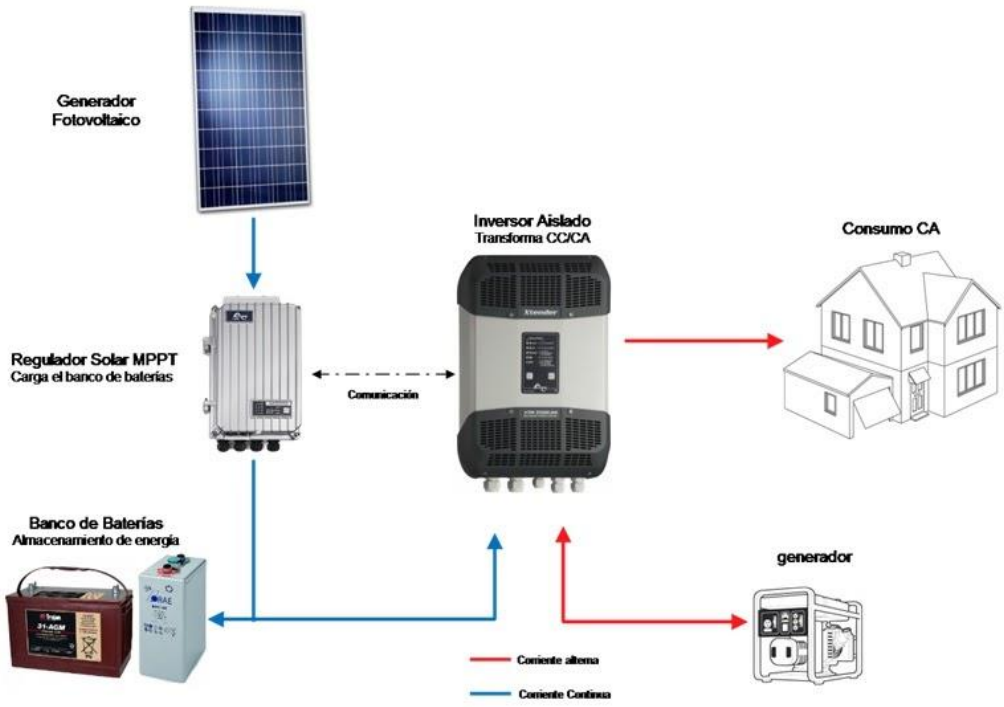


Figure 19. Typical general diagram of an off-grid PV installation in a house. Source: Flux Solar

2.2.2. Grid connection installation

- For the sale of energy:
  - Photovoltaic power plants: also known as solar farms, these are power plants that generate electricity solely using photovoltaic technology. They usually bring together several PV installations from different owners, with the aim of selling all the electricity generated. As several installations are located on the same site, sharing infrastructure and services, it facilitates maintenance, surveillance and security operations...

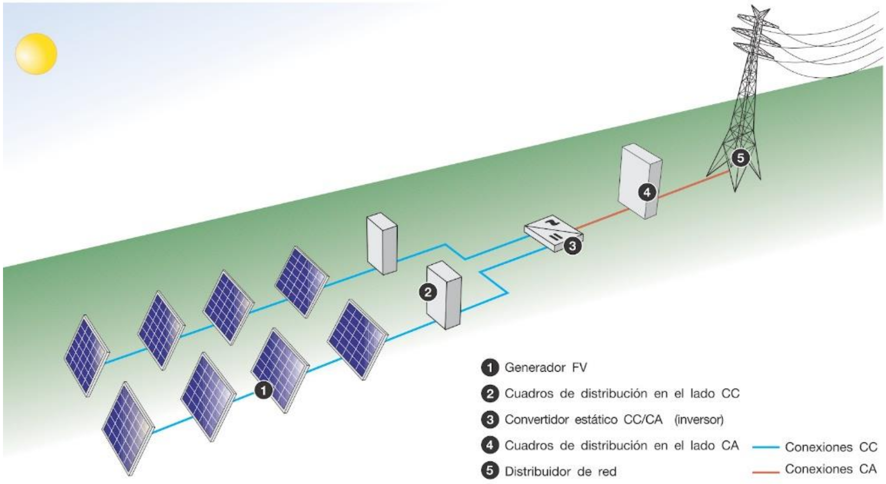


Figure 20. General diagram of a photovoltaic power plant. Source: GlobalElectricity

- In buildings: large PV installations in buildings such as industrial buildings, in which, for example, a PV array is installed either on the roof or in architectural integration, which in addition to covering the demands of the building, also sells to the grid. This case will be seen in the modalities of the regulation, which will be presented later.

- Self-consumption:

  It can be seen in the following diagram that there is a grid connection in addition to the photovoltaic contribution. These installations offer the advantage of distributed generation instead of centralised generation, which is one of the strong points of the energy transition. In addition, as the energy is produced close to the area of consumption, it has lower losses than that produced in large, traditional, centralised power plants, where there are losses in transmission lines and transport costs. Furthermore, this production takes place during the day, when demand is higher than at night.

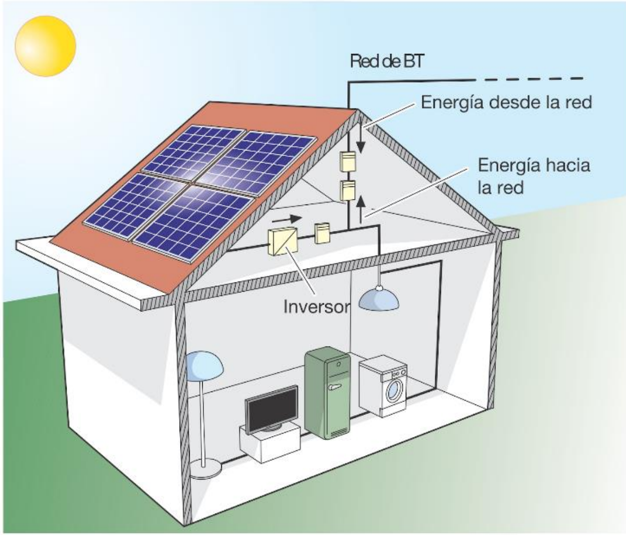


Figure 21. Building (dwelling or industrial building) with grid-connected, self-consumption PV installation. Source: GlobalElectricity.

2.3 - MODULE CHARACTERISTICS

2.3.1 - I-V curve

The I-V curve is the characteristic curve of a photovoltaic panel which, by means of a graph of the current and voltage values, represents its operating points according to the environmental conditions.

As can be seen in the example in figure 22 below, there is a voltage and current operating point for which the maximum output power is obtained, called Pmp, and the corresponding operating values, Imp and Vmp. The maximum voltage value that the panel can give is the no-load voltage (Voc), when the current given by the module is zero, by definition, i.e. when no load has been connected to it and it is therefore in no-load condition. Likewise, the maximum current value is the short-circuit current (Isc) when there is practically no resistance and therefore the voltage drop is zero.

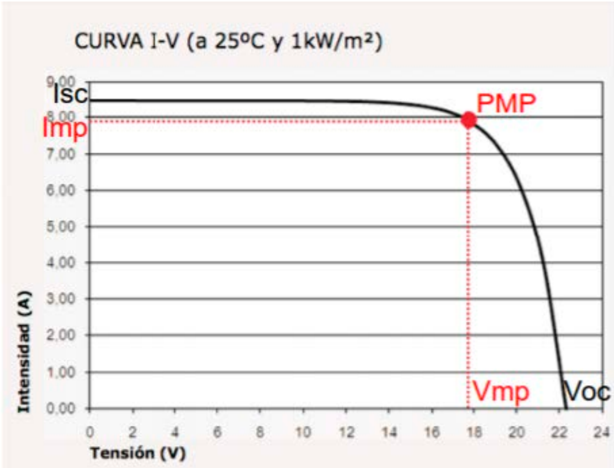


Figure 22. Example of I-V curve for an Atersa panel model A-150P. Source: Atersa data sheet

The performance of PV modules (their I-V curve, as well as their characteristics and data sheet ratings) is generally given under the internationally accepted standard measurement conditions, EMC or STC, which are defined by:

- Solar irradiance = 1000 W/m2
- Cell temperature = 25ºC
- Spectral distribution (1) = AM 1.5 G

It should be noted that there are conditions other than the standard laboratory measurement conditions above, which are more similar to the real behaviour of the panel, such as TONC conditions. This refers to those in which the cell is at nominal operating temperature, i.e. the temperature reached when the module is subjected to irradiance of 800 W/m2 with AM1.5G, ambient temperature 20ºV and wind speed of 1m/s. In order to have an accurate working behaviour of the panel under these circumstances, the parameters of the characteristic curve must be recalculated. To do this, the modifications introduced by the new irradiance and temperature values with respect to the reference STCs can be calculated trivially by means of conversion formula.

The values of the I-V operating curve of a panel vary with varying irradiance and temperature. When the irradiance decreases with respect to the standard irradiance (1kW/m2), maintaining the temperature, this also means a reduction in the panel's output current values. On the other hand, the temperature affects the voltage in a proportionally inverse way, i.e., by maintaining an irradiance value, when the temperature increases, the voltage decreases and therefore the power produced; while when the temperature decreases, the voltage increases and with it the power produced. Each panel has its specific temperature coefficients that cause the variations of the different parameters; these are given in their technical data sheets.

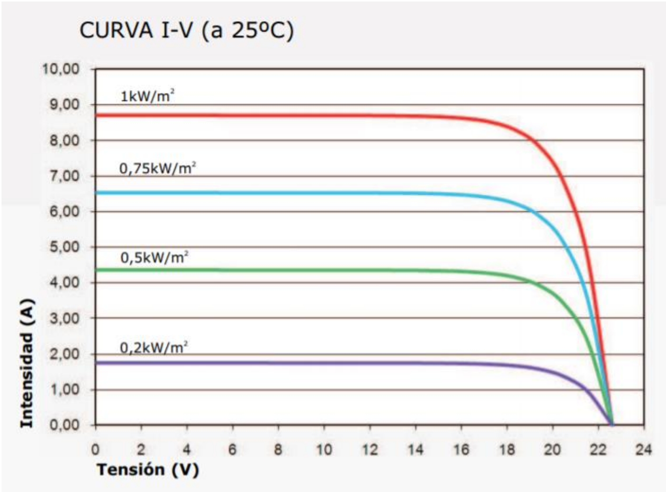


Figure 23. Variation of I with irradiance, for an Atersa panel model A-150P. Source: Atersa data sheet.

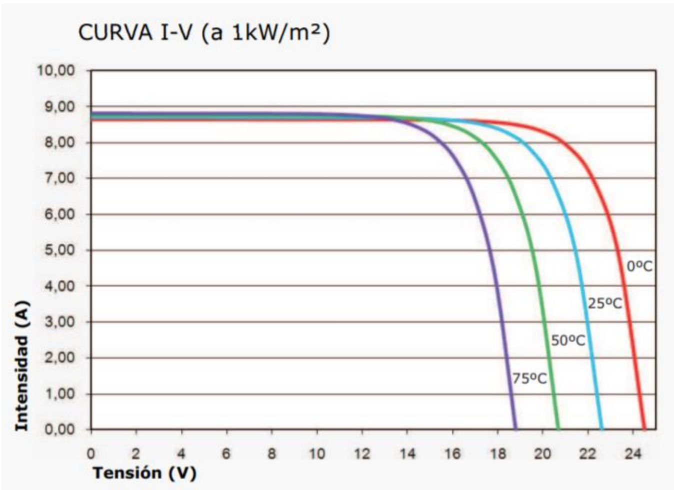


Figure 24. Variation of V with temperature, for an Atersa panel model A-150P. Source: Atersa data sheet

From the I-V curve, a second panel operating curve can be obtained, the P-V curve (shown in dashed red line in figure 25), which indicates the output power of a module according to its voltage. It can be seen that the maximum power peak is obtained at the same operating point of Imp and Vmp of the I-V curve.

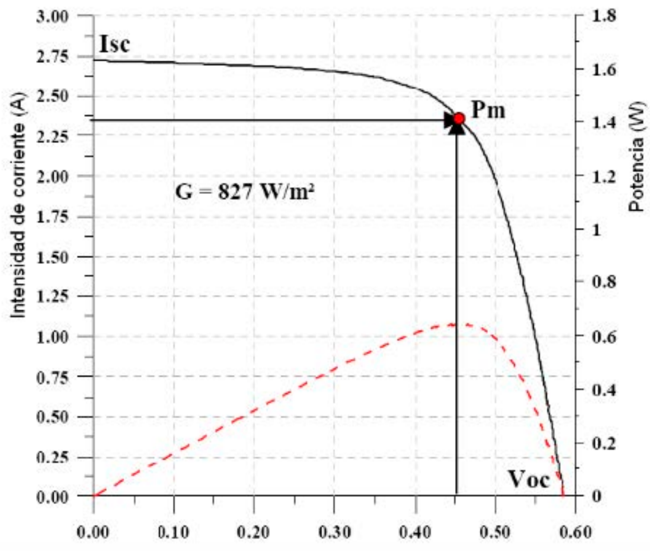


Figure 25. P-V curve in red and I-V characteristic curve in black, of a 100cm2 basic PV cell Source: FPUNE Paraguay, project "Solar Station".

2.3.2 - Protective diodes

Throughout the lifetime of the panel, the panel will sometimes be affected by shadows, due to elements that may temporarily land on it, such as leaves, birds, etc. It is vitally important that the panel has protection elements so that its operation is not impaired and there are no faults in some of the cells of the module. These elements are the protection diodes and are available in two different arrangements: bypass diodes and blocking diodes. Each has the function of protecting the panel against two possible situations. The following figure shows, in addition to the different elements of the panel, the location of the protection diodes. These are normally encapsulated in a watertight box at the rear of the panel, from where the connection terminals come out.

Figure 26. Parts of a conventional PV panel. Source: Own creation

Bypass diodes: These mitigate (not eliminate) the effects of shadows on certain parts of the photovoltaic modules. When there is a shadow on a cell, it does not receive radiation and therefore its output current becomes zero, leaving it in open circuit. To prevent the open circuit from cancelling out the current of all cells in the same series, these diodes are introduced to provide an alternative path, preventing it from overriding the operation of the entire panel. One diode is usually incorporated for each set of cells grouped in series. Figure 27 shows simulation sequences that clarify the operation of these diodes.

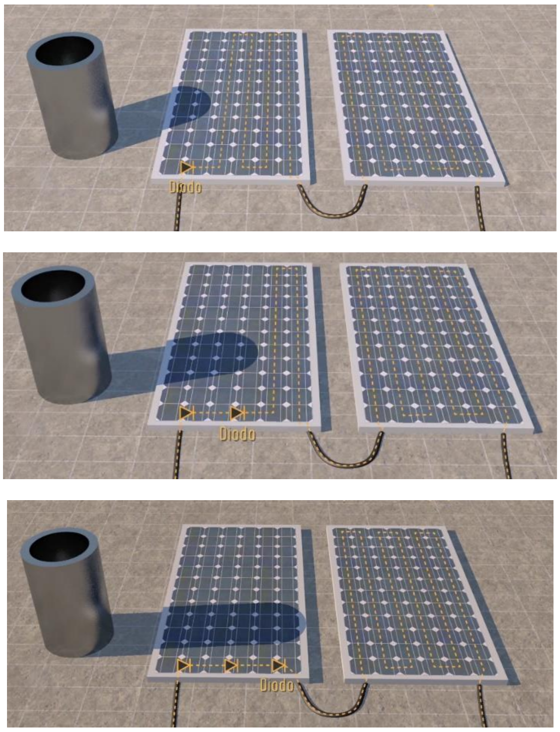


Figure 27. Three shadow simulation sequences illustrating the operation of bypass diodes. Source: CCEEA.

It can be seen in the first image how as the shadow enters affecting the first strips of cells, the first diode is activated, causing the current to bypass the first two columns of cells, and leaving the remaining two thirds of the panel in normal operation. In the next image the shadow advances across the module and the second bypass diode is activated, so the module generates one third of its capacity. In the third image, the shadow blocks the module completely, cancelling its output, but the bypass diodes allow the current to flow in the direction it was going, so as not to cancel the output of the other panels. This simulation is very important in order to visualise and understand the importance of the placement of the modules according to the possible surrounding shadows to which the installation may be subjected. With this in mind, it can be affirmed that it will be less harmful for a shadow to affect a module longitudinally than transversally, as in the case of the simulation in fig. 27; since, although the transversal shadow observed allows the panel to continue working thanks to the diodes, the performance it gives is much more diminished than a longitudinal shadow, as it affects a greater number of series of panels.

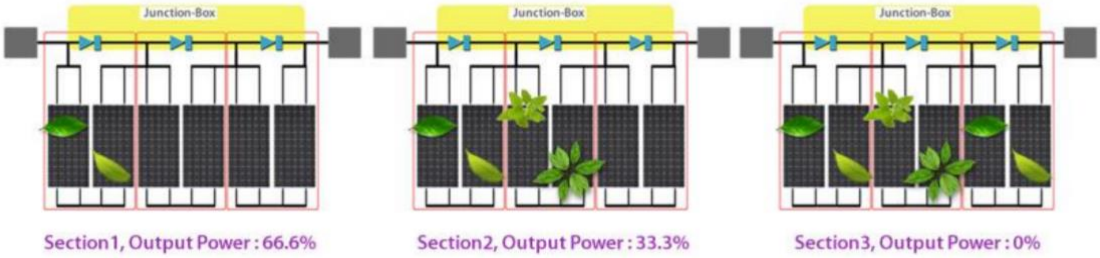


Figure 28. Schematic diagram of bypass diode operation. Source: Own

Figure 29. Example of J.Box schematic (left) and photo (right) of the back of the PV panel, with 2 and 3 bypass diodes respectively. Source: Solar Channel.

Bypass diodes also serve to reduce the risk of overheating caused by the shading of a panel, in which case part of the cells would behave as resistive, switching from energy producing to energy consuming, and dissipating heat. The explanation of this requires keeping in mind the previous points of this project, where it has been explained that a cell basically consists of a p-n junction, which can be modelled electrically as the action of a diode (not to be confused with protection diodes) in parallel with a resistor and a current source. If the cell does not receive radiation, it cannot supply current, so it behaves like an open circuit. This diode will not allow current to flow in this direction, so the current will flow through the internal resistance of the cell. In small modules this protection is not necessary as it does not reach high temperatures and does not reach the point of risk of rupture.

This overheating phenomenon causes hot spots, which can be identified with a thermal imaging camera, as shown in figure 30.

Even in the event of a panel failure, the panel voltages are readjusted by changing the direction of some currents, which would also cause the faulty cell to draw current instead of generating it. Bypass diodes minimise this problem.

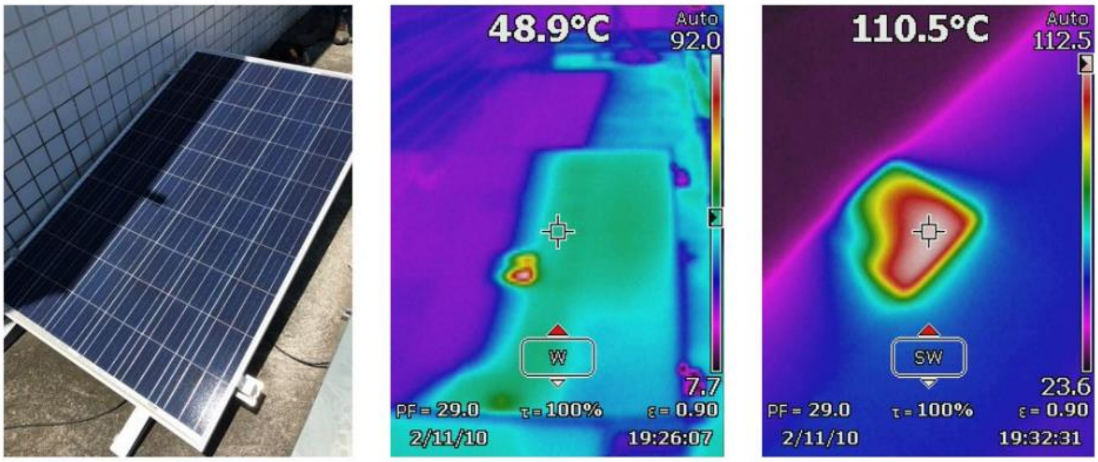


Figure 30. Module affected by hot spots caused by shading and analysed with a thermal imaging camera. Source: Solar Channel.

As can be seen in figure 30, there are no hot spots in the fully shaded portion, as the bypass diode diverts the current. However, there is a small portion of shadow that is not sufficient to activate the second bypass diode. In this region there is a hot spot with a temperature of 110.5ºC.

From this derives the great importance of avoiding shading at the design stage of the system, as well as a good maintenance of dirt, not only to maintain maximum production but also because of the issue of hot spots. It will be convenient and interesting, both to avoid the maximum energy losses due to shading and to protect the chain from possible damages, to choose PV panels during the design, which contain at least three bypass diodes in their inner box (j.box).

- Blocking diodes: protect the panel by preventing the current flow from being reversed between blocks of photovoltaic panels when they are connected in parallel, when one or more of them are shaded and therefore their voltage is lower than that of the rest. If these diodes were not present, as the voltage on the shaded panel is lower than that of the rest of the voltage generating panels, then the current would flow towards them, acting as energy consumers instead of generators, and they could break down. It also prevents, in installations with battery connection, the battery from discharging through the panel when it is not working due to lack of radiation or shading.

  These diodes are usually incorporated in the junction box that groups the various strings of panels connected in parallel. If the system is controlled by a regulator (usually a function of the inverter itself), these additional diodes can be dispensed with, as they are integrated in the regulator.

  Figure 31 shows a diagram of where the blocking diodes would be located, and figure 32 shows the location of both protection diodes: the bypass diodes and the blocking diodes.

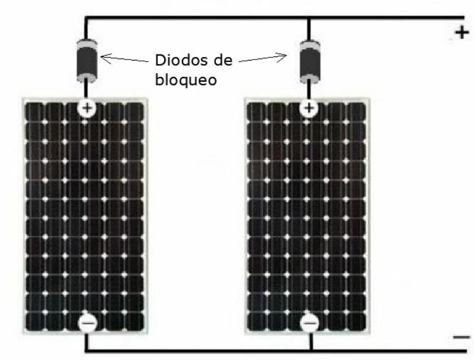


Figure 31. Locating blocking diodes for panels connected in parallel and/or to a battery. Source: MPPT Solar.

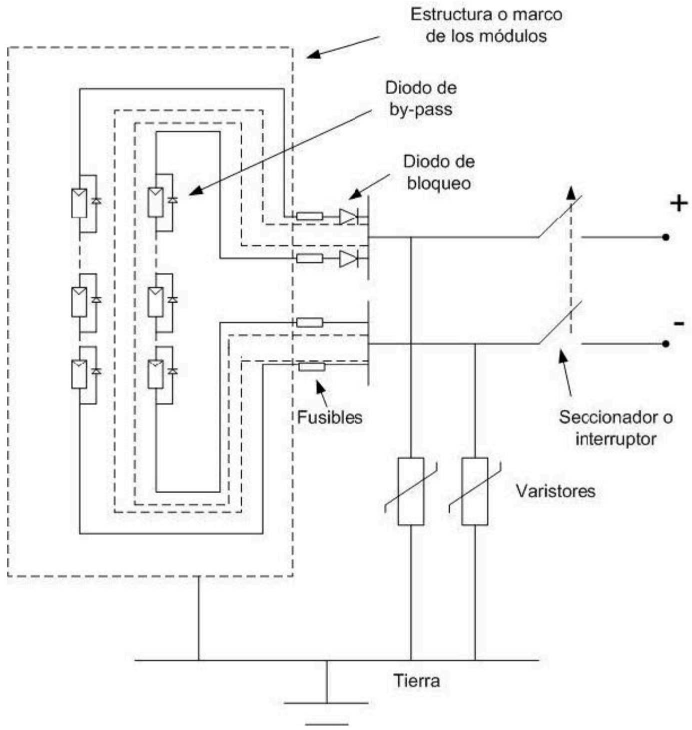


Figure 32. Location of both protection diodes of a module. Source: OPEX Energy.

2.4 - MAXIMUM POWER POINT TRACKING, MPPT

As seen above, in the I-V curve of a panel there is one of all the operating points of the curve where the maximum extractable power is obtained from the panel, the point Pmp=Vmp·Imp, located at the elbow of the characteristic curve; this point is called the maximum power point (MPP). There are techniques to maximise the power extraction of a PV panel under all conditions, and the most commonly used technique in the industry today is the one that tries to keep the panel operating at the MPP point. This technique is called Maximum Power Point Tracker (MPPT).

The purpose of the MPPT system is to continuously sample the PV cell output and apply the appropriate resistance (load) to obtain the maximum power for any given environmental conditions, which can be highly variable. MPPT devices are typically integrated into an electronic system, an electrical power converter; it can either be a so-called charge controller or built into the inverter itself.

It basically continuously adjusts the impedance observed by the solar array in order to maintain the operation of the PV system at or as close as possible to the peak power point of the PV panel, with the mentioned changing conditions such as solar irradiance, temperature and demand load. It does this by means of a specific algorithm. There are several algorithms; the most common are the following:

- Disturbance and observation (P&O): disturb the operating voltage and, depending on the outputs, makes modifications to ensure maximum power.

- Incremental conductance: compares the incremental conductance with the instantaneous conductance of the PV system. Depending on the result, it increases or decreases the voltage until the maximum power point MPP is reached. In contrast to the P&O algorithm, the voltage remains constant once the MPP is reached.

- Fractional open-circuit voltage: This algorithm is based on the principle that the maximum power point voltage, Vmp, is always a constant fraction of the open-circuit voltage, Voc. The open-circuit voltage of the PV array cells is measured and used as input to the controller.

The latter algorithm can be seen modelled in an example using Simulink, as shown in figure 33, which is incorporated within the intelligent processor unit of the charge controller (dc-dc converter).

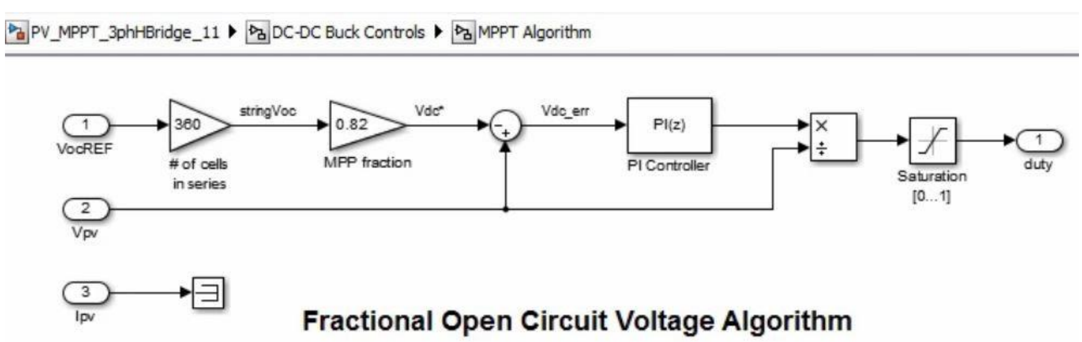


Figure 33. Simulation in Simulink (Matlab) of the fractional open-circuit voltage algorithm. Source: MathWorks

The importance of these explanations related to MPPT tracking lies mainly in understanding the connection of the PV strings in an inverter.

Below, in figure 34, you can see an electrical schematic of an inverter with MPPT tracker incorporated in the regulator stage. There are 4 MPPT's, one for every two DC input terminals of the inverter. This means that the two strings connected to the same tracker will operate in a similar way to operate at their optimum. Therefore, it is of vital importance that these two strings that correspond to the same tracker are series of panels arranged in the same orientation and inclination, which will work in very similar conditions (in case of shadows, for example), so that otherwise one of the strings would not be affected, working better than the other but limited/conditioned by the one with the lower production.

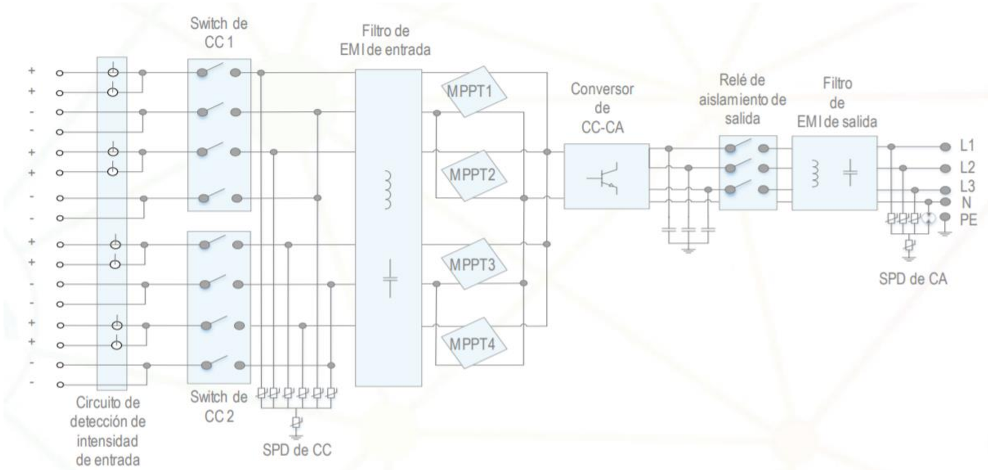


Figure 34. Wiring diagram of an inverter with independent MPPT trackers. Source: HUAWEI SUN2000-36KTL catalogue.

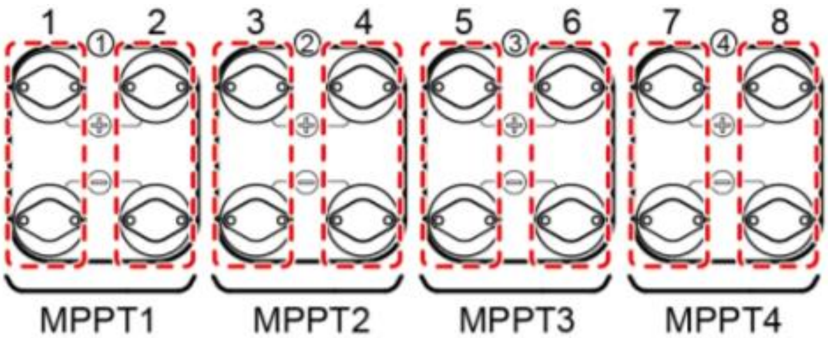


Figure 35. Terminals of the same inverter corresponding to the same MPPT tracker. Source: HUAWEI SUN2000-36KTL catalogue.

2.5 - NATIONAL SITUATION OF PHOTOVOLTAIC ENERGY: REGULATORY CONTEXT.

After a long period of paralysis at national level in Spain of the promotion of photovoltaic energy, caused by unfavourable and limiting regulations in this sector, with the entry into force on 5 April 2019 of the new Royal Decree 244/2019, there has been a drastic change and considerable improvement, seeing this sector boosted again and having a powerful resurgence that is giving rise to a large number of new photovoltaic installations and an interest in them that was previously discouraged, especially for self-consumption installations such as the one in the present project.

The global situation for the energy transition and the state market demanded a new regulatory framework for the development of self-consumption facilities, replacing RD 900/2015. In response to this request, RD-Law 15/2018 was published in October 2018, which established urgent measures for the energy transition and consumer protection, repealing previous measures such as the 'sun tax', among others. With regard to self-consumption, this RD-Law modified the previous regulations, establishing what were the new modalities, which became two: (i) self-consumption without surpluses and (ii) self-consumption with surpluses; as well as regulating shared self-consumption. Likewise, in line with European guidelines, self-consumption charges were eliminated, also opening up the possibility of surplus compensation and administrative simplification for this type of installation. These modifications are finally implemented in RD 244/2019, which gives continuity to what was established in RDL15/2018.

This new RD244/19 regulates the administrative, technical and economic conditions for self-consumption of electricity. Its main aspects to be highlighted are dealt with in the following subsections.

2.5.1 - Main features of the new RD 244/19

The main characteristics established by RD244/19 of April 2019 are:

- 3 modalities of self-consumption: (i) without surpluses, (ii) with surpluses subject to compensation and (iii) with surpluses not subject to compensation.

- Regulation of collective self-consumption.

- For photovoltaic installations, the installed power shall be the maximum power of the inverter.

- Eliminates the limitations on the maximum installed generation power up to the contracted power of the associated consumer. In other words, it is no longer necessary for the installed power to be less than or equal to the contracted power.

- It allows the consumer and the owner of the installation to be different natural or legal persons.

- Simplification of procedures:

    - Installations without surpluses or those with surpluses of up to 15kW do not need access and connection permits.
    - For installations of up to 100kW connected to low voltage, the access contract with the distributor will be made ex officio by the distribution company.
    - Facility for the registration of self-consumption.

- Establishes the economic regime. Several possibilities are implemented depending on the type of self-consumption:

    - Self-consumption with surpluses can (i) sell the energy in the pool, or (ii) compensate surpluses on a monthly basis, by valuing the surplus hourly energy - simplified compensation of surpluses - or (iii) compensate surpluses on a monthly basis.
    - The amount to be compensated may never exceed the monthly valuation of the hourly energy consumed. c) The self-consumption producer with surpluses that is not compensated will receive the relevant economic considerations for the surplus energy sold.

- Automatic registration in the self-consumption registers for certain cases.

- Establishes the metering equipment to be installed:

    - In general, only one bi-directional metering device is required at the border point.
    - Collective self-consumption, with surpluses not covered by compensation with several supply contracts or non-renewable technology must have 2 pieces of equipment. One for consumption and another to measure net generation.
    - In certain cases, the metering meter may be located outside the border point.

2.5.2 - New forms of self-consumption

Self-consumption is understood as the consumers' own production by means of generators, to cover part or all of the electricity they need for their consumption, whether it is a company, home or any other installation. The new RD244/2019 of April, establishes (in the following subsections) the classification of modalities to which one can apply when installing and processing a PV installation for self-consumption, which can be done as an individual or collective. That is to say, as a single consumer, or on the other hand, more than one consumer associated to the generation installations, all of them belonging to the same self-consumption modality and having communicated to the distributor (directly or through its distributor) the same agreement signed by all the participants that includes the self-consumption distribution criteria, whether in terms of the power of the consumers, their economic contribution to the associated generation installation or any other criteria. In the absence of notification of an agreement on distribution coefficients, the distributor will calculate them ex officio based on the contracted power.

As for collective self-consumption, it may belong to any of the modalities of self-consumption when this is carried out between installations in close proximity to the internal grid. However, in the case of installations close to the grid, it may only belong to the modalities of self-consumption with surplus.

- To be considered as an installation close to the internal grid:

- It is connected to the internal network of the consumer or associated consumers, or connected through direct lines.

- To be considered as an installation close to the grid:

- It is connected at an external point to the internal grid, so that the generating installation is linked to the associated consumers using the public distribution or transmission grid. Grid connections must satisfy at least one of the following criteria:

- The connection is made to LV network that is derived from the same transformer station to which the consumer belongs.

- The distance between generation and consumption connected at low voltage is less than 500 metres. -The generation and consumption are located in the same cadastral reference according to their first 14 digits (with the exception of the autonomous communities with their own cadastral regulations.

2.5.2.1 - Self-consumption without surpluses

These are self-consumption installations that, although connected to the distribution or transmission grid, do not transfer energy to the grid at any time. They must require an anti-discharge system, or in other words, a zero-discharge system, in accordance with ITC-BT-40, to prevent injection into the grid.

The owner of the supply point (consumer) will also be the owner of the generation facilities connected to its grid and will be responsible for any non-compliance that could have consequences on the grid.

In accordance with Law 24/2013, this type of self-consumers will be considered as a single type of subject: the "consumer subject". For this type of self-consumption installations without surpluses, the need to obtain access and connection permits is exempted.

In collective self-consumption without surpluses (only connected to the internal grid), the ownership of the generation installation and the anti-spill mechanism will be shared by all the associated consumers, who will be jointly and severally liable for any failure caused in the grid.

2.5.2.2 - Self-consumption with surpluses

An installation that produces more energy than it consumes instantaneously will therefore have the possibility of injecting this surplus energy into the grid. They can either compensate the energy dumped on a monthly basis - if they comply with the conditions presented in (a) - or sell the surplus energy to the pool.

- Self-consumption with surpluses eligible for compensation:
-
    - In this compensation mechanism, the energy from the self-consumption installation that is not consumed instantaneously or stored by the associated consumers is injected into the grid; when consumers require more energy than that provided by the self-consumption installation, they will buy the energy from the grid at the price set by their supply contract (PVPC or free market agreed with the retailer).
      At the end of the billing period (not exceeding one month), compensation is made between the cost of the energy purchased from the grid and the value of the surplus energy fed into the grid (valued at the market price or at the price agreed between the parties, depending on the supply contract). In any case, the maximum amount that can be compensated will be the amount of energy purchased from the grid. In other words, under no circumstances may the beneficiary obtain income from this activity; at most it may obtain a zero cost on the electricity bill.

In order to qualify for the surplus compensation mechanism, all of the following conditions must be met:

- The generating facility is a renewable source.
- The total power of the associated production facilities is less than or equal to 100kW.
- The installation has not been granted a specific additional remuneration system.

Figure 36 below shows the possible configurations for installations with surpluses that are eligible for compensation, which will always be connections to the internal grid. The savings represented in these diagrams reflect the reductions in bills obtained from energy compensation.

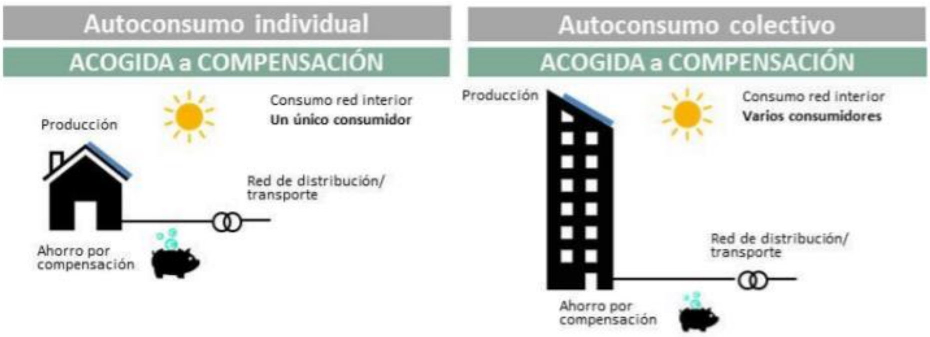


Figure 36. Diagrams of self-consumption with surpluses receiving compensation, left: individual; right: collective. Source: IDAE: Guía del Autoconsumo, 2019.

- Self-consumption with surplus not eligible for compensation

    - It includes those cases that do not meet any of the requirements to belong to the compensation modality, or that voluntarily opt out of the compensation modality.

      The installation will feed surplus energy that is not instantly self-consumed or stored into the grid. This surplus energy will be sold on the electricity market and will receive the same treatment as the rest of the energy produced by renewable sources.

Figure 37. Diagrams of self-consumption WITH surplus NOT eligible for compensation, left: individual; right: collective. Source: IDAE: Guía del Autoconsumo, 2019.

Figure 37 shows possible installations with surpluses that are not covered by compensation, which may be connections to the internal grid or through the grid for nearby installations. In this case, the surpluses are sold to the grid and the resulting market price is obtained for them.

In these cases, the producer must register as a renewable energy producer and enter into a market representation contract. It must comply with the technical obligations imposed on renewable energy producers regarding system operation, remote measurements, etc., and must also comply with the tax and/or fiscal obligations arising from this economic activity.

<u>Summary of modalities:</u>

Autoconsumo INDIVIDUAL (Un consumidor asociado)	o	Autoconsumo COLECTIVO (Varios consumidores asociados)
Instalación PRÓXIMA en RED INTERIOR (conexión a red interior)		Instalación PRÓXIMA a TRAVÉS DE RED
SIN excedentes (individual) Mecanismo anti-vertido	**CON excedentes ACOGIDA a compensación** P<100kW de fuente renovable. Contrato de compensación. No hay otro régimen retributivo.	**CON excedentes NO ACOGIDA a compensación.** Instalaciones con excedentes.
SIN excedentes ACOGIDA a compensación (colectivo) Mecanismo anti-vertido	**CON excedentes NO ACOGIDA a compensación** Resto de instalaciones con excedentes.	

Figure 38. Summary of modalities of RD244/19. Source: Own creation with information from IDAE and based on the new RD244 of April 2019.

2.5.3 - Advantages of the new RD 244/19

In view of the regulatory changes of April 2019, it is interesting to explain the specific improvements and advantages that this entails with respect to previous regulations and that can be taken advantage of for the PV installation that is the subject of this project.

Firstly, for customers opting for the non-discharge modality of self-consumption and for domestic customers (as they do not usually need photovoltaic installations of more than 15kW), the processing of their installations is drastically facilitated, as it only requires the completion of a procedure with the industry delegation of the autonomous community in which the installation is carried out.

For those promoters who opt for the compensation or sale modalities, the procedure is still similar to the one that existed prior to the implementation of the new RD. However, the procedures are speeded up thanks to the new deadlines established. Thanks to the fact that it is possible to change the modality of self-consumption as long as a minimum permanence of 1 year has been maintained, it is also possible to legalise any installation as not discharging to the grid, and begin the procedures to change it to the desired modality later, benefiting from the first moment in which you decide to make your investment, from the benefits of your photovoltaic installation. After the change of modality, the anti-discharge system would simply be removed, so that it can proceed to discharge to the grid.

Apart from these administrative improvements, at the installation level, the work is simplified, allowing the photovoltaic installation to be connected to the main LV electrical panel of the installation, instead of at the grid connection point, eliminating the second meter and consequently greatly facilitating the installation of the self-consumption system, by means of a single bi-directional meter, and allowing a better finish by having everything more centralised, avoiding additional trenches or overhanging cables.

Furthermore, the possibility of shared self-consumption allows industrial customers with lower consumption or neighbourhood communities (whether in a building with a rooftop or in housing developments), the possibility of accessing this technology in a more affordable way and with greater guarantees, as they have a larger installation than they would have if they had to do it individually for each of them.

In short, the application of this Royal Decree welcomes and promotes the implementation of photovoltaic installations and improves their economic benefits. For all these reasons, this project focuses its interest on the self-consumption photovoltaic installation option.

3 - DESIGN REQUIREMENTS

As a prior step to the design, it is necessary to know the previous situation of the building whose roof will be the place where the installation will be projected. To do this, the following is analysed: the characteristics of the site to find out the specific initial state of the place; the initial situation in terms of consumption and electricity billing; as well as a solar study, in which the shaded areas are simulated in order to be able to propose an optimum photovoltaic configuration.

3.1. SITE CHARACTERISTICS

The photovoltaic installation is projected on the roof of an industrial building located in (not shown for privacy reasons), a building owned by the company: (not shown for privacy reasons).

Plan P01 contains all this information regarding the location of the project. Figures 39 and 40 show the location of the building in question.

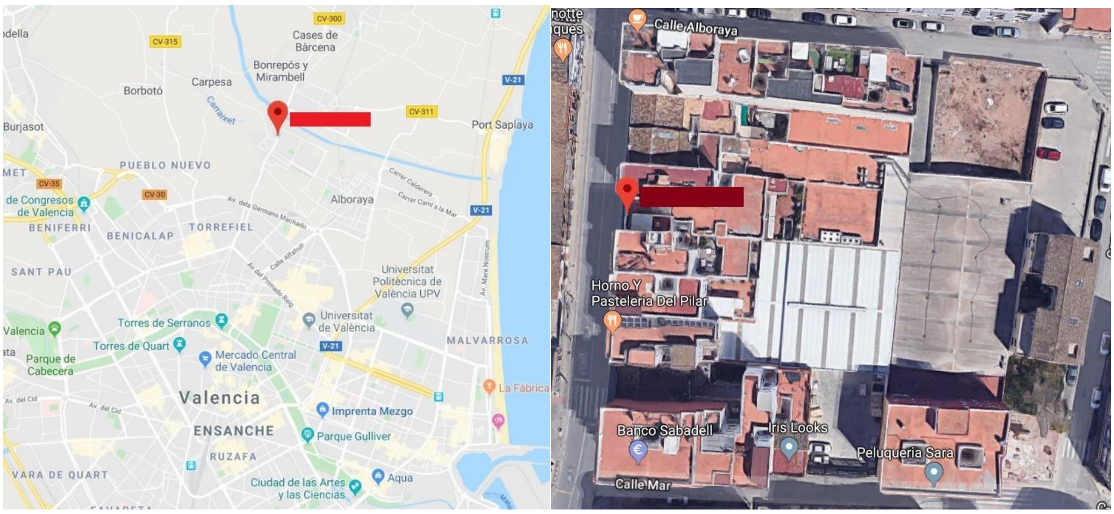


Figure 39. Location of the industrial building. Source: Google Maps

It can be seen that the building has two main east-west gables located to the right of the delimited area in figure 40, in the darkest part of the building, together with another smaller east gable roof located in the upper left corner of the delimited area. It also has another north-south gable roof, the building with the lightest whitish-coloured roof in the delimited area.

In figure 41, with a view from another perspective (looking towards the geographical south), it is possible to appreciate these roof slopes, as well as the dimensions of their spaces, obstacles in them, as well as possible infrastructures and surrounding buildings that cause potential shadows. This is analysed in detail below in the corresponding section of the Solar Study.

The roof of the building consists of sandwich panels with fretwork and skylights, as shown in figure 42.

Figure 44 shows average monthly weather data for the area. It can be seen that the maximum temperature does not usually exceed 27ºC and the minimum is usually around 9º. The wind speed is not excessively high, while the relative humidity is considerable.

Figure 40. Usable roof of the industrial building, outlined in green. Source: Own creation

Figure 41. South view of the roof of the nave. Source: Google Earth Pro

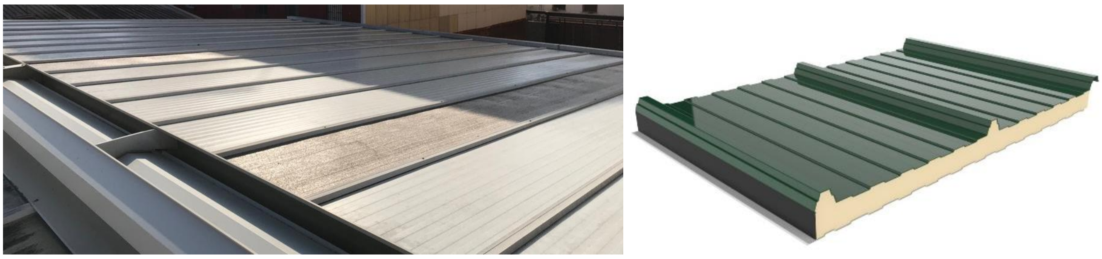
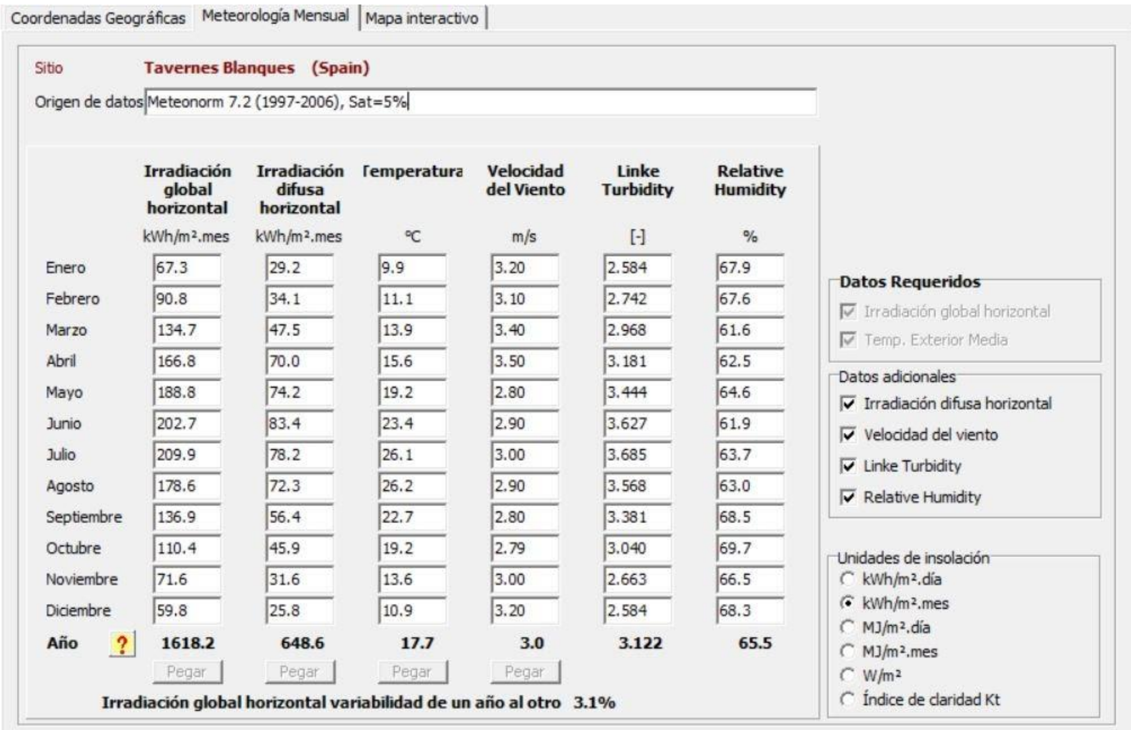


Figure 42. (left) Photograph of an area of the roof of the nave showing the fretwork, skylights and sandwich panels. Source: Own: Own. (right) Section of a typical sandwich panel for roofs. Source: Google Images: Google Images



	Irradiación global horizontal	Irradiación difusa horizontal	Temperatura	Velocidad del Viento	Linke Turbidity	Relative Humidity
	kWh/m².mes	kWh/m².mes	°C	m/s	[-]	%
Enero	67.3	29.2	9.9	3.20	2.584	67.9
Febrero	90.8	34.1	11.1	3.10	2.742	67.6
Marzo	134.7	47.5	13.9	3.40	2.968	61.6
Abril	166.8	70.0	15.6	3.50	3.181	62.5
Mayo	188.8	74.2	19.2	2.80	3.444	64.6
Junio	202.7	83.4	23.4	2.90	3.627	61.9
Julio	209.9	78.2	26.1	3.00	3.685	63.7
Agosto	178.6	72.3	26.2	2.90	3.568	63.0
Septiembre	136.9	56.4	22.7	2.80	3.381	68.5
Octubre	110.4	45.9	19.2	2.79	3.040	69.7
Noviembre	71.6	31.6	13.6	3.00	2.663	66.5
Diciembre	59.8	25.8	10.9	3.20	2.584	68.3
Año	1618.2	648.6	17.7	3.0	3.122	65.5

Figure 43. Meteorological characteristics of the study area. Source: Meteonorm database from PVSyst.

3.2 - INITIAL SITUATION: ANALYSIS OF CONSUMPTION

Based on the electricity bill provided by the customer, the following data corresponding to the CUPS code is obtained. For the prices, an estimate has been made based on the historical prices for indexed periods of the 3.1 A tariff.

DATOS GENERALES			
CUPS	ES002[redacted]		
Tarifa	Tarifa 3.1 A		
Periodo	P1 Punta	P2 Llano	P3 Valle
Potencia	200,0 kW	200,0 kW	200,0 kW
Coste energía	9,47 c€/kWh	8,76 c€/kWh	6,20 c€/kWh

Figure 44. General data of the electricity tariff contracted by the developer (with CUPS partially covered by privacy). Source: Own.

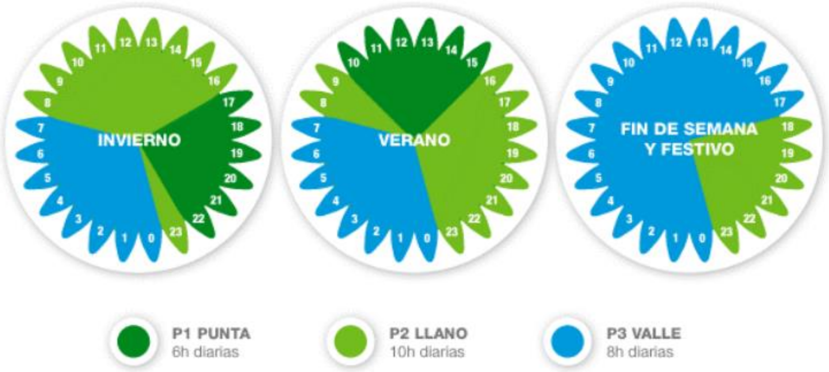


Figure 45. Hourly distribution of periods of the 3.1A tariff applicable to the peninsular system. Source: Gesternova Energía

As can be seen in figure 46, the periods in which it is most expensive to purchase energy for a large part of the year (with the exception of public holidays), i.e. the green zones (peak and flat) coincide with the generation periods of a photovoltaic installation. In particular, in the summer season, the peak period (the most expensive period) coincides exactly with the period of maximum production of a photovoltaic installation.

The consumption recorded by the customer over the last full year (January-December 2018) was obtained from the VIVO energía portal using the CUPS code, whose active energy readings (in kWh) are shown in the attached graph in figure 47 below, grouped according to the hourly periods of the tariff they have contracted, 3.1A.

It can be seen how in several cases the contracted power of 200kW is exceeded, resulting in financial penalties for excess power.

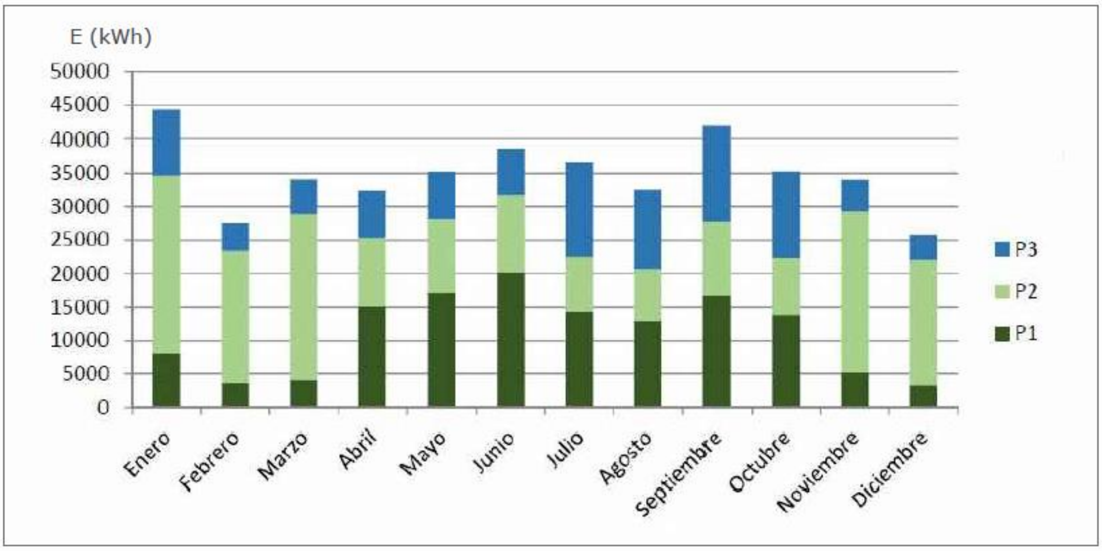


Figure 46. Energy consumption of the industrial plant (purchased from the grid) grouped according to the hourly periods of the contracted tariff 3.1A, for each month of the last year. Source: Own creation based on data from the Vivo Energía portal.

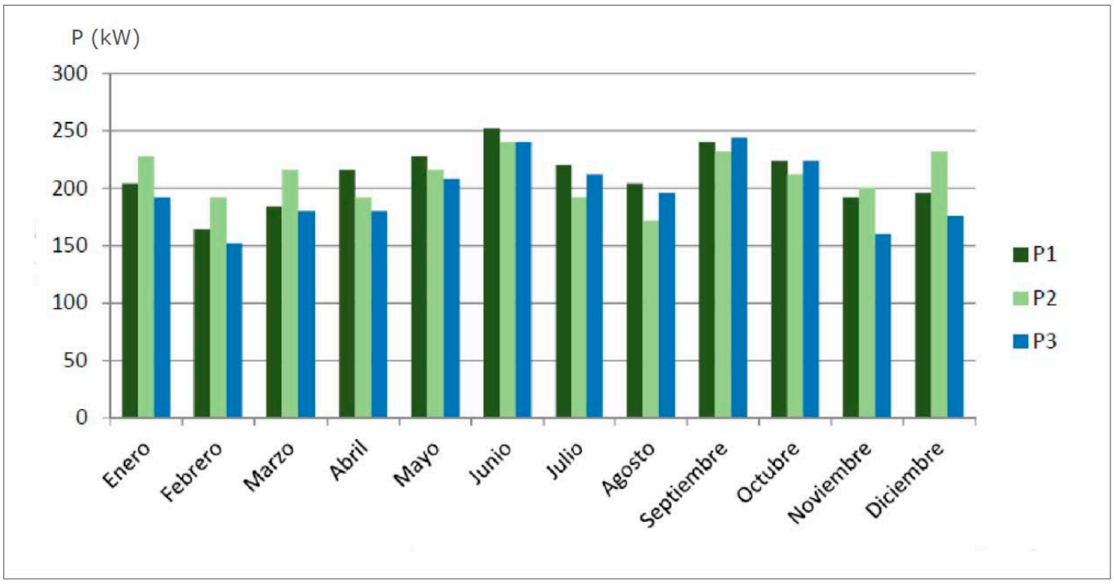


Figure 47. Power readings registered by the maximeter for each hourly period of the contracted tariff 3.1A, for each month of the last year. Source: Own creation based on data from the Vivo Energía portal.

Based on the consumption indicated, the associated costs are shown in figure 49. For the calculation of this estimate, the prices indicated in the invoice provided by the developer have been used. On the other hand, possible penalties have been applied to the power term according to the data recorded by the metering equipment. These penalties for excess power amount to around €2,706/year.

COSTES ENERGÉTICOS ACTUALES	
Total costes energía	34.968,78 €
Total costes potencia	23.449,51 €
I.E.E.	2.986,75 €
Alquiler equipo medida	744,00 €
Coste estimado total anual	**62.149,04 €**

Figure 48.Current annual costs of electricity consumption. Source: Electricity bill data, provided by the developer.

The daily consumption load curve for a standard 'typical' working day in the month of June 2018 is shown below in Figure 50, constructed from the quarter-hourly consumption data provided by the developer. The curve is for June, the month with the highest peak power consumption of the entire standard year. It can be seen that the dark blue curve (Saturday load curve) shows minimum consumption, since weekends are not worked.

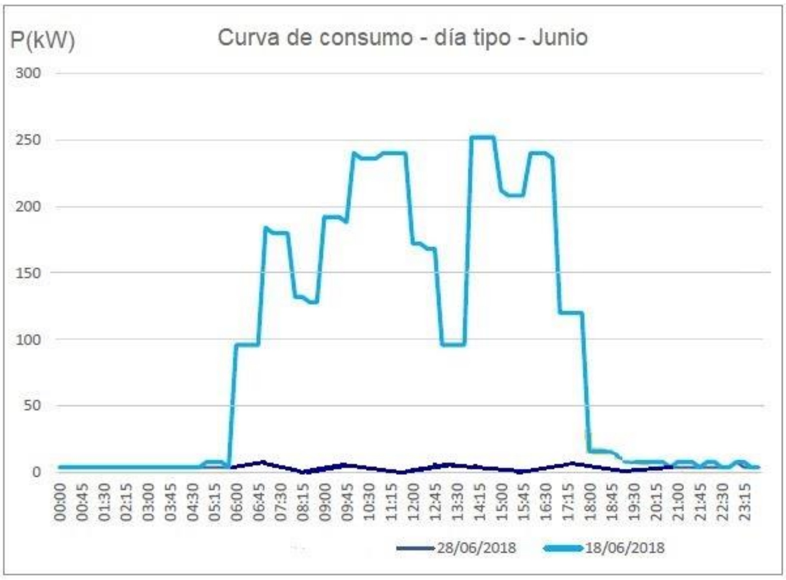


Figure 49.Daily load curve for two standard days in June 2018. In light blue: a standard working day; in dark blue: a non-working day on a weekend, namely Saturday.

In view of the load curve throughout the day, it can be seen that there is no night-time consumption, it is completely diurnal. Therefore, based on this premise - in addition to the facilities in terms of interconnection with the grid brought about by the new RD244/2019 mentioned above - the option of carrying out the installation by means of energy accumulation in batteries is ruled out, given that the contribution generated by the PV installation will be largely self-consumed instantly, except for weekends and specific holidays, when they do not work and therefore there is hardly any electricity consumption in the building. For these reasons, the installation will be designed to be grid-connected. The most appropriate modality will be indicated later in this project, knowing the final solution chosen in terms of installed power, energy production (according to orientations, etc.) among other considerations.

3.3 - SOLAR SURVEY: SHADOW SIMULATION

One of the main design requirements is based on first knowing the situation of shadows on the roof, in order to decide how to design the PV installation, either avoiding these shadows or, if there is not enough space, trying to minimise losses by means of micro inverters or optimisers. To this end, the solar resource has been studied by analysing its trajectory in the earth's atmosphere - and specifically at the study location - throughout the year and throughout the day. The aim is to locate possible shadows on the roof of the building in order to obtain the optimum configuration of the photovoltaic installation so that it is affected as little as possible by shadows throughout its useful life.

First of all, a global view has been obtained, on top of the satellite image, of the solar trajectory lines that would be seen by an observer located on the study roof. It should be noted that, as explained in the introductory subsection on solar geometry, the position of the sun apparently changes as seen from the earth due to terrestrial movements (on its own axis and around the sun). Therefore, the sun's path as seen from the earth varies from one hour of the day to another, and from one day of the year to another. In the following figure 51, a yellow fan can be seen that includes all the solar positions throughout the day and the year, rising from the east (right of this document) and setting in the west (left of this document). This fan is delimited by two extremes: the path of the longest day of the year (and shortest night), i.e. that of the summer solstice (21 June), shown on the left, and the shortest day of the year (and longest night), i.e. that of the winter solstice (21 December), shown on the right.

Figures 52 and 53 also show other fans of the solar position which may be informative.

Figure 50. Fan of the solar position according to times of day and days of the year. Left: 11:00 am on the day of the summer solstice (21 June); Right: 11:00 am on the day of the winter solstice (21 December). Source: Sun Earth Tools (Web application).

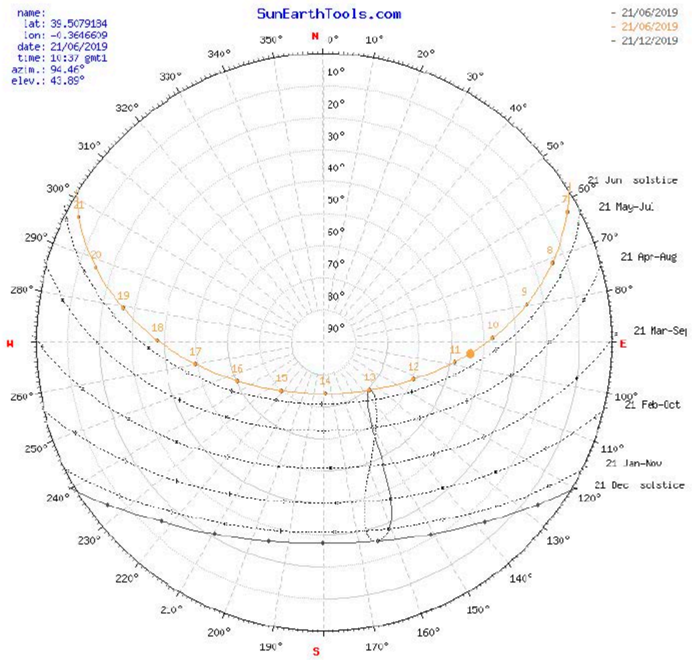


Figure 51. Solar position range by time of day and day of year at the study location. Source: Sun Earth Tools (Web application).

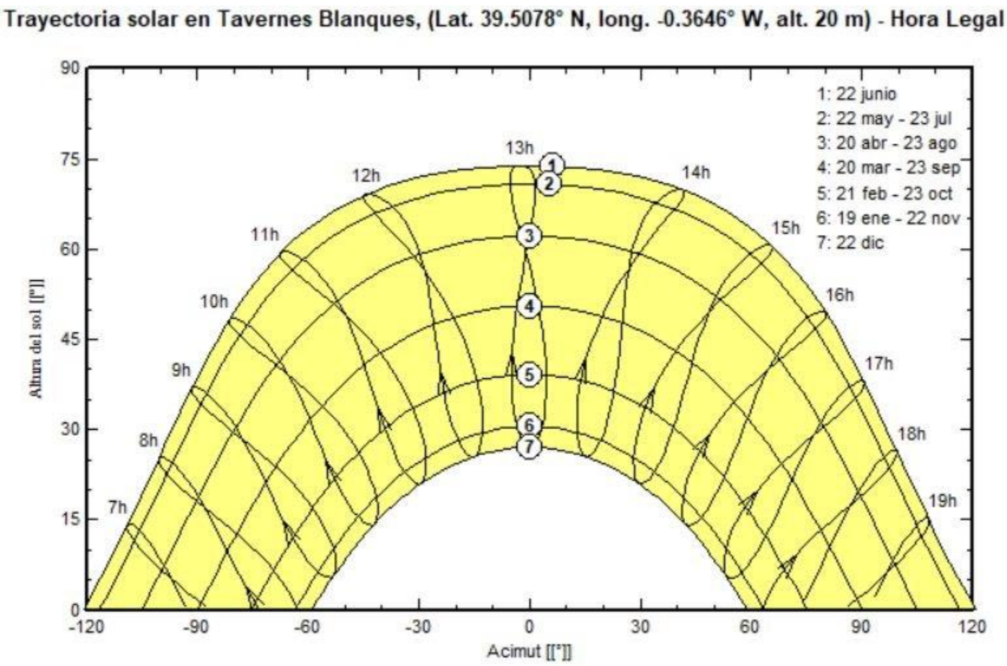


Figure 52. Solar position range by time of day and day of year at the study location. Source: PVSyst.

The following is a simulation of this daily and annual solar trajectory that has been carried out on a virtually modelled construction of the building under study together with the adjacent and surrounding buildings, which are possible generators of shadows. This has been done using a PVSyst software tool that allows this type of simulation to be carried out, called "Construction/perspective of the shading situation".

The building was constructed based on the orientation of the cardinal points located on the plan. The roofs of the main halls under study have been modelled in grey, unlike the rest, in order to distinguish them. As for the houses, buildings or other nearby infrastructures surrounding the building that can be observed, they have been modelled by approximation, with simple building blocks using the tools offered by the programme. In addition, the modelling has been done taking into account the exact dimensions of each infrastructure so that the simulation of shadows according to the solar trajectory is as accurate as possible. The measurements have been obtained using Google Earth Pro tools on the satellite image of the ship and these measurements have been applied to the model of the constructions, giving rise to the situation shown below.

Figure 53 shows the resulting modelling, and figure 54 shows the same from the opposite perspective (looking from the geographical north).

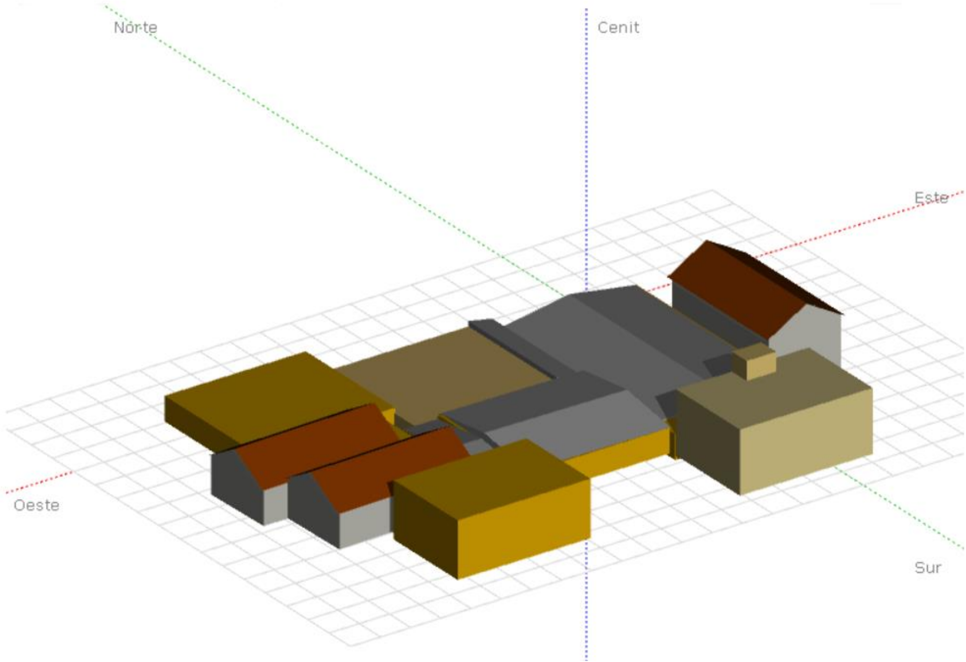


Figure 53. Modelling of the study canopy with adjacent potential shadow-generating objects. Source: Own creation.

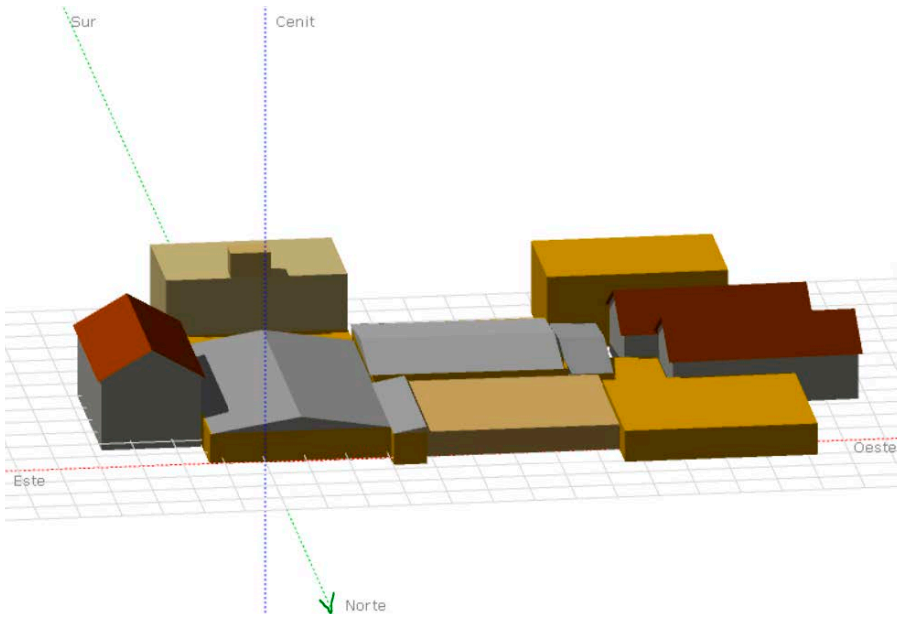


Figure 54. Perspective from another angle (looking south) of the modelling of the study roof with the adjacent potential shadow-generating objects. Source: Own creation.

Returning to the initial perspective of figure 54, we proceeded to generate the three-dimensional fan of all possible solar positions over the study area.

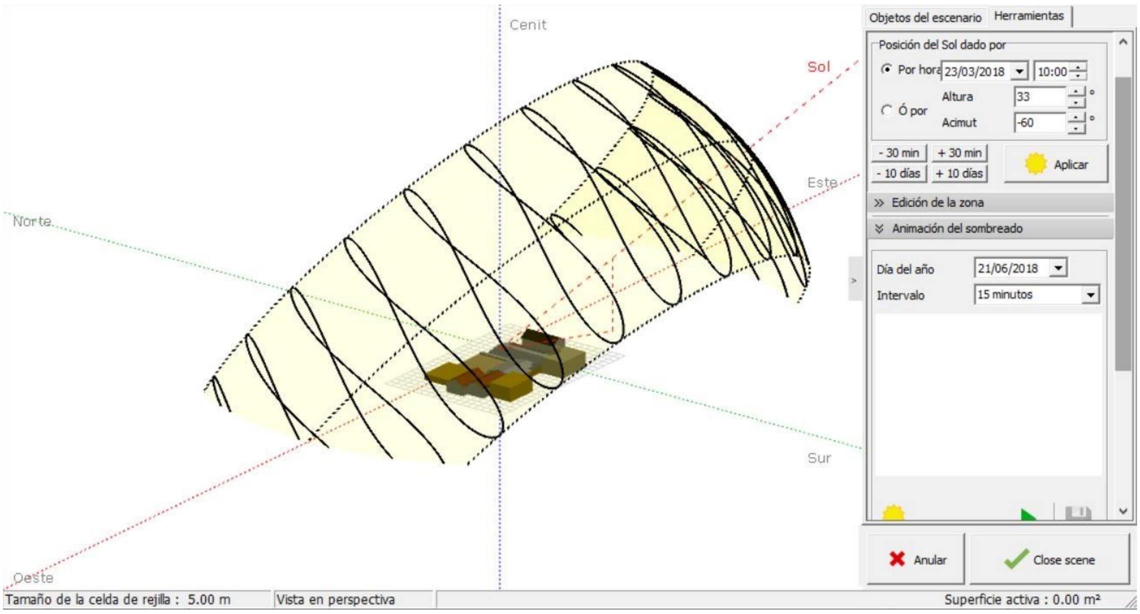


Figure 55. Abacus solar trajectory (daily and annual) over the study area. Source: Own creation.

Finally, a simulation is made of the shadows generated at different times of the day, the most critical times of the day, which may be more harmful to the PV installation to be designed, according to the information of the highest consumption peaks of the load curve in figure 49.

- Simulation 1

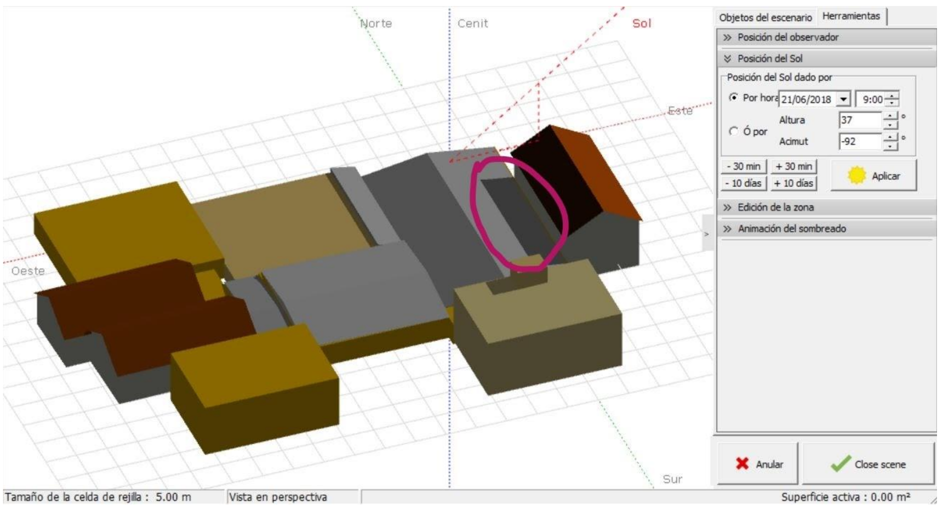


Figure 56. Simulation of shadows generated on 21 June at 9:00h. Source: Own creation.

In the early morning hours of the summer season, shadows can be seen generated by the house that borders on the right with the main East-West water shed, specifically marked in red in figure 57. In the east water, therefore, there will be an area of shade in the mornings at sunrise, which in a limiting case such as the one shown, will be affected up to almost the centre of the water, so modules will not be placed up to that point.

As the morning progresses and the sun rises above a certain height, the shadow disappears (see figure 58) and the study decks will be completely free of shadows for most of the day, as shown in the figure below. This is because in the summer season when this first simulation was carried out, the sun is at its highest position compared to the rest of the year.

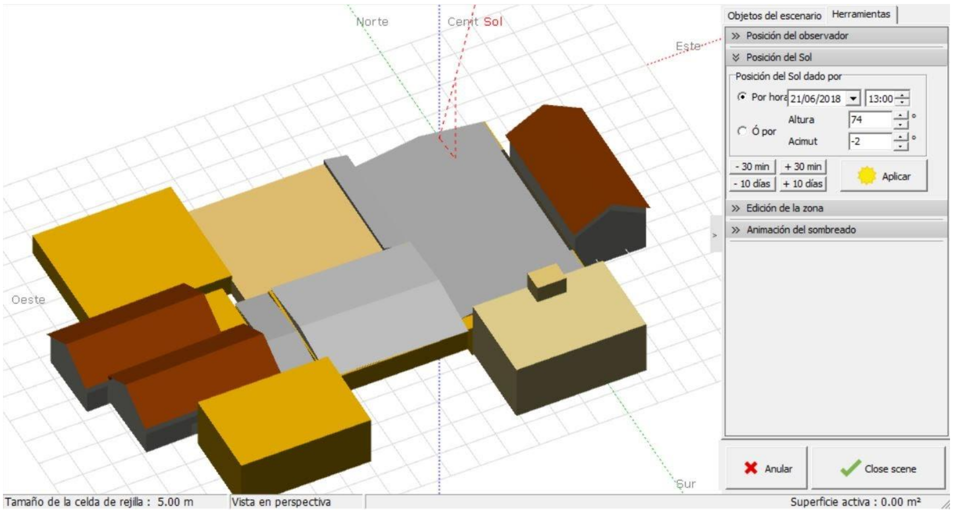


Figure 57. Simulation of shadows generated on 21 June at 13:00h. Source: Own Creation

In the late afternoon, when the last consumption occurs (from 16:30h to 18:00h, according to the load curve), the following shadows would be marked, located in the leftmost part, an area that has a lower height than the main north-south water shed. This area is therefore also excluded from the module placement (see figure 58).

Figure 58. Simulation of shadows generated on 21 June at 18:00h. Source: Own creation.

- Simulation 2

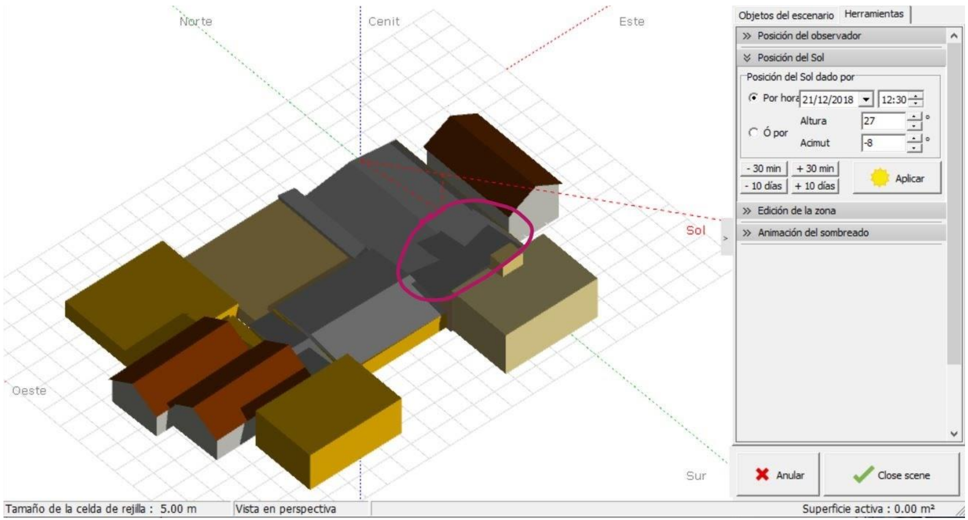


Figure 59. Simulation of shadows generated on 21 December at 12:30h. Source: Own creation.

Figure 59 shows that between 11:00 am and 12:30 pm, when the hall usually has a high consumption, there will be a critical area marked by shadows occupying about a third of the length of the affected hall, in which photovoltaic modules will not be placed either. The area extends approximately up to the ridge line of the joint north-south water shed.

For the time slot between 15h and 16:30h, there are shadows in the same area as in the previous simulation for the late afternoon in June (see figure 60), thus reaffirming the decision not to install PV modules in this area. The simulation is shown below.

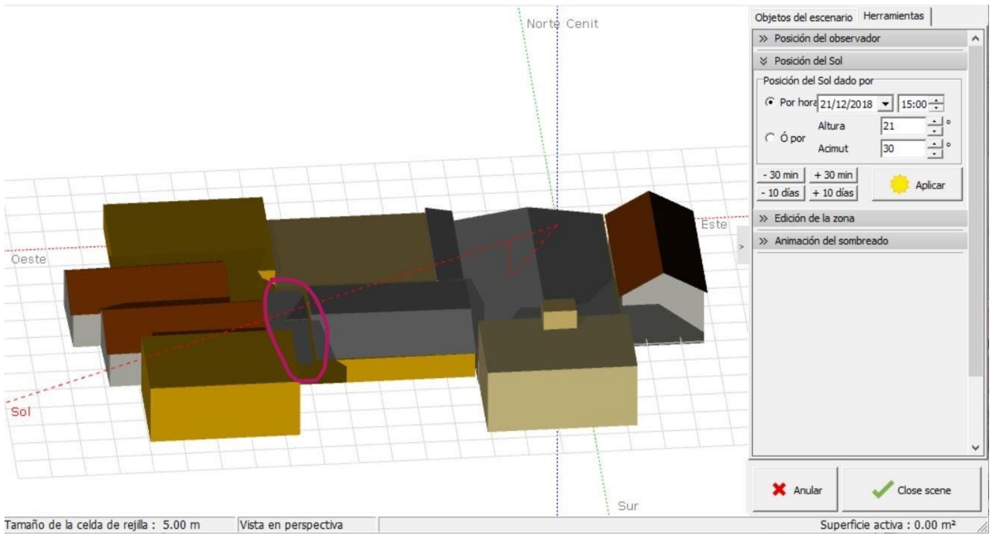


Figure 60. Simulation of shadows generated on 21 December at 15:00h. Source: Own creation.

- Simulation 3

In a third simulation, the solar trajectory is checked in two intermediate situations: in February and in October, shown in figures 61 and 62 respectively. In both cases, both on 24 February at 11:30h and on 22 October at 11h, the same area of the spacecraft affected by shadowing can be observed, so that part of the spacecraft is also discarded.

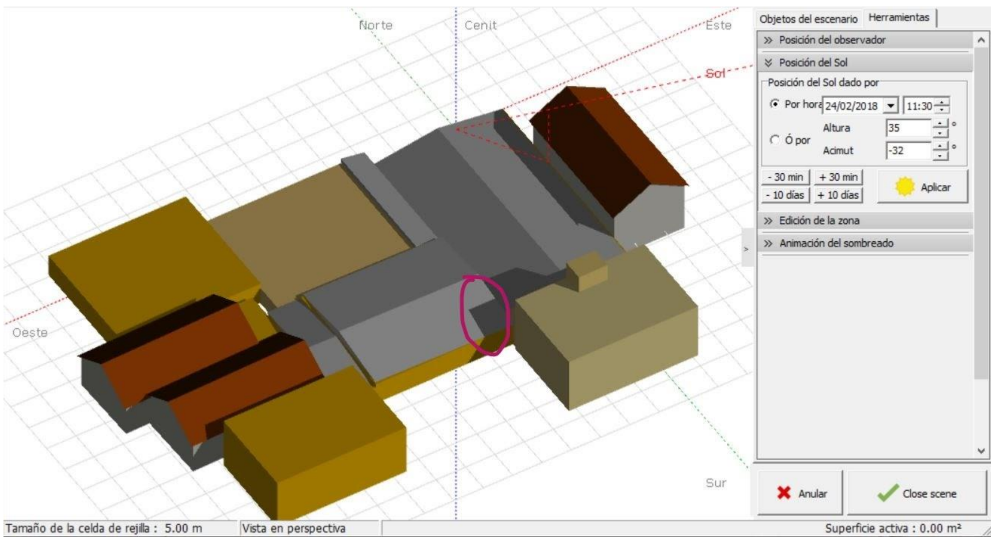


Figure 61. Simulation of shadows generated on 24 February at 11:30h. Source: Own Creation

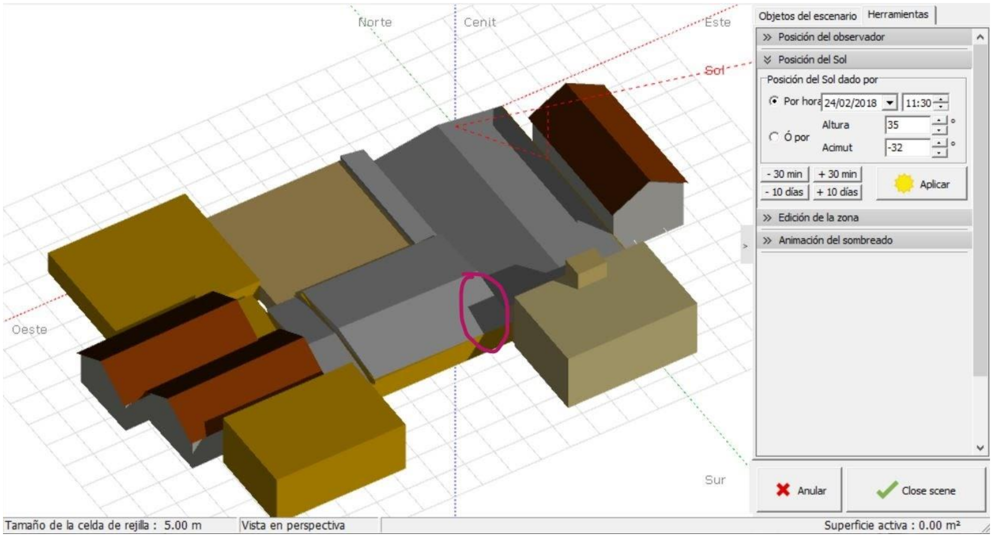


Figure 62. Simulation of shadows generated on 22 October at 11:00h. Source: Own creation.

The photographs in figure 63, in situ on the deck of the east-west water shed, also show some of the shadows detected by the simulation.

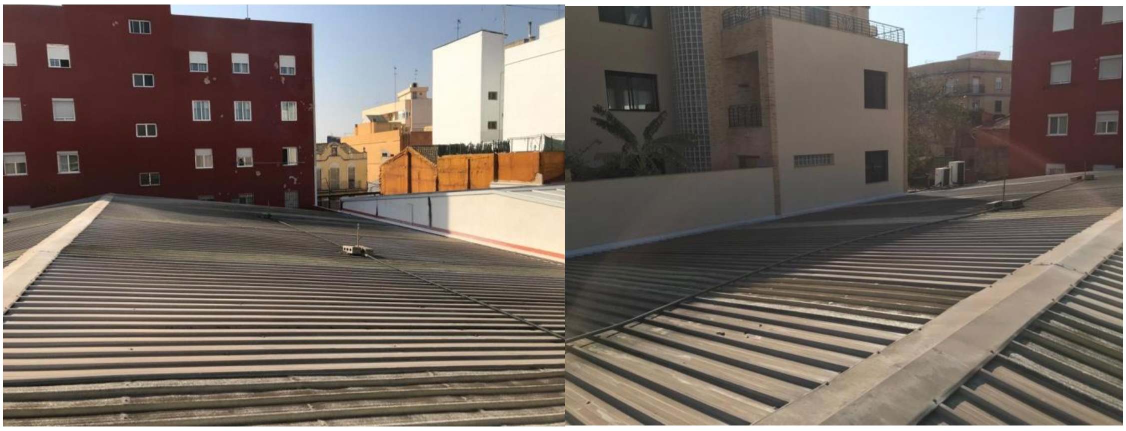


Figure 63. Photographs showing some shadow regions. Source: Own

Based on all the above information and the critical areas affected by shading, those parts of the roof are delimited which will not be used in the following point of proposed PV array configurations, they will be considered as unusable. These areas are shown shaded in figure 65 below.

Figure 64. Areas not suitable for the installation of PV panels. Source: Own creation.

4 - CONFIGURATION OF THE PHOTOVOLTAIC GENERATOR

4.1 - COPLANAR VS SOUTH FACING

There are two halls oriented to two different waters each, and all with an inclination of 6º. Firstly, there is the building with the white roof seen in the satellite image in figure 65, which has two sides: north and south. Therefore, in this case it is clear that the south water will be used to arrange the coplanar panels and thus have the optimum orientation, which is the geographic south since the area is located in the northern hemisphere. As for the inclination, it will not be the optimum for the whole year - which would be approximately 30º for this location at a latitude of 39º - but it will favour production in the summer because the sun is higher. In the aforementioned area (south water), there is the option of mounting the panels on a structure to give it a higher pitch than the current 6º pitch of the roof, with a 26º structure on top of it, to have the panels at 30º. However, it was decided to keep them coplanar as it is not crucial to give them a greater inclination because, in fact, in view of their consumption (figure 50), they have a slightly higher production during the summer months as a whole. In the colder months on average, they have a lower production (with the exception of the January peak).

As for the other water in the same building, with north orientation, it is possible either to make them coplanar, or not to make them coplanar, or to introduce a structure for their elevation towards the south orientation, just like the other water. A coplanar north water, in some installations, depending on the case of the roofs, available space, etc., can be profitable and even the most comfortable and advantageous option, as well as saving the installation of a structure and avoiding possible counterproductive effects due to the wind on the structure. However, in this case it was decided that it was not necessary to study this in depth, as it has been observed that it would require the installation of more PV modules to achieve this profitable performance, which implies more installed power, and in this case, it was decided to offer options to not exceed 100kW nominal in order to be eligible for the surplus compensation modality, as will be seen later on. In addition, in this particular case, this option is more complex because there are some pipes of considerable size obstructing the building, which are saved by the structure.

The other adjoining bay is available, on two different sides: east-west. This is the one that can be seen with the darker roof (grey-brown) in the satellite image. Two possibilities arise here: a structure can be installed to raise the PV panels so that they are in the optimum orientation for maximum production, i.e. south, as in the previous hall; or the available orientation of the roof to east-west can be used.

4.2 - PROPOSED 4 CONFIGURATIONS TO CHOOSE FROM

We are going to present and analyse 4 different possibilities based on the variables mentioned above. Common to all of them is the decision to take advantage of the south water, arranging the panels there in a coplanar manner. Therefore, the variables will be: to place or not to place a structure in the north water to rectify the orientation of the panels towards the south; and the other variable will be to orientate the panels in the east-west water shed towards the south, or to place them coplanar with these orientations east and west. For the following proposals, the dimensions of a 350Wp PV panel, commonly used, have been used.

- All south facing

Figure 65.Proposal A, all modules facing south. Source: Own creation.

- All south facing (with north water rectification)

Figure 66. Proposal B, all modules facing south. In addition, modules on the north water with structure to rectify them to south orientation as well. Source: Own creation.

- One ship coplanar east-west and one ship coplanar south

Figure 67. Proposal C, south facing modules on the white roof and east-west facing modules on the brown roof. Source: Own creation.

- One east-west coplanar nave and the other south (with north water rectification)

Figure 68.Proposal D, south facing modules on the white roof and east-west facing modules on the brown roof. In addition, modules on the north water with structure to rectify them to south orientation. Source: Own creation.

4.2.1 - Energy contribution of each proposal

- Alternative A

Mes	Egen (kWh)
En	3840
Feb	4650
Mar	6860
Abr	8070
May	9520
Jun	9690
Jul	9910
Ag	8840
Sept	6990
Oct	5450
Nov	4070
Dic	3500
TOTAL (A)	**81390**

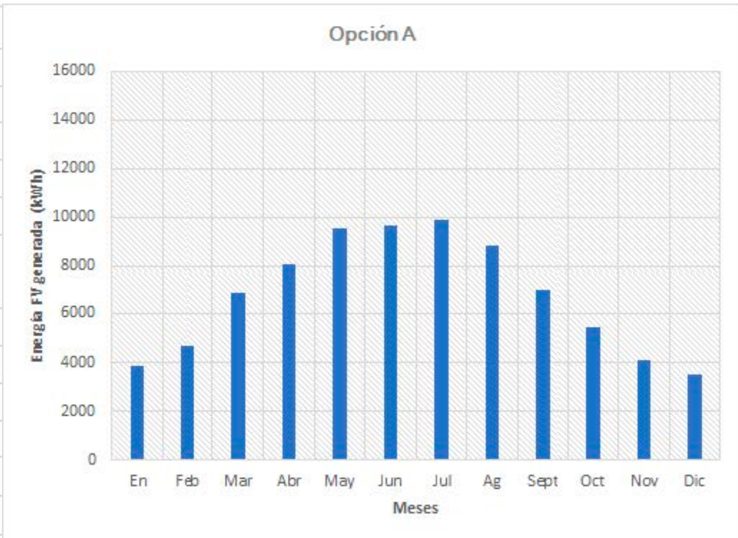


Figure 69.Proposal energy generation (A): all south. Data source: PVGIS.

- Alternative B (Alternative A + north structure)

Mes	Egen (kWh)
En	5230
Feb	6340
Mar	9340
Abr	11000
May	13000
Jun	13200
Jul	13500
Ag	12000
Sept	9520
Oct	7420
Nov	5550
Dic	4770
TOTAL (B)	**110870**

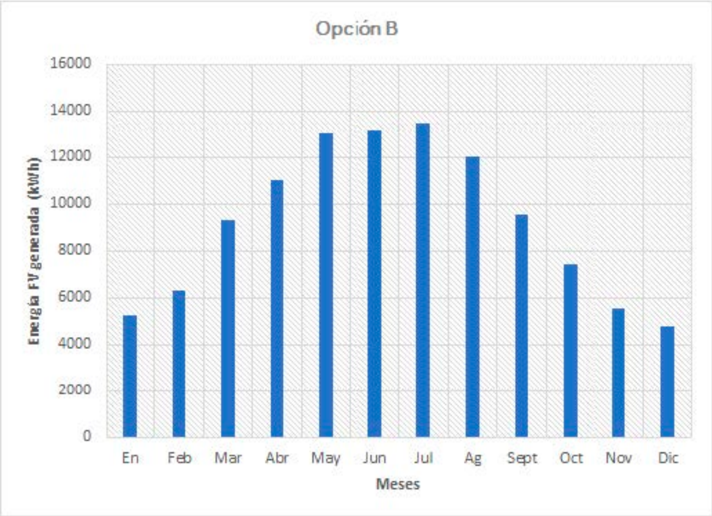


Figure 70.Proposal energy generation (B): all south + north water rectified to south. Data source: PVGIS.

- Alternative C

Mes	Egen (kWh)
En	4530
Feb	5680
Mar	8640
Abr	10430
May	12470
Jun	12800
Jul	13050
Ag	11500
Sept	8900
Oct	6740
Nov	4850
Dic	4070
TOTAL (C)	**103660**

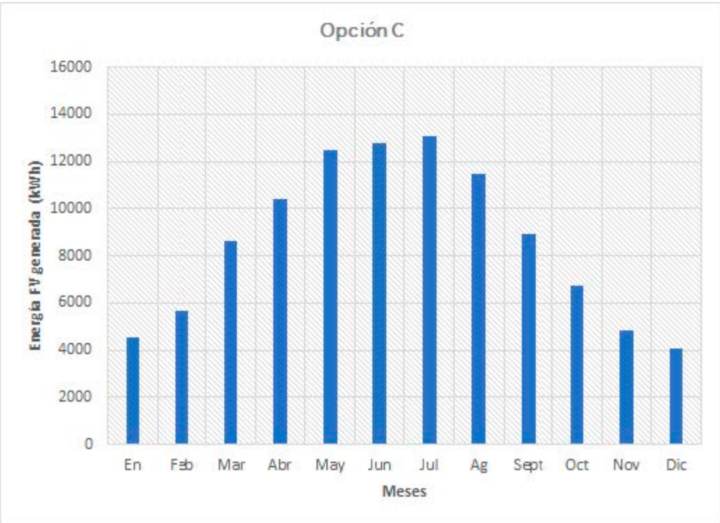


Figure 71.Power generation of the proposal (C): Part south and part east-west. Data source: PVGIS.

Mes	Egen(kWh)
En	6307
Feb	7474
Mar	11725
Abr	13637
May	14554
Jun	14856
Jul	15914
Ag	13671
Sept	10020
Oct	9613
Nov	5981
Dic	6268
TOTAL (D)	**130019**

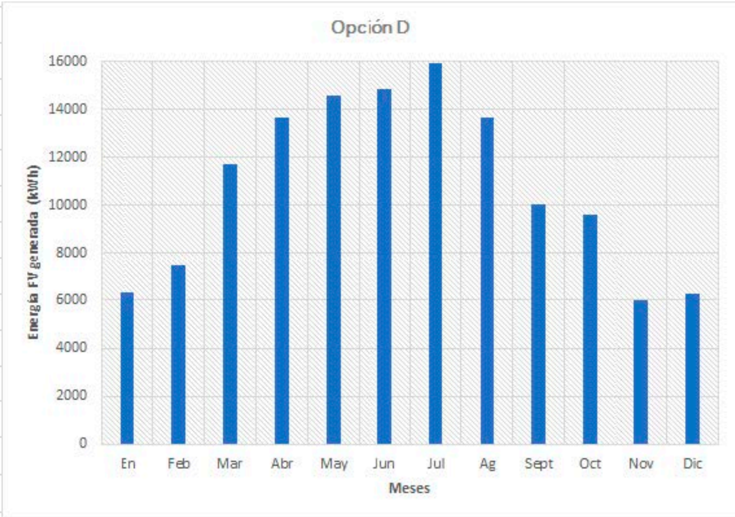


Figure 72.Power generation of the proposal (C): Part south and part east-west, + north water rectified to south. Data source: PVGIS.

It is worth mentioning that the PVGIS provides the production data for installations with uniform characteristics in terms of their inclination, orientation, assembly, losses, etc., whereas in this installation, there are different areas with different characteristics due to the difference in water orientations and so on. Therefore, to obtain the productions shown above, a simulation has been carried out for each proposal using PVGIS but for each particular zone, and subsequently adding up the contributions of each one to give the total monthly contribution of each proposal. This has been done using Excel and the basic tools it has for operations between cells.

Below is a comparative summary table of all the information in figures 70, 71, 72 and 73 for the 4 proposed alternatives.

Opción	Inclinación, β (º)	Azimut, α (º)	Orientación	Nº Paneles tot	P (kWp)	E (kWh/año)	Ratio (kWh/kWp)
A	6	0	Sur	166	58,1	81.390	1.401
B	6	0	Sur	226	79,1	110.870	1.402
C	6	0, 90, -90	Sur, Oeste, Este	220	77	103.660	1.346
D	6	0, 90, -90	Sur, Oeste, Este	280	98	130.019	1.327

Table 1. Comparative summary of the different proposals. Source: Own creation

4.3 - FINAL SELECTION AND JUSTIFICATION OF PV CONFIGURATION

The inclusion of the structure in the north-facing water is, at first sight, very beneficial given the considerable increase in energy production that is obtained. This can be seen by looking at the difference in energy generated between option B compared to option A, and option D compared to option C. Therefore, although it will require a higher investment by the developer, it will maximise the usable roof area. Therefore, the final choice is between option B and option D. Both have the north water rectification with south-facing structure; they differ in that in B they are all south-facing and in D it combines several orientations. In option B all the panels (226) are south-facing: 60 are coplanar to a south water, another 60 are south-facing with a structure on the north water and the remaining 106 are arranged on the east and west water in separate rows with a south-facing structure. On the other hand, option D has 280 panels with different orientations: 120 facing south, 60 facing east and 100 facing west.

It can be seen that option B has a higher output ratio (per unit panel) than option D. However, these performance improvements that are achieved by arranging the panels of the east-west roof to the south by structure (option B), are compensated by the increase of panels that fit coplanar to the east-west waters of that building (option D). This is because the rows of modules would generate shadows between them (see figure 74), so it is necessary to place them with a spacing between rows (see calculations justifying the distance between rows in Annex I). This means that not all of the useful surface of the roof is used, whereas with coplanar panels, a greater number of panels can be installed, and therefore a greater installed power, ergo, greater energy production.

In addition to this, the installation of what would be the structure to bridge the 6º to the east or west and orientate the modules to the south in option B, involves not only greater technical complexity in terms of engineering and assembly, but also a considerable increase in investment, compared to the coplanar.

As for the rectifying structure to the south of the north water, this will also be 6º, parallel to the existing south one, as will be seen later in the description, since giving it more inclination means exceeding the height of the ridge, which is a useful criterion for not exceeding and ensuring structural safety against winds, above all, which would have to be calculated in detail and studied in depth.

It is essentially on the basis of the above that it is decided to choose the Option D configuration, but a number of additional advantages offered by the east-west configuration have also been taken into consideration, which are presented below.

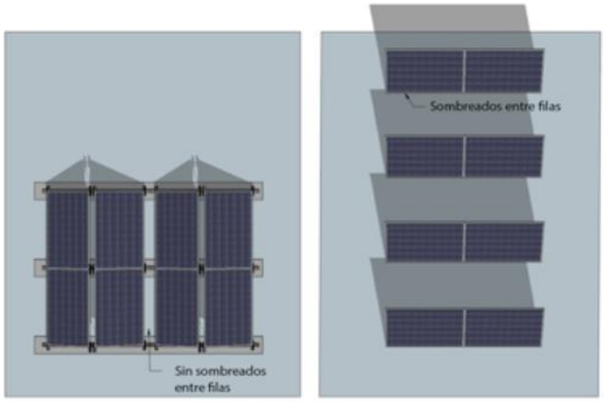


Figure 73.Shadow effects. Left: East-West arrangement; Right: South arrangement with shadows between rows. Source: Monsolar.

The east-west orientation achieves an effect on the daily PV production curve that is beneficial in this case, based on the load curve of the industrial plant. This effect consists of a widening of the photovoltaic curve, as shown in figure 75, in such a way that production is extended in the early and late hours of the day. The start of production is brought forward, thanks to the panels facing east, since the sun rises at this cardinal point; at the same time, there is also an extension of production at the end of the day, thanks to the panels facing west, since the sun sets at this other cardinal point. However, as a consequence, the production peak at midday (when the sun is at its highest point) is reduced, compared to traditional installations whose orientation is based on the south, as can be seen in figure 74.

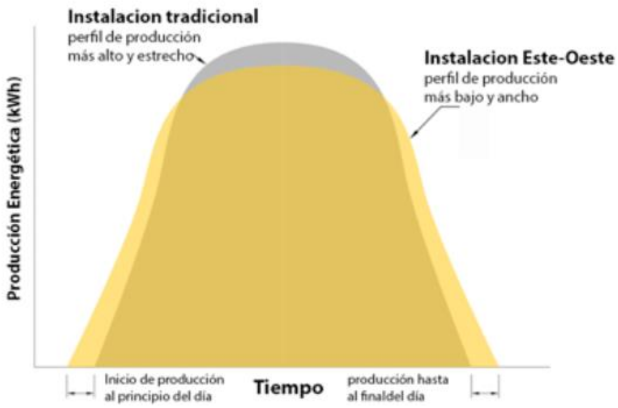


Figure 74. Effect of the widening of the PV production curve in an east-west installation. Source: MonSolar

As already mentioned, in this case study, this effect is beneficial because the load curve of the industrial plant (see the example in figure 50, in section 3 above) does not have a large central peak, but rather more distributed peaks. It can be seen that they start their consumption very early, around 6:00 am, which favours the arrangement of some panels towards the east so that they capture solar energy as early as possible in the morning with the sunrise in the east. Around midday, they stop, where consumption is reduced by more than half, resuming in the early afternoon with high consumption, which benefits from the fact that most of the panels of Option D are oriented towards the West, reinforcing these consumptions until sunset. In addition, it should be remembered that, with this selected alternative, most of the panels of the installation also face south in zones 1 and 2 (see table 2), which favours good performance and a high overall contribution to mid-morning consumption peaks.

Figure 75.East-West configuration. Source: MonSolar.

On the other hand, another reason that reinforces the choice of the coplanar east-west method with respect to the south-facing elevation structure is the fact that the installation has a better aerodynamic profile (see figure 76), drastically reducing the pressure exerted by the wind, compared to a south-facing configuration which is much more vulnerable to north winds. In the first case, there is less exposure to the wind as it is coplanar to the east-west watershed.

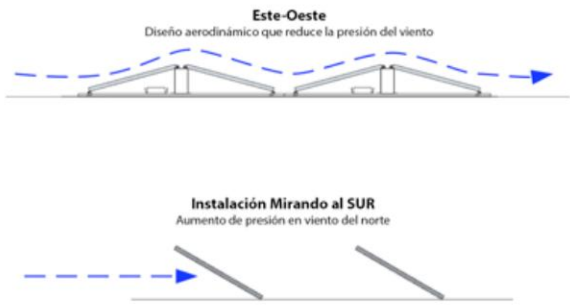


Figure 76.Wind effect in east-west vs. southbound configuration with structure. Source:

5 - ANALYSIS OF TECHNOLOGICAL ALTERNATIVES

This section studies the different technological alternatives for the configuration and elements of the planned photovoltaic installation, from which those best suited to the situation of the case study will be selected.

5.1 - TYPES OF PHOTOVOLTAIC PANELS

Depending on the formation of the constituent material of the cells, you will have one type of panel or another, which are commonly distinctive in appearance and colour. The classification distinguishes between panels of:

- Crystalline Silicon
  - Monocrystalline
  - Polycrystalline
- Slim Layer
  - Amorphous hydrogenated silicon
  - CiS/CiGS
  - CdTe
- Multi-union
- Emerging
  - Perovskite cells
  - Dye-sensitised c. Organic
  - Quantum dots

Although multi-junction cells are currently the most efficient, they are still very expensive and experimental, and are therefore only used in very specific applications where a lot of power is required in a small size.

Crystalline silicon cells are the most common and commercially used worldwide. Based on this first classification, the distinction between the two types of crystalline Si is made on the basis of the difference in the internal structure of the crystal lattice.

In polycrystalline solar panels, the multicrystals are randomly oriented. If the chemical process of silicon crystals is taken one step further, polycrystalline cells will become more ordered and uniform monocrystalline cells. This process is more time-consuming and costly, but it results in higher panel efficiency, as this structure offers higher electrical conductivity, even though the principle of operation of both is the same. Numerically, the efficiency of a polycrystalline panel is around 16-19% and monocrystalline is up to 25%.

Monocrystalline panels are often used when there is not much surface area available for installation. In addition, they behave better with diffuse radiation, which is why they are more recommendable for Nordic countries or countries with low solar incidence, and in cold climates, as these panels are less resistant to overheating.

In contrast, polycrystalline panels are cheaper, so if you have a large surface area to install them, they are more convenient because the lower efficiency is compensated by being able to install more panels. They are the most commonly used, and are recommended in areas with high solar incidence and higher temperatures, because under these conditions they are able to withstand better and generate more energy than other panels. Figures 78 and 79 show images of their differences in appearance.

One of the main technological barriers of photovoltaic panels and a current challenge is their efficiency limit, which is around a maximum of 25% for the most commonly used commercial panels, and around a maximum achieved in the laboratory of 46% with multi-junction cells plus built-in concentrator (see figure 79).

It is worth mentioning that for the calculation of the approximate energy contribution of each panel configuration proposed previously in the Report, the polycrystalline module technology has been used by default as it is the most commonly used. This will be the one chosen for this project, as will be seen later in the section of this report on "Final selection and justification" of the technology to be used.

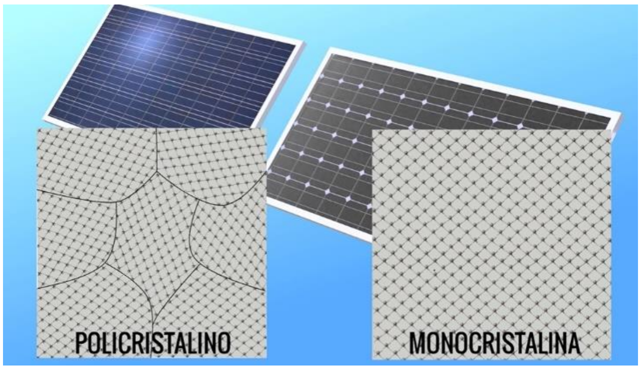


Figure 77. Comparison in appearance and molecular structure of both types of crystalline Si, left: polycrystalline, right: monocrystalline. Source: Learn Engineering.

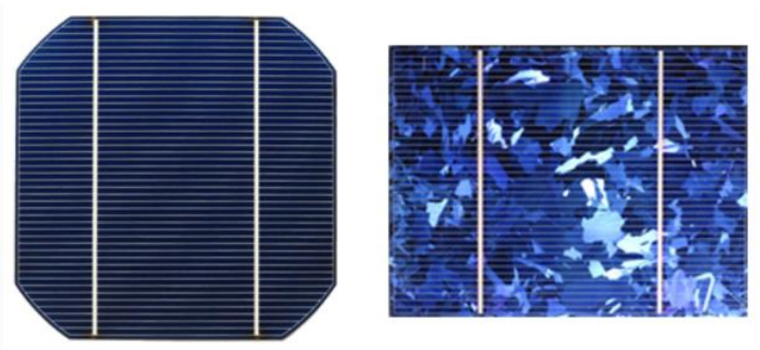


Figure 78.Comparison in appearance and molecular structure of both types of crystalline Si, left: polycrystalline, right: monocrystalline. Source: Solar-energia.net.

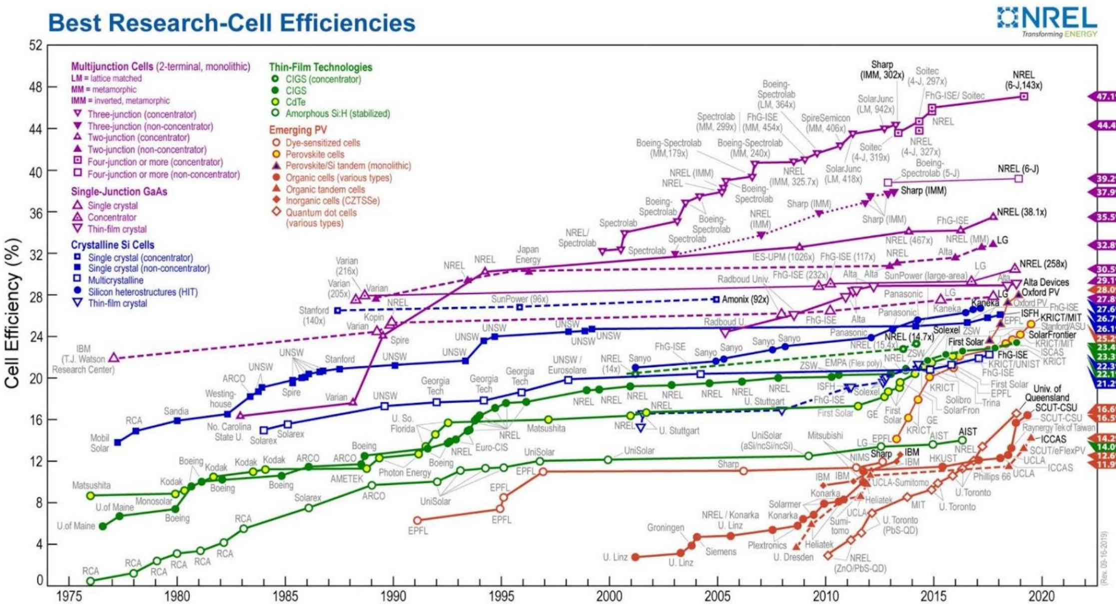


Figure 79.Graph of the efficiency evolution of the different photovoltaic technologies between 1975 and 2020. Source: NREL

5.2 - TYPES OF INVERTERS

The main task of an inverter - a power electronic converter that transforms DC to AC - in a PV system is to deliver at its output a sinusoidal current with low harmonic content (minimum THD) and high power factor (as close to 1 as possible to minimise reactive power), as well as being synchronised to the frequency set by the grid, especially if it is connected to the grid. Most types of commercially available grid-connected inverters are designed to have their inputs directly connected to the PV array, as well as to operate at the maximum power point of the PV array.

Although all inverters serve the same basic function, different types of inverters can be distinguished according to how they are connected to the PV array and how they operate:

- central inverters
- string inverters (string inverters)
- Multistring inverters (Multistring inverters)
- Microinverters (Module inverters)
- Central inverters with power optimisers

5.2.1 - Central inverters

A single inverter controls the entire system. All strings, consisting of modules connected in series (strings), are brought together in a parallel connection via a combiner box, after which they are connected to the inverter. It should be noted that the current input of each string will be added together, usually with an increase in the cable cross-section before entering the inverter. In addition, all the strings will be subjected to the same voltage, hence the need in this configuration to have blocking diodes to protect each string in the event that its voltage decreases with respect to the other strings, or other equivalent protections and considerations.

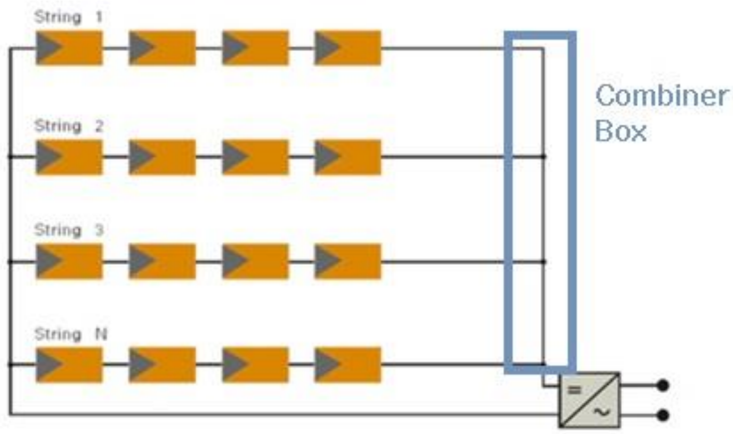


Figure 80.Centralised inverter scheme. Source: Aros Solar Technology

- Advantages:

This solution offers limited economic investment, simplicity of installation and lower maintenance costs.

- Disadvantages:

This typology is especially sensitive to partial shading, limiting the optimal utilisation of each string, which will be affected by the most limiting string, since the inverter will optimise (with MPPT tracking) its operation by that string with the lowest production, therefore some will operate below their real production potential. A single inverter presents more risk of failure to the overall system. Inverter monitoring only measures total output, preventing remote analysis of whether a panel or strings require replacement due to failure.

- It is appropriate and often used for solar fields (or other large open field PV projects) that are uniform in orientation, tilt and shading conditions.

5.2.2 - String inverters

Each string, i.e. each circuit or string of panels in series, is connected to its inverter, representing an independent mini-installation. In each string the current through all the panels is the same, and the contribution of the voltages of each panel is added directly. With this configuration it is intended that each specific zone has an inverter with which to work at the same inclination and orientation (same irradiance) and can optimally adjust the PMP, solving the appearance of shadows without affecting the rest of the plant. See figure 82.

- Advantages: In this decentralised configuration, higher yields are obtained with respect to centralised inverters, as each inverter has a specific MPPT for each string, reducing losses due to shading. There is also less wiring on the DC side.
- Disadvantages: Higher investment and maintenance costs; more wiring on the AC side.

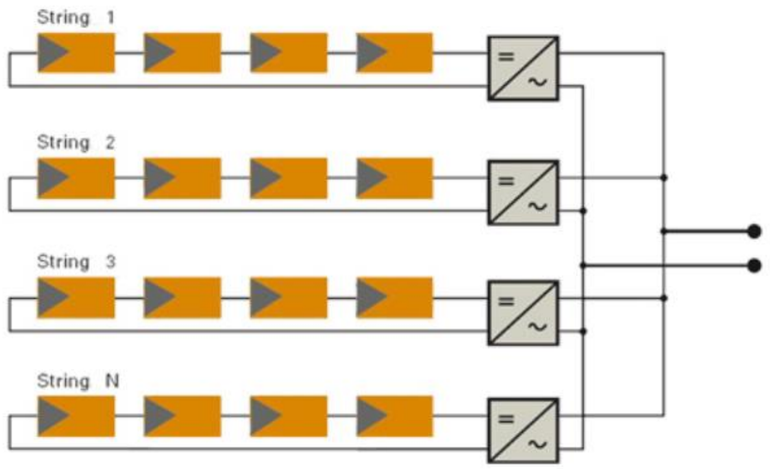


Figure 81.Schematic of string inverter. Source: Aros Solar Technology

5.2.3 - Multistring inverters

This is the intermediate typology between central inverters and string inverters, as it allows the connection of several strings with different operating conditions: different orientations, inclinations, power, shading, etc. On the DC generator side, the strings are connected to specific inputs controlled by independent MPPTs, and are then linked together in the dc-ac conversion stage, functioning as a centralised inverter but with the most optimised efficiency. See figures 82 and 83.

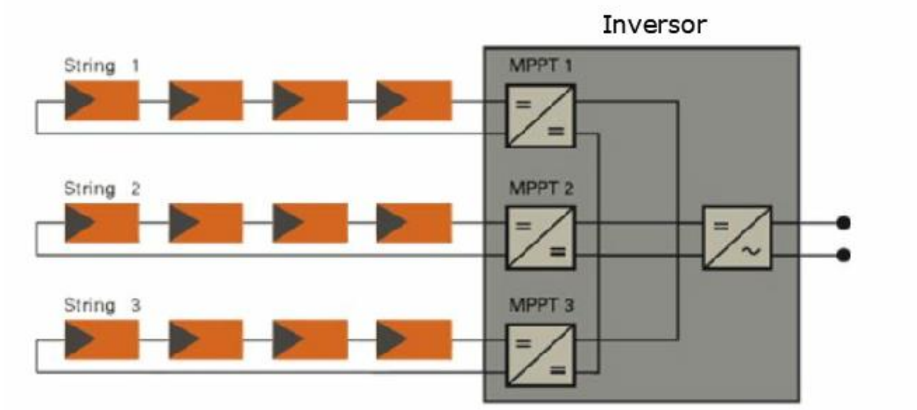


Figure 82.Multistring inverter schematic. Source: Aros Solar Technology.

It combines the advantages of a centralised inverter with the optimum operating point monitoring of decentralised inverters. It is worth mentioning that modules in series achieve higher yields when they are grouped according to similar operating conditions (orientation, incident solar radiation, inclination, shading, etc.). In this configuration, it is advisable to connect strings that are arranged for similar operation to the inverter inputs with the same MPPT, and those strings that will have different conditions should be connected to different MPPT inputs.

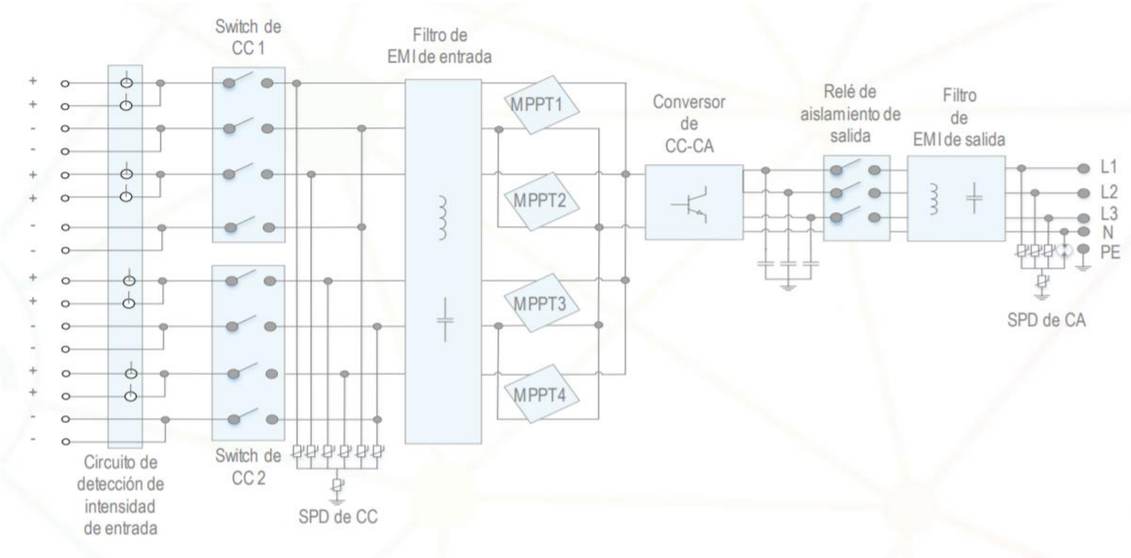


Figure 83.Wiring diagram of a multistring inverter (with independent MPPT trackers). Source: Catalogue HUAWEI SUN2000-36KTL

5.2.4 – Microinverters

This typology works in the opposite way to centralised inverters, instead of having one inverter for a set of panels, there is a compact inverter for each solar panel. Thus, instead of a series connection in direct current, a parallel connection in alternating current is used. This configuration ensures that all the panels individually operate at PMP, as each microinverter has MPPT tracking. Here the PV panel and inverter are conceived as a single unit, and there are even microinverters so small that they can even be placed inside the panel's own j.box. See figure 85.

- Advantages:

Better shading behaviour; possibility of individual monitoring of each panel, so less time wasted searching for faults; simple grounding, integrated directly into the microinverter circuit; higher energy production than a centralised inverter system, for the same installed power. Thanks to parallel connection, each solar panel operates independently of the rest of the system, so problems in one module do not affect others. It can operate effectively even with many operational differences in orientations, inclinations, shadows, etc. They allow panels of different powers to be added to the same central inverter string without affecting production, which is interesting for those installations with free space with the possibility of expanding panels in the future after installation.

- Disadvantages:

High investment cost. The yield of a modular inverter is lower than that of higher power inverters, although this difference is compensated by a better adjustment of the PMP to the performance of each panel. Maintenance is more complex, as there is a microinverter in each panel. If access to the array is difficult, for example on the roof of a house, microinverters are generally not the best option. Their integration with storage systems such as batteries is more complex as they require two additional power conversion steps: because the panel output power is converted to AC immediately at the output of each module, it must be reconverted to DC for battery storage and then converted back to AC for use.

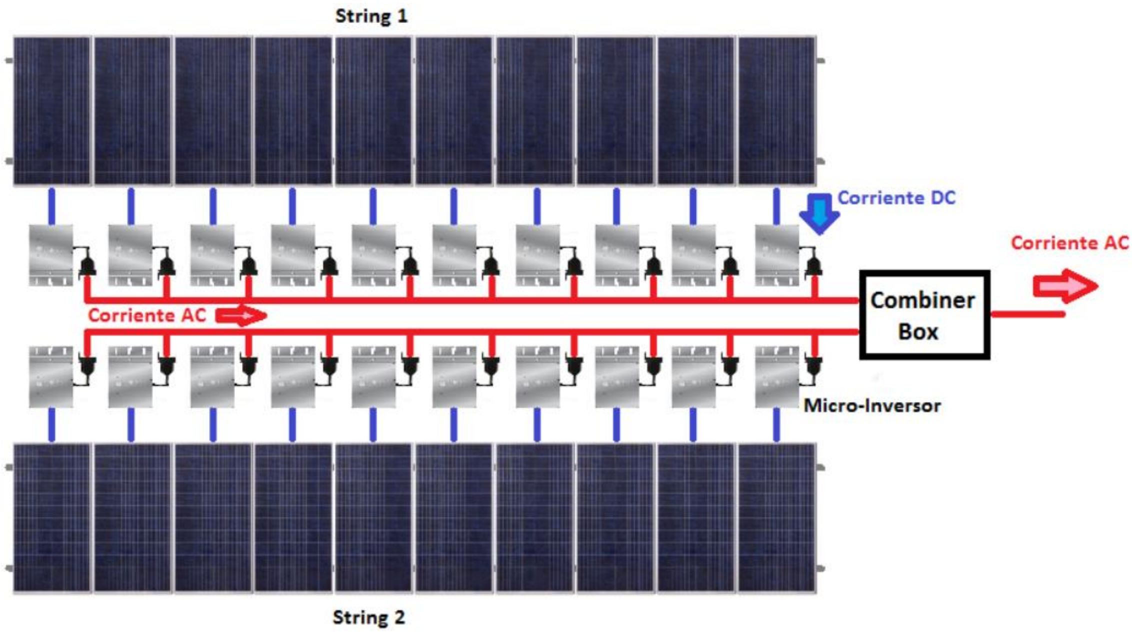


Figure 84.Scheme of microinverters. Source: Alpha Tecnics-Solar Energy & Energy Efficiency.

5.2.5 - Central inverters with power optimisers

This typology is a hybrid between microinverters and central inverters. The system uses a central inverter, but the modules are not directly connected to the series circuit; instead, each module (or every 2 or 3 modules) is connected via a power optimiser, and at the same time the optimisers are connected in series. The cost of this system is also intermediate between one with microinverters and a conventional one with centralised inverters. They work by separating the two main inverter functions - optimisation (MPPT tracker) and conversion - to do the optimisation at the panel level and the DC-AC conversion stage at the string or array level.

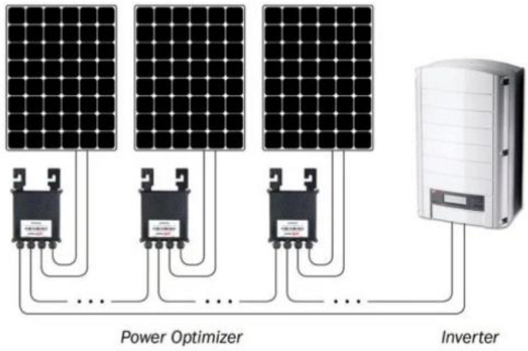


Figure 85.Central inverter system with optimisers. Source: SolarEdge.

- Advantages:

They are lower cost than microinverters (although still higher than the cost of a central inverter). Optimisers have a long lifetime. Like microinverters, they allow panel-by-panel monitoring to compare efficiencies and find faults easily; they allow optimisation of the operation of individual panels; they allow panels of different power ratings to be added to the same string as the central inverter without affecting production. They have wider voltage ranges than microinverters.

- Disadvantages:

Still relies on a central inverter whose lifetime is typically no more than 10-15 years, and a failure of the central inverter still causes the entire system to fail. Adding additional panels to a system already sized for the capacity of the central inverter is more expensive than with microinverters, because in this case you need another new central inverter to add a few panels, which increases the cost per additional panel.

5.3 - FINAL SELECTION AND JUSTIFICATION OF THE TECHNOLOGY TO BE USED

At this point, with all the information presented on possible alternatives, we proceed to the final selection of the technologies to be used for the installation.

Crystalline silicon technology was chosen for the panel, as it is the most widely used in the sector, is commercially available and has a good quality-price ratio; specifically, polycrystalline technology was chosen, as it works better under conditions of high solar incidence and high temperatures, as in this case. In addition, these are sufficient and monocrystalline ones are not required, as they have a fairly large useful surface area. For this reason, a 350Wp power unit from the manufacturer Canadian Solar was chosen, specifically the KuMax CS3U 350P model, whose dimensions (2000x992mm) have been used in the distribution of the configuration alternatives in the plans presented. Therefore, the installation will have a peak power of: 280 panels x 350Wp/panel = 98kWp.

For the inverter, the multistring type is chosen, i.e. it allows the connection of different strings with different operating conditions. This technology is selected because the installation will have several sets of panels with different orientations and therefore different operating conditions, therefore, a central inverter would not be viable because it would have a very poor performance. A string inverter is also not viable because numerous inverters would be required, which would make the installation too expensive. Microinverters and power optimisers would also make the installation too expensive, and in this case they are not necessary, since an exhaustive study of shadows has already been carried out, discarding the most critical areas, and therefore, the final projected installation will already be mostly free of shadows, so there is no need to optimise at such a precise level for each individual panel.

The multistring inverters chosen are the Huawei SUN2000, one with 36kW power and the other with 60kW power, as will be seen in the corresponding section.

6 - DESIGN AND DESCRIPTION OF THE CHOSEN PROPOSAL

6.1 - GENERAL DESCRIPTION

As seen in previous sections, the selection of the proposal, in summary, includes PV panels with polycrystalline technology and multistring inverters. Regarding the configuration of the installation, option D has been selected, with 280 modules in total.

The photovoltaic power plant will be located on the roof of the industrial building and will be privately accessible. It will have an installed peak power of 98 kWp and a nominal power of 96 kW, the maximum output power offered by the 2 inverters that will accompany the photovoltaic modules. These will be of 60 and 36 kW (as will be seen in the description of the inverters), and will be distributed in groups according to the capacity of each of the different strings of modules: there will be a configuration of 9 strings of PV panels in parallel connected to the 60kW inverter, and another 5 strings of PV panels in parallel on the other 36kW inverter. Each string will constitute a string, i.e. a string of PV modules in series, with 20 modules connected in series per string (see drawings P03 and P05 in document E of the drawings, and supporting calculations in Annex I).

As for the configuration of the system, a total of 280 modules will be arranged as shown in table 2 (see also drawing P03 of the distribution by strings).

	Nº módulos	Orientación paneles	Agua Nave	Estructura adicional	Nº Strings
Zona 1	60	Sur	Sur	No (Coplanares)	3
Zona 2	60	Sur	Norte	Sí (Escuadras-barras)	3
Zona 3	60	Este	Este	No (Coplanares)	3
Zona 4	100	Oeste	Oeste	No (Coplanares)	5

Table 2. General configuration of the photovoltaic power plant. Source: Own creation

All the strings in all the areas will be arranged without covering the existing roof skylights, in order to maintain the entry of natural light into the building. Sufficient space will also be provided between the aforementioned strings of panels both for the placement of the wiring conduits and to facilitate proper maintenance.

The proposed photovoltaic plant will be configured with the equipment shown in table 3, which will be detailed in the following sections.

Nº de paneles	280
Modelo de paneles	KuMax CS3U-350P (Canadian Solar)
Potencia unitaria	350 Wp
Potencia pico total	98 kWp
Nº de inversores	2
Modelo de inversores	Huawei SUN2000-36KTL Huawei SUN2000-60KTL
Potencia nominal inversores	96 kW (1x36kW + 1x60kW)

Table 3.Equipment overview. Source: Own creation.

6.2 - PHOTOVOLTAIC PANELS

The photovoltaic panels will be from the manufacturer: Canadian Solar, specifically the model: KuMax CS3U-350P, with a peak power per panel of 350Wp.

With 144 high efficiency polycrystalline silicon solar cells, with tempered glass and high transmission that provides a module efficiency of up to 17.64%, minimising installation costs and maximising the performance provided by the system per unit area.

A robust, corrosion-resistant anodised aluminium frame, independently tested to withstand wind, snow and other weather loads, ensures a stable mechanical life of the modules.

The manufacturer guarantees the power and productivity for 25 years and the product for 10 years.

The junction box is equipped with 3 bypass diodes (bypass diodes), which prevent the possibility of failure or decrease in productivity of the photovoltaic cells, which make up the panel, and its circuit, due to partial shading of one or several modules within a set.

Each panel is fitted with an IP68 junction box and terminal connection plug MC TYCO PV4 (commonly referred to as MC-4).

Tables 4 and 5 summarise the general characteristics of the KuMax 350Wp modules. In addition, the complete technical documentation is attached in Annex IV.

The electrical measurements are referenced under STC standard conditions:

- Cell temperature = 25°C
- Irradiance = 1000W/m2
- Spectrum = AM 1.5

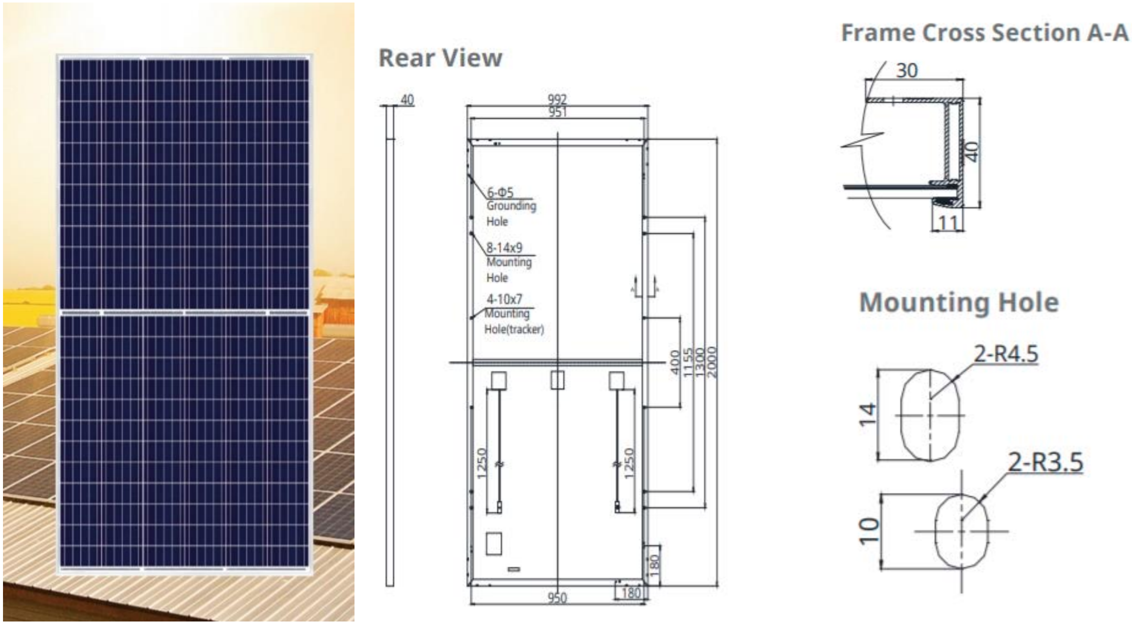


Figure 86.View of the panel model: KuMax 350Wp, from Canadian Solar. Source: Canadian Solar data sheet.

Aspectos eléctricos	
Potencia máxima/pico (Pmax)	350 Wp
Corriente en el punto de máxima potencia (Imp)	8,94 A
Tensión en el punto de máxima potencia (Vmp)	39,2 V
Corriente de cortocircuito (Isc)	9,51 A
Tensión de circuito abierto (Voc)	46,6 V

Table 4.Main electrical characteristics of the KuMax 350Wp module. Source: Own creation based on data from the data sheet

Aspectos físicos	
Longitud	2000 mm
Anchura	992 mm
Espesor	35 mm
Peso	22,5 kg

Table 5.Main physical characteristics of the KuMax 350Wp module. Source: Own creation based on data from the data sheet.

6.3 - SUPPORTING STRUCTURES

Anodised aluminium structures will be used to support the modules coplanar to the roof. These are roof structures, fixed by means of metal clamps that will be attached to the existing roof profiles, i.e. to the corrugations of the sandwich panels on the roof of the building.

The material to be used is raw aluminium capable of resisting the load produced by the weight of the modules, in addition to possible overloads from wind and snow, in accordance with the Technical Building Code (CTE), part II, DB SE and DB SE-AE. Its installation is such that once the life of the installation is over, if required, it is possible to dismantle the structure, leaving the surface in its original state.

The fastening points of the modules to the structure will be made in such a way that they are perfectly fastened and they are allowed a slight expansion due to the working temperature at which they can work according to the season of the year and meteorological variability of the area. Therefore, the design, the construction of the structure and the fixing system of the photovoltaic modules will allow thermal expansions, without transmitting loads that could affect the integrity of the modules.

The aluminium used ensures good electrical insulation. The formation of galvanic couples between the structure and the frame of the photovoltaic panel shall be avoided.

The modules shall be fixed to the structure by means of stainless-steel screws, in accordance with the MV-106 standard.

The aforementioned structures will be coplanar to the roof of the industrial building in zones 1, 3 and 4; with an inclination of 6º above the horizontal, the same as the roof itself. As the modules are completely coplanar, the horizontal force is negligible, due to the fact that the area of action is minimal, and the vertical force is eliminated as it is multiplied by sin 0º.

Galvanised steel bars are anchored to the roof, and trapezoidal guides (or omegas) are installed on top of them, which act as rails and are fastened to the bars by means of screws. On top of the guides, the so-called interclamps and endclamps will be fitted, which will hold the module to the structure and anchor it to the adjoining modules.

As the modules will be placed horizontally, transverse to the rib, the trapezoidal guides/rails will be arranged longitudinally in the direction of the rib, as shown in figure 89.

The justification of the structural resistance in the building is presented in Annex I, calculations.

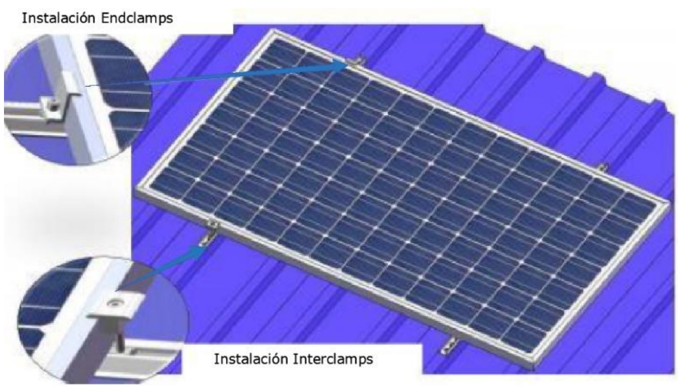


Figure 87. Sample of interclamp and endclamp fastening. Source: Solar Portal.

Figure 88.Sample of the trapezoidal fastening screwed to the plate on the rib. Source: Solar Portal

Figure 89.Photograph of an example installation showing the attachment to the ribbed roof. Source: Own.

Figure 90.Example of integrated fastening. Source: Own

6.4 - NORTH WATER RECTIFYING STRUCTURE

A 3D modelling has been made, using the software 'SketchUp Pro', of the structure that will go in the north water to give the panels a south orientation. This structure can be seen in detail projected from different viewing angles of the building - figures 92, 93, 94, 95 - as well as a model with the 60 photovoltaic modules of this zone 2 (according to table 2) arranged on the structure (3 strings of 20 modules) - figures 96, 97, 98, 99, 100.

In order to carry out the modelling, the first step was to construct the two halls using the construction tools offered by the programme, mainly by means of extrusions. Then, the structure formed by triangular squares was projected, also using the basic tools - mainly the line pencil. The same basic tools were used for the approximation of the obstacle in the water of the building, which interferes with the positioning of the structure. As for the modules, a pre-built module unit from Sketchup's 'Warehouse', the gallery of 3D elements, has been used.

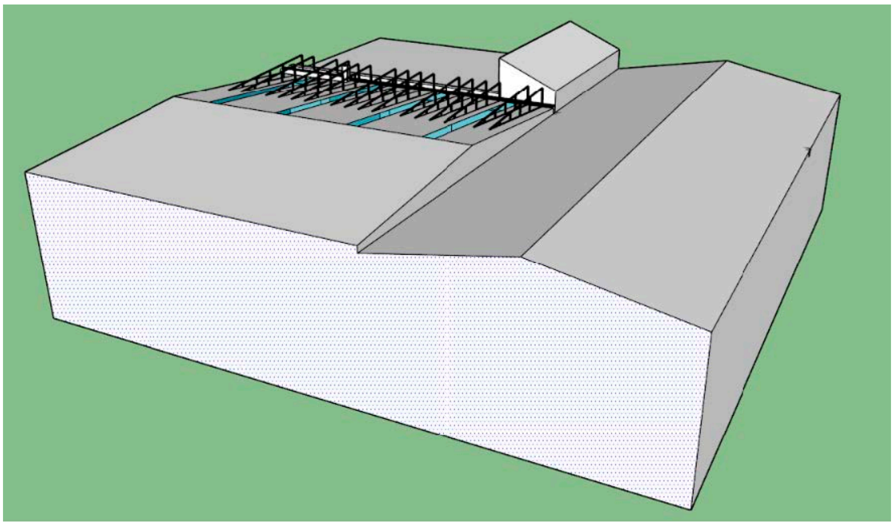


Figure 91.Modelling of the North Water structure - Front view. Source: Own creation in SketchUp.

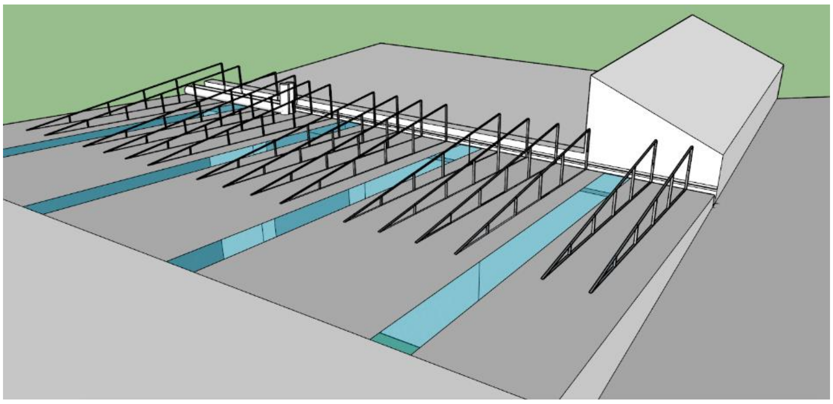


Figure 92.Modelled North Water structure - Close-up front view. Source: Own creation in SketchUp

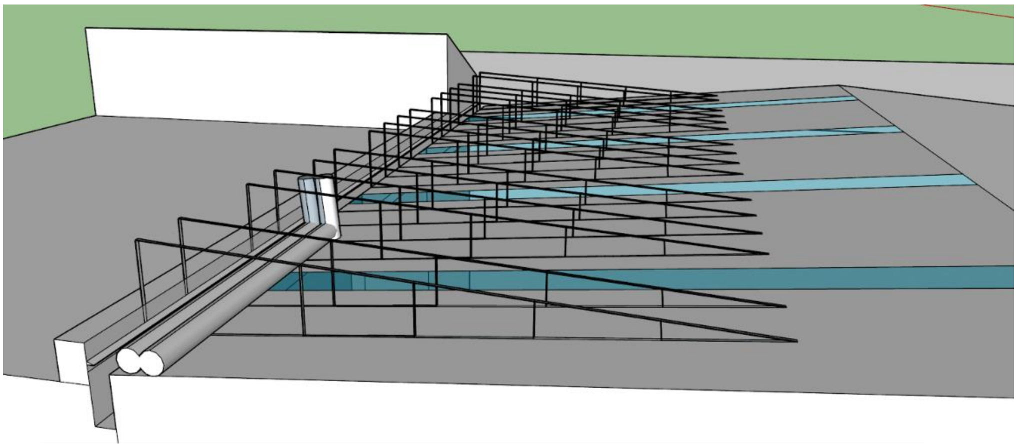


Figure 93.Modelled North Water structure - Left side view. Source: Own creation in SketchUp.

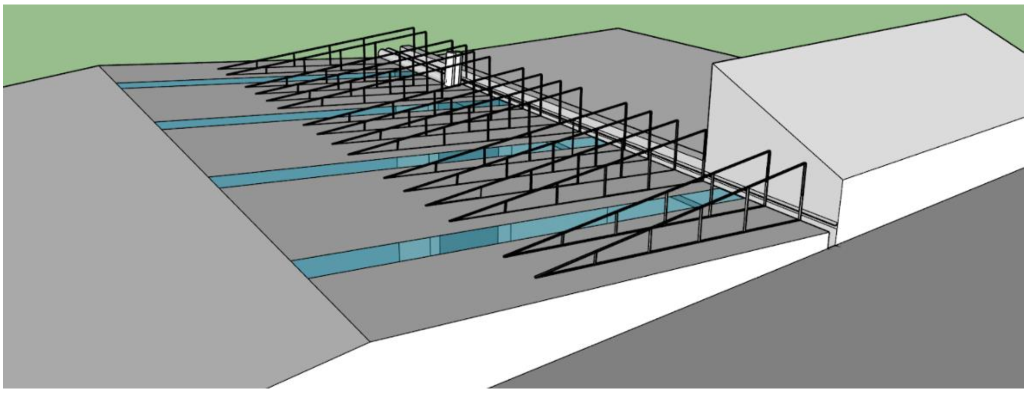


Figure 94.Modelled North Water structure - Right side view. Source: Own creation in SketchUp

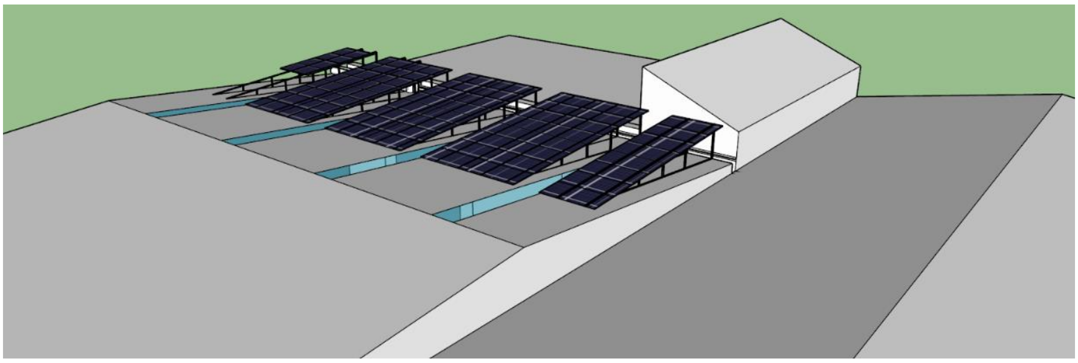


Figure 95.Modelling of the North Water structure with the fv-modules - Close-up front view. Source: Own creation in SketchUp.

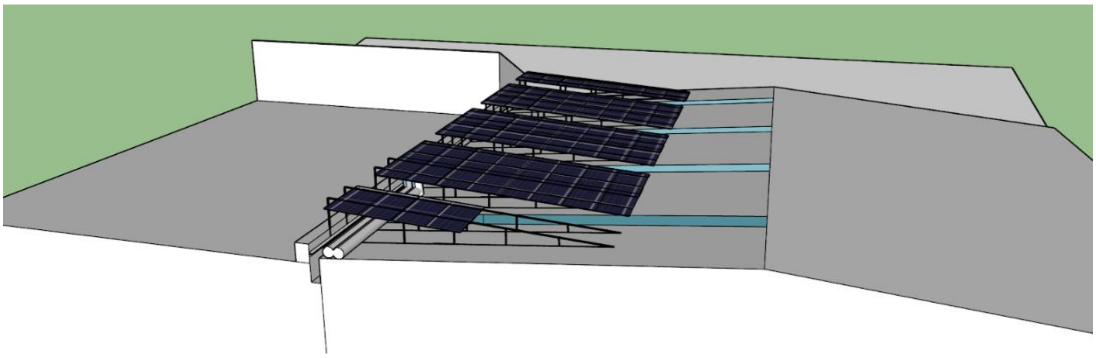


Figure 96.Modelling of the North Water structure with the fv modules - Left side view. Source: Own creation in SketchUp

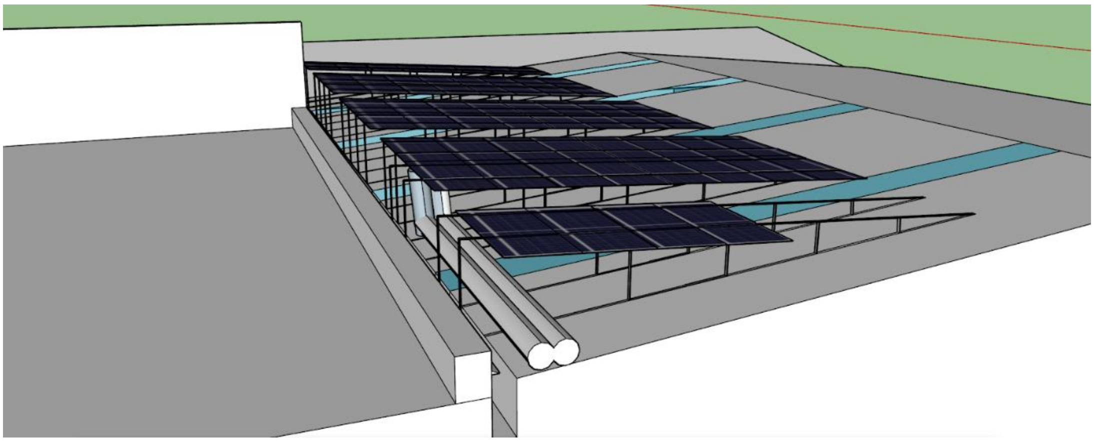


Figure 97.Modelling of the North Water structure with the fv-modules - Close-up left side view. Source: Own creation in SketchUp.

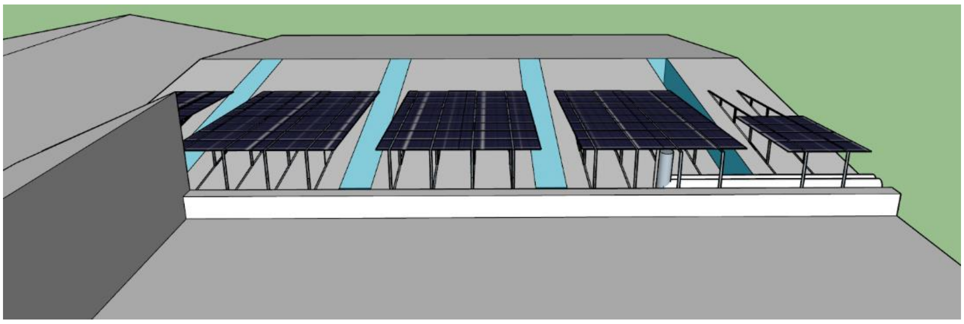


Figure 98.Modelling of the North Water structure with the fv modules - Rear view. Source: Own creation in SketchUp.

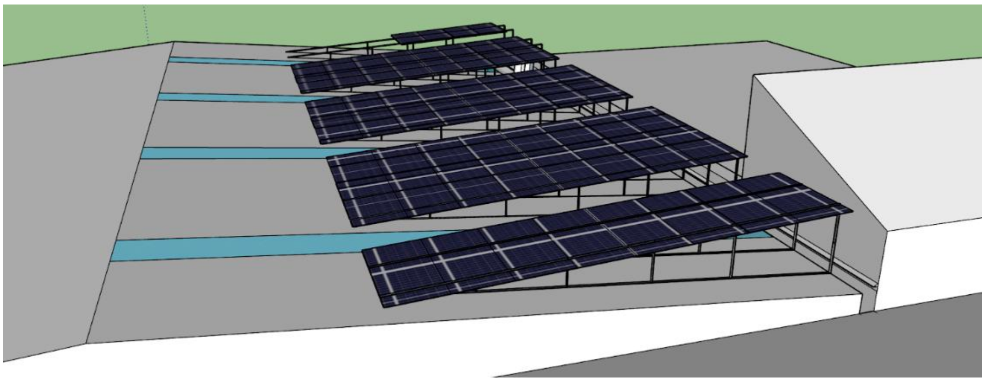


Figure 99.Modelling of the North Water structure with the fv-modules - Right side view. Source: Own creation in SketchUp

A total of 16 triangular brackets will be used as shown in the previous figures, of which 12 will be of type 1 and 4 of type 2, according to plans P09 and P10.

The 4 type 2 brackets will be of a different construction to the others, since there is an obstacle (a pipe, as can be clearly seen in figure 98) that prevents the longest support of the bracket to the ground from being used, so this is done on the adjacent available wall. In addition, they will be attached to the end of the roof in order to take advantage of both the wall for structural resistance and the wall of the small roof to the east, which acts as a windbreak.

The triangular brackets will have a total inclination of 12º, since an initial 6º will be needed to save the inclination of the water itself, to bring it to the horizontal plane, and then an additional 6º so that the modules have this inclination, to arrange them with the same inclination as the coplanar modules of zone 1 (the South Water which is right next to the North Water behind the ridge). Figures 101 and 102 show graphically the relative inclination between the square-roof mentioned above, and show how the structure is parallel to the roof of the South water. It was decided not to give them a higher inclination because, although it would generate more energy production, it would be more affected by the force of the wind as it would be higher and therefore more dangerous. In the same way, it was decided to place the structure as close to the back as possible, away from the ridge, to make it safer from the wind as well, since having the structure behind it would be more sheltered and protected, and the wall behind it could also be used as an additional support.

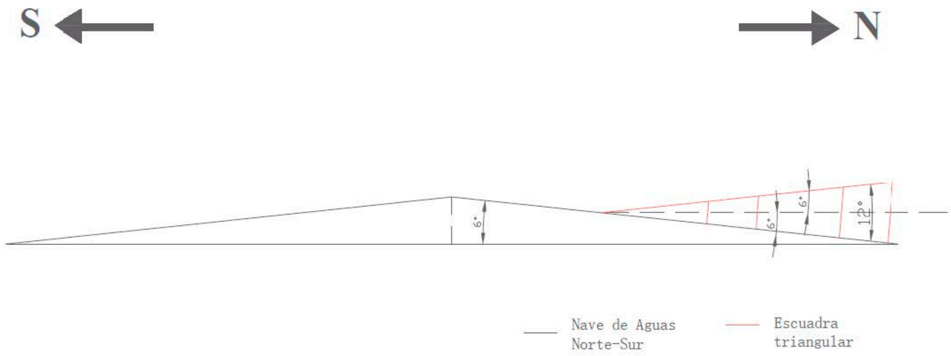


Figure 100. Inclination of the north water structure. Source: Own creation in Autocad

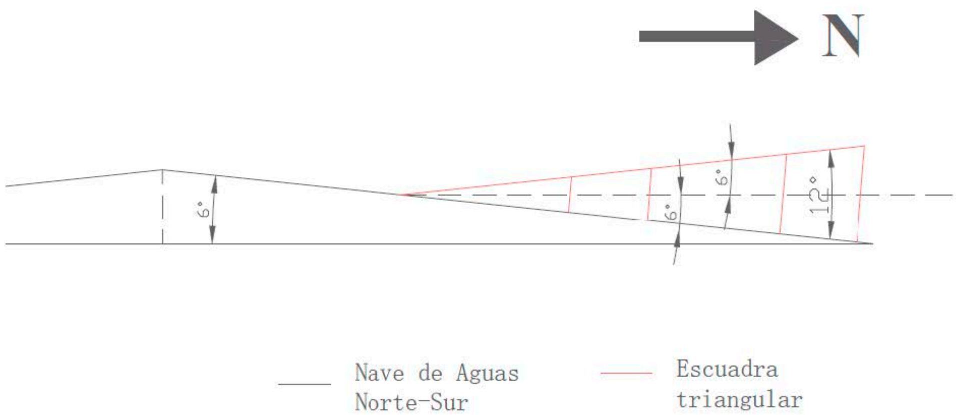


Figure 101.Inclination of the north water structure, enlarged view. Source: Own creation in AutoCAD.

The triangular bracket structure shall be composed of bars joined together by welding. The bars will be rectangular galvanised steel profiles to guarantee good electrical insulation and avoid the formation of galvanic couples between the structure and the frame of the photovoltaic panel. The dimensions of each bar shall be 40x40x2mm, in galvanised steel, and in such a way that they withstand the various loads that affect them, according to the calculations made in Annex I. They will form the structure in triangular brackets that will be screwed at their base to the roof trusses.

The bars of the base of the bracket on the roof shall be placed on the part of the ribs and each module arranged horizontally shall be supported on two triangular brackets. The module frame shall be connected to the brackets by means of the screwed trapezoids, in which, in turn, the interclamps and endclamps are arranged, which allow the fastening to the structure and between the modules. In addition, every two triangular brackets will have a cross at the end with two plates, by means of bolting, to ensure the correct fastening, integration and stability of the structure as a whole, as shown in figure 103.

Figure 102.Example of the cross brace for the structure. Source: Own.

Figure 103.Example of a structure with triangular brackets. Source: Own.

6.5 - INVERTER.

The inverters to be used are from the manufacturer Huawei. Two inverters of different power ratings will be installed, models: SUN2000-36KTL and SUN2000-60KTL, of 36kW and 60kW respectively. This gives an overall nominal power of 96 kW for the installation.

The inverters act as a source synchronised with the grid and have control microprocessors and PLC communications. They are connected on the DC side to the photovoltaic generator, and on the AC side to the internal grid that supplies the building.

The inverter is characterised by an electronic power conversion stage, which provides galvanic isolation between the DC and AC parts. Microprocessors are used to guarantee the sine curve with minimum distortion. The control logic used guarantees, in addition to full automatic operation, the monitoring of the maximum power point (MPP) and avoids possible losses during stand-by periods (Stand-By). It is capable of transforming into alternating current and delivering at its output the power that the photovoltaic generator generates at any given moment, operating from a minimum threshold of solar radiation.

In addition, it allows the automatic disconnection-connection of the photovoltaic installation in the event of a loss of voltage or frequency of the grid, avoiding island operation, a safety guarantee for the maintenance workers of the electricity distribution company. The grid connection thresholds are as follows:

- In frequency: 50 Hz (maximum 51Hz and minimum 49Hz)
- In voltage: 0.85Um to 1.1Um.

It also acts as a permanent insulation monitor for the automatic switch-off and switch-on of the PV system in the event of loss of insulation resistance, together with the floating configuration for the PV generator to ensure the protection of people.

Tables 6 and 7 present the summarised characteristics of the selected inverters; the specific characteristics in detail can be found in the complete table in the data sheet attached in Annex IV.

Inversor 1: HUAWEI SUN 2000-36KTL	
Entrada	
Máx.tensión entrada	1100 V
Máx. intensidad por MPPT	22 A
Máx. intensidad de cortocircuito por MPPT	30 A
Tensión de entrada inicial	250 V
Rango tensión de operación de MPPT	200 V - 1000 V
Tensión nominal de entrada	620 V @380Vac/400Vac
Máx. cantidad de entradas	8
Cantidad de MPPT	4
Salida	
Potencia nominal activa de CA	36 kW
Máx. potencia aparente de CA	40 kVA
Tensión nominal de salida	230 V / 400 V
Frecuencia nominal de red de CA	50 Hz / 60 Hz
Intensidad de salida nominal	52.2 A @ 400 Vac
Máx. intensidad de salida	57.8 A @ 400 Vac
Máx. distorsión armónica total	< 3%

Table 6. Main features of the 36KW inverter. Source: Own creation based on data from the data sheet.

Figure 104.Image of the Huawei SUN2000-36KTL 36kW inverter. Source: Huawei catalogue.

The 36KTL inverter features intelligent monitoring of 8 total input strings, of which there are 4 MPPT; power line communication (PLC) support and intelligent I-V curve diagnostic support. It also has an integrated Residual Current Monitoring Unit (RCMU) and DC disconnection.

The 60 KTL inverter features intelligent monitoring of 12 total input strings, of which there are 6 MPPT; power line communication (PLC) support and intelligent I-V curve diagnostic support. It also has an integrated Residual Current Monitoring Unit (RCMU) and DC disconnect.

Inversor 2: HUAWEI SUN 2000-60KTL	
Entrada	
Máx.tensión entrada	1100 V
Máx. intensidad por MPPT	22 A
Máx. intensidad de cortocircuito por MPPT	30 A
Tensión de entrada inicial	250 V
Rango tensión de operación de MPPT	200 V - 1000 V
Tensión nominal de entrada	620 V @380Vac/400Vac
Máx. cantidad de entradas	12
Cantidad de MPPT	6
Salida	
Potencia nominal activa de CA	60 kW
Máx. potencia aparente de CA	66 kVA
Tensión nominal de salida	230 V / 400 V
Frecuencia nominal de red de CA	50 Hz / 60 Hz
Intensidad de salida nominal	86.7 A @ 400 Vac
Máx. intensidad de salida	95.3 A @ 400 Vac
Máx. distorsión armónica total	< 3%

Table 7. Main features of the 60KW inverter. Source: Own creation based on data from the data sheet.

Figure 105.Image of the Huawei SUN2000-60KTL 36kW inverter. Source: Huawei catalogue.

The justification of the inverter equipment in terms of power is detailed in Annex I of 'Supporting calculations'. The string configuration is also detailed, selecting the number of panels per string as well as the number of strings connected to each inverter input, so that they operate in a balanced way, and checking the adequacy of current and voltage values acceptable by the inverters. In addition, this distribution can be seen graphically in drawings P03 and P05.

6.5.1 - Monitoring of inverters

Each inverter has an integrated wifi monitoring system that acts as an interface between the solar power installation and the outside world. It is possible to display measurements and general information about the inverter status on the LCD display of the device. The RS-485 serial interface enables connection to a PC via the communication software. The presence of an Internet access interface via an Ethernet connection makes remote queries possible.

6.5.2 - Location of inverters

The inverters will be located inside the industrial building, close to the control panel (see drawing P02).

The location of the control and protection panel (CBT in alternating current) in the same location as the inverters allows easy connection of the input and output cables of each inverter. In addition, it allows the relevant openings for electrical disconnection upstream of each inverter and downstream of the building's CGBT. The inverters have DC disconnectors (DC switch) to be able to cut off electrically downstream of the inverter. Maintenance work can therefore be carried out on the inverter in complete safety.

Ventilation in the location of the inverters is guaranteed by natural ventilation, as it is a large area without restriction to the natural flow that ventilates it. They will be wall-mounted, so they will have enough space around them to favour ventilation to avoid overheating and thus favour their optimum operation. As they are located in an interior space (the inside of the building), their protection against external agents or inclement weather is guaranteed.

6.6 - WIRING

The electrical circuit will mainly consist of three parts to be considered:

- A direct current part from the photovoltaic panels to the inverters.
- An alternating current section from the inverters to the protection panel.
- A final alternating current section, also from the protection panel of the PV installation to the general electrical panel at the head of the building.

The DC wiring will be made up of single-pole Cu cables of type RV-K 0.6/1kV and section 6mm2 according to the conductor calculations (see Annex I). This cable will be insulated with cross-linked polyethylene (XLPE), with PVC sheath, flexible conductor, and flame retardant, in accordance with standard UNE 21123-2. The Reviflex model from the manufacturer Grupo Revi, or similar, shall be used.

Figure 106.Single-pole RV-K 0.6/1kV cable for the DC side. Source: Revi Group.

The colour code used for the AC and DC cables will be as indicated in the section corresponding to wiring in document C of the Specifications.

For the alternating part, single-pole Cu cables of type RZ1-K 0.6/1kV (AS) and sections 16mm2, 35mm2 and 70mm2 will be used, each of which will be respectively for: the output of the 36kW inverter, the output of the 60kW inverter and the output of the junction of both, as shown in the single-line diagram (see drawing P11). These cables shall be of flexible conductor, cross-linked polyethylene insulation (XLPE) and polyolefin sheath. They will be high safety (AS), i.e., flame and fire retardant, low smoke and toxic gas emission and halogen-free, in accordance with standard UNE 21123-4. The Ecorevi model from the manufacturer Grupo Revi shall be used; or the 334 model from the manufacturer Cables RCT; or similar.

1. Conductor	Cobre electrolítico flexible (Clase V) según UNE-EN 60228, EN 60228 e IEC 60228
2. Aislamiento	Polietileno reticulado (XLPE) tipo DIX 3 según UNE 21123, HD 603 S1 e IEC 60502-1
3. Cubierta	Poliolefina termoplástica tipo DMZ-E según UNE 21123 y UNE-HD 603-1 y ST8 según IEC 60502-1

Figure 107.RZ1-K (AS) 0.6/1kV single-pole cable for AC side. Source of supply: RCT cables.

As for the choice of cable cross-sections, this is attached in Annex I of the supporting calculations, and has been made on the basis of two criteria: the thermal criterion and the voltage drop criterion. Both criteria depend mainly on the characteristics of the cable chosen, such as the resistance offered by the cable. The thermal criterion is based on the Joule effect, in which a conductor through which an electric current circulates will heat up, acting as a thermal energy dissipating resistance. A cable will be chosen with a cross-section such that it will withstand the heating to which it will be subjected depending on the current circulating, which will have to be less than that admissible by the cable. The higher the current, the greater the heating and, therefore, the greater the cross-section required. The voltage drop criterion will depend on the type of section and its length. This criterion is usually more restrictive than the previous one. Specifically, for any working condition, the conductors should have sufficient cross-section so that the voltage drop does not exceed 1.5% in any case, according to the Technical Specifications (PCT-C-REV of July 2011) for grid-connected photovoltaic installations.

6.7 - CHANNELS

For the LV installation of both the DC part (between modules on the roof and from the end of the string to the inverter) and the AC part (inverter to the protection panel), hot galvanised grid tray (commonly known as rejiband) shall be used, perforated as shown in figure 109. The rejiband cable tray is composed of electro-welded mesh rods that provide great resistance and elasticity, and with a safety edge, thus preventing damage to the wiring or the installer. It is manufactured in accordance with international standard IEC 61537 and this type of tray provides adequate ventilation and high resistance to the trunking system. The main purpose of the trays is the support and conduction of the cables. The dimensions of the rejiband will be 3000x200x35mm, therefore, they will be placed one after the other joined together, in sections of 3 metres (the length of each unit). This conduit will be covered by a straight stainless steel blind metal cover, to keep the wiring laid on the trays protected and sheltered. The cover shall be from the manufacturer Pemsa or similar, with dimensions 3000x200x20mm. It is pressure-mounted (without screws or fixings), as can be seen in figure 110.

The conduits used shall comply with the requirements established in the UNE-EN 61537 standard for 'Tray and ladder tray systems for cable management', and shall be CE certified.

Figure 108.Rejiband and lid (left and right respectively). Source: Pemsa Catalogue

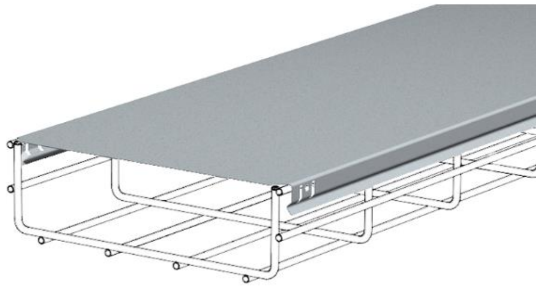


Figure 109.Installation of the rejiband with straight blind cover. Source: Pemsa.

6.8 - PROTECTIONS AND SWITCHGEAR OF THE PHOTOVOLTAIC SYSTEM

Adequate electrical protection in the self-consumption photovoltaic installation is of vital importance to ensure the health and safety of both the people responsible for its operation and maintenance, as well as the equipment itself and the electrical grid to which it is connected. To this end, a distinction must be made between the (a) direct current and (b) alternating current parts, since both include different systems for their protection. In addition, the protections already built into the inverter shall also be taken into account.

The protection system must comply with the requirements presented in the current regulations, which, according to Article 11 of Royal Decree 1663/2000 (on the connection of photovoltaic installations to the low voltage grid), will include the following:

- Manual main switch, which will be a magneto-thermal switch with a short-circuit current greater than that indicated by the distribution company at the connection point. This switch shall be accessible to the distribution company at all times so that manual disconnection can be carried out.
- Automatic differential circuit breaker, in order to protect people in the event of any element of the installation being bypassed.
- Automatic interconnection circuit breaker, for the automatic disconnection-connection of the photovoltaic installation in the event of a loss of voltage or frequency of the grid, together with an interlocking relay.
- Protection for the maximum and minimum frequency interconnection (51 and 49 Hz, respectively) and maximum and minimum voltage (1.1 and 0.85 Um, respectively).

According to this standard, it enables the inverter equipment to integrate the protections mentioned in (iii) and (iv). Therefore, in the case of the present project, given the inverter equipment chosen, it will integrate the protection functions of maximum and minimum voltage and maximum and minimum frequency, as well as the automatic disconnection-connection manoeuvres to avoid island operation, a safety guarantee for the maintenance workers of the electricity distribution company. All the protections that integrate the selected inverter equipment are shown in table 8.

Therefore, in this case, it will only be necessary to have the additional protections of the main switch, circuit breaker and differential switch, which will be located in the AC electrical panel of the photovoltaic installation itself, as described in the corresponding section below. The choice of these protections is made in Annex I of the supporting calculations.

In addition, the following protection elements will be included, according to the technical considerations of the REBT of 2002 and the safety proposals set out in the IDAE's PCT specifications:

- Class II insulation in all components: modules, wiring, etc.
- Grounding of the module frame and structure, as well as the inverter casing and any other metallic element, in accordance with current regulations. That is to say, all the masses of the PV installation, both of the DC and AC sections, will be connected to a single earth, which will be independent from the neutral of the distribution company, in accordance with the REBT.
- Protection against overcurrent in the DC section (in this case this is also integrated in the inverter, see table 8).
- Reverse polarity protection on the DC side (in this case this is also integrated in the inverter, see table 8).

6.8.1 - Protections integrated in the inverter

The inverters chosen have a series of protections integrated in the equipment itself, as shown in table 8 extracted from the inverter characteristics table, whose part of protections is the same for both the 36kW and the 60kW Huawei, therefore both have the same protections listed.

	Protección
Dispositivo de desconexión del lado de entrada	Sí
Protección contra funcionamiento en isla	Sí
Protección contra sobreintensidad de CA	Sí
Protección contra polaridad inversa de CC	Sí
monitorización de fallas en strings de sistemas fotovotaicos	Sí
Protector contra sobreintensidad de CC	Tipo II
Protector contra sobreintensidad de CA	Tipo II
Detección de aislamiento de CC	Sí
Unidad de monitorización de la intensidad Residual	Sí

Table 8. Protections integrated in the Huawei 36KTL and 60KTL inverters. Source: Huawei 36KTL Y 60 KTL data sheet..

With the protections that the selected inverter equipment integrates, it complies with the directives mentioned in the IDAE's PCT for the grid connection of a PV installation, therefore, protecting against: short circuits in alternating current, voltage or grid frequency out of range, overvoltages, disturbances present in the grid such as micro-cuts, pulses, cycle defects, absence and return of the grid. In addition, it also protects the direct current zone against overcurrents, insulation failure, reverse polarity, among others, such as the monitoring of faults that may be present in the connected strings.

6.8.2 - Protections against direct contact

Protection against direct contact consists of protecting people against the dangers that may arise from contact with the active parts of the electrical materials in the installation. This will be achieved mainly through the application of the following measures detailed in the ITC-BT-24 and according to standard UNE 20.460-4-41, which are:

-Protection by insulation of active parts. -Protection by means of barriers or enclosures with degrees of protection IP XXB. -Protection by means of obstacles. Protection by means of remote out-of-reach protection. -Complementary protection by residual current devices.

The protection against direct auxiliary contacts provided by the selected inverter equipment consists of:

(a) On the DC side: The inverter has an isolation monitor on the DC side of the generator panel set. This ensures that, if the insulation resistance drops below the set safety values, the inverter will switch off and trigger an alarm indicating the fault. This prevents possible direct contact of live parts due to insulation damage.

(b) On the AC side: a residual current detection device with adjustable sensitivity 300mA shall be provided and associated with the AC output circuit breaker.

6.8.3 - Protections against indirect contacts

Protection against indirect contacts consists of protecting people against the dangers which may arise from contact with parts which have been energised as a result of an insulation fault.

The two main types of protection for this purpose in the planned installation, in accordance with ITC-BT-24, are as follows:

- Protection by automatic power cut-off: for this there must be adequate coordination between the installation's earthing system, described in section 6.9 of this project, together with the operation of the differential detection device. This condition implies the installation of the corresponding protective conductors linking the earths of all electrical equipment with the general earthing of the installation. It also implies that the appropriate protective device is selected to disconnect the fault current in an appropriate time, according to the earthing scheme.
- Protection by the use of Class II materials (double insulated or reinforced) or equivalent insulation.

(a) In the direct current part:

Taking into account that in this part of the installation there is no differential current cut-off device, the way to limit the value of the fault current will be by means of the insulation resistance (Riso), keeping it at an adequate value. The standard stipulates that in PV systems without galvanic isolation - without a transformer - as in the present installation, the Riso must be at least 2000 k per kW of inverter input voltage [7]. Compliance with these values is monitored by the inverter.

Basically, it will consist of a configuration with a floating scheme and the use of a permanent insulation controller, which warns of a possible fault and automatically disconnects-connects the PV installation in the event of a loss of insulation resistance. This device is included in the inverter as mentioned above. [8]

Any protection against indirect contacts must ensure that any accidental contact of an active conductor with a metallic part does not cause a shunt to earth through a person touching the racks, supports or metal casings of plates, trays, etc. As explained in section 6.9.1 of this project, the IT system of the floating scheme fully ensures this protection in the continuous part of the photovoltaic plants, as there is no risk of indirect contacts, and there is not even a risk of earth leakage through the person, when this person directly touches a single active conductor. This means that the level of safety achieved with this arrangement is comparable to that achieved in ordinary AC installations with earth leakage circuit breakers, but with the advantage for floating generator PV installations that this safety does not depend on the correct functioning of an earth leakage circuit breaker or any other device, but is an inherent safety feature of the installation itself. On the other hand, to improve protection against direct contact, good insulation (Class II or equivalent) of live metal parts is recommended. In addition, inverter inputs shall use M16 cable glands for safe string connections.

(b) On the AC side:

Against indirect contacts on the AC side, the installation will be automatically cut off by means of a residual current device with adjustable sensitivity of 300mA, associated with the main circuit breaker (IGA) at the AC output of the inverter, both being located in the AC protection electrical panel (see single-line diagram in drawing P11). This earth leakage circuit breaker will provide full protection (i.e. against indirect contacts in addition to direct contacts) if it is complemented with an adequate earthing of the earths, otherwise it will only work against direct contacts. In order to avoid untimely tripping, this differential switch shall be of the automatic reclosing or high immunity type.

6.8.4 - Protections against overcurrent: overloads and short circuits.

The installation will have the following protections against overloads and short circuits, in accordance with the legislation in force.

(a) In the direct current part:

In order to protect the direct current input of the inverter against overcurrent, the inverter's own internal circuit incorporates a fuse for each input pole.

In addition, according to the indications of the UNE 60364-7-712 standard, an on-load circuit breaker must be provided for repair, maintenance or safety purposes. Thus, at the DC input of the inverter, the inverter has an on-load disconnecting switch, the "DC switch".

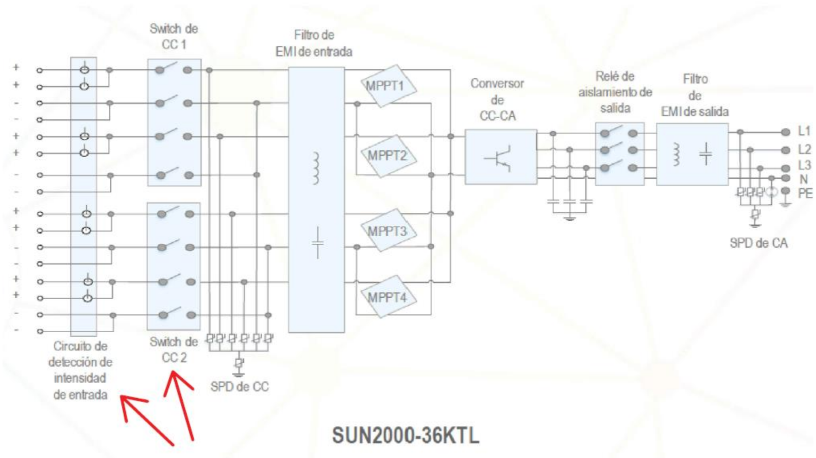


Figure 110.Indication of the inverter's DC-side input current sensing circuit, together with the dc isolator/switch, in the 36kW inverter wiring diagram. Source: Huawei 36KTL data sheet.

(b) On the alternating current side:

In order to protect against overcurrents that could damage the AC circuit of the PV installation, a magneto-thermal circuit breaker of suitable ratings according to each inverter line shall be installed at the output of each inverter (see single-line diagram in drawing P11). The calculations are attached in the corresponding section in Annex I.

At the 36 kW inverter output there will be an 80A circuit breaker, and at the 60 kW inverter output there will be a 125A circuit breaker. Both will be Legrand DX circuit breakers, 4-pole, class C curve, and breaking capacity (PdC) of 16kA, see figure 112.

The output of both will be joined in a larger magnetothermal protection, which will be a 200A circuit breaker that will work together with a differential relay with adjustable 300mA sensitivity and associated toroid. See figures 113 and 114.

Figure 111.DX3 - 4p circuit breaker; left: 80A gauge, right: 125A gauge. Source: Legrand catalogue.

The IGA will be the DPX3-250-4P-25kA-200A moulded case model, from Legrand, see figure 113. With adjustable thermal from 0.8 to 1 In and adjustable magnetic from 5 to 10 In.

The differential relay will be electronic model RGU-10 from Circutor (see figure 114) prepared for connection to the external toroidal current transformer coil of the WGC series from Circutor. Type A superimmunised, with high-frequency current filtering and high immunity, with true rms measurement (TRMS), for accurate leakage current monitoring, under IEC 62020 standard. Being able to visualise the instantaneous leakage value on the display, together with the pre-alarm indications, provides information on the status of the lines being protected, and enables good preventive maintenance to be carried out. The toroid will be a closed coil, from the WGC-80 series with a diameter of 80mm.

The differential with magneto-thermal protection will operate before the main switch, except for short circuits of a certain importance coming from the network from the connection point.

Figure 112.Moulded case circuit breaker, DPX3-250, 4p, 200 A rating. Source: Legrand catalogue.

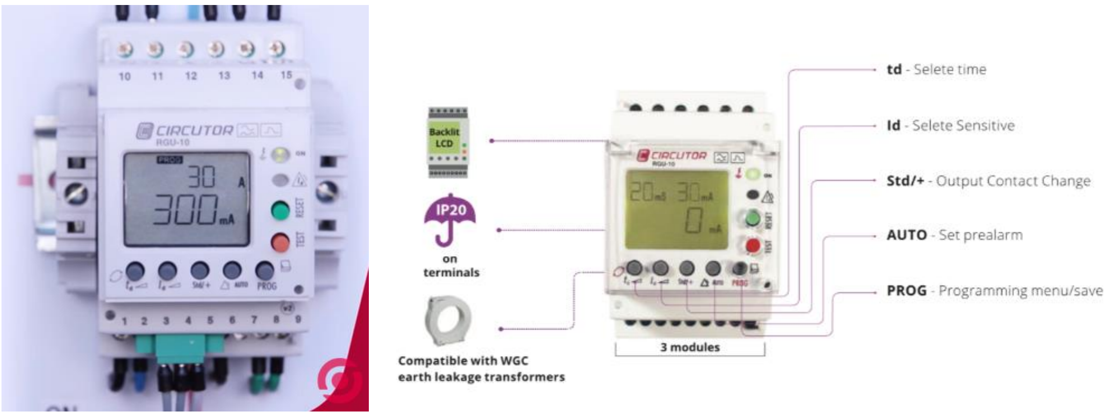


Figure 113.Electronic differential relay RGU-10. Source: Circutor catalogue.

Figure 114.WGC-80 toroidal coil transformer. Source: Circutor catalogue.

Figures 114 and 115 represent the differential block with external toroid. These elements add the differential protection function to the DPX circuit breaker in figure 113, which will be used as an IGA.

Type C and/or type B curved circuit breakers are used when there are no high inrush currents.

6.8.5 - Protections against overvoltage.

To ensure protection against overvoltages such as lightning strikes, associated induced electromagnetic fields, surges and surges transmitted by the connection lines, etc., a protection system based on the following measures is used:

- Equipotential bonding: based on achieving equipotentiality of the earths by using a single earthing electrode for the entire installation. This prevents potential differences between the different elements of the system in the event of a lightning strike.
- Installation of SPD surge arresters: these are connected in parallel and limit the voltage value to avoid damage due to surges, absorbing possible peaks. These will be type II (type 2 or class C) as shown in figure 116.

(a) On the DC side:

Here the PV generator components and the inverter must be protected. In addition to equipotential grounding, the inverter incorporates an SPD to dissipate overvoltages on the DC side, located as shown in Figure 116 in the electrical diagram of the Huawei SUN2000 36KTL inverter.

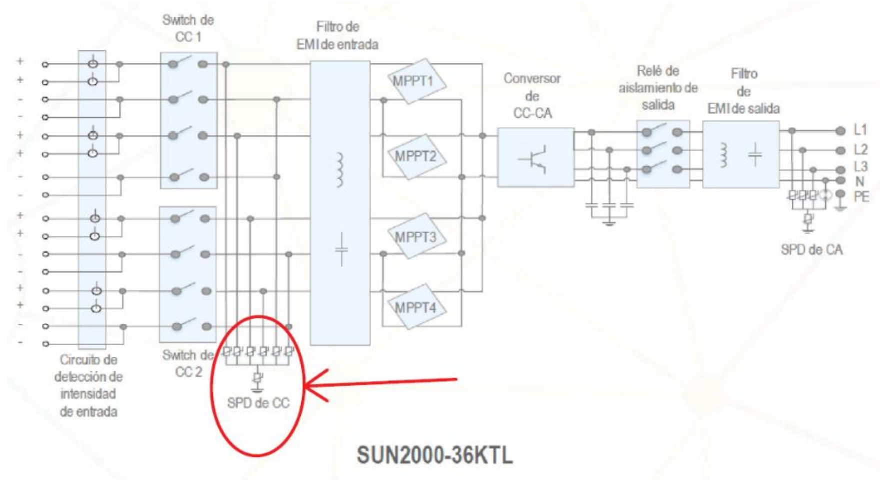


Figure 115.DC side surge protector indicated on the 36kW inverter wiring diagram. Source: Huawei 36KTL data sheet.

(b) On the AC side:

To protect the PV system against surges from the mains the inverter itself has a surge arrester on the AC side, located as shown in figure 117 in the wiring diagram of the Huawei SUN2000 36KTL inverter.

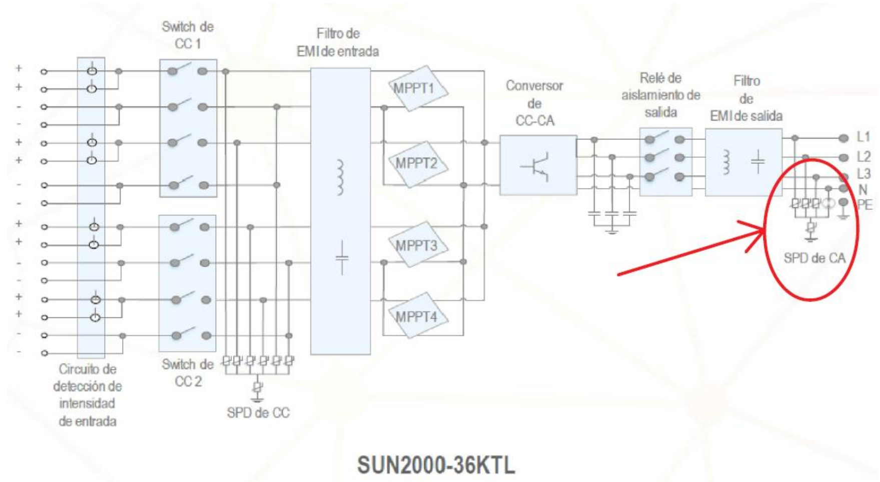


Figure 116. AC side surge protector indicated on the wiring diagram of the 36kW inverter. Source: Huawei 36KTL data sheet.

6.8.6 - Electrical control and protection panel.

As established in the previous points, between the inverter output and the point of connection to the building's general electrical distribution panel, the relevant additional protections will be installed, which will be intercalated by means of an AC electrical protection panel of the PV installation. The electrical panel will include:

- The protections mentioned above: 1 80A magneto-thermal circuit breaker, 1 125A magneto-thermal circuit breaker, 1 200A automatic general circuit breaker with associated differential and toroidal relay. See table 9.

- 1 photovoltaic power supply system data logger device. This will be the Smartlogger 1000 model, from the manufacturer Huawei. This device is complementary to the inverter and is responsible for port convergence, protocol conversion, data collection and storage, and monitoring and maintenance of the PV contribution.
- 1 Countis E40 series bi-directional smart energy meter from SOCOMEC. This device intelligently manages the energy input and consumption and provides useful data for monitoring purposes (see figure 118).
- 2 Schuko plug sockets with magneto-thermal protection switch to supply power to the measuring devices and a back-up socket, in case, for example, a wifi signal amplifier needs to be included.
- The protective box, forming the electrical panel.

PROTECCIONES DE ALTERNA			
Elemento	**Uds**	**Ubicación**	**Características técnicas**
Magnetotérmico de calibre 80 A, Legrand DPX3 160 4P 16kA	1	Caja de protecciones de AC	Vn = 400 V In = 80 A PdC = 16 kA
Magnetotérmico de calibre 125 A, Legrand DPX3 160 4P 16kA	1	Caja de protecciones de AC	Vn = 400 V In = 125 A PdC = 16 kA
Interruptor Automático Diferencial de 200 A de Legrand DPX3 250 4P 25kA, de caja moldeada. (IGA+relé+toroidal)	1	Caja de protecciones de AC	Vn = 400 V In = 200 A PdC = 25 kA $I_{\Delta n}$ = 300mA

Table 9. Summary of the protections of the AC switchboard. Source: Own creation.

The metering equipment, as mentioned above, will be a modular digital power meter from the manufacturer SOCOMEC and from the Countis E40 series, as shown in figure 118. It provides the function of a bi-directional meter for active electrical energy, reactive energy and active power (kWh, kVArh and kW), which is shown directly on an LCD display. This equipment, belonging to the E4x series, is designed for three-phase lines. A connection diagram is included in drawing P06.

Figure 117. SOCOMEC smart meter COUNTIS E40 series. Source: RS electrical and electronic components.

6.8.6.1 - Location and characteristics of the switchboard

The AC control and protection panel will be located inside the building, next to the inverters and the building's existing general distribution panel.

The NXW5 series junction box from CHINT, measuring 600x600x250mm, will be used. This range of metal panels are made of galvanised steel, with earth connection between the box and the door, and pre-drilled openings for cable entry. In addition to the ease of assembly and installation, these cabinets have a high degree of protection, IP54, and are manufactured in accordance with the UNE-EN 60439-1 standard.

The panel has been modelled using Legrand's XL PRO program, as shown in figure 119, without the three-phase electrical cable connections, so that it would not be too full of information, with only one phase and neutral of the single-phase extension for the sockets. In addition, figure 120 shows an example photograph of the type of box to be used as the switchboard.

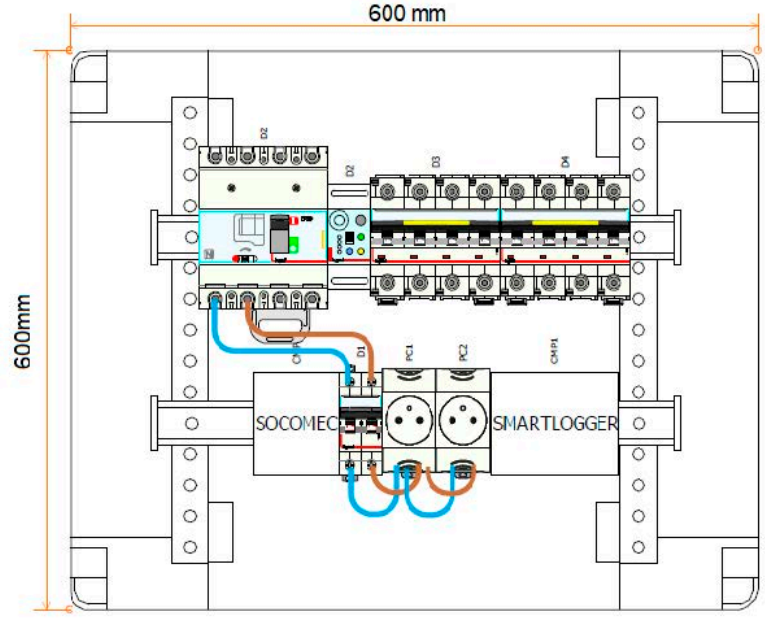


Figure 118. Model of the electrical panel with the units it incorporates. Source: Own creation in Legrand's XLPRO software.

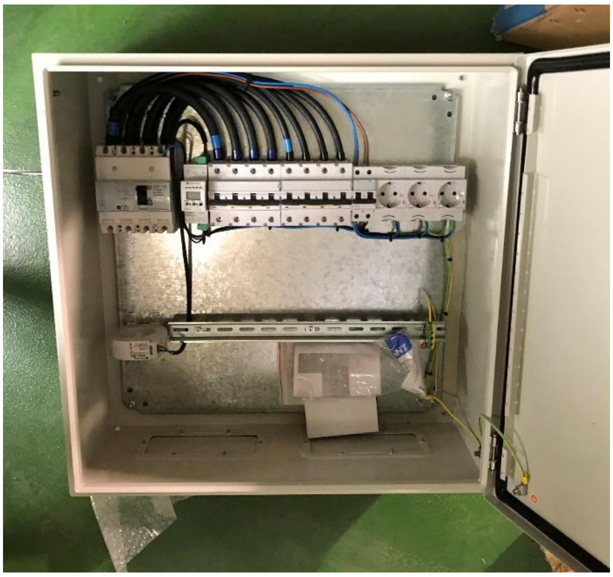


Figure 119.Photo example of the type of box to be used, with some units pre-assembled. Source: prop

6.9 - GROUNDING

Earthing is established mainly in order to limit the voltage that may be present at a given moment in the metallic masses, to ensure the performance of the protections and to avoid or reduce the risk of a breakdown in the electrical materials used.

The connection or earthing (PaT) involves the direct electrical connection, without fuses or protection, by a part of the electrical circuit or by a conductive part that does not belong to it, by means of an earth connection with an electrode or group of electrodes buried in the ground.

The earthing system must ensure that dangerous potential differences do not occur in all installations, buildings and the surrounding ground surface and, at the same time, allow the passage of fault currents or atmospheric discharge currents to earth.

The PaT of the photovoltaic installation will be carried out in accordance with the provisions of ITC-BT-18 of the REBT, and in such a way that the PaT conditions of the distribution company's network are not altered, ensuring that there are no transfers of defects to the network, on the basis of Article 12 of Royal Decree 1663/2000.

Grounding will be carried out by unifying the grounding of all the elements that make up the self-consumption photovoltaic installation. According to the recommendations of the IDAE's 2011 PCT, all the masses of the PV installation, both in the continuous and alternating sections, will be connected to a single earth [10]. Therefore, in this case, they will all be connected to the earth of the existing building, forming a single PaT. This earth will be independent from the neutral of the distribution company in accordance with the REBT, as well as from the earths of the rest of the supply. There will also be a separation between the direct current part and the alternating current part of the installation; which in the installation of this project, given that the inverter is transformeress (TL) - therefore it does not have a transformer - will not be a galvanic separation, but an equivalent separation is achieved in the electronic stage of the dc-ac converter of the inverter itself. In addition, there will be galvanic isolation between the internal grid and the utility grid via the medium to low voltage inverter in the transformer substation.

In this way, there will be an equipotential grounding network for all the metal parts of the aforementioned components of the PV installation.

In the earthing circuit, the protective conductors shall connect the earths to earth. The protective conductors shall run through the same direct current and alternating current conduits of the installation. The minimum cross-section of these conductors is given in accordance with ITC-BT-18. The calculations are made in the corresponding section of Annex I of the supporting calculations.

Therefore, the protection conductors will be made of copper and will have different sections depending on the wiring section:

- DC installation from modules to inverters: S = 6mm2, bare copper.
- AC installation from inverters passing through the AC switchboard to CGBT: S = 35mm2 of copper using green-yellow identification wiring.

6.9.1 - PV generator float mode configuration

Grounding systems comprise both equipment grounding (protective earth) and the grounding of an active conductor (system ground) if applicable.

In this case, in order to provide complete safety and protection for people in the continuous part, [8] this photovoltaic generator will be arranged in a "floating" configuration, i.e. the two conductors of the continuous part, positive and negative, are isolated from earth, although there is a protective earth to which the metallic masses of the system will be connected: module frames, structure, rejiband, as well as any other metallic element of the roof, etc. This 'floating generator' arrangement coincides with the system that the REBT calls IT in electrical distribution, and is quite common in photovoltaic installations of this type. Therefore, a floating system has no connection to system earth, i.e. it is isolated from earth, but it does have a protective earth (connected to all metallic parts/equipment grounds).

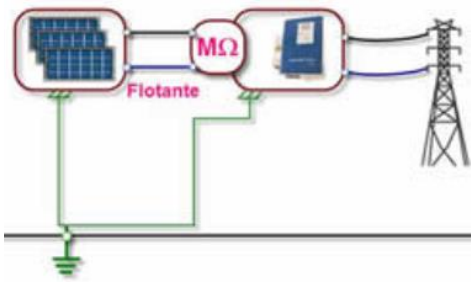


Figure 120. Example of a floating generator scheme, in this case directly connected to the grid. Source: Ulhi [8].

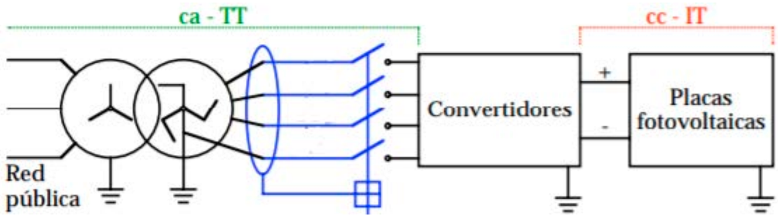


Figure 121.Example of a floating generator or IT scheme, in this case directly connected to the grid. Source: [9].

With this arrangement, if any one of the wires from the plates, positive or negative, comes into electrical contact with a metal part, which is earthed, the only effect is that the electrical potentials of that wire, of the metal part and of the earth are the same, and there is no shunt current to earth. If a person now touches the metal part (indirect contact), there is no shunt current through his body either, as the potential difference to which he is subjected is zero, due to equipotentiality, as the metal part and earth are joined, behaving as the same point at the same potential. This is true even if the earthing is faulty, in which case the earth connection is made by the person's body. In other words, if a person touches the metal part which was insulated from earth and which has come into contact with an active wire, no current flows through the person, except, at most, that produced initially by the static charges. Therefore, with the two active wires isolated from each other to earth, a first earth fault is not dangerous for people.

If there is now a second contact of the other conductor with the metal part, there is no earth leakage current either, but a short-circuit, because, as mentioned above, the entire metal part is an equipotential surface. If a person now touches the metal part, there is no earth leakage current through it either, as the potential difference between the metal part and earth is still zero. The short-circuit does not cause any damage to the panels either, as the short-circuit current of the photovoltaic panels is only slightly higher than their rated current. The effect of the short-circuit is to cancel the voltage at the input of the DC side of the dc-ac converter, i.e. the inverter, so that the inverter will automatically disconnect from the incoming DC line, as inverters are equipped with an automatic switch that opens when the DC voltage drops to a certain value that makes it impossible to continue delivering power. This disconnection is the best warning of a fault, as the power supply ceases.

There can only be danger to persons if the second earth fault occurs through the earth fault. But this is only the case if a first earth fault has already occurred in one of the wires of a PV array, if this fault has not been repaired, and if the person directly touches the other active wire. This situation is equivalent to direct contact of the person with the two active wires, a contact whose consequences cannot be prevented by a residual current circuit breaker, even in AC installations, if the person is isolated from the earth. [9]

7 - ENVIRONMENTAL IMPACT AND BALANCE SHEET

The environmental impact of a photovoltaic installation in the manufacturing phase of the generating elements and equipment is minimal. The photovoltaic cells currently manufactured are made of silicon, a material obtained from sand and therefore very abundant, and of which excessive quantities are not required. Moreover, the vast majority of the materials used are reusable, or at least can be incorporated into recycling channels at the end of their useful life, significantly reducing the amount of waste. Similarly, the materials used in the structures are usually abundant, safe, recyclable and/or reusable. The main environmental burden is produced in the extraction processes of raw materials, as well as the successive associated transports. However, these are susceptible to improvement by incorporating photovoltaic-sourced electricity technology for both extraction and transport in a transition from fossil fuels to electric technology.

As for the use phase, the environmental impact of the photovoltaic installation is null or practically negligible, as it does not involve emissions of toxic products or pollutants, which is of utmost importance and urgency in the current global climate emergency. In this way, it avoids the incorporation of more atmospheric pollutants that affect both the quality of inhaled air in the short term and climate change in the medium/long term. Nor is there any damage at the hydrological or atmospheric level, nor does it cause noise, nor does it have significant effects at the biotic level, on flora and fauna. Furthermore, as is well known, photovoltaics is a sustainable and renewable energy source, as it makes use of inexhaustible resources, on a human scale, to cover energy needs and therefore forms part of one of the most environmentally friendly energy methods compared to conventional energies.

As another specific element favourable to this photovoltaic installation is that its local application also favours the decentralisation of the electricity system, which saves on the creation of wiring infrastructures for electricity transport, which in turn leads to energy losses.

According to the above, photovoltaic energy helps to reduce specific environmental problems such as:

- The greenhouse effect, caused by CO2 emissions.

- Acid rain, with its consequent water pollution, caused by SOx emissions.

- Smog or photochemical smog in cities, caused by NOx emissions.

Table 10 below shows the quantities of the main pollutants that are no longer emitted into the atmosphere for each kWh of energy produced by renewable energies such as photovoltaic energy, instead of fossil fuels, according to estimates made by the IDAE from studies carried out by CIEMAT and the IEA. The values have been obtained by averaging the emissions generated with coal and natural gas from Table I.3. of the IDAE and subtracting the maximum assumed emissions generated by photovoltaic solar technology from Table I.2 of the IDAE.

Cantidades que se dejan de emitir a la atmósfera por kWh producido con energía solar fotovoltaica en vez de combustibles fósiles	
CO_2	547 g/kWh
SO_2	0,36 g/kWh
NO_x	0,75 g/kWh

Table 10. Amounts saved from being emitted into the atmosphere per kWh produced with solar PV energy instead of fossil fuels. Source: PFER - IDAE [10].

With all this, quantifying the emissions reduced by this 96kW self-consumption installation, the results shown in table 11 are obtained.

Beneficios Medioambientales de la instalación proyectada de autoconsumo de 96kW con produccicón anual de 130.019 kWh/año		
Ahorro de emisiones de CO_2	**71.120**	**kg CO_2/año**
Ahorro de emisiones de CO_2 en 20 años	**1.422.400**	**kg CO_2**
Ahorro de emisiones de SO_2	**46,8**	**kg SO_2/año**
Ahorro de emisiones de NO_x	**97,5**	**kg NO_x/año**
Viviendas equivalentes	**37**	**viviendas**
Nº árboles plantados equivalentes	**142.240**	**árboles**

Table 11. Environmental balance of the planned installation. Source: own creation.

In order to obtain the number of equivalent dwellings, it has been taken into account that the average consumption of a Spanish household is around 3,500 kWh/year, so the electricity production generated by this PV installation is equivalent to supplying around 37 dwellings. As for the number of equivalent trees, it has been estimated that an adult tree retains an average of 0.5 tonnes of CO2 per year, according to data from [12].

8 - PLANNING AND IMPLEMENTATION PROGRAMME

Id.	Tarea	Duración aproximada (días)	Lugar	Precedentes
A	Porte de los elementos PRL, palets de módulos, y demás elementos voluminosos, y posterior subida a cubierta mediante camión pluma.	1	in-situ	-
B	Montaje de PRL prevención colectiva.	2	in-situ	A
C	Construcción de la estructura de la zona 2.	2	ex-situ	-
D	Montaje previo del cuadro eléctrico con todas las protecciones.	0,5	ex-situ	-
E	Instalación de los paneles fotovoltaicos coplanares (zonas 1,3,4).	4	in-situ	B
F	Porte de la estructura de la zona 2, y posterior subida a cubierta mediante camión pluma.	0,5	in-situ	E
G	Instalación de la estructura en la zona 2.	2	in-situ	F
H	Instalación de los paneles fotovoltaicos en la estructura de la zona 2.	2	in-situ	G
I	Colocación de rejiband y cableado.	2	in-situ	H, E
J	Colocación y cableado de los inversores y cuadro de AC.	1	in-situ	I
K	Conexión de los strings y cableado.	0,5	in-situ	J
L	Realizada toda la instalación, se revisa de forma exhaustiva la correcta disposición de la instalación en su totalidad.	0,5	in-situ	K
M	Puesta en marcha de la instalación, pruebas y recepción.	0,5	in-situ	L

Table 12. Summary of the implementation programme. Source: Own creation..

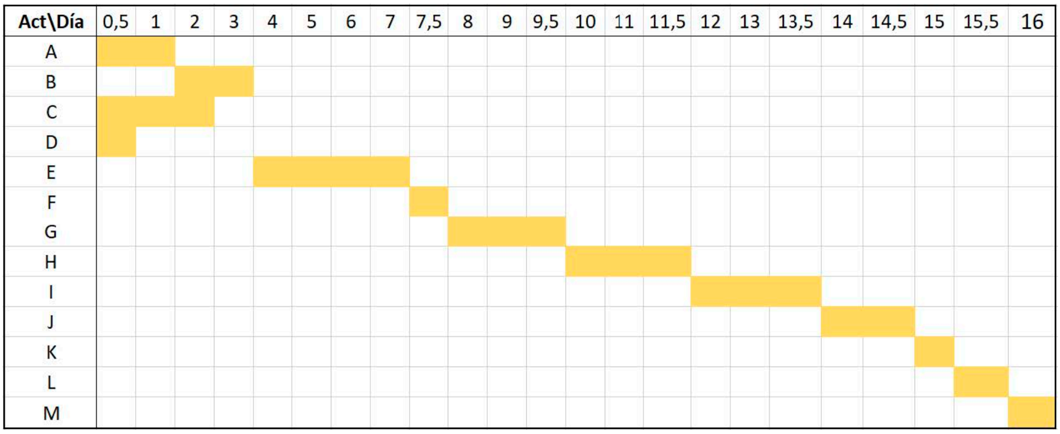


Figure 122. Gantt chart of planning. Source: Own creation.

Since not all tasks will be performed one after the other, but some will be performed ex-situ and in parallel and simultaneously with the work, the total duration of the work is not the sum of the duration of each task, but is obtained by performing the critical path from the Gantt chart attached in Figure 123, resulting in an approximate total duration of 16 working days. Each working day is considered as a full working day of 8 hours. This gives a total duration, including weekends and/or public holidays, of approximately 22 days. Therefore, a maximum execution period (due to unforeseen events, setbacks or problems that may arise) of 1 month (30 days) from the authorisation of the building permit, opening of the work centre and other prior formalities (the processing process is detailed in Annex II) is set.

9 - EXPECTED PRODUCTION

It is important to calculate the share of self-consumed energy versus the total energy generated by the PV system. This will give information (of special interest for the economic study) on how much energy and money will be saved directly on the bill, and how much will be saved indirectly through the surplus energy fed into the grid.

With the quarter-hourly consumptions provided by the client (in this case the promoter of this project), the proportional part of the PV generation that will be self-consumed has been obtained, depending on each month, depending on the expected PV contribution and the consumption profile.

As for the expected generation data, these are obtained through the PVPGIS, as shown above in the corresponding section of this report on the production that each proposal proposed would have, including option D finally chosen and analysed in this section.

Table 13 and figure 124 show the plant's production data, showing the comparison between consumption, the contribution through PV generation and the energy from this PV contribution that is consumed directly by the plant, with the surplus remains discharged into the grid.

Mes	Consumo	Generación FV	Autoconsumo
Enero	44.275 kWh	6.307 kWh	5.421 kWh
Febrero	27.533 kWh	7.474 kWh	5.632 kWh
Marzo	34.018 kWh	11.725 kWh	8.187 kWh
Abril	32.350 kWh	13.637 kWh	8.807 kWh
Mayo	35.225 kWh	14.554 kWh	10.312 kWh
Junio	38.531 kWh	14.856 kWh	10.175 kWh
Julio	36.517 kWh	15.914 kWh	10.306 kWh
Agosto	32.564 kWh	13.671 kWh	8.650 kWh
Septiembre	41.933 kWh	10.020 kWh	7.289 kWh
Octubre	35.258 kWh	9.613 kWh	7.287 kWh
Noviembre	33.976 kWh	5.981 kWh	4.537 kWh
Diciembre	25.696 kWh	6.268 kWh	4.015 kWh
	417.876 kWh	**130.019 kWh**	**90.618 kWh**

Table 13. Expected plant data. Source: own.

Table 17 in the corresponding section of the economic study shows the information broken down, for each of the months, in each of the periods, of energy generated, energy self-consumed, and the surpluses to the grid, and the consequent savings.

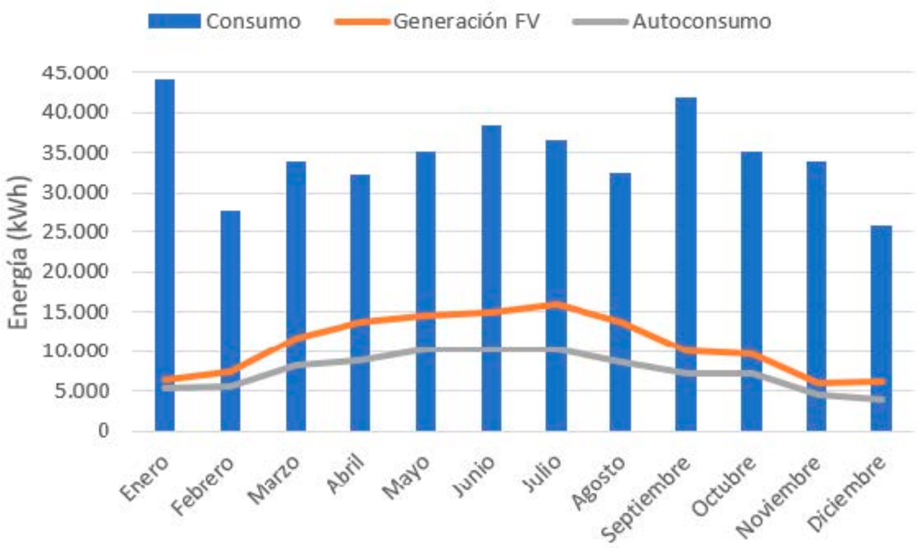


Figure 123. Graph of expected production data. Source: own.

With the commissioning of the installation, the following annual energy balance will be achieved, as shown in table 14.

Energía aportada al consumo actual		
Energía consumida	417.876 kWh	22%
Energía autoconsumida	90.618 kWh	

Energía autoconsumida vs energía generada		
Energía generada	130.019 kWh	70%
Energía autoconsumida	90.618 kWh	

Table 14. Annual energy balance. Source: own

The estimated daily energy input is shown in figures 125 and 126, for a standard working day ('typical day'), for the month of June and the month of March, respectively.

Figure 124. Graph of PV production and consumption forecast, for a standard working day in June. Source: Own creation.

Figure 125. Graph of PV production and consumption forecast, for a standard working day in March. Source: Own creation.

10 - ECONOMIC VIABILITY STUDY

The aim of this section is to obtain information on the operation of the projected plant based on the previous section on expected production, and to carry out an economic analysis to determine its viability, calculating the most useful indicators that favour decision-making and give an overall view of the productivity and efficiency of the installation that is the object of this project.

10.1 - INVESTMENT

The costs of the investment are broken down by chapters and items, detailed and quantified in Document D - Budget, of this project, where you can find both the Material Execution Budget (PEM) and the Contract Execution Budget (PEC). The latter will represent the total cost of the investment.

In summary, the amount of capital earmarked for the total investment of the installation, as calculated in the PEC, amounts to a total of 72,739.81 €.

With regard to the EMP, it is interesting to observe the proportional weight of each of the main elements that make it up, for which purpose the distribution of expenses of the EMP has been carried out (see figure 127).

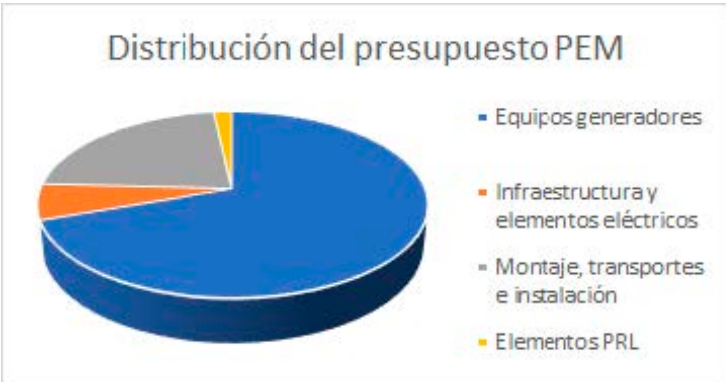


Figure 126. Distribution of EMP expenditure. Source: Own creation.

10.2 - COSTS

As for the operating costs of the PV installation, once it has been completed and commissioned, they are practically nil, except for maintenance costs (O&M), which depend on the type of maintenance contract the developer wishes to use. The O&M expenditure is mainly for module cleaning, preventive and corrective maintenance, monitoring for daily review of production and performance, etc. This expenditure can be assumed to be around €120 per month.

10.3 - SAVINGS

With the start-up of the installation, the following savings in electricity bills are estimated (see table 15). On the one hand, in the energy term, reducing the amount purchased from the grid, and on the other hand, in the power term, in terms of fewer penalties for excess power with respect to the maximum contracted power of 200kW.

Table 17 shows the information broken down for each of the months, in each of the periods, of energy generated, energy self-consumed, and the surpluses to the grid, and the consequent savings.

The energy prices used to obtain the savings are shown in table 16. The price per kWh for the period of PV generation (at peak P1) is an estimate based on historical prices for periods indexed to the 3.1 A tariff. And the kWh price for simplified surplus compensation is an estimated value, which has not yet been established in the sector because of a still recent and premature regulation RD244. This estimate is an indicative value of the price offered by the retailer Holaluz right now for the surplus energy dumped, one of the only retailers that is already offering simplified compensation.

FACTURA ELÉCTRICA: AHORRO ANUAL			
TÉRMINO DE ENERGÍA	Ahorro por la energía autoconsumida	90.618 kWh	8.862 €
	Ahorro por compensación de excedentes vertidos	39.401 kWh	2.127 €
TÉRMINO DE POTENCIA	Ahorro en penalizaciones de sobrepaso de potencia contratada (por un menor consumo de potencia)	200 / 200 / 200	2.706 €
EQUIPO DE MEDIDA EN PROPIEDAD			744 €
TOTAL AHORRO ANUAL PREVISTO			**14.439 €**

Table 15. Expected annual savings on electricity bills. Source: own.

Coste kWh en periodo de generación	0,0978 €/kWh
Precio kWh en compensación simplificada de excedentes	0,054 €/kWh

Table 16. Prices used to obtain bill savings. Source: own.

		CONSUMO	FV GEN.	FV AUTOCONSUMO	FV EXCEDENTES	AHORRO AUTOCONS.	AHORRO POR COMPENS. EXC.
Enero	P1	8.121 kWh	73 kWh	73 kWh	0 kWh	7,27 €	0,00 €
	P2	26.437 kWh	4.353 kWh	4158 kWh	195 kWh	382,95 €	10,53 €
	P3	9.717 kWh	1.881 kWh	1780 kWh	101 kWh	0,00 €	5,45 €
Febrero	P1	3.750 kWh	154 kWh	0 kWh	154 kWh	15,07 €	8,32 €
	P2	19.594 kWh	4.963 kWh	4914 kWh	49 kWh	452,60 €	2,65 €
	P3	4.189 kWh	2.358 kWh	0 kWh	2.358 kWh	0,00 €	127,33 €
Marzo	P1	4.103 kWh	526 kWh	526 kWh	0 kWh	40,73 €	0,00 €
	P2	24.836 kWh	7.481 kWh	7440 kWh	41 kWh	612,59 €	2,21 €
	P3	5.079 kWh	3.718 kWh	0 kWh	3.718 kWh	0,00 €	200,77 €
Abril	P1	150.884 kWh	6.601 kWh	5917 kWh	684 kWh	588,79 €	36,94 €
	P2	10.193 kWh	3.035 kWh	2429 kWh	606 kWh	223,68 €	32,72 €
	P3	7.073 kWh	4.001 kWh	0 kWh	4.001 kWh	0,00 €	216,05 €
Mayo	P1	17.067 kWh	7.151 kWh	6649 kWh	502 kWh	661,57 €	27,11 €
	P2	11.039 kWh	3.971 kWh	3060 kWh	911 kWh	281,80 €	49,19 €
	P3	7.119 kWh	3.432 kWh	0 kWh	3.432 kWh	0,00 €	185,33 €
Junio	P1	20.245 kWh	6.968 kWh	6968 kWh	0 kWh	693,28 €	0,00 €
	P2	11.464 kWh	3.928 kWh	3154 kWh	774 kWh	290,44 €	41,80 €
	P3	6.822 kWh	3.961 kWh	0 kWh	3.961 kWh	0,00 €	213,89 €
Julio	P1	14.312 kWh	7.060 kWh	6421 kWh	639 kWh	539,41 €	34,51 €
	P2	8.213 kWh	4.029 kWh	3338 kWh	691 kWh	215,33 €	37,31 €
	P3	13.992 kWh	4.824 kWh	0 kWh	4.824 kWh	0,00 €	260,50 €
Agosto	P1	12.912 kWh	6.798 kWh	5848 kWh	950 kWh	482,37 €	51,30 €
	P2	7.758 kWh	3.498 kWh	1979 kWh	1.519 kWh	182,27 €	82,03 €
	P3	11.894 kWh	3.375 kWh	0 kWh	3.375 kWh	0,00 €	182,25 €

Septiembre	P1	16.780 kWh	5.029 kWh	4092 kWh	937 kWh	407,15 €	50,60 €
	P2	10.926 kWh	1.912 kWh	1492 kWh	420 kWh	137,45 €	22,68 €
	P3	14.227 kWh	3.079 kWh	0 kWh	3.079 kWh	0,00 €	166,27 €
Octubre	P1	13.858 kWh	5.373 kWh	4499 kWh	874 kWh	447,70 €	47,20 €
	P2	8.530 kWh	1.489 kWh	1231 kWh	258 kWh	113,35 €	13,93 €
	P3	12.870 kWh	2.750 kWh	0 kWh	2.750 kWh	0,00 €	148,50 €
Noviembre	P1	5.213 kWh	44 kWh	43 kWh	1 kWh	4,32 €	0,05 €
	P2	24.124 kWh	4.328 kWh	4138 kWh	190 kWh	381,11 €	10,26 €
	P3	4.639 kWh	1.609 kWh	0 kWh	1.609 kWh	0,00 €	86,89 €
Diciembre	P1	3.278 kWh	31 kWh	31 kWh	0 kWh	3,12 €	0,00 €
	P2	18.723 kWh	4.152 kWh	3586 kWh	566 kWh	330,28 €	30,56 €
	P3	3.695 kWh	2.085 kWh	2080 kWh	5 kWh	0,00 €	0,27 €
TOTAL		**417.876 kWh**	**130.019 kWh**	**90.618 kWh**	**39.401 kWh**	**8.862,00 €**	**2.127,00 €**

Table 17. Calculation of the estimated breakdown of production and savings. Source: own.

10.4 - ECONOMIC DEVELOPMENT OF THE INVESTMENT

Table 18 shows an annual evolution of the Cash Flow (CF) together with the accumulated balance sheet, and figure 128 shows the same, in a visual form, in a graph.

Considerations:

-The annual increase in the price of electricity has not been taken into account, although it is most likely that it will continue to increase, and therefore the savings each year will be higher than the calculated forecast. However, as this is not known with certainty, it has not been taken into account in the calculations.

This has been done with a 25-year horizon as this represents the approximate lifetime of installations of this type.

-An approximate CPI of around 1.53% has been considered.

-Net profit (Bn) has been calculated by deducting corporate tax (currently 25%) from gross profit (Bb).

Evolución económica anual de la inversión							
Inversión inicial instalación: 72.739€							
IPC: 1,53%							
Año	**Gastos**	**Amortización**	**Ahorros**	**Bb**	**Bn**	**FC**	**Balance**
0	72.739 €	-	-	-	-	-	-72.739 €
1	1.440 €	2.910 €	14.439 €	10.089 €	7.567 €	10.477 €	-62.262 €
2	1.462 €	2.954 €	14.660 €	10.244 €	7.683 €	10.637 €	-51.625 €
3	1.484 €	2.999 €	14.884 €	10.401 €	7.800 €	10.800 €	-40.826 €
4	1.507 €	3.045 €	15.112 €	10.560 €	7.920 €	10.965 €	-29.861 €
5	1.530 €	3.092 €	15.343 €	10.721 €	8.041 €	11.133 €	-18.728 €
6	1.554 €	3.139 €	15.578 €	10.885 €	8.164 €	11.303 €	-7.425 €
7	1.577 €	3.187 €	15.816 €	11.052 €	8.289 €	11.476 €	4.051 €
8	1.601 €	3.236 €	16.058 €	11.221 €	8.416 €	11.652 €	15.702 €
9	1.626 €	3.285 €	16.304 €	11.393 €	8.544 €	11.830 €	27.532 €
10	1.651 €	3.336 €	16.553 €	11.567 €	8.675 €	12.011 €	39.543 €
11	1.676 €	3.387 €	16.807 €	11.744 €	8.808 €	12.195 €	51.738 €
12	1.702 €	3.439 €	17.064 €	11.924 €	8.943 €	12.381 €	64.119 €
13	1.728 €	3.491 €	17.325 €	12.106 €	9.079 €	12.571 €	76.689 €
14	1.754 €	3.545 €	17.590 €	12.291 €	9.218 €	12.763 €	89.452 €
15	1.781 €	3.599 €	17.859 €	12.479 €	9.359 €	12.958 €	102.410 €
16	1.808 €	3.654 €	18.132 €	12.670 €	9.503 €	13.156 €	115.567 €
17	1.836 €	3.710 €	18.410 €	12.864 €	9.648 €	13.358 €	128.924 €
18	1.864 €	3.766 €	18.691 €	13.061 €	9.796 €	13.562 €	142.487 €
19	1.893 €	3.824 €	18.977 €	13.261 €	9.945 €	13.770 €	156.256 €
20	1.922 €	3.883 €	19.268 €	13.464 €	10.098 €	13.980 €	170.236 €
21	1.951 €	3.942 €	19.563 €	13.670 €	10.252 €	14.194 €	184.431 €
22	1.981 €	4.002 €	19.862 €	13.879 €	10.409 €	14.411 €	198.842 €
23	2.011 €	4.064 €	20.166 €	14.091 €	10.568 €	14.632 €	213.474 €
24	2.042 €	4.126 €	20.474 €	14.307 €	10.730 €	14.856 €	228.330 €
25	2.073 €	4.189 €	20.788 €	14.525 €	10.894 €	15.083 €	243.413 €

Table 18.Annual economic development of investment. Source: Own creation.

Figure 127.Graph of the annual economic evolution of investment. Source: Own creation.

Figure 127 shows graphically the same information on annual economic evolution. As for the profitability indicators, which are presented in the following section, they have been calculated using Excel's internal formulas. Being:

$$VAN = -Io + \sum_{n=1}^{25} \frac{FCn}{(1+ir)^{n-1}} \; donde\ ir\ representa\ el\ interes\ real$$

$$TIR \rightarrow El\ valor\ de\ i\ que\ hace\ el\ VAN = 0 \rightarrow -Io + \sum_{n=1}^{25} \frac{FCn}{(1+ir)^{n-1}} = 0$$

$$PR = \frac{Ig}{FC\ promedio\ anual}$$

10.5 - ANALYSIS OF RESULTS

Table 19 shows a summary of the most relevant economic indicators used to consider the viability of the investment.

Profitability indicators	Value
VAN	192.045,75 €
TIR	18.2 %
PR	5.8 Years

Table 19. Economic indicators obtained. Source: Own creation

Since a NPV>0 and IRR>ir are obtained, this directly indicates that the investment is economically viable and profitable. The values are not negligible, which ensures an advantageous contribution to the value of the company and its profits, offering high profitability. As for the approximation of the Payback Period (PR) through the formula that uses the average annual FC, exposed above, it is obtained that it is about 5 years and 10 months, which is not a long period of time for a company, being a really interesting investment.

11 - CONCLUSIONS

With this report document, it is understood that the solution chosen from among the proposals put forward has been adequately described in depth, both in terms of its justification and its correct execution.

In view of the results obtained in the economic study, a favourable conclusion is drawn in favour of the execution of the installation, given its high viability and profitability. As for the repercussion on the environment, as has been analysed, high reductions in emissions and pollution are obtained and therefore a greener stamp for the company. For all these reasons, it is considered that the objectives set by the promoter for the implementation of this installation are clearly and notably achieved.

Although it is true that the projected installation will not cover the totality of its network consumption, it is also worth highlighting the limitations offered by the roof and the available useful surface area. In this sense, the possibilities offered by the existing roof have been efficiently exploited.

12 - STANDARDS AND LEGAL PROVISIONS APPLIED

For the designs and installations planned in this work, the following regulations are applicable, which have been taken into consideration.

- Royal Decree 244/2019, of 5 April, which regulates the administrative, technical and economic conditions for the self-consumption of electrical energy.

- Royal Decree-Law 15/2018, of 5 October, on urgent measures for energy transition and consumer protection.

- Royal Decree 900/2015, of 9 October, which regulates the administrative, technical and economic conditions of the modalities of electricity supply with self-consumption and production with self-consumption.

- Resolution of 4 November 2002 of the Directorate General of Industry, Energy and Mines, which develops the Order of 9 September 2002, of the Regional Ministry of Science, Technology, Industry and Commerce, which adopts standardisation measures in the processing of files in the field of Industry, Energy and Mines (Supplement BORM no. 284, of 10/12/2002).

- RD 1578/2008 of 26 September, on remuneration for the activity of electricity production using photovoltaic solar technology for installations after the deadline for maintaining the remuneration of Royal Decree 661/2007, of 25 May, for this technology (B.O.E. no. 234 of 27 September).

- CORRECTION of errors in Royal Decree 1578/2008, of 26 September, on remuneration for the activity of electricity production using photovoltaic solar technology for installations after the deadline for maintaining the remuneration of Royal Decree 661/2007, of 25 May, for this technology.

- Order ITC/82/2009 of 30 January, postponing the deadline for submitting applications for photovoltaic installations to the remuneration pre-assignment register, established in Royal Decree 1578/2008 of 26 September, published on 21 January, number 27, page 10,431.

- Royal Decree 661/2007 of 26 May 2007, which regulates the production of electricity under the special regime. Introducing special features affecting administrative authorisation procedures, special regime, access and connection to the distribution network for photovoltaic solar installations.

- Royal Decree 1663/2000, of 29 September, on the connection of photovoltaic installations to the low-voltage grid.

- Law 48/1998 of 30 December 1998 on procurement procedures in the water, energy, transport and telecommunications sectors, which transposes Directives 93/38 EEC and 92/13 EEC into Spanish law.

- Law 54/97 of 27 November 1997 on the electricity sector.

- Royal Decree 1955/2000, of 1 December 2000, which regulates the transmission, distribution, commercialisation, supply and authorisation procedures for electrical energy installations.

- Low Voltage Electrotechnical Regulations (REBT) approved by Royal Decree 842/2002 of 2 August 2002, published in BOE no. 224 of 18 September 2002.

- Complementary Technical Instructions for Low Voltage (ITC-BT).

- Technical Building Code (CTE): Structural Safety (DB-SE), Calculation Bases, and Actions in Building (DB-SE-AE).

- Occupational Health and Safety Regulations (L31/95).

- Iberdrola connection installations. Protection and measurement boxes NI 42.722.00.

- UNE EN 62 052-11: Electrical energy measuring equipment (a.c.). General requirements, tests and test conditions. Part 11: Measuring equipment.

- UNE Standards related to photovoltaic installations.

- UNE-EN-9488 2001 Solar energy. Vocabulary (ISO 9488:1999)

- UNE-EN-60891 1994 Procedure for correction with temperature and irradiance of the I-V characteristic of crystalline silicon photovoltaic devices.

- UNE-EN 60904-1 2007 Photovoltaic devices. Part 1: Measurement of the intensity-voltage characteristic of photovoltaic modules.

- UNE-EN 60904-2 1994 Photovoltaic devices. Part 2: Requirements for reference solar cells.

- UNE-EN 60904-2/A1 1998 Photovoltaic devices. Part 2: Requirements for reference solar cells.

- UNE-EN 60904-3 1994 Photovoltaic devices. Part 3: Fundamentals of measurement of solar photovoltaic devices for terrestrial use with reference spectral irradiance data.

- UNE-EN 60904-5 1996 Photovoltaic devices. Part 5: Determination of the equivalent cell temperature of photovoltaic devices by the open circuit voltage method.

- UNE-EN 60904-6 1997 Photovoltaic devices. Part 6: Requirements for reference solar modules.

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- UNE-EN 61173 1998 Overvoltage protection of photovoltaic energy producing systems.

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- UNE- EN 61829 2000 Crystalline silicon photovoltaic fields. Measurement in silicon of I-V characteristics.

- UNE-EN 61646 1997 Thin film modules. Design qualification and type approval.

- UNE-EN 61835 2006 Crystalline silicon photovoltaic fields. On-site measurement of I-V characteristics.

- High Voltage Regulation RD 223, 2008 of 15 January.

- Royal Legislative Decree 2/2008, of 20 June, approving the revised text of the Land Law.

- Law 4/2009, of 14 May, on Integrated Environmental Protection.

- Decree 48/1998 on environmental protection against noise.

13 - PROGRAMMES USED

For the design and calculation of the photovoltaic system of this project, the following programmes and tools have been used:

- Google Earth Pro:

A computer programme that displays a virtual terrestrial globe that allows multiple cartography to be visualised, based on satellite photography. Useful for obtaining an accurate 3D visualisation of the ship in question and for obtaining information on the spaces and measurements of the ship.

- AutoCAD: (version 2020):

Design software used to create the 2D plans for this project.

- SketchUp Pro:

Graphic design and modelling software in three dimensions (3D), very useful for the design of elements of the installation and projection of spaces.

- PVGIS:

Web application that provides an inventory of geographic data in a cartographic base of the solar energy resource, and allows the evaluation of electricity generation from photovoltaic systems in Europe, Africa and West Asia.

- SunEarthTools:

Web application with a collection of tools for calculating parameters useful in the design of photovoltaic installations, such as calculations of the position of the sun at a location on a geographical map.

- PVSYST (version 6.8.5):

Software that allows the design, simulation and data analysis of a photovoltaic installation. It also has a 3D construction space enabled specifically for shadow modelling and simulation.

- Microsoft Excel:

Spreadsheet software, with advanced tools for data analysis, processing and visualisation.

- Legrand XL PRO:

Software for the design and modelling of electrical power cabinets and panels. It has numerous options of modular switchgear to be included and different dimensions.

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ANNEX I - CALCULATIONS -

1.1. Total installed capacity

The total installed capacity of the rooftop PV plant is summarised below:

Cantidad Paneles FV KuMax	280 paneles
Potencia pico por panel	350 Wp
Potencia pico total instalación FV	98 kWp

Table 20. Summary of installed capacity. Source: Own creation

Given the selection of proposal D, there are a total of 280 PV panels, each with a peak power of 350Wp, therefore the arrangement of all panels together forms a PV generating installation whose total installed peak power is

$$280 paneles * 350 \frac{Wp}{panel} = 98000Wp = 98kWp$$

(1)

The 280 photovoltaic panels are expected to be in operation all at the same time, unless one or more of them break down. Therefore, they will all be operating simultaneously, with a simultaneity coefficient of 1. At the same time, the Huawei inverters, models: SUN2000 36KTL and SUN2000 60KTL will also be operating simultaneously.

The 280 photovoltaic panels are expected to be in operation all at the same time, unless one or more of them break down. Therefore, they will all be operating simultaneously, with a simultaneity coefficient of 1. At the same time, the Huawei inverters, models: SUN2000 36KTL and SUN2000 60KTL will also be operating simultaneously.

1.2. Calculation of the inverter equipment

For the calculation of the inverters required, normal operation below the peak power installed in panels is considered, given the various common losses, whether due to sub-optimal irradiation, inclination and orientations other than those of maximum generation, possible shadows, etc.

The Huawei SUN2000-36KTL and the Huawei SUN2000-60KTL are chosen as inverters, with nominal powers of 36kW and 60kW respectively. Therefore, the total power offered by the sum of the two is 96 kW. According to the manufacturer's recommendations, in order for the inverter to operate properly and at maximised efficiency, the generator power should not exceed about 1.1 times the output power of the inverter, so that it does not operate heavily loaded. The calculation in (2) shows that this guideline is fulfilled.

$$98\ kW * 1.1 = 105\ kWp$$
$$98kWp\ < 105\ kWp$$

(2)

1.3. PV generator design and configuration

To size and distribute the configuration of the PV generator, the voltage and current ranges supported by the selected inverters must be considered, since the maximum and minimum input voltage of an inverter determines the maximum and minimum number of panels in series that can be connected to it, respectively. Similarly, the maximum and minimum input current of an inverter determines the maximum and minimum number of parallel strings it can operate with, respectively.

1.3.1. Number of panels in series per branch

- Minimum number of panels in series:

In order to achieve a sufficient voltage for the connection and operation of the inverter, as well as the MPP point search operation, the inverter must have a minimum voltage at its input, which is achieved by having several panels connected in series in a string. To this end, it must be taken into account that the voltage generated by each panel is lower the higher the temperature. For the calculations, a hypothetical extreme case of a maximum cell temperature of 85ºC, the most unfavourable case, has been considered. Furthermore, Vmp (25ºC) = 39.2 V under STC conditions (Tª=25º) and a voltage temperature coefficient of V= -0.29%/ºC according to the technical data of the panel used.

$$Vmp(Tcell) = Vmp(25ºC) - \beta * (Tcell - 25)$$

(3)

$$Vmp \min panel = Vmp\ (70ºC) = 39.2 - 0.0029(85 - 25) = 39\ V$$

(4)

The minimum string size is then calculated for each of the two inverters.

- For SUN2000-36KTL inverter:

$$Nmin = \frac{Vmin\ (inversor)}{Vmo \min(panel)} = \frac{250\ V}{39\ V\ /panel} = 6.4\ paneles\ \rightarrow 7\ paneles\ en\ serie$$

(5)

- For SUN2000-60KTL inverter:

$$Nmin = \frac{Vmin(inversor)}{Vmo\min(panel)} = \frac{200}{\frac{39}{panel}} = 5.1\, paneles \;\rightarrow 6\, paneles\ en\ serie\ minimo$$

(6)

- Maximum number of panels in series:

To ensure that the maximum permissible input voltage of the inverter is not exceeded, the maximum number of panels to be connected in series must be calculated. To do this, it must be taken into account that the voltage generated by each panel is higher the lower the temperature. For the calculations, it has been considered that the temperature of the cell could drop to a minimum temperature of around -10ºC. Furthermore, in this case, the maximum voltage can be limited either by the voltage at the MPP point (Vmp) or by the no-load voltage (Voc), so it will be calculated for both and we will see which is the most limiting. Applying the formula (3) we have:

$$Vmp\max panel = Vmp\ (-10ªC) = 39.2 - 0.0029\ (-10 - 25) = 39.3\ V$$

(7)

$$Voc\max panel = Voc(-10ºC) = 46.6 - 0.0029(-10 - 25) = 46.7\ V$$

(8)

The calculation of the minimum string size for each of the two inverters is as follows.

- For SUN2000-36KTL inverter:

Vmp:

$$Nmax = \frac{Vmp\max(inversor)}{Vmp\max(panel)} = \frac{1000V}{39.3\ V/panel} = 25.4\, panels \;\rightarrow 25\, panel\ en\ serie\ máx$$

(9)

Voc:

$$Nmax = \frac{Vmp\max(inversor)}{Voc\max(panel)} = \frac{1100V}{46.7\ V/panel} = 23.5\, panels \;\rightarrow 23\, panel\ en\ serie\ máx$$

(10)

- For SUN2000-60KTL inverter:

Vmp:

$$Nmax = \frac{Vmp\max(inversor)}{Vmp\max(panel)} = \frac{1000V}{39.3\ V/panel} = 25.4\, panels \;\rightarrow 25\, panel\ en\ serie\ máx$$

(11)

Voc:

$$Nmax = \frac{Vmp \max(inversor)}{Voc \max(panel)} = \frac{1100V}{46.7\ V/panel} = 23.5\ panels\ \rightarrow 23\ panel\ en\ serie\ máx$$

(12)

Based on the above results, a string size of between 7 and 23 panels in series should be chosen for the 36kW inverter, and between 6 and 23 panels in series for the 60kW inverter. A string size of N=20 modules is finally chosen for both inverters.

The decision of this value has been made taking into account the efficiency curve, which can be seen in figure 129 for the 36kW inverter (the curve for the 60kW inverter is practically the same). In this case, it can be seen that at an input voltage of around 620V the inverter works at maximum efficiency. Whereas for voltages much higher (around 850V) its efficiency decreases a little, and around 480V the inverter operates at even lower efficiency.

Therefore, choosing a string size of N=20 and considering a nominal voltage per panel of Vmp=39.2V would result in a nominal string voltage of 20x39.2=**784V**, which is around the **620V** curve that provides high efficiency.

In addition, 20 module size strings are convenient to handle in this type of installation and is quite widespread in practice, giving satisfactory results.

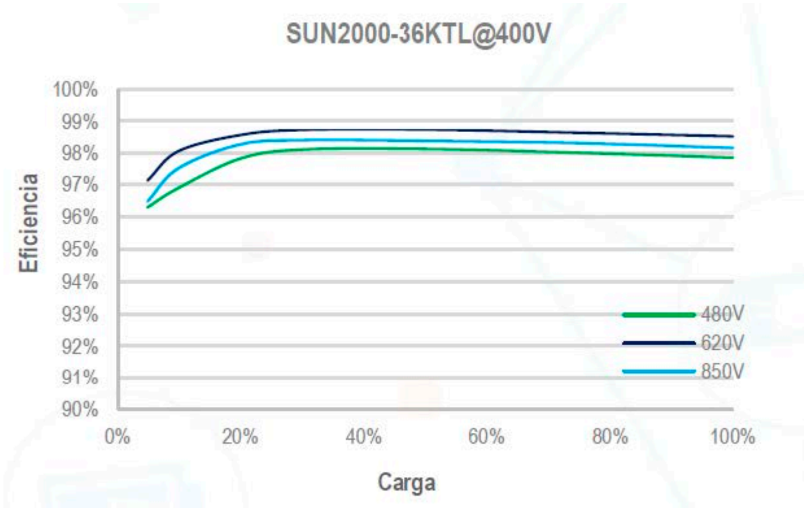


Figure 128. Load-dependent efficiency curve for different input operating voltages of the 36kW inverter. Source: Huawei SUN2000-36KTL inverter data sheet.

1.3.2. Number of parallel strings per inverter

As the installation is 280 modules in total, and a string size of 20 modules in series has been chosen, there will be a number of parallel strings:

$$Nstrings = \frac{280}{20\ panels/string} = 14\ strings$$

(13)

The 36kW inverter has 8 string inputs (with 4 MPPT) and the 60kW inverter has 12 string inputs (with 6 MPPT), as indicated in the data sheets. Therefore, there are 20 total inputs available between the two inverters, which is sufficient for the 14 strings of the installation. The 14 strings are distributed between the two inverters in such a way that the 36KTL inverter with 8 inputs occupies 5 inputs and the 60KTL inverter with 12 inputs occupies 9 inputs, which means that both inverters are equally loaded, around 70%. The string allocation between the two inverters will be such that the type of string connected is also balanced in terms of its orientation, so that both inverters operate with the same approximate output pattern. In addition, all individual MPPT inputs shall be occupied where possible, and in cases where the strings that are connected are directed towards the same MPPT, these shall be similar strings in terms of tilt and orientation so that they have a similar output and not one does not limit the other according to the maximum power point tracking.

The distribution explained above can be checked in drawings P03 and P05.

To finally check that the strings and inverters are suitable, it must be verified that the current generated by the parallel association calculated above does not exceed the maximum admissible input current of the inverters. In this case, the inverters chosen have the maximum rated currents per MPPT as well as the maximum short-circuit currents per MPPT as limits established in their technical data sheets. Both inverters have 1 MPPT tracker every 2 inputs, as can be seen for example in figures 34 and 35 of the 36KTL, therefore the current generated by 2 strings in parallel will have to be checked to verify the established limit.

- For SUN2000-36KTL inverter:

$$2 * Imp \ \leq Imax - mppt \ \rightarrow 2 * 8.94A \ \leq 22\ A \rightarrow 17.88\ A \ \leq 22\ A \ \rightarrow ok$$

(14)

$$2 * Isc \ \leq Imax, sc - mppt \ \rightarrow 2 * 9.51A \ \leq 30\ A \rightarrow 19.02\ A \ \leq 30\ A \ \rightarrow ok$$

(15)

Using as data:

Imp=8.94A (from KuMax350P panel catalogue, to STC)

$Imax\text{-}mppt$=22A (from Huawei SUN2000-36KTL inverter catalogue)

Isc=9, 51A (from KuMax350P panel catalogue, to STC)

$Imax,sc\text{-}mppt$=30A (from Huawei SUN2000-36KTL Inverter Catalogue)

For SUN2000-60KTL inverter:

We have the same intensity limits as the 36KTL, therefore the same procedure is performed giving the same favourable results from equations (14) and (15).

As all conditions are fulfilled, the selected inverters are well adapted to the PV generator layout.

1.4. Sizing of power cabling

The electrical wiring is calculated on the basis of 2 criteria: the thermal criterion and the voltage drop criterion.

The thermal criterion, whereby a cable is chosen (depending on the type of conductor, insulation, installation model, etc.) with a cross-section such that its maximum admissible current is greater than that which will circulate through said cable, provided that the thermal energy generated by the joule effect is adequately dissipated and does not exceed the thermal limit of the wiring so that it is not damaged. For this purpose, a table provided by the REBT is used which indicates the admissible current of the conductors (IZ) according to their section and insulation for different conditions or standardised installation methods. In addition, in the event that methods other than these standardised methods are used in the installation, correction factors are used, also according to tables provided by rebt, in which they are corrected mainly according to issues of:

-Influence due to cable grouping or proximity between circuits. This takes into account that in groups of cables it is more difficult to dissipate the heat generated by the Joule effect.

-Influence of ambient or ground temperature.

-Influence of the thermal resistivity of the ground.

In addition, for cable sizing according to the maximum admissible current, it will be multiplied by 1.25 as a safety factor, therefore, 125% of the maximum current that the direct current line is going to carry will be considered, as established in section 5 of ITC-BT-40.

The voltage drop criterion is that according to which the section of a cable is dimensioned so that the voltage drop produced throughout its length is less than the maximum admissible value defined in the REBT, which is 1.5% in the DC section from the generator panels to the inverter, and 1.5% in the AC section in the section from the inverter to the connection point in the general distribution panel.

1.4.1. DC wiring

On the DC side, the short-circuit current, ISC, will be used for the sizing of the wiring section, as this is the maximum current that can flow through the cable.

Characteristics per branch:

Nº módulos	20
Potencia	7 kWp
Corriente de cortocircuito	9,51 A
Tensión de circuito abierto	932 V
Tensión nominal	784 V
Longitud cable máxima	60 m

Table 21. Main characteristics per PV module branch. Source: Own creation.

As far as the power conductors are concerned, there shall be one line (electrical circuit) per string, from each string to the inverter. This shall consist of two active conductors (phase and neutral).

Thermal criteria

The calculation is carried out as explained in the introductory part of the method. For each line of the continuum strings, it is assumed that a maximum of:

$$I_L = 1.25 * I_{sc} = 1.25 * 9.51 = 11.89\ A \quad (16)$$

As these are single core cables on perforated trays, installation method 'F' as shown in Figure 130 shall be used.

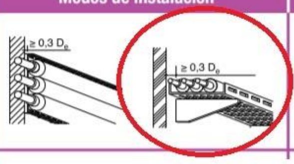
Ref.	Modos de instalación	Descripción	Tipo
31		Cables unipolares (F) o multipolares (E) sobre bandejas de cables perforadas.	E o F

Figure 129. Installation modes. Source: Prysmian Table 52-B2, according to UNE 20460-5-523 and according to Table B of ITC-BT-19 on installation modes.

Table 22 below shows the range of admissible currents to be consulted according to cable cross-section, considering the installation method F mentioned above. As for the insulation of the cables, they will be XLPE as previously defined in the corresponding wiring section in the report of this project. The number 2 of 'XLPE2' indicates that there are two active conductors in the installation (in this case phase and neutral of the DC part).

Número de conductores con carga y naturaleza del aislamiento												
A1		PVC3 70 ºC	PVC2 70 ºC		XLPE3 90 ºC	XLPE2 90 ºC						
A2	PVC3 70 ºC	PVC2 70 ºC		XLPE3 90 ºC	XLPE2 90 ºC							
B1				PVC3 70 ºC	PVC2 70 ºC		XLPE3 90 ºC		XLPE2 90 ºC			
B2			PVC3 70 ºC	PVC2 70 ºC		XLPE3 90 ºC	XLPE2 90 ºC					
C					PVC3 70 ºC		PVC2 70 ºC	XLPE3 90 ºC		XLPE2 90 ºC		
D*	VER SIGUIENTE TABLA											
E						PVC3 70 ºC		PVC2 70 ºC	XLPE3 90 ºC		XLPE2 90 ºC	
F							PVC3 70 ºC		PVC2 70 ºC	XLPE3 90 ºC		XLPE2 90 ºC
mm²	2	3	4	5	6	7	8	9	10	11	12	13
Cobre 1,5	11	11,5	13	13,5	15	16	16,5	19	20	21	24	25
2,5	15	16	17,5	18,5	21	22	23	26	26,5	29	33	34
4	20	21	23	24	27	30	31	34	36	38	45	46
6	25	27	30	32	36	37	40	44	46	49	57	59
10	34	37	40	44	50	52	54	60	65	68	76	82
16	45	49	54	59	66	70	73	81	87	91	105	110
25	59	64	70	77	84	88	95	103	110	116	123	140
35	72	77	86	96	104	110	119	127	137	144	154	174
50	86	94	103	117	125	133	145	155	167	175	188	210
70	109	118	130	149	160	171	185	199	214	224	244	269
95	130	143	156	180	194	207	224	241	259	271	296	327
120	150	164	188	208	225	240	260	280	301	314	348	380
150	171	188	205	236	260	278	299	322	343	363	404	438
185	194	213	233	268	297	317	341	368	391	415	464	500
240	227	249	272	315	350	374	401	435	468	490	552	590
300	259	285	311	349	396	423	461	516	547	640	674	713

Table 22. Current ratings in amperes, for unburied Cu cables, in air (40ºC). Source: Table A.52-1 bis of Prysmian, based on table 1 of ITC-BT-19..

In addition, since there will be several circuits grouped in the same tray, coming from the two active cables of each string, a correction factor for proximity between circuits must be considered, according to table 23.

Punto	Disposición	Número de circuitos o cables multiconductores									Instalación tipo
		1	2	3	4	6	9	12	16	20	
1	Empotrados, embutidos (dentro de un mismo tubo, canal o grapados sobre una superficie al aire	1,0	0,80	0,70	0,70	0,55	0,50	0,45	0,40	0,40	A a F
2	Capa única sobre los muros o los suelos o bandejas no perforadas	1,00	0,85	0,80	0,75	0,70	0,70	0,70	0,70	0,70	C
3	Capa única en el techo	0,95	0,80	0,70	0,70	0,65	0,60	0,60	0,60	0,60	
4	Capa única sobre bandejas perforadas horizontales o verticales	1,0	0,90	0,80	0,75	0,75	0,70	0,70	0,70	0,70	E y F
5	Capa única sobre escaleras de cables, abrazaderas, etc.	1,0	0,85	0,80	0,80	0,80	0,80	0,80	0,80	0,80	

Table 23.Correction factors for circuit grouping. Source: Table A.52-3 of Prysmian catalogue, based on UNE 20560-5-523.

It is worth mentioning that table 23 considers multi-conductor cables and the cables in this installation are single-core, but there is no equivalent table for them in terms of correction factor, so this one is used, which will be on the safety side. Furthermore, it should be noted that this table considers only a single layer on perforated trays. In this installation, however, as there are 14 strings and 2 active conductors per string, there will be 28 conductors. Therefore, at the most unfavourable point where all 28 conductors are grouped in the tray, there will be 4 layers of 7 conductors, as shown in figure 131. Furthermore, as there is more than one layer, an additional coefficient must be used, according to table 24.

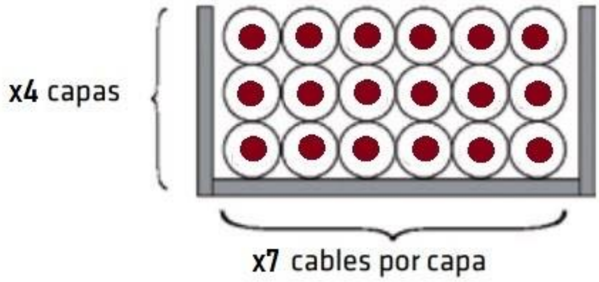


Figure 130. Maximum grouping of conductors of the planned installation (4 layers x 7cables=28 single-pole conductors). Source: Own creation..

Número de capas	2	3	4 o 5	6 a 8	9 o más
Coeficiente	0,8	0,73	0,7	0,68	0,66

Table 24. Additional reduction factor for cables installed in multiple layers. Source: Table complementary to A.52-3, the same as table F of ITC-BT-19.

Therefore, with 7 wires per layer, table 23 (between 6 and 9 wires) gives a factor of about 0.73. To this is applied the second additional reduction, according to table 24, of 0.7. This leaves a correction factor of Fc=0.730.7=0.51.

With all this, if we choose from table 22 a cable of S=1.5mm2, whose admissible current is IZ=25 A, to which we apply the reduction coefficient and we are left with:

$$I'z = 25 * 0.51 = 12.75 \ > Il = 11.89\ A \ \rightarrow ok\ for\ thermal\ criterium$$

(17)

However, as will be seen below, this cross-section is not sufficient according to the voltage drop criterion, so the cross-section will have to be increased.

Voltage drop criteria

As mentioned above, the maximum voltage drop on this section must not exceed 1.5%. To calculate it, the formula (18) of the voltage drops for a single-phase line, with two active conductors, will be used.

$$\Delta V_{rama}(\%) = \frac{2 * L * P}{c * S * U_{fn}^2} * 100$$

(18)

Where:

L = 60 m →	Maximum branch length
P = 7 Kw = 7103 W	Power per string
c = 56 m/(Ωmm2)	Cu conductivity at 29ºC
U_{fn} = 20V_{mp} = 20x39,2 = 783 V	Nominal string voltage

The length was used for the worst-case scenario. For this purpose, the string with the longest cable length from its generation to the inverter is L= 60m.

$$\Delta\text{Vrama}(\%) = \frac{2 * 60 * 7 * 10^3}{56 * 1.5 * 783^2} * 100 \ > \ \Delta\text{Vmax} = 1.5\% \ \rightarrow \text{no cumple crit. caída tensión}$$

(19)

Substituting the data for S=1.5mm2 gives a voltage drop of more than 1.5%, according to (19), so it would not comply. For this reason, a larger cross-section must be chosen. In this case, we will proceed by imposing a maximum voltage drop of 0.5% in this section.

$$\Delta\text{V}_{\text{rama}}(\%) = 0.5 = \frac{2 * 60 * 7 * 10^3}{56 * S * 783^2} * 100 \ \rightarrow Despejando\ S = 4.89\ mm^2$$

(20)

Therefore, the next higher commercial cross-section is S=6mm2. Although the 4mm2 cable would also work because it has a lower voltage drop than the maximum of 1.5%, according to the 0.5% imposed for the planned installation, the 4mm2 cable would not comply. Therefore, it was chosen to use S=6mm2 cable, which not only complies not only with the regulations, but also with a greater restriction due to its own voltage drop criteria of 0.5%. Furthermore, as it is a larger cross-section than the 1.5mm2 , which already meets the thermal criterion, so this one will also do so. Both 4mm2 and 6mm2 cross-sections are commonly used in the continuous part of photovoltaics, and both are equally suitable.

Therefore, the maximum real voltage drop on the DC side will be:

$$\Delta\text{Vrama} = \frac{2 * 60 * 7 * 10^3}{56 * 6 * 783^2} = 0.0039\ V = 0.39\%$$

(21)

Cableado de corriente continua (strings-inversores)		
Tramo	Sección	Tipo cable
String 1 (20 módulos en serie) hasta inversor	Fx6mm^2 + Nx6mm^2	Cables RV-K 0,6/1kV unipolares de Cu con aislamiento XLPE y recubrimiento de protección de PVC
String 2 (20 módulos en serie) hasta inversor	Fx6mm^2 + Nx6mm^2	
String 3 (20 módulos en serie) hasta inversor	Fx6mm^2 + Nx6mm^2	
String 4 (20 módulos en serie) hasta inversor	Fx6mm^2 + Nx6mm^2	
String 5 (20 módulos en serie) hasta inversor	Fx6mm^2 + Nx6mm^2	
String 6 (20 módulos en serie) hasta inversor String 7 (20 módulos en serie) hasta inversor	Fx6mm^2 + Nx6mm^2 Fx6mm^2 + Nx6mm^2	
String 8 (20 módulos en serie) hasta inversor	Fx6mm^2 + Nx6mm^2	
String 9 (20 módulos en serie) hasta inversor	Fx6mm^2 + Nx6mm^2	
String 10 (20 módulos en serie) hasta inversor	Fx6mm^2 + Nx6mm^2	
String 11 (20 módulos en serie) hasta inversor	Fx6mm^2 + Nx6mm^2	
String 12 (20 módulos en serie) hasta inversor	Fx6mm^2 + Nx6mm^2	
String 13 (20 módulos en serie) hasta inversor	Fx6mm^2 + Nx6mm^2	
String 14 (20 módulos en serie) hasta inversor	Fx6mm^2 + Nx6mm^2	

Table 25. Wiring of the DC part. Source: own creation

1.4.2. AC wiring

The system consists of two three-phase inverters, with a total rated power of 96 kW. The necessary protections, which are calculated in the corresponding section, will be installed in a switchboard called the AC switchboard. The AC wiring will be divided into three sections: from the 36kW inverter to the main IGA switch located in the AC switchboard, from the 60kW inverter to the IGA located in the AC switchboard, and from the IGA in the AC switchboard to the main switchboard (main distribution switchboard of the LV building, the CGBT). At the IGA switch, the lines of both inverters will be joined (each with cables with their respective appropriate cross-sections) and the power cables will come out of it at a higher cross-section, since they will carry the sum of the currents supplied by both inverters.

As they are three-phase inverters, 4 cables will come out of each inverter: 3 active phases and the neutral. In this case, as the alternating circuits are for indoor installation, the neutral section will be the same as the phase conductors, in accordance with the REBT regulations.

1.4.2.1. Wiring of the 36KTL inverter to the AC board

Thermal criteria

The maximum current that will circulate through the inverter's three-phase output cables will be the maximum current that the inverter itself can provide at its output, which, for the model under analysis, the Huawei SUN2000-36KTL, is 57.8 A at 400V, according to its technical data sheet. Applying the safety oversizing of 125% in accordance with the regulations, the result is as follows:

$$Il = 1.25 * Imax.inv = 12.25 * 57.8 = 72.25\ A$$

(22)

Table 22 above is used, in this case in accordance with column 11, i.e. with the same installation method F, and on this occasion XPLE3 cables (as this section is a three-phase circuit). It is obtained that the next higher current that will support the 72.25 A is 91 A, which corresponds to a cable section of 16mm2. Given that there is no additional grouping of cables, and as there is only one circuit, the correction factor will be 1. Therefore, for a cable of S=16mm2 we have:

$$Iz\ (S = 16mm^2) = 91A\ > Il = 72.25\ A\ \rightarrow si\ cumple\ por\ crit.\text{térmico}$$

(23)

Voltage drop criterion

As mentioned above, the maximum voltage drops over the entire AC section must not exceed 1.5%, therefore, for this section, which makes up half of the route, the voltage drop should not be greater than half of 1.5%, i.e. 0.75%. To calculate it, the formula (24) for the voltage drop for a three-phase line with three active conductors will be used.

$$\Delta\,\text{V}_{\text{Tramo 1}}(\%) = \frac{L * P}{c * S * U_{fn}^2} * 100$$

(24)

Where:

L = 3m	Maximum length of the section
P = 36 kW=36x10^3 W	Maximum output power of the inverter
c = 56 m/(Ωmm2)	Cu conductivity at 29ºC
Ufn = 400 V	Nominal voltage of the section

Substituting for S=16mm2:

$$\Delta\,\text{V}_{\text{Tramo 1}}(\%) = \frac{3 * 36 * 10^3}{56 * 16 * 400^2} * 100 = \ 0.0753\% < 0.75\%\ \rightarrow si\ cumple\ crit.\,caída\ tensión$$

(25)

<u>AC SIDE SECTION 1:</u>

16mm2 section is suitable, it meets both criteria. Therefore: 3Fx16mm2+Nx16mm2.

1.4.2.2. Wiring of the 60KTL inverter to the AC switchboard

Thermal criterion

Proceeding in an equivalent manner to the previous process, we have the following. The maximum current that will circulate through the inverter's three-phase output cables will be the maximum current that the inverter itself can provide at its output, which, for the model under analysis, the Huawei SUN2000-60KTL, is 95.3 A at 400V, according to its technical data sheet. Applying the safety oversizing of 125% in accordance with the regulations, the result is as follows:

$$Il = 1.25 * Imax.inv = 12.25 * 95.3 = 119.1\ A$$

(26)

Using table 22 above, with the same installation method F, and in this case XPLE3 cables (as this section is a three-phase circuit), we obtain that the next higher current that will withstand the 119.1 A is 144 A, which corresponds to a cable section of 35mm2. Given that there is no additional grouping of cables, and as there is only one circuit, the correction factor will be 1. Therefore, for a cable of S=35mm2 we have:

$$Iz\ (S = 35mm^2) = 144A\ > Il = 119.1\ A\ \rightarrow si\ cumple\ por\ crit.\text{térmico}$$

(27)

Voltage drop criteria

As mentioned above, the maximum voltage drops over the entire AC section must not exceed 1.5%, so for this section, which makes up half of the route, the voltage drop should not be greater than half of 1.5%, i.e. 0.75%. To calculate it, the formula (28) of the voltage drop for a three-phase line with three active conductors will be used.

$$\Delta\,\mathrm{V}_{\mathrm{Tramo\ 2}}(\%) = \frac{L * P}{c * S * U_{fn}^2} * 100$$

(28)

Where:

L = 3m	Maximum length of the section
P = 60 kW=36x10^3 W	Maximum output power of the inverter
c = 56 m/(Ωmm2)	Cu conductivity at 29ºC
Ufn = 400 V	Nominal voltage of the section

$$\Delta\,\mathrm{V}_{\mathrm{Tramo\ 2}}(\%) = \frac{3 * 60 * 10^3}{56 * 16 * 400^2} * 100 = \ 0.0574\% < 0.75\%\ \rightarrow si\ cumple\ crit.\,caída\ tensión$$

(29)

<u>AC SIDE SECTION 2:</u>

35mm2 section is suitable, meets both criteria. It will therefore have: 3Fx35mm2+Nx35mm2

1.4.2.3. Wiring from the AC switchboard to the main switchboard of the building

Thermal criterion

This third AC section runs specifically from the main switch IGA of the AC switchboard to the main switchboard of the building. At the IGA the currents of both inverter lines (the other two sections) are joined, so the maximum current that will circulate will be the sum of the maximum currents of the other two sections, that is to say, it will be: 57,8 + 95,3 = 153 A.

Applying the safety oversizing of 125% in accordance with the regulations, the result is as follows:

$$Il = 1.25 * Imax.tramo3 = 12.25 * 153 = 191.2\ A$$

(30)

Using table 22 above, with the same installation method F, and in this case XPLE3 cables (as this section is a three-phase circuit), it is obtained that the next higher current that will withstand the 119.1 A is 224A, which corresponds to a cable section of 70mm2. Given that there is no additional grouping of cables, and as there is only one circuit, the correction factor will be 1.

$$Iz\ (S = 35mm^2) = 224A\ > Il = 191.2\ A\ \rightarrow si\ cumple\ por\ crit.\text{térmico}$$

(31)

Voltage drop criterion

As mentioned above, the maximum voltage drops over the entire AC section must not exceed 1.5%, therefore, for this section, which makes up half of the route, the voltage drop should not be greater than half of 1.5%, i.e. 0.75%. To calculate it, the formula (32) for the voltage drop for a three-phase line with three active conductors will be used.

$$\Delta\ V_{\text{Tramo 3}}(\%) = \frac{L * P}{c * S * U_{fn}^2} * 100$$

(32)

Where:

L = 3m	Maximum length of the section
P = 96 kW=36x10^3 W	Maximum output power of the inverter
c = 56 m/(Ωmm2)	Cu conductivity at 29ºC
Ufn = 400 V	Nominal voltage of the section

$$\Delta\ V_{\text{Tramo 3}}(\%) = \frac{3 * 60 * 10^3}{56 * 16 * 400^2} * 100 = \ 0.0574\% < 0.75\%\ \rightarrow si\ cumple\ crit.caída\ tensión$$

(33)

AC SIDE SECTION 3:

70mm2 section is suitable, meets both criteria. Therefore: 3Fx70mm2+Nx70mm2.

Finally, it is checked that the total voltage drop on the AC section is less than 1.5%. Since section 1 and section 2 are parallel, their voltage drops do not add up (in fact they should be approximately equal). Therefore, we check the voltage drop for the two paths: section 1-section 3 and section 2-section 3.

$$\Delta VTramo1(\%) + \Delta VTramo3(\%) = 0{,}0753 + 0{,}046 = 0{,}12\% < \Delta Vmax.AC = 1{,}5\% \rightarrow \text{cumple} \quad (34)$$

$$\Delta VTramo2(\%) + \Delta VTramo3(\%) = 0{,}0574 + 0{,}046 = 0{,}1\% < \Delta Vmax.AC = 1{,}5\% \rightarrow \text{cumple} \quad (35)$$

In summary, the 3 sections studied on the AC side have the following wiring from table 26.

Cableado de corriente alterna		
Tramo	Sección	Tipo cable
Tramo 1: Inversor 36KTL hasta cuadro AC	$3Fx16mm^2 + Nx16mm^2$	Cables RZ1-K (AS) 0,6/1kV unipolares de Cu con aislamiento XLPE y recubrimiento de poliolefina.
Tramo 2: Inversor 60KTL hasta cuadro AC	$3Fx35mm^2 + Nx35mm^2$	
Tramo 3: Cuadro AC hasta cuadro general	$3Fx70mm^2 + Nx70mm^2$	

Table 26. Wiring of the AC part. Source: own creation.

1.5. Calculations of protections

In the section corresponding to protections of the memory of the present project, the minimum requirements by regulations for protections in this type of installations are exposed.

1.5.1. DC protective switchgear

Protection of the Huawei SUN2000-36KTL and Huawei SUN2000-60KTL inverters themselves, class II up to 1100Vdc, against overloads by means of a specific circuit that protects each input of the strings, and against over voltages by means of an SPD surge arrester.

Bearing in mind that this part of the installation does not have a residual current cut-off device, the way to limit the value of the fault current will be by means of the insulation resistance (Riso), keeping it at a suitable value. The standard stipulates that in PV systems without galvanic isolation - without a transformer - as in the present installation, the Riso must be at least 2000 k per kW input voltage of the inverter. Compliance with these values is controlled by the inverter.

Basically, it will consist of a floating scheme configuration and the use of a permanent insulation monitor, which warns of a possible fault, and executes the automatic disconnection-connection of the PV system in case of loss of insulation resistance. This device is already included in the inverter as mentioned above.

Any protection against indirect contacts must ensure that any accidental contact of an active conductor with a metallic part does not cause a shunt to earth through a person touching the frames, supports or metal casings of plates, trays, etc. As explained in the corresponding section on earthing in this project report, the IT system of the floating scheme fully ensures this protection in the continuous part of the photovoltaic plants, as there is no risk of indirect contacts, and there is not even a risk of earth leakage through the person, when this person directly touches a single active conductor. This means that the level of safety achieved with this arrangement is comparable to that achieved in ordinary AC installations with earth leakage circuit breakers, but with the advantage for floating generator PV installations that this safety does not depend on the correct functioning of an earth leakage circuit breaker or any other device, but is an inherent safety feature of the installation itself. Furthermore, to improve protection against direct contact, good insulation (Class II or equivalent) of live metal parts is recommended. In addition, inverter inputs shall use M16 cable glands for safe string connections.

1.5.2. AC Protective Switchgear

As explained in the section corresponding to protections in the report of this work, given the inverter equipment chosen, it will integrate the protection functions of maximum and minimum voltage and maximum and minimum frequency, as well as the automatic disconnection-connection manoeuvres to avoid island operation, a safety guarantee for the maintenance workers of the electricity distribution company.

Therefore, in this case, it will only be necessary to have the additional protections of the main switch, circuit breaker and differential switch, which will be in the photovoltaic installation's own AC electrical panel.

In order to protect against overcurrent that could damage the AC circuit of the PV installation, a magneto-thermal circuit breaker will be installed at the output of each inverter. Type C and/or type B circuit breakers will be used, those used when there are no high consumption starting currents.

According to UNE 20-460-4-43, UNE EN 60947 and ITC-BT-22 standards, for protection against over currents, the following conditions must be met

$$\text{I diseño de la línea} \leq \text{I asignada dispositivo de protección} \leq \text{I admisible de la línea.}$$

i.e:

$$I_L < I_N < I_Z \qquad (36)$$

and it must also be complied with:

$$I_Z < 1.45 * I_Z \qquad (37)$$

where $I2$ is the current that ensures the effective tripping of the protection device (tripping or fusing depending on whether it is a circuit breaker or a fuse) for a long time (tc according to the standard). As far as the second condition is concerned, i.e. condition (37) will be met as long as condition (36) is met if it is a circuit breaker manufactured in accordance with EN 60898. The same would not apply in the case of fuse protection. As only such circuit breakers are to be used here, only the condition $I_L < I_N < I_Z$.

- AC section 1 (36KTL inverter-AC switchboard):

A current of IL=72.25 A will circulate in this line, with wiring of S=16mm2, which admits up to a maximum current of IZ=91 A. Therefore, applying (36), a suitable calibre to protect this line could be: IN=80 A:

$$72{,}25\ \text{A} < 80\ \text{A} < 91\ \text{A}\ \rightarrow\ \text{Ok}$$

(38)

- AC section 2 (60KTL inverter-AC switchboard):

A current of IL=119.1 A will circulate in this line, with wiring of S=35mm2, which admits up to a maximum current of IZ=144 A. Therefore, applying (36), a suitable calibre to protect this line could be: IN=125 A:

$$119{,}1\ \text{A} < 125\ \text{A} < 144\ \text{A}\ \rightarrow\ \text{Ok}$$

(39)

- Section 3 of AC (AC switchboard - general switchboard for hall distribution):

A current of IL=191.2 A will circulate in this line, with wiring of S=70mm2, which admits up to a maximum current of IZ=224 A. Therefore, applying (36), a suitable calibre to protect this line could be: IN=200 A:

$$191{,}2\ \text{A} < 200\ \text{A} < 224\ \text{A}\ \rightarrow\ \text{Ok}$$

(40)

As far as short-circuit protection is concerned, the breaking capacity (PdC) of the circuit breakers used must be greater than the maximum short-circuits current that will circulate. Since in this case the data of the MV/LV transformer of the building is not available, the simplified formula (41) is used, in which the total short-circuit reactance of the section is approximated by the resistance of the cable.

$$I_{CC} = \frac{0.8\ U_{fn}}{R}$$

(41)

Where:

Ufn = 230 V — Maximum length of the section

$R = \frac{\rho * L}{R}$ — Maximum output power of the inverter

Applying (41) in the most unfavourable section, the maximum short-circuit current of the circuit would be:

R $R = \frac{\left(\frac{1}{56}\right) * 20}{16} = 0.02\ \Omega$ $\qquad I_{CC-max} = \frac{0.8 * 230}{0.02} = 9200\ A = 9.2kA$

(42)

Therefore, using 16kA PdC MCBs > $ICC\text{-}max$=9.2kA , it would already fulfil.

Against indirect contacts on the AC side, the installation will be automatically cut off by means of a residual current device with adjustable sensitivity of 300mA, associated with the main circuit breaker (IGA) on the AC output of the inverter, both of which are located in the AC protection electrical panel (see single-line diagram in drawing P11). This earth leakage circuit breaker will provide full protection (i.e. against indirect contacts in addition to direct contacts) if it is complemented by an adequate earthing of the earths, otherwise it will only work against direct contacts. In order to avoid untimely tripping, such a residual-current device should be either automatically reclosing or highly immune.

In short, as described in the corresponding section of these protections in the report, the following protection switchgear will be used in the AC switchboard of the PV installation, summarised in table 27.

At the 36-kW inverter output there will be an 80A circuit breaker, and at the 60-kW inverter output there will be a 125A circuit breaker. Both will be Legrand DX circuit breakers, 4-pole, class C curve, and breaking capacity (PdC) of 16kA.

The output of both will be combined in a larger magnetothermal protection, which will be a 200A circuit breaker operating in conjunction with a 300mA adjustable sensitivity differential relay and associated toroid.

The IGA will be the DPX3-250-4P-25kA-200A moulded case model from Legrand. With adjustable thermal from 0.8 to 1 In and adjustable magnetic from 5 to 10 In.

The differential relay will be electronic model RGU-10 of the Circutor firm, prepared for connection to the external toroidal current transformer coil of the WGC series of the Circutor firm. Type A super immunised, with high frequency current filtering and high immunity, with true rms measurement (TRMS), for accurate monitoring of leakage currents, under IEC 62020 standard. Being able to visualise the instantaneous leakage value on the display, together with the pre-alarm indications, provides information on the status of the lines being protected, and enables good preventive maintenance to be carried out. The toroid will be a closed coil, from the WGC-80 series with a diameter of 80mm.

The differential with magneto-thermal protection will operate before the main switch, except for short circuits of a certain importance coming from the network from the connection point.

PROTECCIONES DE ALTERNA			
Elemento	Uds	Ubicación	Características técnicas
Magnetotérmico de calibre 80 A, Legrand DPX3 160 4P 16kA	1	Caja de protecciones de AC	Vn = 400 V In = 80 A PdC = 16 kA
Magnetotérmico de calibre 125 A, Legrand DPX3 160 4P 16kA	1	Caja de protecciones de AC	Vn = 400 V In = 125 A PdC = 16 kA
Interruptor Automático Diferencial de 200 A de Legrand DPX3 250 4P 25kA, de caja moldeada. (IGA+relé+toroidal)	1	Caja de protecciones de AC	Vn = 400 V In = 200 A PdC = 25 kA $I_{\Delta n}$ = 300mA

Table 27. Summary of the protections of the AC switchboard. Source: Own creation

1.6. Calculation of earthing

As the photovoltaic generation installation is a self-consumption installation, this installation will be connected to the customer's internal grid, therefore this installation will be connected to the public distribution grid.

Therefore, the masses of the installation will be connected to the grounding of the customer's installation, which is independent of the neutral of the distribution grid. This leaves a suitable earthing system as described in the corresponding section of this project report.

1.7. Design of protective wiring

The protection conductors will run through the same direct current and alternating current conduits of the installation. The minimum cross-section of these conductors is given in accordance with ITC-BT-18 and will depend in each section on the corresponding cross-sections of the phase conductors, as indicated in table 28.

Sección de los conductores de fase de la instalación S (mm^2)	Sección mínima de los conductores de protección S_p (mm^2)
$S \leq 16$ $16 < S \leq 35$ $S > 35$	$S_p = S$ $S_p = 16$ $S_p = S/2$

Table 28. Ratio between the cross-sections of the protective conductors and the phase conductors. Source: Table 2 of ITC-BT-18.

1.7.1. DC protective conductor

As calculated above and as shown in table 25, the cross-sections of the phase conductors of the DC part will be 6mm2, therefore, according to table 28, the DC protective conductors will be bare copper conductors, of S = 6mm2.

1.7.2. Alternating current protective conductor

According to table 26 of the cross-sections for each AC section, as the largest cross-section on the AC side is 70mm2 , then according to table 28, the AC protective conductors are half the size, i.e. S = 35mm2 , insulated copper conductors protected by green-yellow identification wiring.

1.8. Structural load calculation

The bars to be used for the structure of the north water (zone 2) will be rectangular galvanised steel profiles of 40x40x2mm and various lengths, welded together to form the triangular brackets and bolted at the base to the roof trusses. In this section, the structural load of the assembly in this area is checked.

Each bar has a weight per linear metre of: 2.48 kg/m. The estimated length per triangular bracket, considering all the bars of different lengths, is about 23.86m, which means a weight per bracket of 59.2 kg. As there are 16 brackets, all of them have a weight of 947.2 kg. Considering the 60 photovoltaic modules that will be arranged on top, as each module weighs 22.6 kg, this gives a module weight of 1356 kg. In addition, the 154 trapezoids, 118 interclamps and 36 end clamps used in this area, mean an additional weight in fasteners and screws of about 10 kg. As for the cabling, the weight per linear metre is 0.07 kg/m, so that 20 metres of cable would mean an additional 1.4 kg, which is practically negligible, as well as the rejiband conduits. Table 29 summarises the weights of each element and the total, as well as the distribution surface and the consequent weight per unit area that we will use to compare with the maximum regulatory limit.

Elementos Zona 2	Peso unitario	Uds	Subtotal peso
Escuadras triangulares	59,2 kg	16	947,2 kg
Módulos fotovoltaicos	22,6 kg	60	1356 kg
Elementos sujeción y tornillería	N/A	308	20 kg
Cableado (m. de cable)	0,07kg/m	20	1,4 kg

PESO TOTAL	2324,6 kg
SUPERFICIE SOBRE LA QUE SE DISTRIBUYE EL PESO	154,7 m^2
PESO POR UNIDAD DE ÁREA	15,02 kg/m^2

Table 29. Calculation of weight per unit area in zone 2 (worst case). Source: Own creation

As can be seen, the weight per unit area (15.02 kg/m2) is well below the 500kg/m2 of overload established by the CTE for Structural Safety and Actions in Buildings (CTE, DB-SE-AE, Table 3.1), so it is more than acceptable and even with plenty of margin for additional overloads such as rain, wind, etc.

As for the structural load of the rest of the zones, as they are coplanar and are not arranged by means of an additional triangular structure, the weight will in any case always be less than that calculated, simply because they are arranged with fewer elements. In other words, the calculation in table 29 is the most unfavourable situation. Therefore, it is justified that the structure of the building will not be affected, i.e. the entire photovoltaic system as a whole is acceptable and complies with structural safety.

1.9. Minimum distance between rows of proposals A and B

In proposals A and B of the possible configuration of the photovoltaic generator in the corresponding section in the report of this project, it is proposed to place the modules by means of a south-facing structure on a roof with east-west waters. This would mean arranging the modules in rows one behind the other, which would generate shadows between them. To avoid this, the rows should be separated by a minimum distance, the value of which is to be calculated. The IDAE, in section 5 of Annex III of its Technical Specifications for Grid-connected Installations, establishes a simple method for calculating the minimum distance between rows. This gives an approximate value of the minimum distance, since in this case the modules are installed on a sloping roof with a non-zero azimuth. In any case, it follows that:

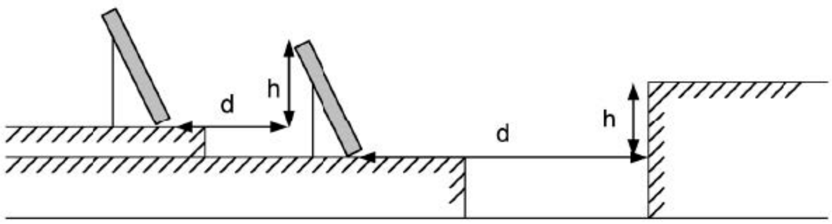


Figure 131. Diagram of distances between rows and obstacles. Source: Fig.7 of Annex III of the IDAE PCT-C-REV-2011.

The distance d, measured horizontally, between rows of modules, or between a row and an obstacle of height h that may cast shadows (see figure 133), is recommended to be such as to avoid shadows on the panel, and to ensure at least 4 hours of sunshine around midday on the winter solstice. For this purpose, establish the formula (43).

$$d \geq h \cdot k$$

(43)

where d and h are the dimensions marked in figures 132 and 133 and k is a dimensionless factor obtained from the latitude of the area according to table 30 or equivalently, formula (44).

$$k = \frac{1}{\tan\left(61º - latitud\right)}$$

(44)

Latitud	29°	37°	39°	41°	43°	45°
k	1,600	2,246	2,475	2,747	3,078	3,487

Table 30. Value of k in the calculation of minimum distance between modules, based on the latitude of the area. Source: Table VII of Annex III of the IDAE PCT-C-REV-2011.

Applied to the present planned installation, this is shown in figure 133 below.

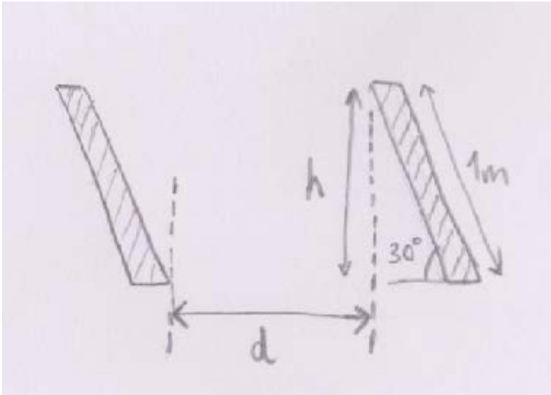


Figure 132. Diagram for the calculation of d and h for the minimum distance between rows, applied to the installation of this project. Source: Own freehand creation.

As can be seen in figure 133, the width of the module, when arranged horizontally, measures 1 metre. And with the hypothetical inclination shown of 30º, the value of h is calculated by applying basic trigonometry, according to equation (45).

$$\sin 30º = \frac{h}{1} \quad \rightarrow \qquad h = 1 \cdot \sin 30 = 0{,}5 \text{ m}$$

(45)

As for k, being in an area of latitude 39º, according to table 30, we have a value of k =2.475 . Therefore, applying (43), the minimum distance will be:

$$\text{dmin} = \text{h} \cdot \text{k} = 0{,}5 \cdot 2{,}475 = 1{,}24 \text{ m}$$

(46)

Finally, it is obtained that the row spacing for proposals A and B will be $\boldsymbol{dmmin}=\mathbf{1{,}24}\boldsymbol{m}$.

ANNEX II - PROCESSING AND LEGALISATION PROCESS -

2.1. Prior to the start of the procedure

Before starting any procedure, it is advisable to check whether the chosen site has any restrictions (environmental and/or urban planning) that would prevent the generation facility from being located there, in order to ensure that the installation can be carried out and that there is no legal impediment to carrying out the installation at the chosen site. To do this, the Town Planning Department of the Town Council of the site can be consulted to see if there is any restriction, for example derived from the General Urban Development Plan (PGOU) or any obligation derived, for example, from a municipal solar ordinance.

The procedures described below are those established, based on RD244/2019, by the IDAE in its Self-consumption Processing Guide.

2.2. Formalities before starting installation

The administrative processing of self-consumption installations may require procedures with 4 entities: at state, regional and local level, in addition to procedures with the distribution company. Depending on the characteristics of each installation, the procedures are different or are exempt from certain parts of the procedure that are necessary for other types or modalities.

For the installation covered by this project, it is proposed that it be covered by the CON surplus modality with compensation. In addition to being an individual type, as there is only one consumer associated with this production facility. This modality, together with the other typologies, has been explained in the corresponding section of the regulatory context in the report (document A of this project). Therefore, the processing process will be based on this chosen modality. It is worth mentioning that the consumer will have to inform the distribution company, directly or through the retailer, of his wish to take advantage of the compensation system, which is a 'procedure' that can be done before starting the installation, although it is discussed in the following section on procedures after the installation has been completed.

- Installation design

The documentation required for the design of the installation depends on the type of grid connection. In this case, as it is low voltage (LV, up to 1kV) and the installed power exceeds 10kW, a technical project must be drawn up and signed by a competent technician. This project, although its purpose is to carry out the Final Degree Project, contains all the necessary information required for the Technical Project for processing.

- Application for a Building Permit and payment of the building and construction tax (ICIO)

The first step is to apply for a Building Permit (LO) from the local administration, i.e. the town council of the locality where the work is to be located, according to the municipal regulations in force in the chosen location.

For this, each local council requires one type of documentation or another, depending also on whether it is a Major Works Licence or a Minor Works Licence. The necessary documents and information for processing the L.O., and whether it should be Minor or Major, can be found by calling the specific town hall directly or through its website, and by carrying out the procedures telematically. In the latter case, a project signed by a competent technician will be required.

Depending on the power of the generation facility, the municipal regulations will define whether it is sufficient to make a responsible declaration and/or a prior communication of the work. In both cases, this type of permit enables the work to begin immediately without waiting for a response. However, municipal regulations may require the application for a building permit. This application may involve an ordinary or simplified procedure, but in any case it requires a response and the granting of the municipal permit.

Likewise, the tax and the construction and works tax (ICIO), regulated by the Ley Reguladora de Haciendas Locales, must also be paid. This tax can be reduced by up to 95%. In addition, local councils can consider rebates on property tax (IBI) of up to 50% of the tax, for investments in renewable energies such as the one in question.

It should also be verified what validity is granted to the building permit in order to take it into account in the planning of the actions and whether the granting of this permit obliges any further procedures to be carried out, such as the presentation of certificates of completion of the work and even re-settlement of the ICIO.

- Access and connection permit, and guarantees or guarantees

As this is an installation with a power of more than 10kW and less than 100kW, access and connection permits must be requested from the distributor and/or marketer, depending on the power of the installation, and therefore guarantees and/or sureties must also be presented. The processing procedure regulated in RD1699/2011 is summarised below:

- 1º- An application for access and connection point is sent to the distribution company. The information in the application will be: contact details of the promoter, location of the generation facility, single-line diagram, proposed connection point with UTM coordinates, owner of the property where the facility is located, technical description of the facility, and proof of having deposited the corresponding financial guarantee with the competent administrative body (Caja General de Depósitos), in accordance with the provisions of RD 1955/2000. If additional documentation is required, the distribution company will request it within 10 days. The study of the connection will not entail any cost.

- 2nd- Response to the application with the proposal of access and connection conditions, by the distribution company, by means of notification to the applicant, within a period of one month. The proposal will remain in force for a period of 3 months from the date of notification to the owner of the installation, before which time the applicant must inform the distribution company of acceptance of the proposed point and conditions. The distribution company may also refuse the application, and the applicant may in turn file a complaint in the event of discrepancy.
- 3º- Once the proposal has been accepted, the applicant must carry out the installation, but as it is less than 100kW it will be exempt from registration in the Administrative Register of Production Installations (RAIPRE).
- Environmental and public utility authorisations

Self-consumption facilities with surpluses and power of less than 100kW, such as the one in this project, should NOT require environmental impact or public utility procedures, except in cases where the site is under some type of protection or specific condition.

- Prior administrative authorisation and construction authorisation

Electricity production facilities with a capacity of less than or equal to 100kW connected directly to a voltage network of less than 1kV, i.e. LV, are excluded and therefore do NOT require prior administrative authorisation and construction authorisation. If the power is greater than 100kW, it would be obligatory to request administrative authorisation, both prior and for construction, from the autonomous community in accordance with the procedures determined by them.

- Opening of work centres

Before the start of the execution of the installation, the labour authority must be notified, both for the opening of work centres and in cases of resumption of activity after major alterations, extensions or transformations. This can be done by means of a telematic/electronic procedure in the corresponding body of each Autonomous Community, in the case of this project it would be GVA Industry.

2.3. Formalities after completion of the installation

After completing the execution of the work in accordance with the REBT and taking into account the energy measurement and management requirements set out in the specific regulations for self-consumption with surpluses, the procedures described below are carried out.

- Installation Certificate and/or End of Work Certificate

Once the installation has been completed, as it has a power greater than 10kW, the certification of the end of the work is carried out by presenting the LV installation certificate to the corresponding body of the autonomous community, as well as a certificate of completion signed by the competent technician certifying that the installation has been carried out in accordance with the technical project of the installation, as indicated in the ITC-BT-04.

- Initial inspection and periodic inspections

In installations connected to LV and with a power of 100kW or less, such as this one, in principle it would not be necessary to undergo an initial inspection by an Authorised Control Body (OCA), as this is not required by ITC-BT-05 on verifications and inspections of the REBT.

However, it is advisable to check with the corresponding Autonomous Community, as the Autonomous Communities usually require all installations to carry out this inspection procedure through an OCA prior to processing the installation certificate.

- Operating authorisation

This is NOT necessary in this case as the planned installation does not affect the territorial scope of more than one Autonomous Community, nor does it have an installed power of more than 50 MW, nor is it located in the territorial sea.

- Access contract for the self-consumption installation

Self-consumption installations with surpluses connected to the internal grid, of any power and connection, such as this one, do not need to sign a specific access and connection contract with the distribution company, except if it is necessary to sign a supply contract for auxiliary production services. However, they do have to have an access contract for their self-consumption installations, whatever it may be, and if they do not have one, one must be formalised with the distribution company or marketing company.

In the case of already having an access contract, the only necessary procedure is to notify the distribution company (either directly or through the marketing company that provides service to the consumer) so that the existing contract is modified and the chosen self-consumption modality is reflected in it.

In the case of installations with surpluses connected to LV and up to 100kW, such as this one, this modification will be made ex officio by the distribution company based on the information that the autonomous communities send them. This information will be obtained directly from the installation certificate that has been completed in the autonomous community.

The modified contract will be sent by the distribution company to the retailer and the consumer within 15 days of receiving the information from the autonomous community.

- Surplus compensation contract

In the case of self-consumption facilities with surpluses that are subject to compensation, such as this one, a surplus compensation contract must be signed between the producer and the associated consumer for the simplified compensation between the deficits of their consumption and the total surpluses of their associated generation facilities. This contract will be necessary in all cases, even if the producer and consumer are the same natural or legal person. For the application of the compensation mechanism, each consumer must send the distribution company, directly or through the retailer, a letter requesting the application of the compensation system.

As the legislative change introduced by the new RD244/19 is still quite early, as it is still in the adaptation phase, for the moment there are few distributors that offer the compensation of surpluses in an effective way, for example Holaluz is recommended.

- Energy supply contract for ancillary services

Ancillary production services are those supplies of electrical energy necessary to provide the basic service in any operating regime of the generation facility.

If the ancillary services are considered negligible, it is not necessary to sign a specific supply contract for the use of these services; this situation will occur in cases where all the following conditions are met:

- Installation close to indoor grid

-Installation power less than 100 kW in any mode.

-In annual computation, the energy consumed by these auxiliary services is less than 1% of the net energy generated by the installation.

- Activity licence

Self-consumption installations with surpluses that are eligible for compensation do not carry out economic activity, so this procedure would NOT be necessary in this case.

- Registration in the regional self-consumption registry

Owners of self-consumption installations with surplus power up to 100kW and connected to low voltage do NOT need to carry out the registration procedure. The Autonomous Regions will carry out the registration of these installations in their autonomous registers ex officio based on the information they receive in application of the REBT.

- Registration in the Administrative Register of Self-consumption of Electrical Energy

All self-consumption installations with surpluses must be registered in the administrative registry of electricity self-consumption, but this step does NOT imply any additional administrative burden for self-consumers as it is a procedure between administrations.

The Ministry will feed its administrative register of self-consumption from the information submitted by the Autonomous Communities. The register is telematic, free of charge and declarative.

- Registration in the administrative register of electricity production facilities (RAIPRE)

Owners of self-consumption installations with surplus power of up to 100kW, such as this one, do NOT need to register in RAIPRE. It will be the Directorate General for Energy Policy and Mines of the Ministry responsible for energy matters who will carry out the registration based on the information from the administrative register of self-consumption. Installations with a surplus of more than 100kW would need to apply for registration in RAIPRE, as they sell energy.

- Energy sales contract

Self-consumption installations with surpluses covered by compensation, such as this one, do NOT require an energy sales contract, but those with surpluses not covered by compensation should formalise a market representation agreement with one of the commercialisation companies for the sale of energy and comply with the fiscal and tax obligations arising from this economic activity. Installations with surpluses can sell directly on the electricity market, for which they must register as generators in the market, for which they must complete the relevant formalities required by the market operator.

2.4. Summary of the processing process

Figure 134 below shows a summary of the procedures to be carried out together with the bodies/entities involved, and those necessary exclusively for the installation covered by this project, marked in red. In addition, figure 135 shows the same necessary procedures in the form of stages or steps, in a proposed order of completion.

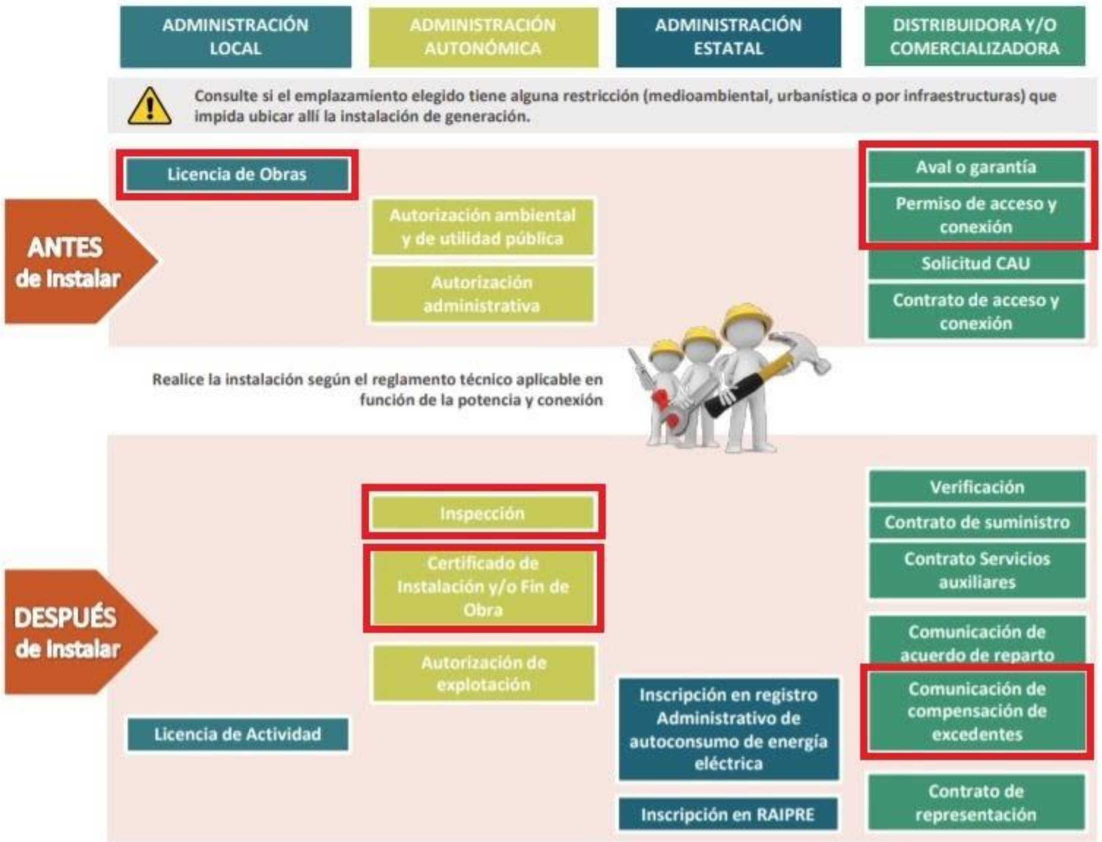


Figure 133. Summary of the necessary processing steps and bodies/entities involved. Source: [13].

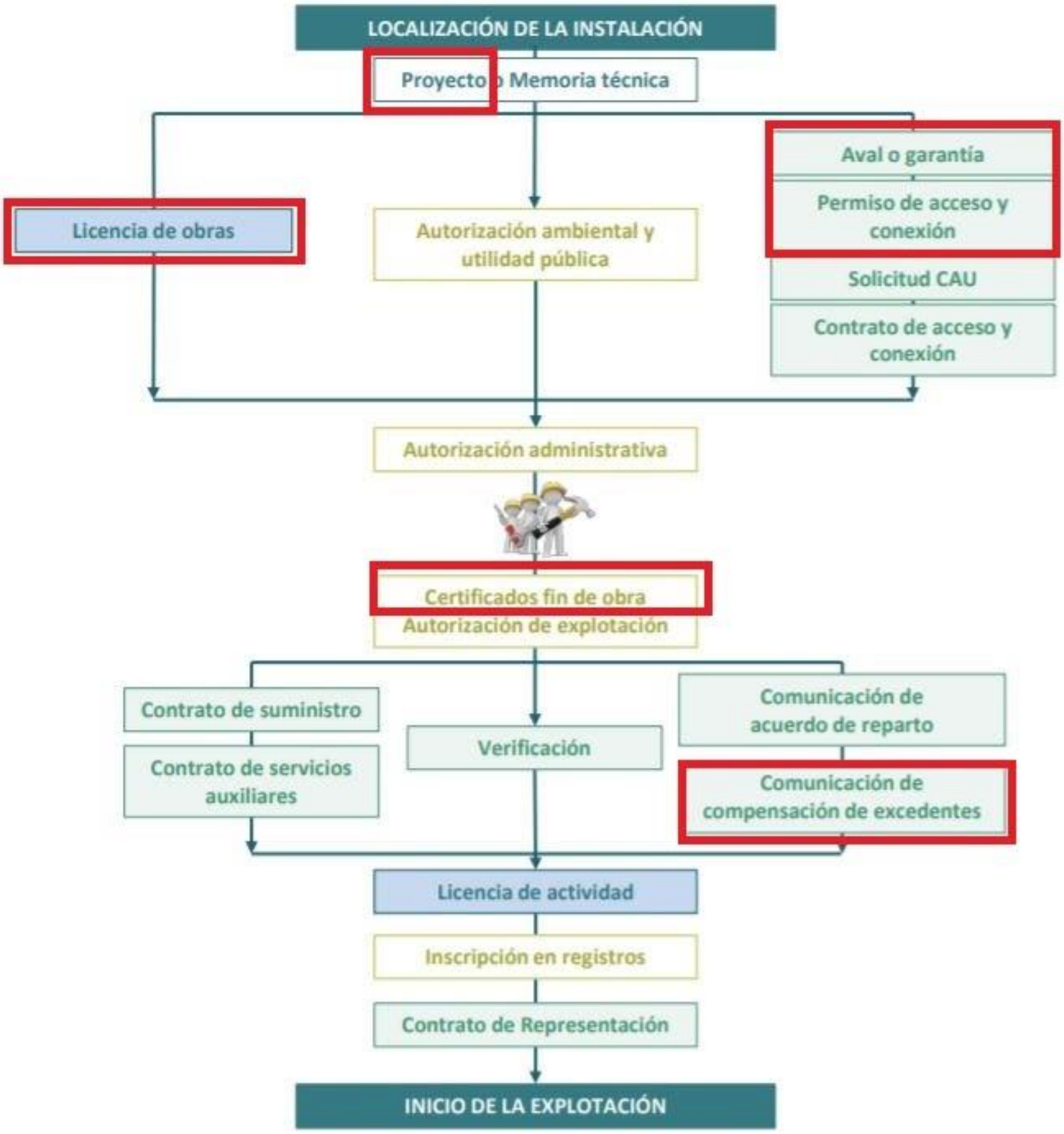


Figure 134. Summary of the steps to be followed in the procedure, in the proposed order. Source: [13].

ANNEX III - BASIC HEALTH AND SAFETY STUDY -

3.1. Purpose, justification and objectives

The purpose of this Basic Health and Safety Study (EBSS) is to analyse the safety conditions, based on R.D. 1627/1997, which establishes the minimum health and safety provisions in construction works. Its application is to the project 'Photovoltaic installation for self-consumption of 96kW on the roof of an industrial plant'.

The aim is to foresee and identify the potential occupational hazards that may occur during the execution of the activities and works of the project covered by this EBSS, in order to avoid or minimise them, ensuring the health and safety of the workers involved, third parties, or any other person who may be affected.

Likewise, the basic premises of what is considered in this EBSS will serve as a provisional document, subject to modifications, of identification and planning of the preventive activity of the work. It will also serve as a forecast of the resources, both technical and human, necessary for the fulfilment of the preventive obligations in the work centre; as well as in accordance with the preventive action plans of the subcontracted company/s, their functional organisation and the means to be used.

This EBSS aims, in summary, to create, on the basis of the aforementioned project, the specific procedures to achieve an accident-free construction site. In view of the above, it is necessary to specify specific objectives, which are defined according to the following sections, whose ordinal transcription is indifferent as they are all considered to be of the same rank:

- To know the project to be built and, if possible, to define the appropriate organisation and technology for the technical and economic execution of the work, in order to be able to analyse and consequently know the possible health and safety risks at work, in order to minimise or avoid them.

- Analyse all the work units contained in the project to be built, in terms of their formal and location factors, coherently with the technology and viable construction methods to be put into practice.

- Define all the potential risks, humanly detectable, that may appear during the course of the works.

- Design processes, installations or preventive elements to be put into practice, as a consequence of the technology to be used. Collective protection and personal protective equipment (PPE) will be used, to be implemented during the whole process of the project activity.

- Establish the safety rules and disseminate the prevention decided for this work, which will be carried out among all those involved in the construction process and, it is hoped that by itself will be able to encourage workers to put it into practice, in order to achieve their best and most reasonable collaboration. Without such inexcusable collaboration, this work will be of no use. For this reason, this set of documents is projected towards the construction company and the workers; it must reach everyone: staff, subcontractors and the self-employed, by means of the mechanisms provided for in the current regulations and in those parts that affect them directly and to the extent that they are concerned.

- Create an environment of occupational health and safety conditions on the site.

- Define the actions to be taken in the event that this technical-preventive intention fails and an accident occurs. It must foresee the rescue and evacuation of the injured, in such a way that the assistance to the injured person is appropriate to their specific case and applied as quickly and carefully as possible.

This authorship of the EBSS declares:

-That it has been its will to first analyse the risks on the project, and as a consequence, the design of as many preventive mechanisms as can be devised to the best of its technical knowledge and understanding, within the technical-economic possibilities and limits allowed.

- That he trusts that, if any preventive gap should arise, the workers affected will be able to detect it and present it so that it can be analysed in all its importance, giving it the best possible solution.

3.2. Project data

-Name and location:

The work which is the subject of this study concerns the '96 kW self-consumption photovoltaic installation on the roof of an industrial plant'.

-General data on the project and the site

Location of the work	(Full address not shown for privacy reasons)
Technical authors of the project	Diego Serrano Guardiola
Technical authors of the study	Diego Serrano Guardiola
Site manager	Diego Serrano Guardiola
Site execution manager	Diego Serrano Guardiola

The budget for the material execution of the project amounts to:

-The budget for the material execution of the project amounts to:

-The Health and Safety budget amounts to: 998,32€

-Of which €819.17 corresponds to collective protection and €179.15 to the rest: PPE and auxiliary installations and services.

-The maximum initial deadline foreseen for the execution of the work is: 30 days.

-The approximate time foreseen for the execution of the work is: 16 days.

-Characteristics of the site:

The photovoltaic installation will be installed on the roof of the existing industrial building, which is made up of two separate buildings, one on the north-south side and the other on the east-west side, both with a total surface area of 1476 m2 . The entire roof is made of sandwich panels formed by single sheet metal and with skylights. The roof does not have a parapet or anything similar, for which the relevant corrective and protective measures will be taken for the workers.

-Number of workers:
The number of workers who will remain simultaneously on site is expected to be between 1 and 10 operatives.

-Existing public services and easements:
There are no services affected.

-Adjoining buildings:
The warehouses adjoin each other and other buildings on private property, as well as public roads. The building where the work is to be carried out has space on the main façade, and for easy access.

-Existing public services:
The plot of the building has the minimum urban services of electricity, water, sewage, telephone, etc.

-Services or obstacles that may hinder the normal development of the works:
There are no overhead connections, so it will be the owner's responsibility to contact the supply companies to determine the possible existence of hidden conduits.

-Access:
Workers' access to the roof will be via a staircase inside the building itself, which has access to the main façade. It will be carried out in accordance with the provisions of this document. As for the material, it will be lifted to the roof using a boom truck type lifting machine. As there is a large part of free area around the building, and the streets that delimit the plot have accessibility conditions, both for vehicles and pedestrians.

-List of companies and self-employed workers on the site:

Nombre de la empresa	Actividad	Representante de seguridad
Diego Serrano Guardiola	Instalaciones fotovoltaicas	Trabajador/a asignado/a en cumplimiento de lo dispuesto en el artículo 32 bis de la Ley 31/1995, de 8 de noviembre (D.A. 14ª)

3.3. Data relevant to the prevention of occupational risks

Construction report

This section complements the Report and Technical Specifications of the Project, and aims to describe in general terms the technical-constructive characteristics for the execution of the photovoltaic installation on the roof defined in the project.

- Description:

- The gabled industrial buildings are developed on a rectangular floor plan. They have single sheet sandwich panels.
- Access to the roof is directly from inside the building itself, and to the same from the public road.
- The structural system is metallic.
- The photovoltaic installation consists of 280 polycrystalline silicon modules joined in 14 branches of 20 modules in series.
- The industrial building is in an adequate state of construction and conservation. It has skylights, so simple twist mesh will be installed in the skylights along the roof where work will be carried out. It does not have parapets at the ends, so perimeter fencing will be installed in the building in areas where the height of the side walls does not reach 0.9 metres.

-Execution process:

The order of installation shall be as follows:

- Installation of the collective protection systems, consisting of:
    - Installation of the simple torsion mesh for the covering of the skylights.
    - Installation of perimeter fencing in the building.
- Installation of the coplanar modules and the support structure after setting out the layout.
- The panels will be installed on the support structure.
- Installation of the rejiband grating tray, for the passage of the roof and drop cables.
- Installation of the wiring, inverters, protection panel, earthing and connections.
- Revision of the entire installation, electrical connections and commissioning. Final configuration of the monitoring systems.

-Considerations:

- Elements may cause cuts or injuries due to blows or falling objects, appropriate PPE must be used.
- Under no circumstances will anyone be allowed to enter the site unless they are wearing the necessary and appropriate safety equipment for working at height. All work will be carried out in accordance with the strictest safety measures and there must be measures on site to protect workers, personal equipment (helmets, boots, gloves, suitable clothing, safety harnesses, etc.).
- The entry of persons not involved in the work will be prohibited. Work will not be carried out in areas close to the manoeuvring of machines and lorries, and there must be a person in charge of indicating, signalling and helping the lorries to manoeuvre.

All this process will be carried out manually where necessary, with mechanical assistance in the process of loading and unloading material, if conditions so require, and always with the express approval of the Project Management.

Activities foreseen on site

In coherence with the summary of the project and work execution plan, the following activities, trades, machinery, auxiliary means and site installations are defined, for which a non-exhaustive and provisional risk assessment is attached, which must be analysed, developed and completed with the provisions of the Prevention Plans and Risk Assessments and Preventive Action Planning (Art.16 LPRL) of each acting company, which will be complemented with the methods and/or procedures of each work of each item (Art.15 LPRL).

-General preliminary work:

- Organisation of the work site.
- Placement of collective protections.
- Laying out on the roof.
- Provisional services.
- Reception of machinery-auxiliary means, and assemblies.
- Collection of materials.

-Assembly of elements:

- Support structure and solar panels.
- Work on sloping roofs.
- Laying and installation of de-energised electrical wiring and grid trays.
- Installation and connection of protection panel.

-For trades and/or tasks whose intervention is the object of occupational risk prevention:

The work activities described, whose trades are implicit in the identification and assessment of risks by tasks or activities, are complemented by the work of the following trades:

- Technical personnel.
- Photovoltaic panel assemblers/officers.
- O.C. Officers.
- Electrical installers.

-Machinery foreseen for the execution of the work.

From the analysis of the work activities and trades, the technology applicable to the work is defined, which will allow, as a consequence, the viability of its execution plan. The use of the following is foreseen

- Forklift
- Transport: truck with arm/plume for the transport of materials.
- Lifting: the same truck with arm/feather for lifting modules, PRL elements or other heavy elements.
- Machinery: machine tools in general (radials, cutters, electric drills, etc.).

3.4. Time limit for execution and maximum number of workers.

In order to execute the work in a maximum period of 30 days, the global calculation of the influence on the market price is used, as well as the necessary labour. The maximum number of workers will be 10, which will serve as a basis for the calculation of the necessary number of personal protective equipment and possible temporary facilities for workers. This includes all persons involved in the execution and assembly process on roofs, and other processes involving serious risks in their execution, regardless of their company affiliation or contracting system.

3.5. Temporary facilities for workers.

Given the volume of work and workers foreseen, and the conditions of the installation itself, on an existing building equipped with toilets and drinking water, it is not necessary to provide provisional installations or connections for this work.

3.6. Standards or standard preventive measures

The following is a description of standards or preventive measures, arranged according to a standard classification of each one.

A) Standard preventive rules for cables

The size or cross-section of the wiring shall be as specified and in accordance with the electrical load to be withstood.

-All conductors used shall be insulated with a rated voltage of at least 1000 volts and free of appreciable defects (tears, chinks and the like). Defective sections will not be accepted in this respect.

-The laying of cables to cross roads, as indicated above, shall be carried out at ground level or overhead; if it is carried out at ground level, it shall be placed in the passage area, between planks as protection for load distribution and "cable passage" signalling:

-In the event of having to make splices between hoses, the following shall be taken into account:

(i) They shall always be raised. It is forbidden to put them in the ground.
(ii) Provisional joints between hoses shall be made using standardised, damp-proof, watertight connections.
(iii) Definitive connections shall be made using standardised watertight safety junction boxes.

-The routing of the electrical supply hoses shall not coincide with the provisional water supply to the plants.

B) Standard prevention rules for circuit breakers.

- They shall expressly comply with those specified in the Low Voltage Electrotechnical Regulations (R.D. 842/2002).
- Switches shall be installed inside standardised boxes, fitted with an entrance door with a safety lock.
- The switch boxes will have a standardised "danger, electricity" sign on the door.
- Switch boxes shall be hung on vertical walls.

C) Standard prevention rules for switchboards.
If installed:

- They shall be made of plastic materials, weatherproof type, with door and safety lock (with key), according to UNE-20324 standard and IP55 protection degree.
- They shall have a "danger, electricity" sign attached to the door.
- They shall be hung, where appropriate, by their own anchorages to the façade or vertical walls.
- They shall have sockets for standardised, shielded connections for outdoors, in a number determined according to the calculation carried out. Recommended degree of protection IP45, IK08.

D) Standard prevention rules for power sockets.

- Power sockets shall be fitted with all-pole circuit breakers so that they can be de-energised when not in use.
- Power sockets on switchboards shall be made from distribution boards, using standardised shielded plugs (protected against direct contact) and, wherever possible, with interlocking.
- The voltage shall always be on the "female" plug, never on the "male" plug to avoid direct electrical contacts.

E) Standard prevention rules for circuit protection.

- The installation shall have all the necessary circuit breakers.
- Circuit breakers must be installed on all power supply lines to switchboards and on power supply lines to electrically operated machines, apparatus and machine tools.
- General circuits must also be protected by circuit-breakers or circuit-breakers.
- All electrical circuits must be protected by means of differential circuit breakers.

  These differential circuit breakers shall be installed in accordance with the following sensitivity: 300mA (according to REBT).

F) Standard prevention rules for earthing.

- The general earthing system shall comply with the specifications detailed in instruction ITC-BT-18 of the current REBT.
- In the event of having to have a transformer on site, it shall be fitted with an earth connection in accordance with the regulations in force and the standards of the electricity supply company in the area.
- The metal parts of all electrical equipment will have an earth connection.

-The first phase of earthing will be carried out by means of a spike or plate to be located next to the main switchboard, from which it will be distributed to all the installation's receivers. When the definitive earthing of the building has been carried out, this will be the one used for the protection of the provisional electrical installation on site.

-The earthing wire shall be protected in yellow and green. It is expressly forbidden to use it for other uses. Only bare conductor or copper cable of at least 35mm2 section may be used in the horizontally buried sections, which will be considered as the artificial electrode of the installation.

-The general earthing network shall be a single network for the whole installation, including the earthing connections of the rails for the stay or movement of cranes.

-Electrical receivers equipped with double insulation protection systems and those supplied by means of a circuit separation transformer will not have a protective conductor, in order to avoid their referencing to earth. All other motor or machine housings shall be properly connected to the general earthing system.

-The earth connections shall be located in the ground in such a way that their operation and efficiency is that required by the installation.

-The conductivity of the ground shall be increased by periodically pouring water on the place where the spike (plate or conductor) is driven.

-The connection point (plate or conductor) shall be protected inside an accessible pit.

3.7. Prevention of risks of damage to third parties

The passage of possible passers-by, workers from other buildings, and the workers themselves, must be protected against the possible fall of objects from the site.

- The enclosure of the site itself will serve to prevent access to the site by personnel from outside the site, thus avoiding accidents.
- There will be signposting at the accesses to the site, both pedestrian and machinery accesses.
- During the entry and exit of lorries (or other equipment), traffic (both pedestrian and automobile) will be controlled to prevent possible accidents or being run over.

3.8. Risk identification and assessment

This risk analysis forecast must come from the documentation of the acting company/companies (in accordance with the provisions of Chapter III of Law 31/1995), which will have been drawn up based on Article 4.3 of the Prevention Services Regulations, and prepared on paper before the start of the works; this is a prior work necessary for the specification of the foreseeable risk scenarios during the execution of the works, therefore, and as recommended in the Technical Guide for Construction Works published by the INSHT. A realistic approximation of what can happen on site is set out.
The following risk analysis and assessment was carried out in accordance with the INSHT, both on the project of the work and as a consequence of the technology used.
In any case, the risks analysed here will be resolved by means of the necessary collective protection, individual protection equipment and signalling, in order to neutralise or minimise them.

Method used in the risk assessment

The method used makes it possible to carry out, by direct assessment of the situation, an evaluation of the risks for which there is no specific regulation as such. The method is as follows.

1st - Definition of the seriousness of the consequences:

The severity of the consequences that may be caused by the hazard in the form of harm to the worker. Consequences can be slightly harmful, harmful, or extremely harmful. Examples are shown below.

Slightly harmful	Examples: -Small cuts and bruises -Dust irritation of the eyes -Headaches -Discomfort -Discomfort and irritation
Harmful	Examples: -Cuts -Burns -Concussions -Major sprains -Minor fractures -Deafness -Asthma -Dermatitis Musculo-skeletal disorders -Musculoskeletal disorders Minor illness leading to minor incapacity - Disease leading to minor disability
Extremely harmful	Examples: -Electrocution -Amputations -Major fractures -Intoxications -Multiple injuries -Cancer and other chronic illnesses that severely shorten life

2°-Probability:

Once the severity of the consequences has been determined, the probability of such a situation occurring can be low, medium or high:

Low	It is very rare for damage to occur
Medium	Damage will occur on some occasions
High	Whenever this situation arises, damage is likely to occur.

This method is applied to each work unit analysed in this safety report and which corresponds to the construction process of the installation, in order to allow "the identification and evaluation of risks, but with the assessment of the effectiveness of the prevention adopted and applied".

In other words, the risks initially detected in each work unit are analysed and evaluated, eliminating or reducing their consequences by adopting technical and organisational solutions, changes in the construction process, adoption of preventive measures, use of collective protection, PPE and signage, until a trivial, tolerable or moderate risk is achieved, and being weighted by applying the established criteria for occupational accidents published by the General Directorate of Statistics of the Ministry of Labour and Social Affairs.

5º-Code of interpretation of abbreviations:

Probabilidad	Protección	Consecuencias	Estimación del riesgo	
B Baja M Media A Alta	c Colectiva i Individual	Ld Ligeramente dañino D Dañino Ed Extremadamente dañino	T Riesgo trivial To Riesgo tolerable M Riesgo moderado	I Riesgo importante In Riesgo intolerable

Preliminary work. General activities

- Organisation on the construction site

ANÁLISIS Y EVALUACIÓN INICIAL DE RIESGOS

Actividad: **La organización en el lugar en el que se va a construir** — Lugar de evaluación: **sobre planos**

Nombre del peligro identificado	Probabilidad			Protección		Consecuencias			Estimación riesgo				
	B	M	A	c	I	Ld	D	Ed	T	To	M	I	In
Sobreesfuerzos, golpes y atrapamientos durante el montaje de elementos de obra.	X				X	X			X				
Caídas al mismo nivel por irregularidades del terreno, barro, escombros...	X				X	X			X				
Caídas a distinto nivel por rampas, escaleras, laderas de fuerte pendiente...	X				X		X			X			
Golpes contra o por objetos	X				X		X			X			
Atropellos	X			X			X				X		

Interpretación de las abreviaturas

Probabilidad	Protección	Consecuencias	Estimación del riesgo	
B Baja M Media A Alta	c Colectiva i Individual	Ld Ligeramente dañino D Dañino Ed Extremadamente dañino	T Riesgo trivial To Riesgo tolerable M Riesgo moderado	I Riesgo importante In Riesgo intolerable

- Installation of collective protection.

ANÁLISIS Y EVALUACIÓN INICIAL DE RIESGOS													
Actividad: **Colocación protecciones colectivas.**								Lugar de evaluación: **sobre planos**					
Nombre del peligro identificado	Probabilidad			Protección		Consecuencias			Estimación del riesgo				
	B	M	A	c	i	Ld	D	Ed	T	To	M	I	In
Sobre esfuerzos, golpes y atrapamientos por la manipulación de equipos	X				X	X			X				
Caídas al mismo nivel	X				X	X			X				
Caídas a distinto nivel	X				X		X			X			
Caídas de altura por perímetro, lucernarios, claraboyas, y fallo estructura cubierta	X				X		X					X	
Golpes contra o por objetos	X				X		X			X			
Corte con objetos y máquinas herramientas													

Interpretación de las abreviaturas				
Probabilidad	Protección	Consecuencias	Estimación del riesgo	
B Baja M Media A Alta	c Colectiva i Individual	Ld Ligeramente dañino D Dañino Ed Extremadamente dañino	T Riesgo trivial To Riesgo tolerable M Riesgo moderado	I Riesgo importante In Riesgo intolerable

- Stakeout on roof

ANÁLISIS Y EVALUACIÓN INICIAL DE RIESGOS													
Actividad: **Replanteo sobre cubierta**								Lugar de evaluación: **sobre planos**					
Nombre del peligro identificado	Probabilidad			Protección		Consecuencias			Estimación del riesgo				
	B	M	A	c	i	Ld	D	Ed	T	To	M	I	In
Sobre esfuerzos, golpes y atrapamientos por la manipulación de equipos	X				X	X			X				
Caídas al mismo nivel	X				X	X			X				
Caídas a distinto nivel	X				X		X			X			
Caídas de altura	X				X		X					X	
Golpes contra o por objetos	X				X		X			X			

Interpretación de las abreviaturas				
Probabilidad	Protección	Consecuencias	Estimación del riesgo	
B Baja M Media A Alta	c Colectiva i Individual	Ld Ligeramente dañino D Dañino Ed Extremadamente dañino	T Riesgo trivial To Riesgo tolerable M Riesgo moderado	I Riesgo importante In Riesgo intolerable

- Receipt of machinery, auxiliary means and assemblies

ANÁLISIS Y EVALUACIÓN INICIAL DE RIESGOS													
Actividad: **Recepción de maquinaria, medios auxiliares y montajes.**								Lugar de evaluación: **sobre planos**					
Nombre del peligro identificado	**Probabilidad**			**Protección**		**Consecuencias**			**Estimación del riesgo**				
	B	**M**	**A**	**c**	**i**	**Ld**	**D**	**Ed**	**T**	**To**	**M**	**I**	**In**
Caída a distinto nivel, (salto desde la caja del camión al suelo de forma descontrolada, empujón por penduleo de la carga).	X						X			X			
Sobresfuerzos por manejo de objetos pesados.	X				X	X			X				
Caídas a nivel o desde escasa altura, (caminar sobre el objeto que se está recibiendo o montando).	X				X	X			X				
Atrapamiento entre piezas pesadas.	X				X	X			X				
Cortes por manejo de herramientas o piezas metálicas.	X				X	X			X				

Interpretación de las abreviaturas

Probabilidad	Protección	Consecuencias	Estimación del riesgo	
B Baja M Media A Alta	c Colectiva i Individual	Ld Ligeramente dañino D Dañino Ed Extremadamente dañino	T Riesgo trivial To Riesgo tolerable M Riesgo moderado	I Riesgo importante In Riesgo intolerable

- Collection of materials

ANÁLISIS Y EVALUACIÓN INICIAL DE RIESGOS													
Actividad: **Acopio de materiales**								Lugar de evaluación: **sobre planos**					
Nombre del peligro identificado	**Probabilidad**			**Protección**		**Consecuencias**			**Estimación del riesgo**				
	B	**M**	**A**	**c**	**i**	**Ld**	**D**	**Ed**	**T**	**To**	**M**	**I**	**In**
Caída a distinto nivel, (salto desde la caja del camión al suelo de forma descontrolada, empujón por penduleo de la carga).	X						X			X			
Sobresfuerzos por manejo de objetos pesados.	X				X	X			X				
Caídas a nivel o desde escasa altura, (caminar sobre el objeto que se está recibiendo o montando).	X				X	X			X				
Atrapamiento entre piezas pesadas por penduleo en la descarga y ubicación.	X				X	X			X				
Cortes por manejo de herramientas o piezas metálicas.	X				X	X			X				

Interpretación de las abreviaturas

Probabilidad	Protección	Consecuencias	Estimación del riesgo	
B Baja M Media A Alta	c Colectiva i Individual	Ld Ligeramente dañino D Dañino Ed Extremadamente dañino	T Riesgo trivial To Riesgo tolerable M Riesgo moderado	I Riesgo importante In Riesgo intolerable

- Assembly of support structure and fv plates

ANÁLISIS Y EVALUACIÓN INICIAL DE RIESGOS													
Actividad: **Montaje de estructura soporte y placas fv**								Lugar de evaluación: **sobre planos**					
Nombre del peligro identificado	Probabilidad			Protección		Consecuencias			Estimación del riesgo				
	B	M	A	c	i	Ld	D	Ed	T	To	M	I	In
Desprendimiento de los acopios de piezas	X				X		X			X			
Golpes en las manos	X				X	X			X				
Caída desde altura por golpe de penduleo de la carga	X			X	X		X				X		
Caída desde altura de las piezas prefabricadas, durante las maniobras de izado y reparto. (montantes, elementos metálicos, paneles....	X				X		X			X			
Caída de objetos desde altura durante trabajo	X			X	X			X				X	
Caída de personas a distinto nivel, al caminar o trabajar sobre lucernarios o aleros de cubierta.	X			X	X		X			X			
Caída de personas desde altura por los lucernarios o aleros de cubierta.	X			X	X		X				X		
Caída de personas al mismo nivel (obra sucia, desorden).	X				X	X			X				
Proyección violenta de partículas (viento fuerte…).	X			X	X		X			X			
Cortes al utilizar los tronzadores manuales (ausencia o neutralización de la protección del disco).		X		X	X		X				X		
Electrocución por anulación de tomas de tierra de la maquinaria eléctrica o por conexiones peligrosas, (empalmes directos con cable desnudo; empalmes con cinta aislante simple; cables lacerados o rotos).		X		X	X		X					X	
Sobresfuerzos por posturas obligadas, carga al hombro de objetos pesados.	X				X	X			X				
Golpes en general por objetos en manipulación.	X				X	X			X				
Pisadas sobre objetos punzantes (desorden de obra).	X				X	X			X				
Los riesgos derivados de trabajos sobre superficies de cubierta mojadas (resbalones; caídas).	X				X	X			X				
Caída de objetos sobre las personas (tornillería, elementos metálicos,).	X						X			X			
Atrapamiento por manejo de elementos metálicos.	X				X		X				X		
Quemaduras por chapas metálicas expuestas al sol	X				X		X			X			
Quemaduras por el sol		X			X		X			X			
Estrés térmico por calor (golpe de calor en verano) o frío (en invierno)		X			X		X				X		

- Work on the roof

ANÁLISIS Y EVALUACIÓN INICIAL DE RIESGOS													
Actividad: **Cubierta inclinada.**								Lugar de evaluación: **sobre planos**					
Nombre del peligro identificado	Probabilidad			Protección		Consecuencias			Estimación del riesgo				
	B	M	A	c	i	Ld	D	Ed	T	To	M	I	In
Caída de personas desde altura, (ausencia de petos; huecos horizontales).	X			X	X		X			X			
Caída de personas a distinto nivel, (huecos horizontales).	X			X	X		X			X			
Caída de personas al mismo nivel, (desorden, inclinación de la cubierta…).	X				X		X			X			
Caída de objetos a niveles inferiores.	X			X	X		X				X		
Sobresfuerzos, (trabajar de rodillas, agachado o doblado durante largo tiempo; sustentación de objetos pesados).		X			X	X				X			
Contacto con elementos calientes (quemaduras).	X				X	X			X				
Quemaduras causadas por la exposición al sol	X				X	X			X				
Golpes o cortes por manejo de herramientas manuales.	X				X	X			X				
Los derivados del uso de medios auxiliares.	X			X	X		X			X			

- Laying and installation of de-energised electrical wiring and grid trays

ANÁLISIS Y EVALUACIÓN INICIAL DE RIESGOS													
Actividad: **Tendido e instalación cableado eléctrico sin tensión y bandejas de rejilla.**								Lugar de evaluación: **sobre planos**					
Nombre del peligro identificado	Probabilidad			Protección		Consecuencias			Estimación del riesgo				
	B	M	A	c	i	Ld	D	Ed	T	To	M	I	In
Caída de personas desde altura, (ausencia de petos; huecos horizontales).	X			X	X		X			X			
Caída de personas a distinto nivel, (huecos horizontales).	X			X	X		X			X			
Caída de personas al mismo nivel, (desorden, inclinación de la cubierta…).	X				X		X			X			
Caída de objetos a niveles inferiores.	X			X	X		X				X		
Sobresfuerzos, (trabajar de rodillas, agachado o doblado durante largo tiempo; sustentación de objetos largos y/o voluminosos).		X			X	X				X			
Contacto con elementos calientes (elementos metálicos expuestos al sol: quemaduras).	X				X	X			X				
Quemaduras causadas por la exposición al sol	X				X	X			X				
Golpes o cortes por manejo de herramientas manuales.	X				X	X			X				
Los derivados del uso de medios auxiliares.	X			X	X		X			X			

By trades and/or tasks whose intervention is subject to the prevention of occupational risks

- Technical Staff

ANÁLISIS Y EVALUACIÓN INICIAL DE RIESGOS													
Actividad: **Personal técnico**						Lugar de evaluación: **sobre planos**							
Nombre del peligro identificado	Probabilidad			Protección		Consecuencias			Estimación del riesgo				
	B	M	A	c	i	Ld	D	Ed	T	To	M	I	In
Sobresfuerzos, golpes y atrapamientos por la manipulación de equipos	X				X	X			X				
Caídas de altura por: perímetros, huecos, faldones de cubierta con fuerte pendiente…	X						X				X		
Caídas al mismo nivel	X				X	X			X				
Caídas a distinto nivel por: perímetros, huecos faldones…).	X				X		X			X			
Hundimiento de la superficie de apoyo	X			X	X		X			X			
Golpes y/o Atrapamientos por los medios de elevación y transporte de cargas a gancho.	X				X		X			X			
Estrés /Carga mental	X						X			X			
Los derivados del padecimiento de enfermedades no detectadas: epilepsia, vértigo.	X							X			X		

- Assembler/Officer

ANÁLISIS Y EVALUACIÓN INICIAL DE RIESGOS													
Actividad: **Montador/Oficial**									Lugar de evaluación: **sobre planos**				
Nombre del peligro identificado	Probabilidad			Protección		Consecuencias			Estimación del riesgo				
	B	M	A	c	i	Ld	D	Ed	T	To	M	I	In
Caída de personas desde altura, (trabajos en cubierta, rodar por la pendiente).	X			X	X		X			X			
Caída de personas al mismo nivel, (rodar por la cubierta con recogida).	X				X		X			X			
Caída de personas a distinto nivel, (huecos en el suelo, lucernarios).	X			X	X		X			X			
Caída de objetos a niveles inferiores.	X				X		X				X		
Sobresfuerzos, (trabajar de rodillas; agachado o doblado durante largo tiempo; sustentación de objetos pesados).		X			X	X				X			
Quemaduras con la chapa de cubierta por exposición al sol.	X				X	X			X				
Golpes o cortes en las manos y pies por manejo de herramientas manuales.	X				X	X			X				
Golpes o cortes en las manos y pies por manejo de piezas metálicas.	X				X	X			X				
Hundimiento de la superficie de apoyo	X			X	X		X			X			
Golpes y/o Atrapamientos por los medios de elevación y transporte de cargas.	X						X			X			
Los derivados del uso de medios auxiliares.	X						X			X			
Atrapamientos entre objetos en fase de montaje.	X				X		X			X			
Los derivados del padecimiento de enfermedades no detectadas: epilepsia, vértigo.	X							X			X		
Quemaduras por chapas metálicas expuestas al sol	X				X		X			X			
Quemaduras por el sol		X			X		X			X			
Estrés térmico por calor (golpe de calor en verano) o frío (en invierno)		X			X		X				X		

Machinery foreseen for carrying out the work

- Truck with transport boom/plume

ANÁLISIS Y EVALUACIÓN INICIAL DE RIESGOS

Actividad: **Camión con brazo/pluma de transporte** — Lugar de evaluación: **sobre planos**

Nombre del peligro identificado	Probabilidad			Protección		Consecuencias			Estimación del riesgo				
	B	M	A	c	i	Ld	D	Ed	T	To	M	I	In
Atropello de personas por: (maniobras en retroceso; ausencia de señalista; espacio angosto).	X						X			X			
Vuelco del camión grúa por: (superar obstáculos del terreno; errores de planificación).	X						X			X			
Atrapamientos, (maniobras de carga y descarga).	X						X			X			
Golpes por objetos, (maniobras de carga y descarga).		X					X				X		
Caídas al subir o bajar a la zona de mandos por lugares imprevistos.		X					X				X		
Desprendimiento de la carga por eslingado peligroso.	X							X			X		
Golpes por la carga a paramentos verticales u horizontales durante las maniobras de servicio.	X						X			X			
Ruido.		X			X	X			X				
Contacto eléctrico directo o por arco voltaico	X			X			X					X	

- Machine tools in general (radials, cutters, electric drills, etc.).

ANÁLISIS Y EVALUACIÓN INICIAL DE RIESGOS

Actividad: **Máquinas herramienta eléctricas en general: radiales, cizallas, cortadoras, taladro eléctrico…y asimilables.** — Lugar de evaluación: **sobre planos**

Nombre del peligro identificado	Probabilidad			Protección		Consecuencias			Estimación del riesgo				
	B	M	A	c	i	Ld	D	Ed	T	To	M	I	In
Cortes por: (el disco de corte; proyección de objetos; voluntarismo; impericia).		X			X		X				X		
Quemaduras por: (el disco de corte; tocar objetos calientes; voluntarismo; impericia).		X			X	X				X			
Golpes por: (objetos móviles; proyección de objetos).		X			X		X				X		
Proyección violenta de fragmentos, (materiales o rotura de piezas móviles).		X			X		X				X		
Caída de objetos a lugares inferiores.		X					X				X		
Contacto con la energía eléctrica, (anulación de protecciones; conexiones directas sin clavija; cables lacerados o rotos).		X					X				X		
Vibraciones.		X			X		X				X		
Ruido.		X			X	X				X			
Polvo.		X			X	X				X			
Sobre esfuerzos, (trabajar largo tiempo en posturas obligadas).		X			X	X				X			

3.9. Collective protection to be used on site

From the analysis of occupational risks that has been carried out and the specific problems posed by the construction/installation on site, it is planned to use the following:

- Covering of skylights to protect against falls from height.
- Perimeter fencing to protect against falls from height.
- 300mA selective calibrated differential circuit breaker against indirect contacts.
- Multi-purpose fire extinguishers, efficiency 21A 113 B C.
- Temporary lifeline for anchoring workers while installing the collective PRL.

3.10. Personal protective equipment to be used on site

From the risk analysis carried out, it can be seen that there are a number of risks which could not be resolved by installing collective protection. These are risks intrinsic to the individual activities to be carried out by the workers and by the rest of the people involved in the work. Consequently, it has been decided to use:

- Safety helmets, assessed for safety according to the UNE-EN397 standard.
- Tool belts.
- Safety goggles against projections and impacts, and sun protection, assessed for safety according to UNE-EN 166.
- Full grain leather and canvas gloves, safety assessed according to UNE-EN 388.
- Filtering paper dust mask, safety assessed according to UNE en 1827 and UNE-EN 140.
- Work clothes based on cotton jacket and trousers, according to UNE EN 340.
- Reinforced canvas and split leather safety boots with synthetic plastic soles, according to UNE-EN 344, UNE-EN 345 and UNE-EN 346.
- Harness for anchoring workers to the temporary lifeline while they install the collective PRL.

3.11. Signposting of risks

In order to improve its effectiveness, the designed prevention requires the use of the following list of signage as a complement to the collective protection and the PPE provided. It has been decided to use standardised signage to remind all those working on the site or those approaching from outside of the site of the existing risks at all times.

- Warning of suspended loads
- Warning of undetermined danger
- Warning of electrical hazards
- Warning of fire; flammable materials.
- Hazard warning strip.
- Mandatory head protection, according to UNE-EN 397.
- Mandatory hand protection, according to UNE-EN 388.
- Obligatory ear protection, according to UNE-EN 352.
- Compulsory foot protection.
- Compulsory eye protection.
- First aid equipment.

3.12. Measures for assistance in the event of an accident at work

Although the overall objective of this EBSS is to prevent accidents at work, there are causes that are difficult to control that may cause them to happen. It is therefore necessary to make provision for first aid to attend to those who may be affected.

Wounds and small cuts on the skin:

Although apparently not serious, when the skin is broken, they alter its protective barrier function. As a result, they create an entry point for possible infection, which can become a major complication.

When this type of wound occurs, we can see its extent with the naked eye, but do not trust it if it is not very extensive as it may be deep, e.g. caused by a nail or a piece of metal.

Prevention: Remove all boards and metal elements and keep the cuts clean.

First aid:

- Clean the wound with soap and water or antiseptic product to prevent risk of infection.
- Dry the wound thoroughly and protect it with a plaster or gauze.
- Consult a doctor about the appropriateness of tetanus vaccination.
- Do not apply alcohol, ointments or powders containing antibiotics to the wound. Do not use cotton wool as it frays easily.

-For nosebleed wounds: plug the nose with two fingers, leaning forward (if we do it backwards, the victim will swallow the blood), for 10 minutes. If the wound does not stop bleeding, insert a gauze plug soaked in hydrogen peroxide, and seek medical assistance for the injured person.

Foreign bodies:

- In eyes: if the body is small and free (speck of dust, sawdust, etc.) try to drag it out with a gauze by making the patient blink frequently. Do not rub the eye. If you do not manage to drag it out, do not insist, go to the nearest emergency centre indicated in section 4.2 of this document.
- In ears: never attempt to remove a foreign body lodged in the ear with pins or other sharp objects. Do not pour water, especially cold water. Put the patient in expert hands if you see the slightest difficulty in removing the foreign body.
- In the nose: try to expel it by forced expiration ("blowing"), pressing the nostril that is not obstructed against the nasal septum. Do not introduce water or manipulate with sharp objects. If it does not come out, consult a doctor.
- On the skin: if it is a splinter, metal tip or bulky object, try to remove it carefully. If we notice the slightest resistance, stop the attempt.

Injuries to the joints:

Usually caused by falls, bad footing, slipping, etc. The symptoms by which we can recognise a sprain (strain) or dislocation (a bone slipping out of place) are:

- Localised pain in the damaged joint.
- Inflammation or swelling in the area (deformity in the case of dislocation).
- Difficulty in making movements (more or less marked in the case of sprains and very noticeable in the case of dislocations).
- Comparing the affected joint with the healthy joint.

First aid:

- Keep the injured area at rest and apply cold (ice) to it.
- Immobilise the affected area with a bandage or with the help of a triangular scarf.
- Take the injured person to the nearest health centre for assessment.

Bone injuries (fractures):

Usually caused by falls; they are of the open type when there is injury to the skin, or closed if there is no injury to the skin. The open type is the more dangerous of the two as the wound can cause infection of the bone.

First aid:

- Do not move the injured person, or allow him/her to move the supposedly injured area. This will help to control the pain.
- Handle, if necessary and essential, the injured area with extreme care.
- Immobilise (by means of scarves, cloth strips, sticks, padded splints, etc.) the area where the fracture is suspected to be, to avoid aggravating the fracture.
- Transport the affected person to the nearest health centre or call the emergency number.

Burns:

May be: 1st degree (reddening skin), 2nd degree (appearance of blisters with clear fluid inside), or 3rd degree (appearance of blackish or dark brown crust).
First aid:

- Cool the affected area immediately with cold water for 10-20 minutes.
- Cover the burn with clean cloths.
- Do not remove clothing near the burn, as it may be stuck to the skin. Only remove clothing if it is soaked in very hot liquids or caustic products (bleach, diluted hydrochloric acid, ammonia, etc.) to prevent further burning.
- Do not prick the blisters in the case of 2nd degree burns, as they can become infected.
- If the person is on fire, prevent them from running; extinguish the flames with a blanket or similar, or by rolling them on the floor.
- Systematically ensure that any person who has suffered a burn is examined by a doctor so that the most appropriate treatment can be prescribed for each type of injury.
- Avoid using on burns: oil, vinegar, toothpaste, mud, etc.; although they may relieve the pain momentarily, they can have a negative effect on the healing of the damaged area. It is best to use water.

Electrical accidents: electrocution.

First of all, it is essential to make sure that the victim is not in contact with the current before touching him. In the event that he is still in electrical contact:

A. If it is low voltage, the first thing to do is to cut off the electrical supply. Otherwise:
    - Isolate yourself from the ground (with wooden planks) and try to separate the victim from the current, with the help of a wooden stick (broom). Do not use metal objects.
    - Once out of danger, assess the victim's condition and start cardiopulmonary resuscitation if necessary.

B. In the case of medium or high voltage, do not try to separate the victim from the electrical cable, as a piece of wood would not be sufficient insulation. Notify the electricity company to cut off the power supply and the emergency services at the same time.

Cardiopulmonary resuscitation ("mouth-to-mouth" and cardiac massage):

1. Place the victim in a horizontal position with the head tilted back and see if the victim is breathing. If the victim is not breathing, start mouth-to-mouth resuscitation, giving two consecutive breaths, and check the carotid pulse (on both sides of the "nut").

2. If there is a pulse, continue artificial respiration at a rate of approximately 12 breaths per minute.

3. If there is no pulse, start basic cardiopulmonary resuscitation (artificial respiration + cardiac massage), at a rate of 2 breaths every 15 compressions, maintaining a rate of 80-100 compressions per minute.

-Cardiac massage should be performed on a firm surface.
-Periodically check for the return of spontaneous pulse, which would mean that resuscitation has been successful.

-Cardiac massage should be performed over the lower third of the sternum. To be effective, the rib cage must be sunk 4-5cm and it must be rhythmic.

Evacuation of injured persons:

The evacuation of casualties, who, due to their injuries, require it, is provided for by the ambulance service notified via 112. Emergency measures:

FIRST

In the event of an accident, remain calm and have the emergency number shown below in a visible place from the telephone:

<u>112</u>

SECOND

The first aid kit shall be located in a place that is easy to find and known by all the workers, and shall be accessible.

THIRD

The following recommendations and rules are established in the event of possible accidents:

1. Warn and ask for help.
2. Speak to the victim and ask what has happened or how he/she is feeling.
3. Do not move the injured person if it is not strictly necessary, so as not to aggravate the accident.
4. Assess the extent of the injury.
5. Reassure the injured person.
6. Call the emergency service (112) if necessary and explain what happened.
7. Wait for the arrival of specialised personnel.
8. Act only if necessary: burns, electrocution...
9. Notify the Technical Management

-The contractor will inform the Health and Safety Coordinator in the execution phase, if there is one, immediately of any accident regardless of its seriousness, so that the latter is aware of it.

-Similarly, it is obliged to draw up an accident investigation report when required to do so by the Health and Safety Coordinator in the execution phase, its drafting being obligatory in the case of serious, very serious or fatal accidents.

3.13. Works subsequent to the work

The work to be carried out after the work consists mainly of periodic maintenance (cleaning, adjustment or repair) of the PV panels, their wiring or the supporting structure. This requires access of workers to the roof with the risks mentioned above, mainly the risk of falling from height. The preventive or protective measures to be taken, except for edge protection, will be the same as those contemplated in this document for the installation phase, and this EBSS will be used for the execution of said works. It shall remain in the hands of the Owner, who shall take custody of this document and shall hand it over to the workers attending the workplace, in order to comply with the provisions of Art.4 of RD171/2004. If necessary, they must review the preventive documentation in order to adapt it to the conditions of the installation.

The following rules and instructions should be considered:
Cleaning of fv modules:

- Attention must be paid to the risk of slipping due to spilled water. To reduce this risk, safety shoes with non-slip soles must be worn.
- At times of the year with higher levels of solar radiation, protective gloves for the hands and sun cream should be used to avoid sunburn. Water acts as a magnifying glass for solar radiation.
- Avoid contact between water and accessible live parts.
- NEVER handle live parts, especially during the cleaning operation as this will increase the humidity.

Inverter operation:

- Special attention must be paid to electrical hazards. Make sure that the power supply to the inverter is disconnected. Due to the nature of inverter operation (presence of capacitors) it is necessary to wait for a period of time, called discharge time (approx. 60s) before acting on the inverter. ALWAYS use a multimeter to verify the absence of voltage.
- If it is not possible to carry out the work without voltage, insulated gloves suitable for the rated voltage must be used, with work gloves on them, insulated tool, spray mask.

Operation on PV modules:

- PV modules are a source of electrical energy; therefore the risk of electrical contact will always be present if exposed to radiation.
- When working on a module ALWAYS disconnect it from the series.
- NEVER touch the inside of the connectors of the PV module when it is under solar radiation. If it is necessary to work on the connectors, ALWAYS isolate the PV module beforehand, or turn it upside down or cover it with an opaque element.
- The same safety measures shall be taken in the case of having to work on the diode box of the PV module.
- ALWAYS work on firm, mainly dry ground.
- When transporting a PV module on deck, attention must be paid to the wind, as the module can act as a sail.
- The temperature of the fv module can sometimes be high, so gloves must be worn, and it is essential to use them in the summer season.

3.14. Other considerations and prohibitions

- It is forbidden to carry weights equal to or greater than 25 kg by hand (or by shoulder) on this construction site.
- Walking on the skylights is prohibited.
- It is forbidden to connect cables to the electrical supply panels on site without the use of the appropriate male-female plugs for this purpose.

- The ladders to be used shall be of the "scissor" type, equipped with non-slip shoes and an opening limiting chain, to avoid risks due to work carried out on slippery, unsafe or narrow surfaces.
- It is forbidden to erect scaffolding using stepladders in the form of a trolley, in order to avoid risks due to work on unsafe and narrow surfaces.
- The tools to be used by electricians and fitters must be protected against electrical contact by standardised insulating material.
- Electrical cutting or drilling tools may not be left on the ground or left running, even if they are in residual motion.

3.15. Procedure for notifying new actions

In the event of new actions to be carried out that are not contemplated in the safety plan, the contractor is obliged to notify the health and safety coordinator in the execution phase, sufficiently in advance, and to send him an annex to the EBSS for its subsequent approval. Work on the said annex to the EBSS may not commence until such approval has been given.

3.16. SS level control appointment documents

These documents are applicable during the performance of the awarded work. It is envisaged to use the same documents normally used for this function by the awarded contractor, in order not to interfere with his own organisation of risk prevention. As a minimum, it is envisaged to use the following contents:

- Document of appointment of the Preventive Resource Presence, if necessary.
- Document authorising the operation of various machines.

Control of access to the site

The contractor will consider authorised personnel, both of its subcontractors and self-employed workers, if they exist, as well as its own workers, to be all those who have the following documentation in order:

- Identification documentation
- PRL course
- Medical certificate

This documentation will be requested and checked by the contractor's personnel prior to the entry of said personnel on site.

3.17. Training and information on health and safety

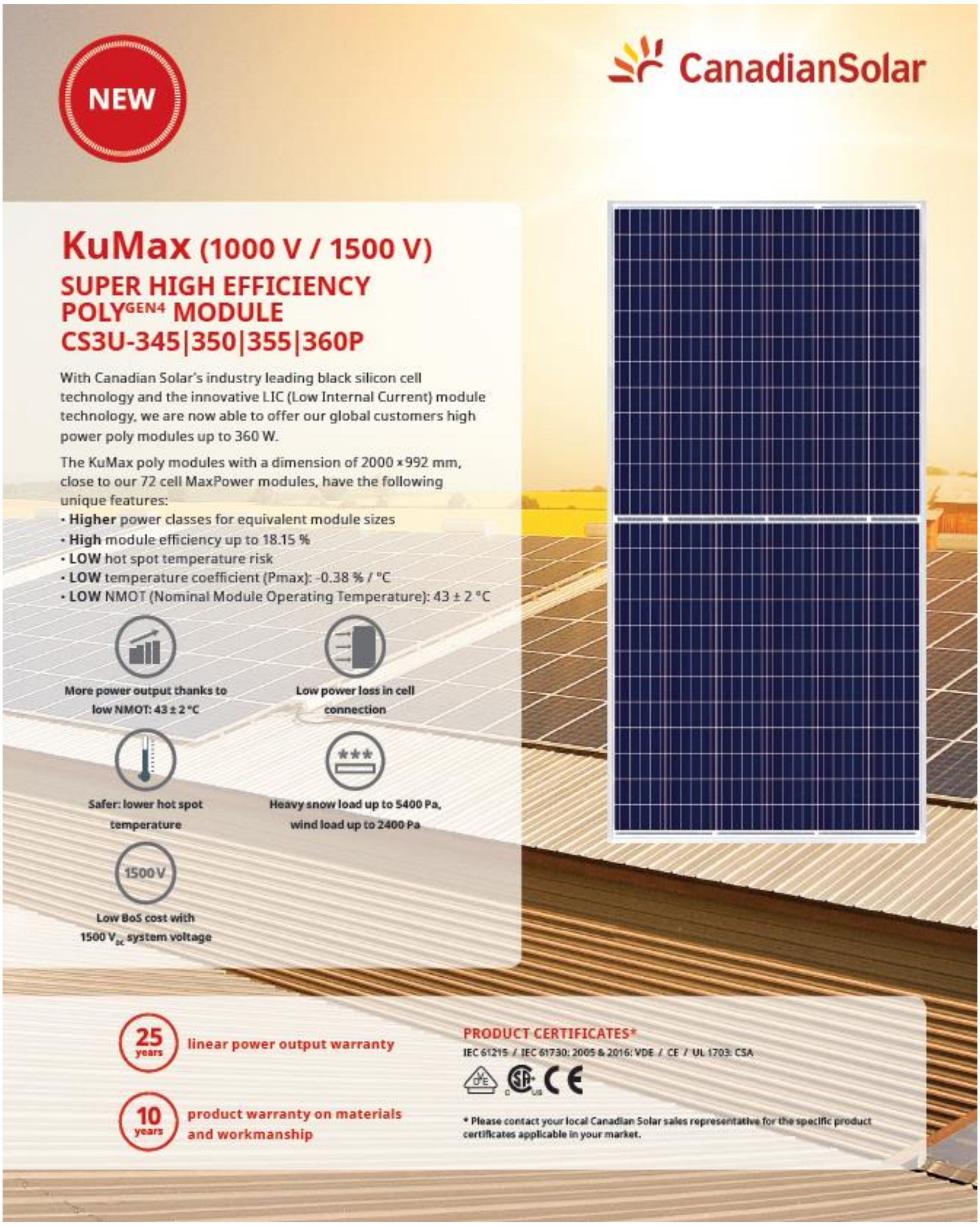
The training and information of workers in occupational hazards and in the safe working methods to be used are essential for the successful prevention of occupational hazards and to carry out the work without accidents. Therefore, workers will be informed (Art.18 LPRL), and will receive the relevant theoretical and practical training, sufficient, adequate and in accordance with the requirements of the current General Agreement of the Construction Sector 2007/2011, in order to satisfy Art.12 of RD 1109/2007. Thus, all workers shall be aware of the risks inherent to their work activity and the correct use of collective protection and personal protective equipment.

3.18. Penalties

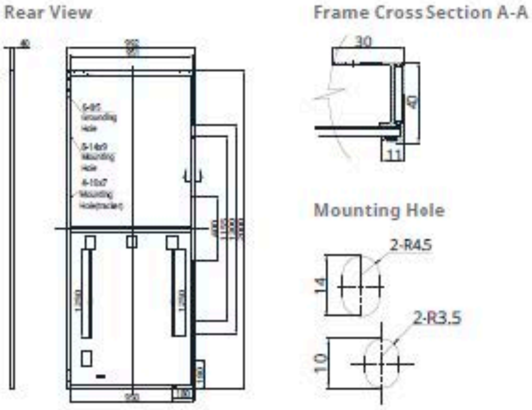
The Proprietor may take disciplinary measures against companies that repeatedly fail to comply with the Safety Regulations. Disciplinary measures that The Owner may adopt unilaterally (being compatible with and independent of those that may be imposed on the companies for other circumstances contemplated in the legislation in force):

- Prohibition of access to the site
- Economic withholdings via invoicing
- Termination of the contract, etc.

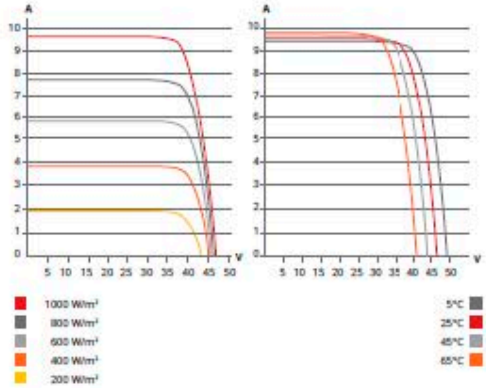
ANNEX IV - TECHNICAL DOCUMENTATION -



ENGINEERING DRAWING (mm)



CS3U-355P / I-V CURVES



ELECTRICAL DATA | STC*

CS3U	345P	350P	355P	360P
Nominal Max. Power (Pmax)	345 W	350 W	355 W	360 W
Opt. Operating Voltage (Vmp)	39.0 V	39.2 V	39.4 V	39.6 V
Opt. Operating Current (Imp)	8.86 A	8.94 A	9.02 A	9.10 A
Open Circuit Voltage (Voc)	46.4 V	46.6 V	46.8 V	47.0 V
Short Circuit Current (Isc)	9.43 A	9.51 A	9.59 A	9.67 A
Module Efficiency	17.39%	17.64%	17.89%	18.15%
Operating Temperature	-40°C ~ +85°C			
Max. System Voltage	1000 V (IEC / UL) or 1500 V (IEC / UL)			
Module Fire Performance	TYPE 1 (UL 1703) or CLASS C (IEC 61730)			
Max. Series Fuse Rating	30 A			
Application Classification	Class A			
Power Tolerance	0 ~ + 5 W			

* Under Standard Test Conditions (STC) of irradiance of 1000 W/m2, spectrum AM 1.5 and cell temperature of 25°C.

MECHANICAL DATA

Specification	Data
Cell Type	Poly-crystalline, 156.75 × 78.38 mm
Cell Arrangement	144 [2 × (12 × 6)]
Dimensions	2000 × 992 × 40 mm (78.7 × 39.1 × 1.57 in)
Weight	22.6 kg (49.8 lbs)
Front Cover	3.2 mm tempered glass
Frame	Anodized aluminium alloy, crossbar enhanced
J-Box	IP68, 3 diodes
Cable	4.0 mm² & 12 AWG
Cable Length	1670 mm (65.7 in)
Connector	T4 (IEC / UL)
Per Pallet	27 pieces
Per Container (40' HQ)	594 pieces

ELECTRICAL DATA | NMOT*

CS3U	345P	350P	355P	360P
Nominal Max. Power (Pmax)	255 W	259 W	263 W	266 W
Opt. Operating Voltage (Vmp)	35.6 V	35.8 V	36.0 V	36.1 V
Opt. Operating Current (Imp)	7.17 A	7.24 A	7.29 A	7.37 A
Open Circuit Voltage (Voc)	43.3 V	43.5 V	43.7 V	43.9 V
Short Circuit Current (Isc)	7.61 A	7.68 A	7.74 A	7.80 A

*Under Nominal Module Operating Temperature (NMOT), irradiance of 800 W/m2, spectrum AM 1.5, ambient temperature 20°C, wind speed 1 m/s.

TEMPERATURE CHARACTERISTICS

Specification	Data
Temperature Coefficient (Pmax)	-0.38 % / °C
Temperature Coefficient (Voc)	-0.29 % / °C
Temperature Coefficient (Isc)	0.05 % / °C
Nominal Module Operating Temperature	43±2 °C

PARTNER SECTION

The aforesaid datasheet only provides the general information on Canadian Solar products and, due to the on-going innovation and improvement, please always contact your local Canadian Solar sales representative for the updated information on specifications, key features and certification requirements of Canadian Solar products in your region.

Please be kindly advised that PV modules should be handled and installed by qualified people who have professional skills and please carefully read the safety and installation instructions before using our PV modules.

CANADIAN SOLAR (USA) INC. August 2017 | | PV Module Product Datasheet V5.552_E1_NA
3000 Oak Road, Suite 400, Walnut Creek, CA 94597, USA | www.canadiansolar.com/na | sales.us@canadiansolar.com

Inversor de String Inteligente

SUN2000-36KTL

Inteligente

- monitorización inteligente de 8 strings y resolución rápida de problemas.
- Soporte de comunicaciones por línea de alimentación eléctrica (PLC).
- Soporte de diagnóstico inteligente de curvas I-V.

Eficiente

- Máxima eficiencia del 98,8%, eficiencia europea del 98,6% (@480Vac)
- Máxima eficiencia del 98,6%, eficiencia europea del 98,4% (@380Vac / 400Vac)
- 4 MPPT para adaptarse de manera versátil a distintas disposiciones

Seguro

- Desconexión de CC integrada; mantenimiento seguro y práctico.
- Unidad de monitorización de la intensidad Residual (RCMU) integrada.
- Diseño sin fusibles.

Confiable

- Tecnología de enfriamiento natural.
- Clase de protección IP65.
- Protectores de sobreintensidad tipo II tanto para CC como para CA.

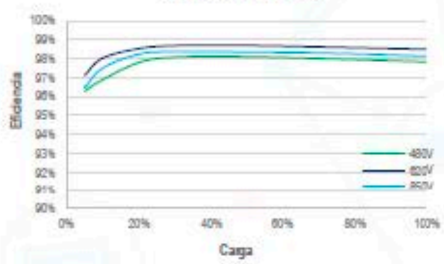
Inversor de String Inteligente (SUN2000-36KTL)

HUAWEI

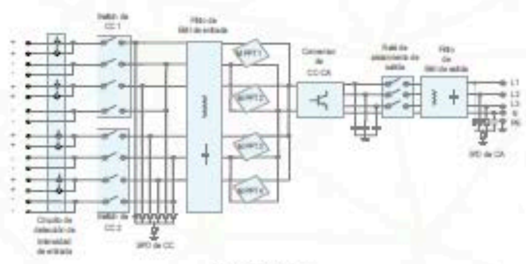
Especificaciones técnicas	SUN2000-36KTL
	Eficiencia
Eficiencia máxima	98.8% @480 Vac; 98.6% @380 Vac / 400 Vac
Eficiencia europea	98.6% @480 Vac; 98.4% @380 Vac / 400 Vac
	Entrada
Máx. tensión de entrada	1,100 V
Máx. intensidad por MPPT	22 A
Máx. intensidad de cortocircuito por MPPT	30 A
tensión de entrada inicial	250 V
Rango de tensión de operación de MPPT	200 V ~ 1000 V
tensión nominal de entrada	620 V @380 Vac / 400 Vac; 720 V @480 Vac
Máx. cantidad de entradas	8
Cantidad de MPPT	4
	Salida
Potencia nominal activa de CA	36,000 W
Máx. potencia aparente de CA	40,000 VA
Máx. potencia activa de CA (cosφ=1)	Default 40,000 W; 36,000 W optional in settings
tensión nominal de salida	220 V / 380 V, 230 V / 400 V, default 3W+N+PE; 3W-PE optional in settings 277V / 480 V, 3W+PE
Frecuencia nominal de red de CA	50 Hz / 60 Hz
intensidad de salida nominal	54.6 A @380 Vac, 52.2 A @ 400 Vac, 43.4 A @480 Vac
Máx. intensidad de salida	60.8 A @380 Vac, 57.8 A @400 Vac, 48.2 A @480 Vac
Factor de potencia ajustable	0.8 LG ... 0.8 LD
Máx. distorsión armónica total	< 3%
	Protección
Dispositivo de desconexión del lado de entrada	Sí
Protección contra funcionamiento en isla	Sí
Protección contra sobreintensidad de CA	Sí
Protección contra polaridad inversa de CC	Sí
monitorización de fallas en strings de sistemas fotovoltaicos	Sí
Protector contra sobreintensidad de CC	Tipo II
Protector contra sobreintensidad de CA	Tipo II
Detección de aislamiento de CC	Sí
Unidad de monitorización de la intensidad Residual	Sí
	Comunicación
Visualización	Indicadores LED, Bluetooth + APP
RS485	Sí
USB	Sí
Comunicación por líneas de alimentación eléctrica (PLC)	Sí
	General
Dimensiones (ancho x altura x profundidad)	930 x 550 x 283 mm (36.6 x 21.7 x 11.1 pulgadas)
Peso (con soporte de montaje)	62 kg (136.7 lb.)
Rango de temperatura de operación	-25 °C ~ 60 °C (-13°F ~ 140°F)
Enfriamiento	Convección natural
Altitud de operación	4,000 m (13,123 ft.)
Humedad relativa	0 ~ 100%
Conector de CC	Amphenol Helios H4
Conector de CA	Terminal de PG resistente al agua + Conector OT
Clase de protección	IP65
Topología	Sin transformador
	Cumplimiento de normas *(Más información disponible a pedido)*
Certificado	EN 62109-1/-2, IEC 62109-1/-2, IEC62116
Código de red	IEC 61727, BDEW 2008, G59/3, UTE C 15-712-1, CEI 0-16,CEI 0-21, RD661/2007, RD 1699/2011, RD 413/2014, PO 12.3, EN-50438-Turkey, EN-50438-Ireland, PEA, MEA, Resolution No.7, NRS 097-2-1

Curva de eficiencia

SUN2000-36KTL@400V



Esquema eléctrico



SUN2000-36KTL

Inversor de String Inteligente

SUN2000-60KTL-M0

Inteligente

- monitorización inteligente de 12 strings y resolución rápida de problemas.
- Soporte de comunicaciones por línea de alimentación eléctrica (PLC).
- Soporte de diagnóstico inteligente de curvas I-V.

Eficiente

- Máxima eficiencia del 98,9%, eficiencia europea del 98,7% (@480Vac)
- Máxima eficiencia del 98,9%, eficiencia europea del 98,7% (@380Vac / 400Vac)
- 6 MPPT para adaptarse de manera versátil a distintas disposiciones

Seguro

- Desconexión de CC integrada; mantenimiento seguro y práctico.
- Unidad de monitorización de la intensidad Residual (RCMU) integrada.
- Diseño sin fusibles.

Confiable

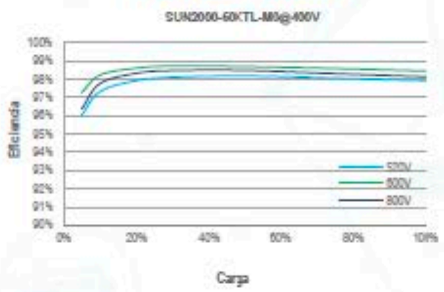
- Tecnología de enfriamiento natural.
- Clase de protección IP65.
- Protectores de sobreintensidad tipo II tanto para CC como para CA.

Inversor de String Inteligente (SUN2000-60KTL-M0)

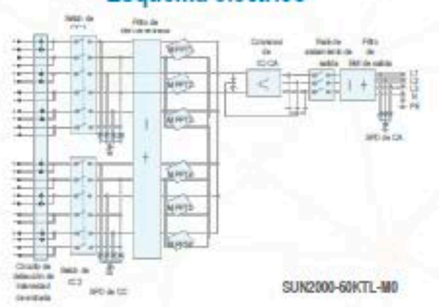
HUAWEI

Especificaciones técnicas	SUN2000-60KTL-M0
	Eficiencia
Eficiencia máxima	98.9% @480 Vac; 98.7% @380 Vac / 400 Vac
Eficiencia europea	98.7% @480 Vac; 98.5% @380 Vac / 400 Vac
	Entrada
Máx. tensión de entrada	1,100 V
Máx. intensidad por MPPT	22 A
Máx. intensidad de cortocircuito por MPPT	30 A
tensión de entrada inical	200 V
Rango de tensión de operación de MPPT	200 V~1,000 V
tensión nominal de entrada	600 V @380 Vac / 400 Vac; 720 V @480 Vac
Máx. cantidad de entradas	12
Cantidad de MPPT	6
	Salida
Potencia nominal activa de CA	60,000 W
Máx. potencia aparente de CA	66,000 VA
Máx. potencia activa de CA (cosφ=1)	66,000 W
tensión nominal de salida	220V / 380V, 230V / 400V, default 3W+N+PE; 3W+PE optional in settings 277V / 480V, 3W+PE
Frecuencia nominal de red de CA	50 Hz / 60 Hz
intensidad de salida nominal	91.2 A @380 Vac, 86.7 A @400 Vac, 72.2 A @480 Vac
Máx. intensidad de salida	100 A @380 Vac, 95.3 A @400 Vac, 79.4 A @480 Vac
Factor de potencia ajustable	0.8 LG ... 0.8 LD
Máx. distorsión armónica total	< 3%
	Protección
Dispositivo de desconexión del lado de entrada	Sí
Protección contra funcionamiento en isla	Sí
Protección contra sobreintensidad de CA	Sí
Protección contra polaridad inversa de CC	Sí
monitorización de fallas en strings de sistemas fotovoltaicos	Sí
Protector contra sobreintensidad de CC	Tipo II
Protector contra sobreintensidad de CA	Tipo II
Detección de aislamiento de CC	Sí
Unidad de monitorización de la intensidad Residual	Sí
	Comunicación
Visualización	Indicadores LED, Bluetooth + APP
RS485	Sí
USB	Sí
Comunicación por líneas de alimentación eléctrica (PLC)	Sí
	General
Dimensiones (ancho x altura x profundidad)	1,075 x 555 x 300 mm (42.3 x 21.9 x 11.8 pulgadas)
Peso (con soporte de montaje)	74 kg (163.1 lb.)
Rango de temperatura de operación	-25°C ~ 60°C (-13°F ~ 140°F)
Enfriamiento	Convección natural
Altitud de operación	4,000 m (13,123 ft.)
Humedad relativa	0 ~ 100%
Conector de CC	Amphenol Helios H4
Conector de CA	Terminal de PG resistente al agua + Arandela
Clase de protección	IP65
Topología	Sin transformador
	Cumplimiento de normas (Más información disponible a pedido)
Certificado	EN 62109-1/-2, IEC 62109-1/-2, EN 50530, IEC 62116, IEC 62910, IEC 60068, IEC 61683
Código de red	IEC 61727, VDE 4105/0126, UTE C 15-712-1, EN 50438, CLC/TS 50549-1, CEI 0-16/21, C10/11, RD 1699, PO 12.9

Curva de eficiencia



Esquema eléctrico



Cable eléctrico Cable 06/1 Kv Flexible

REVIFLEX RV-K 0,6/1kV

revi@grupo-revi.com
+34 988 215 454
grupo-revi.com

Cables unipolares y multipolares con conductor flexible, aislamiento de polietileno reticulado (XLPE) y cubierta de PVC.

Aplicaciones

Adecuados para el transporte y distribución de energía eléctrica en instalaciones fijas protegidas o no. Adecuados para instalaciones interiores y exteriores, sobre soportes, al aire, en tubos o enterrados

Características

Aislamiento	**Polietileno reticulado tipo DIX 3 según UNE-HD-603-1**
Clasificación CPR	**Eca**
Colores	**Negro**
Comportamiento fuego	**No propagador de la llama de acuerdo con UNE-EN 60332-1-2**
Conductor	**Cobre clase 5 según UNE-EN 60228**
Cubierta	**PVC tipo DMV18 según UNE-HD 603-1**
Embalaje	**Rollos de 100m plastificados y bobinas**
Identificación unipolar	**Colores**
Norma	**UNE 21123-2**
Secciones	**1x 1.5 a 300mm2, 2, 3, 4, 5 x 1.5 a 50mm2 , 7, 10 y 12, 14, 16, 19, 24, 27, 30, 37, 44, 52 y 61 x 1.5 y 2.5 mm2, 7, 10 y 12 x 4mm2 x 4 mm**
Temperatura	**90°C**
Tensión de ensayo	**4000V**
Tensión nominal	**0.6/1kV**

Datos técnicos

Seccion mm2	Espesor aislamiento mm	Diametro mm	Resistencia a 20 °C Ohm/km
1,5	0,7	5,7	13,3
2,5	0,7	6,2	7,98
4	0,7	6,5	4,95
6	0,7	7,6	3,3
10	0,7	8,6	1,91
16	0,7	9,6	1,21
25	0,9	11,4	0,78
35	0,9	12,5	0,554
50	1	14,5	0,386

Cable eléctrico Cable 06/1 Kv libre halogenos

ECOREVI RZ1-K 0,6/1kV (AS)

revi@grupo-revi.com
+34 988 215 454
grupo-revi.com

Cables unipolares y multipolares con conductor flexible, aislamiento de polietileno reticulado (XLPE) y cubierta de poliolefina.

Aplicaciones

Adecuados para el transporte y distribución de energía eléctrica en instalaciones fijas protegida o no. Adecuado para instalaciones interiores y exteriores, sobre soportes, al aire, en tubos o enterrados. Especialmente adecuados para instalaciones en locales donde se requiera una baja emisión de humos y gases corrosivos en caso de incendio, por ejemplo en locales de pública concurrencia.

Características

Aislamiento	**Polietileno reticulado Tipo DIX 3 según UNE-HD 603-1**
Colores	**Verde**
Comportamiento fuego	**No propagador de la llama según UNE-EN 60332-1-2, No propagador del incendio de acuerdo con EN 60332-3-24, Baja opacidad de humos según EN 61034-2, Libre de halógenos según UNE-EN 50525-1 Anexo B**
Conductor	**Cobre clase 5 según UNE-EN 60228**
Cubierta	**Poliolefina ignifugada de acuerdo con UNE 21123-4**
Embalaje	**Rollos de 100 m plastificados ó bobinas**
Identificación unipolar	**Colores**
Norma	**UNE 21123-4**
Secciones	**1x 1.5 a 300mm2, 2, 3, 4, 5 x 1.5 a 50mm2 , 7, 10 y 12, 14, 16, 19, 24, 27, 30, 37, 44, 52 y 61 x 1.5 y 2.5 mm2, 7, 10 y 12 x 4mm2 x 4 mm**
Temperatura	**90ºC**
Tensión de ensayo	**3500V**
Tensión nominal	**0.6/1kV**

Datos técnicos

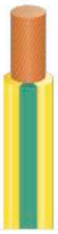
Seccion mm2	Espesor aislamiento mm	Diametro mm	Resistencia a 20 °C Ohm/km
1,5	0,7	5,7	13,3
2,5	0,7	6,2	7,98
4	0,7	6,5	4,95
6	0,7	7,6	3,3
10	0,7	8,6	1,91

16	0,7	9,6	1,21
25	0,9	11,4	0,78
35	0,9	12,5	0,554
50	1	14,5	0,386
70	1,1	16,4	0,272
95	1,1	18,5	0,206
120	1,2	20,7	0,161
150	1,4	22,5	0,129
185	1,6	25,2	0,106
240	1,7	28,3	0,0801
300	1,8	30,9	0,0641

Cable eléctrico Cable 300/500 V - 450/750 V Flexible

C.U.FLEX H07V-K

revi@grupo-revi.com
+34 988 215 454
grupo-revi.com



Cables unipolares sin cubierta con conductor flexible con aislamiento de PVC.

Aplicaciones

Instalación en conductos situados sobre superficies, empotrados y en sistemas cerrados análogos.

Características

Aislamiento	**PVC TI1 según UNE-EN 50363-1**
Clasificación CPR	**Eca**
Colores	**Negro, marrón, gris, azul, amarillo-verde, rojo, blanco, naranja, rosa, violeta y turquesa.**
Comportamiento fuego	**No propagador de la llama de acuerdo con UNE-EN 60332-1-2**
Conductor	**Cobre clase 5 según UNE-EN 60228**
Embalaje	**1.5 rollos de 200m plastificados, las demás secciones de rollos de 100m**
Identificación unipolar	**Colores**
Norma	**UNE-EN 50525-2-31**
Secciones	**1.5 a 50 mm2**
Temperatura	**70ºC**
Tensión de ensayo	**2500V**
Tensión nominal	**450/750V**

Datos técnicos

Sección mm2	Espesor mm	Diámetro mm	Resistencia a 20 °C Ohm/km	Peso aprox. Kg/Km
1,5	0,7	3	13,3	19
2,5	0,8	3,6	7,98	31
4	0,8	4,2	4,95	47
6	0,8	4,8	3,3	70
10	1	6,25	1,91	120
16	1	7,3	1,21	190
25	1,2	9,1	0,78	297
35	1,2	10,3	0,554	400
50	1,4	12,65	0,386	560
70	1,4	14,1	0,272	785
95	1,6	16,4	0,206	1025

SmartLogger 1000

HUAWEI

Smart

Active & reactive power control

Simple

Including up to 80 inverters

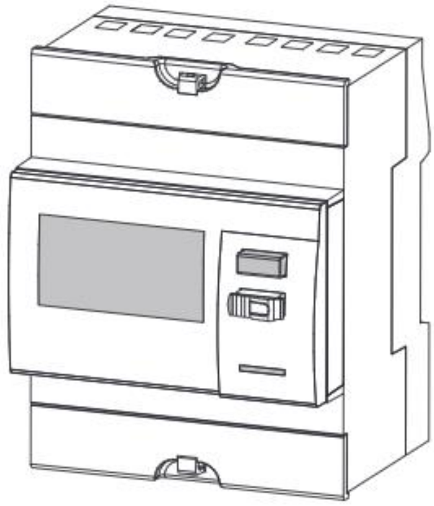
Reliable

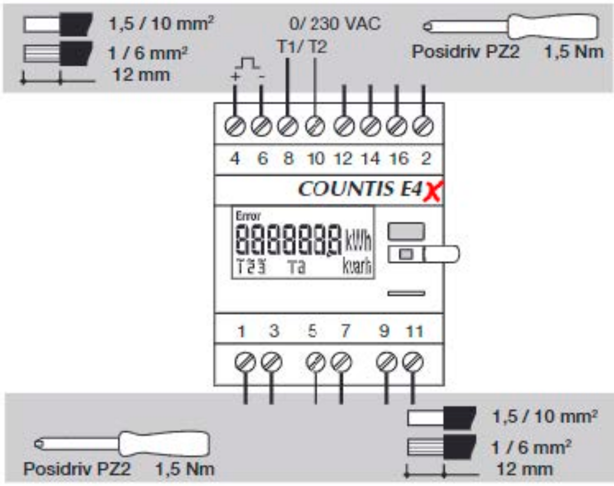
Max. communication range 1,000m

Technical Specification	SmartLogger 1000
	Device Management
Max. Number of Manageable Devices	80
Max. Number of Manageable Smart Inverters	80
	Communication Interface
Electrical Ethernet	ETH x 1, 10 / 100 Mbps
RS485	COM x 3, 2400 / 4800 / 9600 / 19200 / 115200 bps
Digital / Analog Input / Output	DI x 4, DO x 3, AI x 2
	Communication Protocol
Ethernet	Modbus-TCP, IEC 60870-5-104
RS485	Modbus-RTU, IEC 60870-5-103 (standard), DL / T645
	Interaction
LCD	3.5 inch Graphic LCD
LED	LED Indicator x 3
WEB	Embedded WEB
USB	USB 2.0 x 1
	Environment
Operating Temperature Range	-20°C ~ 60°C (-4°F ~ 140°F)
Relative Humidity (Non-condensing)	5% ~ 95%
Max. Operating Altitude	4,000 m (13,123 ft.)
	Electrical
Power Supply	100 V ~ 240 V, 50 Hz / 60 Hz
Power Consumption	Typical 3 W, Max. 7 W
	Mechanical
Dimensions (W x H x D)	225 x 140 x 50 mm (8.9 x 5.5 x 2.0 inch)
Weight	0.5 kg (1.1 lb.)
Protection Degree	IP20
Installation Options	Wall Mounting, DIN Rail Mounting, Tabletop Mounting

4.6S OCOMEC COUNTIS E40 bi-directional meter

COUNTIS E Contadores de energía activa y reactiva





Contadores inteligentes
para un ahorro visible

Como un primer paso hacia el ahorro energético, los contadores inteligentes no solo toman lecturas de consumo, sino que estos equipos tienen una gran precisión y permiten medir a la vez otros parámetros eléctricos importantes para la gestión de costes energéticos.
Combinando contadores COUNTIS E con concentradores de impulsos COUNTIS ECi y un software de gestión energética VERTELIS, se beneficiarán de un sistema completo para centralizar y monitorizar de una manera sencilla sus consumos. De esta manera, podrá reducir sus costes energéticos rápidamente.

Visualice la información allí donde la necesita

El simple hecho de saber exactamente cuanta energía se está consumiendo ya le permite **reducir significativamente algunos costes.** Todos los equipos COUNTIS E tienen una pantalla retroiluminada y opcionalmente disponen de comunicación. De esta manera podrá consultar los consumos de manera remota o bien directamente sobre el equipo en el cuadro eléctrico.

Medida fiable y precisa

Los COUNTIS E, conformes a la directiva MID, permiten garantizar la precisión y la fiabilidad del recuento, **algo obligatorio en las aplicaciones de refacturación de energía.**
Nuestros productos están sujetos a unas exigencias de calidad que aseguran una precisión en los valores mostrados y tienen la posibilidad de ser precintados para prevenir modificaciones.

socomec
Innovative Power Solutions

Trifásico TC/5 A		
		
E40/E41/E42 Impulsos	E43/E44 Modbus	E45/E46 M-BUS
• (E42)	• (E44)	• (E46)
	•	
		•
4 módulos	4 módulos	4 módulos
230 … 400 VAC	230 … 400 VAC	230 … 400 VAC
•/•	•/vía COM (E44)	•/vía COM (E46)
•/-	•/vía COM	•/vía COM
	hasta 4 vía COM	hasta 4 vía COM
	vía COM	vía COM
	vía COM	vía COM
	vía COM	vía COM
	• (E43)	• (E45)
clase 1	clase 1	clase 1
clase 2	clase 2	clase 2
clase C (E42)	clase C (E44)	clase C (E46)
•	•	•
configurable		
• (E42)	• (E44)	• (E46)
•	•	•
•	•	•
E40: 4850 **3008** E41: 4850 **3009** E42: 4850 **3015**	E43: 4850 **3017** E44: 4850 **3014**	E45: 4850 **3027** E46: 4850 **3028**
4850 **304U**		

Precinto antifraude MID

Los COUNTIS E conformes a la directiva MID permiten garantizar la precisión y la fiabilidad del recuento, algo obligatorio en las aplicaciones de refacturación de energía.
Disponen de elementos de seguridad para prevenir el fraude o el acceso a diferentes funciones (por ejemplo reset).
La gama COUNTIS E tiene el certificado MID "módulo B+D" atestiguando que el diseño y el proceso de fabricación de los productos ha sido ensayado por un laboratorio acreditado externo.

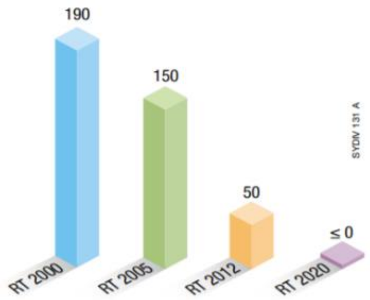
Comunicación en todos los modelos

Todos los contadores COUNTIS E tienen integrada una salida de impulsos o una comunicación en protocolo Modbus o M-BUS.
La comunicación le permitirá:

- centralizar los consumos
- configurar los equipos remotamente vía el software Easy Config
- acceder a los consumos horarios (según periodo de facturacón) para una información detallada de los consumos
- visualizar más parámetros eléctricos: I, V, P, Q, S y FP.

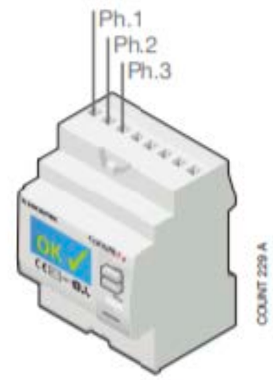
¡Preparado para normativas de eficiencia energética!

Las diferentes normativas, especialmente para los sectores terciario y edificación, tienden a regular el consumo energético y calificar los edificios en función de su eficiencia. Por ello, se recomienda una acción en tres niveles: **la medida de los consumos energéticos, la modificación del comportamiento del usuario y el diseño óptimo del edificio y las instalaciones.**
Los equipos COUNTIS E, DIRIS A, DIRIS N, Línea RETROFIT y el software de gestión VERTELIS responden perfectamente a las exigencias de estas normativas.



Conexión garantizada

Todos los productos COUNTIS E están protegidos frente a conexiones erróneas. La puesta en servicio es más rápida y el funcionamiento correcto del contador está asegurada.



socomec
Innovative Power Solutions

SEDE CENTRAL

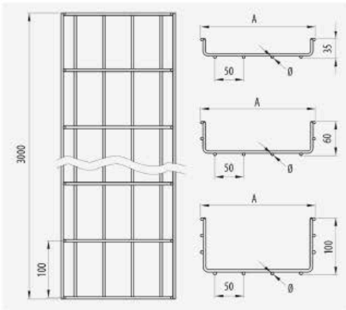
GRUPO SOCOMEC
S.A.SOCOMEC con un capital social de 10 816 800€
R.C.S. Strasbourg B 548 500 149
B.P. 60010 - 1, rue de Westhouse
F-67235 Benfeld Cedex - FRANCE
Tel. +33 3 88 57 41 41
Fax +33 3 88 74 08 00
info.scp.isd@socomec.com

www.socomec.es

pemsa **FICHA TÉCNICA DE PRODUCTO**

Rejiband. Bandejas de Rejilla 21/12/2019

Rejiband 35



CE

Descripción

Bandeja de rejilla de acero de 35 mm de altura, con protección superficial, o inoxidable AISI 304 o 316L con borde de seguridad para soporte y conducción de cables. La bandeja portacables Rejiband® esta compuesta de varillas electrosoldadas en malla que proporcionan una gran resistencia y elasticidad. La facilidad en el montaje, gracias a su flexibilidad y a su sistema Click de conexión rápida sin tornillos para soportes y accesorios, permite ahorrar material y coste de mano de obra. Fabricada según normativa internacional IEC 61537. Su amplia variedad de tamaños y acabados facilita la elección mas adecuada según las necesidades de cada instalación.

Ventajas

Gran resistencia y elasticidad, adaptable a cada instalación proporcionando un ahorro superior al 30% en el montaje.

Borde de seguridad redondeado que evita el daño sobre los cables y el instalador.

Marcado N de Aenor, Certificado UL, Certificado IECC CB de acuerdo con la norma IEC 61537.

Resistencia al fuego E90 (90 minutos, 1000 °C) según DIN 4102-12.

Altura del ala de 35 mm y ancho disponible en 60, 100, 150, 200, 300 y 400 mm con una amplia gama de accesorios.

Aplicaciones

Canalización, transporte y distribución de cables en Instalaciones eléctricas y/o de telecomunicaciones en: Obras civiles, Túneles, Parkings, Edificios Públicos, Centros Comerciales, Centro de Proceso de Datos, Infraestructuras, Aeropuertos, Líneas de Metro, Tren. Sector Terciario y aplicaciones industriales: Navales, Petroquímica, Textil, Químicas, Alimentaria. Aplicaciones interiores en atmósfera seca o exteriores con ambientes húmedos según acabados.

Soluciones

INDUSTRIA ALIMENTARIA · INDUSTRIA QUIMICA FARMACEUTICA · INDUSTRIA PETROQUÍMICA · ENERGÍA · FOTOVOLTAICA · CENTROS DE DATOS · EDIFICACIÓN. TERCIARIO

Características técnicas principales

AISI 304, AISI 316L, Bycro (BC), C8, E.Z., G.C.	35	100, 150, 200, 300, 400, 60	20	-50°/ 150°
A1 No combustible	ETIM EC000853			

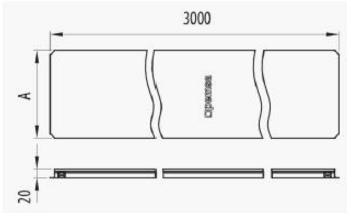
www.pemsa-rejiband.com

pemsa **FICHA TÉCNICA DE PRODUCTO**

Accesorios de montaje 21/12/2019

Tapa Recta

1/4



Descripción

Tapa ciega recta metálica destinada a cubrir los tramos rectos de las bandejas metálicas de rejilla Rejiband®, de chapa Pemsaband® o Inducanal® y de escalera Megaband® consiguiendo mantener a salvo para protección del cableado. Montaje a presión (sin tornillos ni fijaciones). La tapa permanece fija, incluso en posición vertical. Dispone en el extremo de una prolongación de solape que mejora el acoplamiento y estanqueidad de dos tramos rectos de tapa. Fabricada en acero, disponible en diversos acabados y tamaños.

Ventajas

Optimo ajuste de la tapa sobre las bandejas metálicas otorgándoles una gran protección.

Se instala a presión sin necesidad de ninguna fijación.

Acceso sencillo a zonas concretas en caso de tener que realizar alguna modificación en la instalación eléctrica.

Si se combina la tapa con la bandeja de chapa se convierte en Canal protectora en grado IP2X para Pemsaband® e IP4X para Inducanal®.

Disponible en varios acabados: galvanizado sendzimir, galvanizado en caliente y acero inoxidable AISI304 y AISI 316L.

Aplicaciones

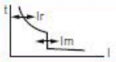
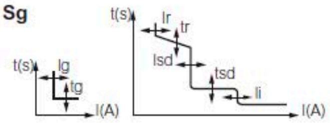
Recomendada para la protección del cableado eléctrico y de telecomunicaciones alojado en bandejas Rejiband®, Pemsaband® y Megaband® en instalaciones eléctricas y de telecomunicaciones en edificios públicos, infraestructuras y obras civiles, instalaciones industriales o sector terciario.

Características técnicas principales

AISI 304, AISI 316L, G.C., G.S. | 100, 150, 200, 300, 400, 450, 500, 60, 600 | 3 | IP44 | -50°/ 150°

A1 No combustible | ETIM EC002403

www.pemsa-rejiband.com

APARATOS	DPX^3 160 magnetotérmico				DPX^3 250 magnetotérmico			
Montaje	Sobre perfil o placa				Sobre perfil o placa			
Poder de corte (kA) (NF EN/IEC 60947-2)	**16 kA**	**25 kA**	**36 kA**	**50 kA**	**25 kA**	**36 kA**	**50 kA**	**70 kA**
380/415 V∿	16	25	36	50	25	36	50	70
220/240 V∿	25	35	50	65	40	60	100	100
Poder de corte en servicio Ics (% Icu)	100	100	100	100	100	100	100	100
Características de funcionamiento								
Frecuencia nominal	50/60 Hz							
Tensión nominal máxima de funcionamiento	690 V (500 V con dif.)				690 V (500 V con dif.)			
Categoría de utilización	A				A			
Ajuste protección magnetotérmica								
 **Térmica**	0,8 a 1 In				0,8 a 1 In			
Magnética	10 In				5 a 10 In			
Ajuste protección electrónica								
S2  **Sg** 	-				-			

Intensidad nominal (In) a 40 °C (A)												
In (A)	16	25	40	63	80	100	125	160	100	160	200	250
Fase	16	25	40	63	80	100	125	160	100	160	200	250
N	16	25	40	63	80	100	125	160	100	160	200	250
N/2	-	-	-	-	-	-	63	100	-	-	-	160
Umbral magnético (Im) (A)(2) de los DPX^3	Fijo								Regulable			
In (A)	16	25	40	63	80	100	125	160	100	160	200	250
Fase	400	400	400	630	800	1000	1250	1600	125-250	200-400	315-630	500-1000
N	400	400	400	630	800	1000	1250	1600	125-250	200-400	315-630	500-1000
N/2	-	-	-	-	-	-	-	-	-	-	-	-
Resistencia (ciclos)												
Eléctrica	8000								8000			
Mecánica	25000								20000			
Diferencial electrónico												
Tipo	Sin o integrado								Sin o integrado			

RGU-10

Descripción

Relé electrónico de protección diferencial serie **WG**, para conectar a los transformadores externos serie **WG** / **WGC**. Relé tipo A superinmunizado, con filtrado de corrientes de alta frecuencia y alta inmunidad. Medida en verdadero valor eficaz (TRMS).

— Visualización de datos por display
— Dispone de dos salidas programables independientes (principal y prealarma)
— Entrada externa para funciones de telemando (230 Vc.a.)

Aplicaciones

Los relés **RGU-10** asociados a los transformadores **WG** permiten una protección diferencial inteligente. Por sus características de diseño aseguran la máxima seguridad y continuidad en el servicio eléctrico, evitándose disparos intempestivos.

El poder de visualizar el valor de fuga instantánea en el display, conjuntamente con las indicaciones de la prealarma, permite tener información del estado de las líneas que se protegen, y realizar un buen mantenimiento preventivo.

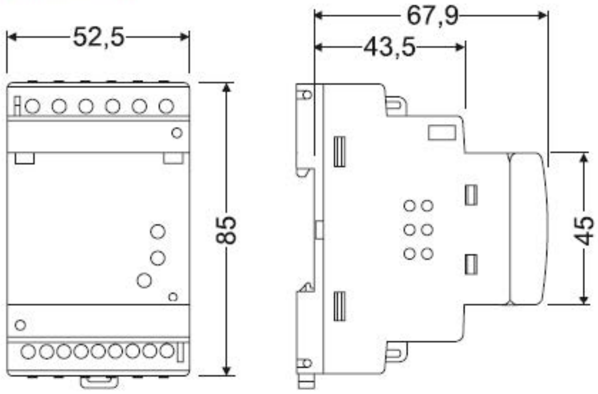
Compatible con los transformadores diferenciales **WGC**

Además, la versión **RGU-10 C** con comunicaciones RS-485, conjuntamente con el software PowerStudio añade la supervisión centralizada en tiempo real, así como registro de históricos para su posterior análisis.

Características técnicas

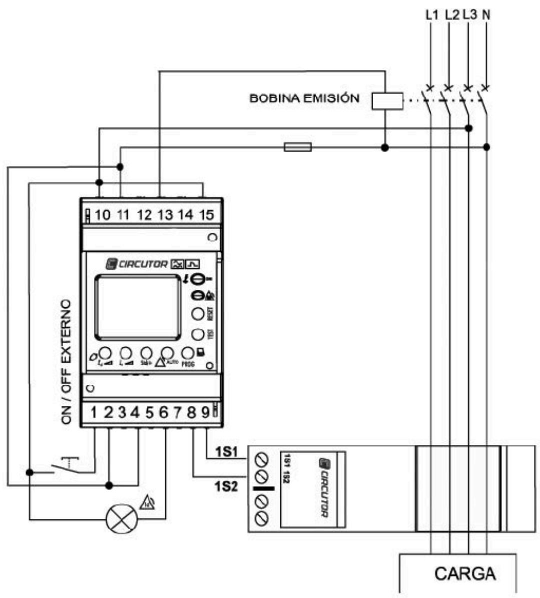
Protección	Clase	A superinmunizada
	Medida	Verdadero valor eficaz (TRMS)
	Sensibilidad	0,03 ... 3 A 0,03 ... 30 A (PROGRAMACIÓN)
	Retardo	Tiempo definido: 0,02 ... 10 s Curva inversa: Instantánea o selectiva
	Transformador diferencial	Externo, Serie **WG / WGC**
	Test y Reset	Mediante pulsadores incorporados, T y R
	Control Remoto	Posibilidad de Test externo
	Elemento de corte asociado	Contactor o Magnetotérmico + bobina de disparo
	Indicación por LED	Tensión alimentación Disparo por fuga Desconexión transformador externo Prealarma
	Visualización por display	Corriente por disparo (display rojo cuando dispara) Programación de parámetros Corriente de fugas instantánea Desconexión transformador externo
	Señalización remota	Prealarma Visualizaciones de parámetros mediante comunicaciones RS-485 (RGU-10 C)
	Control de elemento de corte	Mediante un relé conmutado NA/NC, según conexión con elemento de corte
Características eléctricas	Alimentación auxiliar	230 Vc.a. (± 20 %) 50 / 60 Hz (otros valores bajo demanda)
	Contactos de salida	250 Vc.a., 6 A
	Temperatura de uso	-10 ... +50 °C
Características mecánicas	Fijación	Carril **DIN 46277** (**EN 50022**)
	Dimensiones	3 módulos
	Peso	236 g
	Grado de protección	Bornes IP 20, trascuadro IP 41
Normas	**IEC 60947-2, IEC 60755, IEC 61008, IEC 62020**	

Dimensiones

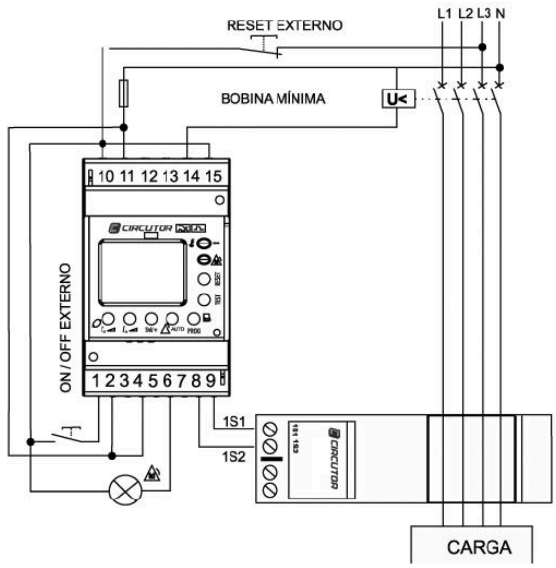


Conexiones

Bobina de emisión



Bobina mínima



Protección y Control

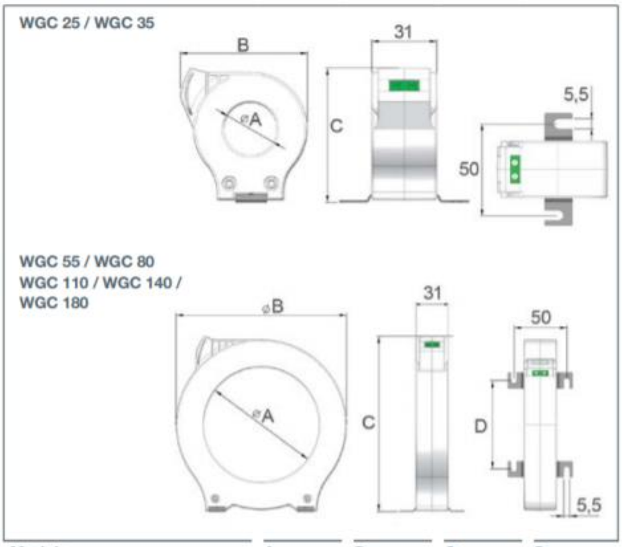
WGC series

Transformadores diferenciales optimizados para la instalación

Transformadores diferenciales

Más inmunizados

CIRCUTOR
Tecnología para la eficiencia energética

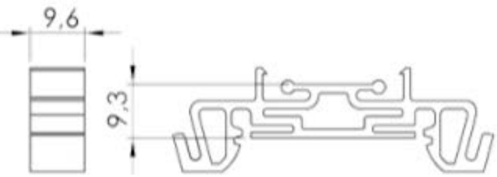


Modelo	A	B	C	D
WGC 25	25	60,5	64	
WGC 35	35	70,5	75,5	
WGC 55	55	92	98	38
WGC 80	80	124,5	130	60
WGC 110	110	163	168	84,5
WGC 140	140	201	206	110
WGC 180	180	252	256	144

Dimensiones

Las dimensiones y formas adoptadas permiten una buena optimización del espacio físico en los cuadros eléctricos, manteniendo las garantías de aislamiento. La introducción de nuevos diámetros interiores determina la posibilidad de potenciar esta característica acorde con el nivel de cableado de la instalación eléctrica.

Dimensiones



Transformadores diferenciales

En esta nueva gama se presentan una serie de mejoras pensando sobretodo en la instalación de los equipos en cuadros de distribución. Además de las fijaciones habituales para su instalación, se añade la posibilidad de hacerlo en carril DIN mediante accesorio, con lo que facilitamos su instalación. Los transformadores

Los transformadores **WGC** disponen de un accesorio para carril DIN que facilita aun más su instalación.

Conexión con borne de 2 hilos que facilita la instalación.

Características técnicas

Aislamiento eléctrico	Seguridad	**IEC 60664-1 / IEC 60664-3**
	Tensión Máxima asignada de servicio	720 V
	Tensión Impulso asignada / polución	3 kV / III
Circuito de medida	Relación de transformación asignada, K_n	30 / 0,06 A
	Precisión en la medida	10 ... 15%
	Corriente térmica continua	60 A
	Corriente térmica de cortocircuito, I_{th}	1,8 kA / 1 seg
	Corriente dinámica, I_{dyn}	2.5 I_{th}
Condiciones de trabajo	Temperatura de trabajo	-20 ... +70º C
	Humedad relativa	95%
	Altitud máxima	2000 m
Características mecánicas	Protección terminales	IP 20 (**IEC 60529**)
	Fijaciones atornillables	M-5
	Carril DIN (con accesorio)	Ver código
	Material carcasa / color	Lexan 923 / RAL 7035
	Clase de autoextinguibilidad	UL 94V-0
	Normativa producto	**IEC 60044-1**
Conexión	Tipo de conexión dos hilos (S1-S2)	Terminal atornillable (tipo tornilllo pzl)
	Dimensiones conductores rígidos/flexibles	0,1 a 2,5 mm² / 27 ... 12 AWG
Conexión a dispositivos de protección y medida (RCD, RCM)	Cableado de sección de hilo ≥ 1 mm²	0 ... 1 m
	Cableado de sección de hilo trenzado y apantallado ≥ 1 mm²	0 ... 10 m
Código	**P10151**	**WGC 25**
	P10152	**WGC 35**
	P10153	**WGC 55**
	P10154	**WGC 80**
	P10155	**WGC 110**
	P10156	**WGC 140**
	P10157	**WGC 180**
	P10158	**WGC 220x105**
	P10159	**WGC 350x150**
	P10160	**WGC 500x200**
	P19921	**PA-TC/WG ***

* Accesorio para carril DIN

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central@circutor.com

Code: C2P181-05

Diseñado por: Dpt. Comunicación. - **CIRCUTOR**, SA.

ANNEX V - SPECIFICATIONS -

1. Object

These technical specifications determine the minimum acceptable conditions for the proper execution of the assembly works for the '96kW photovoltaic self-consumption installation on the roof of an industrial plant' project, specified in the corresponding project document and based on the IDAE's PCT-C-REV-2011.
These works refer to the supply and installation of the materials and prefabricated elements necessary for the construction of a photovoltaic solar energy generating plant and its connection to the grid.
The requirements established herein may be subject to modifications or different solutions based on the particular specifications or due to the nature of the development of the project, provided that these are sufficiently justified in terms of their necessity and do not imply a reduction in the minimum quality requirements specified in this PCT.

2. General

The installation will incorporate all the elements and characteristics necessary to guarantee safety at all times, as well as the quality of supply. The operation of the PV installation must not lead to breakdowns, reduced safety conditions or alterations in excess of those permitted by the applicable regulations, or to dangerous working conditions for installation, maintenance or operating personnel.
The elements located outdoors shall be protected against environmental agents, in particular against the effects of solar radiation, rain, storms and humidity.
The installation shall include all the necessary safety and protection elements for people and equipment of the PV installation, according to the application of the legislation in force.
For reasons of safety and operation of the equipment, the indicators, labels, manuals, etc. of the equipment will be in one of the official Spanish languages, at the installation site.
Once the work has been definitively awarded and before installation, the contractor will present the technician in charge with the catalogues, plans, charts and documents of the different materials.

3. Conditions for materials and equipment

3.1. Quality of materials

The quality of the materials shall comply with the "Technical Standard for Low and Medium Voltage Installations. Technical Implementation Criteria" (NT-IMBT 1400/0201/1) (DOGV NUM 1760 DE 7/04/1992). In addition, all materials and equipment used will have their CE marking. All materials used must be of the highest quality and strictly comply with the specifications of these specifications. Materials may not be used unless they have been previously accepted by the Works Management, and may be rejected by the same, even after they have been installed if they do not comply with the required conditions.
In the event that the brands offered by the contractor do not, in the opinion of the project manager, provide sufficient guarantee, the latter will choose the material, from national manufacturers, and will demand as many official tests and certificates as are necessary to verify with total accuracy that the material is suitable for the work for which it was intended.
As a general principle, at least Class I electrical insulation must be ensured for the elements of the system: generating equipment (modules, inverters), materials (connection boxes and cabinets), except for the DC wiring, which must be double insulated Class II and have a minimum degree of protection of IP65.

3.2. Photovoltaic module

All modules included in the installation shall be of the same model, or in the case of different models, the design must fully guarantee compatibility between them and the absence of harmful repercussions to the installation as a result.
In those exceptional cases where non-qualified modules are used, due justification and documentation of the relevant tests and trials to which they have been subjected must be provided. In any case, any product that does not comply with any of the above specifications must be expressly approved by the site management. In all cases, the standards in force must be complied with.
All PV modules must meet the UNE-EN-61215 specifications for crystalline silicon modules, as well as being qualified by a laboratory of recognised prestige, which will be accredited by the presentation of the corresponding official certificate.
The module shall bear in a clearly visible and indelible manner the model, name or logo of the manufacturer, as well as an individual identification or serial number traceable to the date of manufacture.
The chosen modules shall be fitted with bypass diodes to prevent possible failure of the cell and its circuits due to partial shading, and the enclosure shall have an IP65 degree of protection. If they are composed of side frames, these shall be made of aluminium or stainless steel. And the entire metal structure of the module shall be earthed.
For a module to be acceptable, its actual power and short-circuit current under standard conditions shall be within 5% of its catalogue ratings.
Any module showing manufacturing defects such as cracks, stains, cell misalignment, bubbles in the encapsulant or other defects shall be rejected.

3.3. Supporting structure and attachment

The supporting structure with the installed modules must withstand wind and snow overloads or other climatic factors, in accordance with the Technical Building Code, according to RD 314/2006 and complying with the MV-103 standard.
The design and construction of the structure and the fastening system of the modules will allow the necessary thermal expansions, without transmitting loads that could affect the integrity of the modules, following the manufacturer's indications.
The fixing points for the fv module shall be sufficient in number, taking into account the support area and their relative position, so that no deflections occur in the modules greater than those allowed by the manufacturer and the approved methods for the module model.

The structure shall be designed for the orientation and tilt angle specified for the photovoltaic generator, taking into account ease of assembly and disassembly, and the possibility of element replacements, and not to cause shading.
The structure shall provide surface protection against the action of environmental agents. And the screws shall be made of stainless steel, complying with the MV106 standard. In the case of a galvanised structure, galvanised screws will also be accepted. Always using the same material as the structure.
If it is built with cold-formed laminated steel profiles, it shall comply with the MV-102 standard to guarantee all its mechanical and chemical characteristics. And if it is hot-dip galvanised, it shall comply with the UNE-EN ISO 1461:2010 standard.

3.4. Inverter

It shall act as a self-switched power source, and shall be of a type suitable for connection to the grid, with a variable input power to be able to extract at all times the maximum power that the photovoltaic generator can provide throughout the day.
The self-consumption of the equipment (no-load losses) in stand-by or night mode shall be less than 2% of its nominal power output.
It will comply with the EU directives on Electrical Safety and Electromagnetic Compatibility, both certified by the manufacturer, with electrical protections against:

- A.C. short-circuits
- Mains voltage out of range
- Out-of-range mains frequency
- Overvoltages, by means of varistors, SPD, or similar.
- Grid disturbances such as micro-cuts, pulses, etc.
- Avoid operation in island or isolated mode.

It will have the necessary manual controls and signalling for its correct operation, incorporating suitable automatic controls for its handling, supervision, repair or maintenance. As well as minimum IP30 protection for inverters inside buildings and accessible places.

3.5. Switchgear

The provisions of the current REBT and RD 1663/2000 (Art.11) on protections in photovoltaic installations connected to the low voltage grid will be complied with.
In three-phase grid connections, the protections for maximum and minimum frequency interconnection (51 Hz and 49 Hz respectively) and maximum and minimum voltage (1.1 Um and 0.85 Um respectively) will be for each phase.

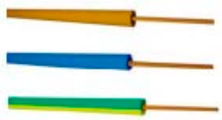
3.6. Wiring

The conductors shall be made of copper and shall have the appropriate cross-section to avoid voltage drops of more than 1.5% and overheating.
The cable shall be long enough so as not to generate stress on the various elements or the possibility of snagging due to the transit of people.
All continuous wiring shall be double insulated (class 2) and suitable for outdoor use, in accordance with standard UNE 21123.

3.6.1. Identification of conductors

It shall be necessary to identify the circuits and electrical elements in the conduits for possible repairs or maintenance. In the continuous part, the two active conductors shall be differentiated according to the following colour codes of their enclosures:

- Red for the positive pole conductor, with female terminal.
- Black for the negative pole conductor, with male terminal.



On the AC side, the three phase cables, the neutral cable and the protection cable shall be differentiated according to the following colour codes of their enclosures:

- Brown, grey or black for each active or phase conductor.
- Blue for neutral conductor.
- Yellow/green for protective conductor.

3.6.2. Trunking

The wiring shall be laid in conduits which shall, in general and if possible, be laid in perfectly delimited areas with a route as straight as possible and if possible parallel to fixed references such as façade lines or kerbs. Likewise, the minimum radii of curvature to be respected in changes of direction, fixed by the manufacturers (or, failing this, those indicated in the standards of the UNE-211435 series), must be taken into account.

3.6.3. Junction or junction boxes

If they are made, the connections between conductors shall be carried out inside suitable boxes: watertight, pre-cut or cone-shaped, and whose enclosures are made of suitable insulating material, and if they are metallic, they shall be duly protected against corrosion. Their dimensions shall be such that they can comfortably house all the conductors to be contained. If the conduit entries in the junction boxes are to be made watertight, suitable cable glands shall be used.

3.7. Earthing

The provisions of RD 1663/2000 (Art.12) on PaT conditions in photovoltaic installations connected to the low voltage grid shall be complied with.
When the galvanic isolation between the LV distribution network and the PV generator is not carried out by means of an isolation transformer, the elements used to guarantee this condition shall be explained in the Project Report.
All the PV installation's masses, both on the DC and AC sides, will be connected to a single earth, which will be independent of the distribution company's neutral, in accordance with the REBT in force.

4. Grid connection

All installations of up to 100kW will comply with the provisions of RD1663/2000 (Art. 8 and 9) on the connection of photovoltaic installations connected to the low voltage grid.

5. Harmonics and electromagnetic compatibility

All PV installations connected to the grid shall comply with the provisions of RD 1663/2000 (Art. 13) on harmonics and electromagnetic compatibility in PV installations connected to the low voltage grid.

6. Measurements

All grid-connected PV installations shall comply with RD 1110/2007, which approves the Unified Regulation of measurement points of the electricity system.

7. Monitoring system

The monitoring system shall be easily accessible to the user and shall provide measurements, as a minimum, of the following variables:

- DC voltage and current at the inverter input.
- Inverter output phase voltage and total inverter output power.
- Solar irradiance at the module plane, measured either with a module or with a cell or equivalent technology.
- Ambient temperature in the shade.
- Inverter output reactive power for installations larger than 5kWp.

The data shall be presented in the form of hourly measurements. Acquisition times, accuracy of measurements and form of presentation shall be in accordance with the JRC-Ispra document "Guidelines for the Assessment of Photovoltaic Plants - Document A", Report EUR16338 EN.

8. Transport and collection of materials

Materials shall be transported with care. They shall not be dragged, knocked or thrown. The heaviest and bulkiest materials shall be transported by crane/plume lorry by road to the building site and from there by appropriate means to the site.
Special care must be taken with photovoltaic modules and inverters, as they may break if knocked.
The contractor shall take note of the materials received and report any anomalies to the site manager.

9. Acceptance and testing

After completion of the work, all surplus material must be removed from the site, the occupied areas must be cleaned and all waste and residues must be removed to the landfill site.

On receipt, the installer shall provide the user with a document-document stating the supply of components, materials and user manuals (and maintenance of the installation, if applicable). This document shall be signed in duplicate by both parties, each retaining one copy. The manuals delivered to the user shall be in one of the official languages to facilitate their correct interpretation.

Prior to the commissioning of the installation, an exhaustive revision of the correct connection of all the main elements must be carried out. As well as taking measurements of values in the different strings and in the inverter.

The tests to be carried out by the installer shall be at least the following:

- Operation and start-up of all the systems.
- Start-up and shut-down tests at different moments of operation.
- Tests of the protection and safety elements and measures.

10. Guarantees

10.1. General Scope of the Guarantee

Without prejudice to any possible claim to third parties, the installation will be repaired in accordance with these general conditions if it has suffered a fault due to a defect in assembly or in any of the components, provided that it has been handled correctly in accordance with the instruction manual.

The guarantee is granted in favour of the purchaser of the installation, which must be duly justified by means of the corresponding guarantee certificate, with the date accredited in the certification of the installation.

10.2. Deadlines

All the elements supplied, as well as the installation as a whole, shall be protected against manufacturing, installation or design defects by a three-year guarantee, except for the photovoltaic modules, for which the minimum guarantee shall be 10 years from the date of signing the provisional acceptance certificate.

However, the installer shall be obliged to repair any malfunctions that may occur if it is found that their origin is due to hidden defects in design, construction, materials or assembly, undertaking to remedy them free of charge.

If the operation of the supply has to be interrupted due to reasons for which the supplier is responsible, or due to repairs which the supplier has to carry out in order to fulfil the warranty stipulations, the period shall be extended by the total duration of such interruptions.

10.3. Financial conditions

The guarantee covers the repair or replacement, if necessary, of components and parts which may prove to be defective, as well as the labour involved in the repair or replacement during the term of the guarantee.

All other expenses, such as travel time, means of transport, possible transport costs for collection and return of the equipment for repair, etc., are expressly included.

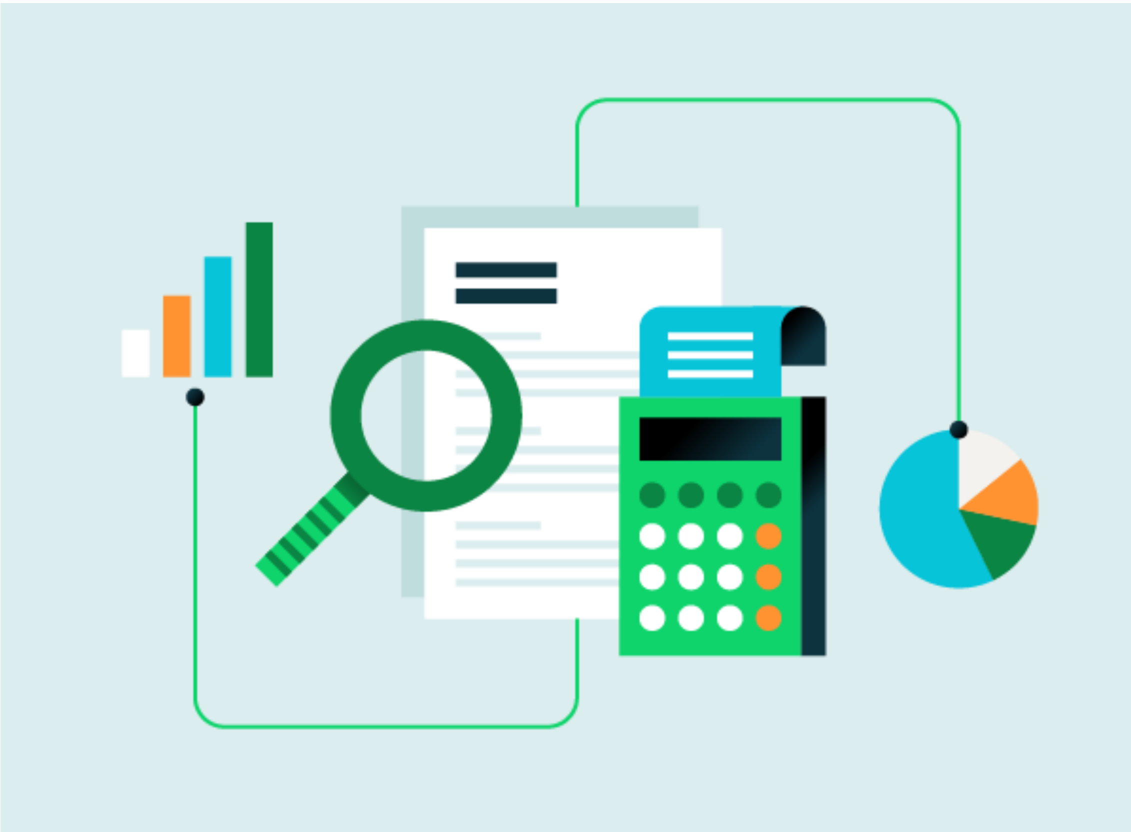
They shall also include the labour and materials necessary to carry out any adjustments and possible adjustments to the operation of the installation.
If the supplier fails to fulfil his obligations under the guarantee within a reasonable period of time, the purchaser of the installation may, after giving written notice, set a final date by which the supplier must fulfil his obligations. If the supplier fails to fulfil his obligations within this final deadline, then the purchaser of the installation may, at the supplier's expense and risk, carry out the necessary repairs himself or contract a third party to do so, without prejudice to any claim for damages incurred by the supplier.

The supplier shall carry out the repairs or replacement of parts as soon as possible after receipt of the fault report, but shall not be liable for any damages caused by the delay in such repairs, provided that it is less than 10 calendar days.

11. Maintenance

If a maintenance contract is agreed between the parties, preventive maintenance work shall be carried out on the basis of the recommendations of the various manufacturers. The detailed conditions of the preventive and corrective maintenance and its scope will be set out in such a separate contract. In any case, these maintenance actions will always be carried out by qualified technical personnel under the responsibility of the installation company, who will draw up a technical report after each of the visits, reflecting the state of the installations and the incidents that have occurred.

ANNEX VI - BUDGET -



1.Breakdown by chapter and item

In order to calculate the economic indicators in the project feasibility study, it is necessary to determine the initial investment of the planned installation. To do this, a budget is drawn up, which includes the cost of both the necessary material and the installation of all the equipment and elements that make up the installation.

Below is the budget broken down and detailed by chapters and items.

Chapter 1: Production equipment					
Item	Ct	UMB	Description	Unit price	Item price
1.1	280	Units	KuMax CS3U-350 photovoltaic modules from Canadian Solar, consisting of high-efficiency polycrystalline silicon cells, with positive tolerance, 350 Wp, dimensions 2000x992x40 mm, anodised aluminium frame and IP68 protection and a weight of 22.6 kg. They are guaranteed for 25 years.	80,50 €	22.540,00 €
1.2	1	Units	Huawei SUN2000-36KTL three-phase inverter, rated output power 36 kW, rated mains voltage 400 V, mains frequency 50 Hz, efficiency 98.6% and IP65 protection. It has 8 total DC inputs, including 4 MPPT inputs. Dimensions 930x550x283mm and weight 62kg. It has intelligent monitoring of 8 strings, power line communications support (PLC) and intelligent diagnostic support for I-V curves.	2.105,80 €	2105,80 €
1.3	1	Units	Huawei SUN2000-60KTL three-phase inverter, rated output power 60 kW with rated mains voltage 400 V, mains frequency 50 Hz, efficiency 98.7% and IP65 protection. It has 12 total DC inputs, including 6 MPPT inputs. Dimensions 1075x550x300mm and weight 74kg. It has intelligent monitoring of 12 strings, power line communications support (PLC) and intelligent diagnostic support for I-V curves.	3.421,56 €	3.421,56 €
1.4	1	Unit	Huawei Smartlogger-1000, an intelligent data logger and monitoring device for solar photovoltaic installations. It has communications with Ethernet connection, RS485, 2G/3G/4G, 4 digital inputs, 2 digital outputs, 4 analogue inputs. Modbus-TCP for connection to Huawei NetEco. Allows monitoring and data logging of up to a maximum of 80 inverters. Dimensions 225x140x50mm and IP20 protection degree.	298,08 €	298,08 €
SUBTOTAL CHAPTER 1					**28.365,44 €**

Chapter 2: Electrical protection panel					
Item	Ct	UMB	Description	Unit price	Item price
2.1	1	Unit	Chint NXW5 metal panel. Made of galvanised steel, with earth connection between box and door, and pre-drilled openings for cable entry. High degree of protection IP54 and dimensions 600x600x250mm.	91,80 €	91,80 €
2.2	1	Unit	Legrand DPX3 160 4P 16kA and 80A rating circuit breaker.	101,76 €	101,76 €
2.3	1	Unit	Legrand DPX3 160 4P 16kA and 125A magneto-thermal circuit breaker.	121,82 €	121,82 €
2.4	1	Unit	Legrand DPX3 250 4P 25kA moulded case circuit breaker, 200A rating. With adjustable thermal from 0.8 to 1 In and adjustable magnetic from 5 to 10 In.	328,16 €	328,16 €
2.5	1	Unit	Circutor RGU-10 electronic relay, prepared for connection with WGC trafo coil. Type A superimmunised, with high-frequency current filtering and high immunity. With true root mean square measurement (TRMS) for accurate leakage current monitoring. The instantaneous leakage value on the display, together with the pre-alarm indications, provides information on the status of the lines being protected and enables good preventive maintenance to be carried out.	103,00 €	103,00 €
2.6	1	Unit	Circutor WGC-80 toroidal trafo, with a closed coil of 80mm diameter. It integrates the current meter and transformer function.	74,00 €	74,00 €
2.7	1	Unit	DPX3 auxiliary emission coil. Allows remote triggering of a DPX3. Coil voltage 200- 277Vac.	26,72 €	26,72 €
2.8	2	Unit	DPX3 160 3P/4P S/PERFIL fixing.	2,94 €	5,88 €
2.9	1	Unit	Legrand TX3 6kA-C 2P circuit breaker, 10A rating.	5,12 €	5,12 €
2.10	3	Unit	Lexic 2P+T modular socket 16A gauge.	5,24 €	15,72 €
2.11	1	Unit	Labour of Dimael Castellón S.L. for the assembly of the complete frame.	170,00 €	170,00 €
SUBTOTAL CHAPTER 2					**1.043,98 €**

Chapter 3: Other electrical elements					
Item	Ct	UMB	Description	Unit price	Item price
3.1	30	Units	Rejiband for support and conduction of electrical cables. Dimensions 3000x200x35mm, hot-dip galvanised, perforated, made up of electro-welded rods that provide great resistance and with a safety edge to prevent damage to the wiring and the installer. It offers adequate ventilation and great resistance to the trunking system.	3,20 €	96,00 €
3.2	30	Units	Stainless steel metal blind cover for rejiband.	2,01 €	60,30 €
3.3	40	Units	Z3 zinc-plated quick connector.	0,28 €	11,60 €
3.4	1000	m	"Halogen-free RV-K cable, section 6mm2. Unipolar, of flexible Cu conductor, with XLPE insulation and PVC sheath. Model Reviflex of the manufacturer Grupo Revi, or similar. For the wiring of the direct current part, from each string of modules to the inverter input".	0,23 €	230,00 €
3.5	12	m	RZ1-K 0.6/1kV cable, section 16mm2. Unipolar, with flexible Cu conductor, XLPE insulation and polyolefin sheath. High safety (AS), i.e., flame retardant, low smoke and toxic gas emission and halogen free. Model Ecorevi of the manufacturer Grupo Revi, or similar. For the wiring of the AC side from the 36kW inverter output to the protection panel.	1,36 €	16,27 €
3.6	12	m	Cable RZ1-K 0,6/1kV, sección 35mm^2. Unipolar, de conductor flexible de Cu, aislamiento de XLPE y cubierta de poliolefina. De alta seguridad (AS), es decir, no propagador de la llama, de baja emisión de humos y gases tóxicos y libre de halógenos. Modelo Ecorevi del fabricante Grupo Revi, ó similares. Para el cableado de la parte de alterna desde la salida del inversor de 60kW hasta el cuadro de protecciones.	2,73 €	32,76 €
3.7	12	m	RZ1-K 0.6/1kV cable, section 70mm2. Unipolar, with flexible Cu conductor, XLPE insulation and polyolefin sheath. High safety (AS), i.e., flame retardant, low smoke and toxic gas emission and halogen free. Model Ecorevi of the manufacturer Grupo Revi, or similar. For the wiring of the AC side from the output of the IGA switch to the connection point in the general electrical distribution board of the building.	5,29 €	63,48 €
3.8	1000	m	Bare earth conductor consisting of stranded copper, of S=6mm2	1,30 €	1.300,00 €
3.9	20	m	Protective earth conductor, S=35mm2, C.U.FLEX H07V-K, manufactured by Grupo Revi or similar.	2,75 €	55,00 €
3.10	40	Units	MC-4 quick connectors for module wiring terminals.	1,13 €	45,20 €
3.11	80	Units	Cu terminals/connection ferrules of different cross-sections and metrics.	1,09 €	87,20 €
3.12	1	Units	Bi-directional value meter for intelligent energy management, model SOCOMEC. With 3 current transformers 250/5A.	286,17 €	286,17 €
3.13	1	Units	TP-Link TL-SG108 Ethernet Switch, 8-port RJ-45.	21,00 €	21,00 €
3.14	1	Units	TP-Link TL-WA855RE Wifi Receiver. Signal booster.	20,90 €	20,90 €
SUBTOTAL CHAPTER 3					**2.325,88 €**

Chapter 4: Structure and fastening of modules					
Item	Ct	UMB	Description	Unit price	Item price
4.1	96	Units	Galvanised steel bars in rectangular profiles of dimensions 40x40x2mm, of various lengths for the construction - by means of these bars joined by welding - of the triangular brackets that form the structure of the north water structure of the building.	8,73 €	838,40 €
4.2	16	Units	2mm thick galvanised steel plates.	0,90 €	14,40 €
4.3	156	Units	End clamp, KIT40 end (Endclamp).	0,32 €	49,92 €
4.4	426	Units	Central clamp, KIT40 intermediate (Interclamp).	0,40 €	170,40 €
4.5	582	Units	Base profile guide (Trapezoidal).	0,39 €	226,90 €
4.6	1300	Units	Small material: screws, threaded fasteners, bolts.	0,11 €	143,00 €
SUBTOTAL CHAPTER 4					**1.443,02 €**

Chapter 5: PRL elements collective protection					
Item	Ct	UMB	Description	Unit price	Item total
5.1	20	Units	Perimeter mesh fastening bars.	4,70 €	94,00 €
5.2	82,6	Units	White perimeter security netting.	1,20 €	99,12 €
5.3	11	Units	25 metre roll of 1.50m Simple Twist Mesh for the safety covering of skylights, with a 50x50mm galvanised steel mesh.	33,75 €	371,25 €
5.4	172	Units	Galvanised steel plates 3000x30x1,5mm for fastening the simple torsion mesh to the roof of the building.	1,90 €	326,80 €
SUBTOTAL CHAPTER 5					**891,17 €**

Chapter 6: Transport, Labour and Installation					
Item	Ct	UMB	Description	Unit price	Item total
6.1	12	h	Estimated material transport. Using a 3.5t boom-crane lorry to carry heavy and bulky material, and also to load the pallets of modules to the deck, as well as the coils, PRL elements, structural profiles, etc.	50,00 €	600,00 €
6.2	2720	km	Estimated mileage Castellón-Tavernes Blanques to be covered by the workers during all the planned days of work.	0,30 €	816,00 €
6.3	512	h	Total hours of work carried out by four operators for the complete assembly and installation of the modules on the roof, wiring, PRL, electrical panel, commissioning, etc.	15,80 €	8.089,60 €
6.4	42	h	Total hours of work carried out by four operators for the complete assembly and installation of the modules on the roof, wiring, PRL, electrical panel, commissioning, etc.	15,8	663,3
SUBTOTAL CHAPTER 6					**10.168,90 €**

2 - Material Execution Budget (PEM)

The following table 31 summarises, according to the subtotal per chapter, all the costs that have been broken down in the previous paragraph above.

Material Execution Budget		
Chapter	**Description**	**Price**
1	Production equipment	28.365,44 €
2	Electrical protection switchboard	1.043,98 €
3	Other electrical equipment	2.325,88 €
4	Structure and module attachment	1.443,02 €
5	PRL elements collective protection	891,17 €
6	Logistics, Labour and Installation	10.168,90 €
Total Price		**44.238,39 €**

The value of the Material Execution Budget amounts to a total amount of FORTY-FOUR THOUSAND, TWO HUNDRED AND THIRTY-EIGHT EUROS AND THIRTY-NINE CENTS, 3 - Contract Execution Budget (PEC) and Total

"The following table summarises all the costs of the installation, considering the EMP together with all other added costs, making up the Contract Execution Budget, and finally including the contractor's fees. costs, making up the Contract Execution Budget, and finally including the project and site management fees, as well as the VAT, making up the Total Budget.

Contract Execution Budget (CEB) and Total Budget		
Item	**Description**	**Price**
1	Production equipment	28.365,44 €
2	Electrical protection switchboard	1.043,98 €
3	Other electrical equipment	2.325,88 €
4	Structure and module attachment	1.443,02 €
5	PRL elements collective protection	891,17 €
6	Logistics, Labour and Installation	10.168,90 €
7	Subtotal MEB	44.238,39 €
8	General expenses, administrative and legalisation costs (12%)	5.308,61 €
9	Industrial Profit (15%)	6.635,76 €
10	**Subtotal CEB**	**56.182,75 €**
11	Engineering Costs (7%)	3.932,79 €
12	**Total**	**60.115,54 €**
13	VAT (21%)	12.624,26 €
	Total including VAT	**72.739,81 €**

The value of the Material Execution Budget amounts to a total amount (including VAT) of SEVENTY-TWO THOUSAND SEVEN HUNDRED AND THIRTY-NINE EUROS AND EIGHTY-ONE CENTS.

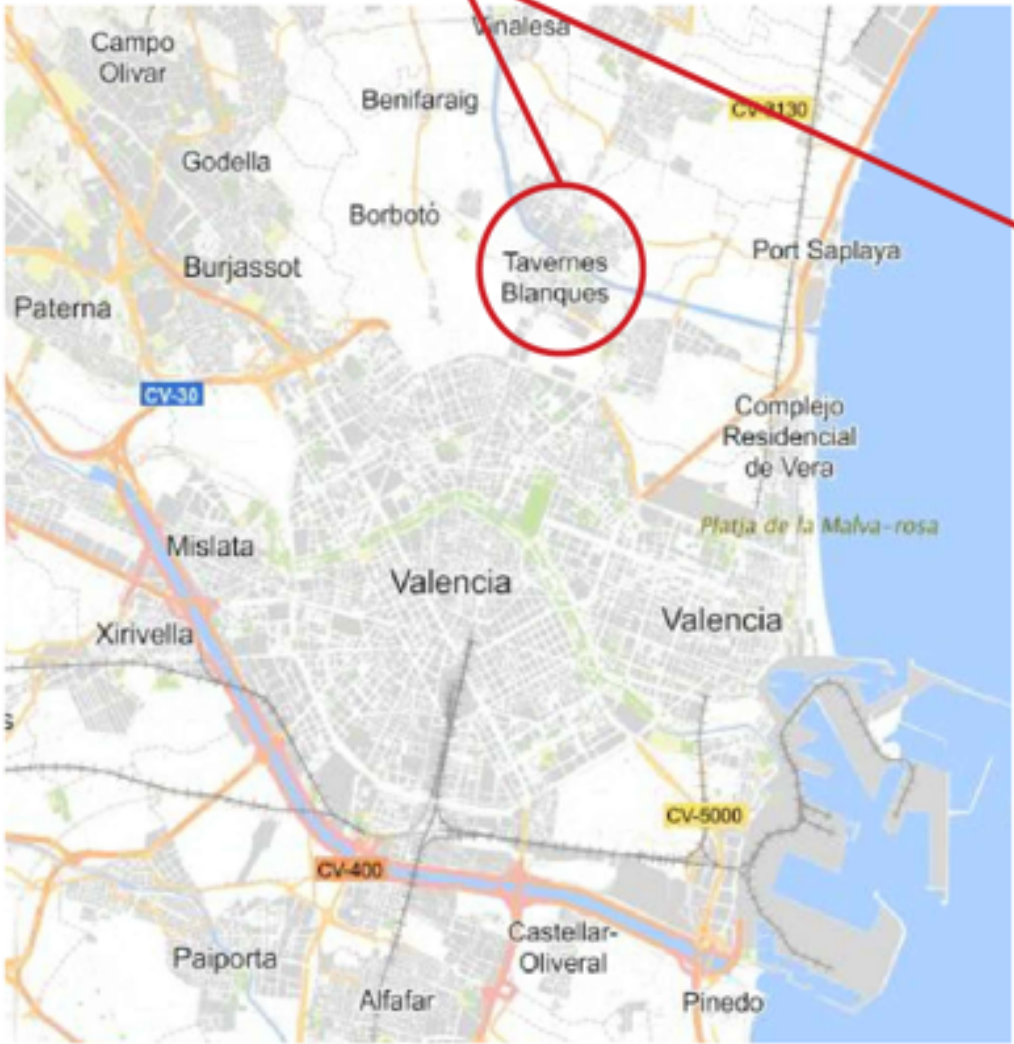
ANNEX VII - LAYOUTS

Referencia catastral: 6666406YJ[redacted]

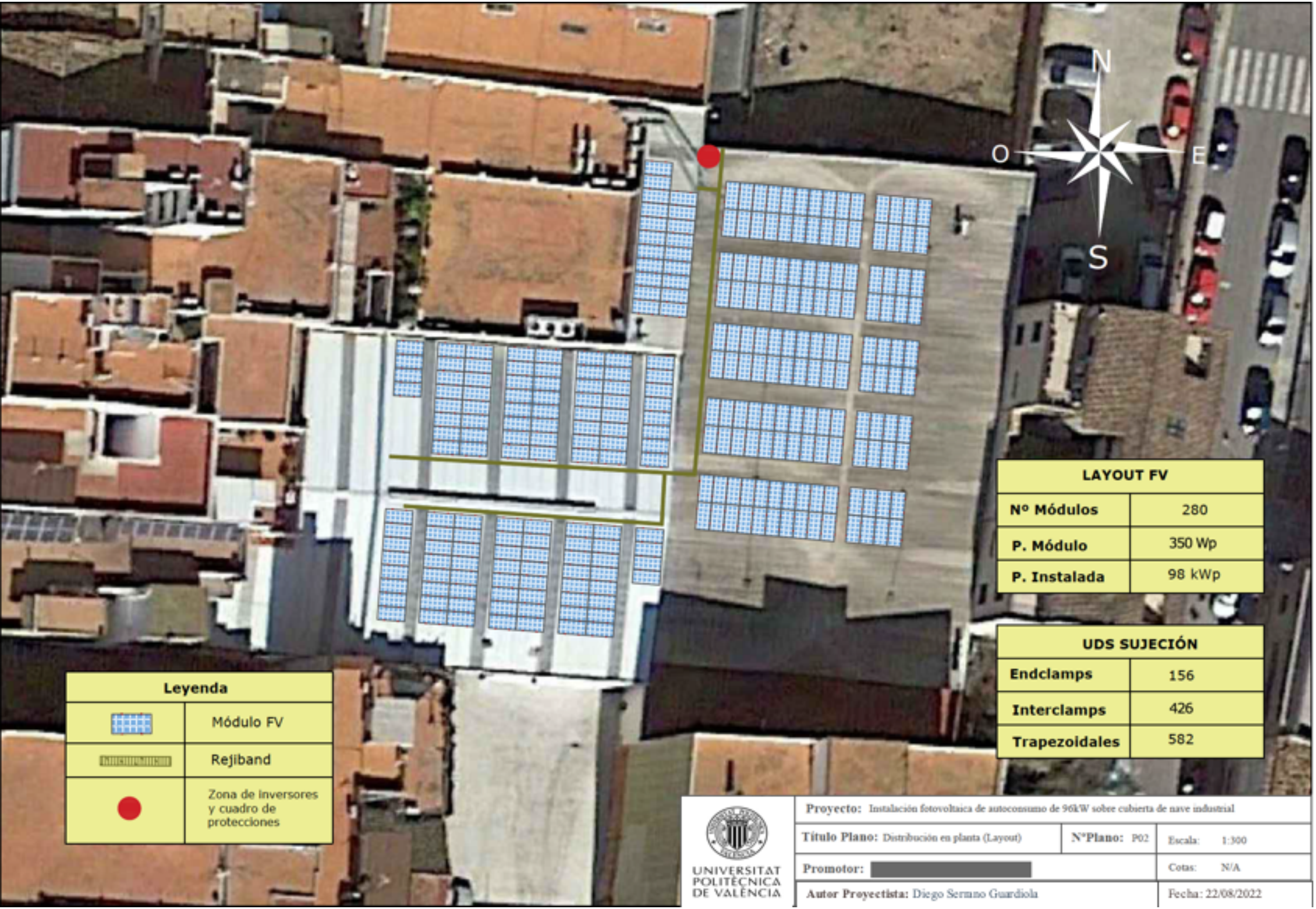
Coordenadas UTM: X: 726.519
Y:4.376.462
Huso: 30

Coordenadas geográficas: latitud: 39º30'28.19" (N)
longitud: 0º21'52.34" (O)

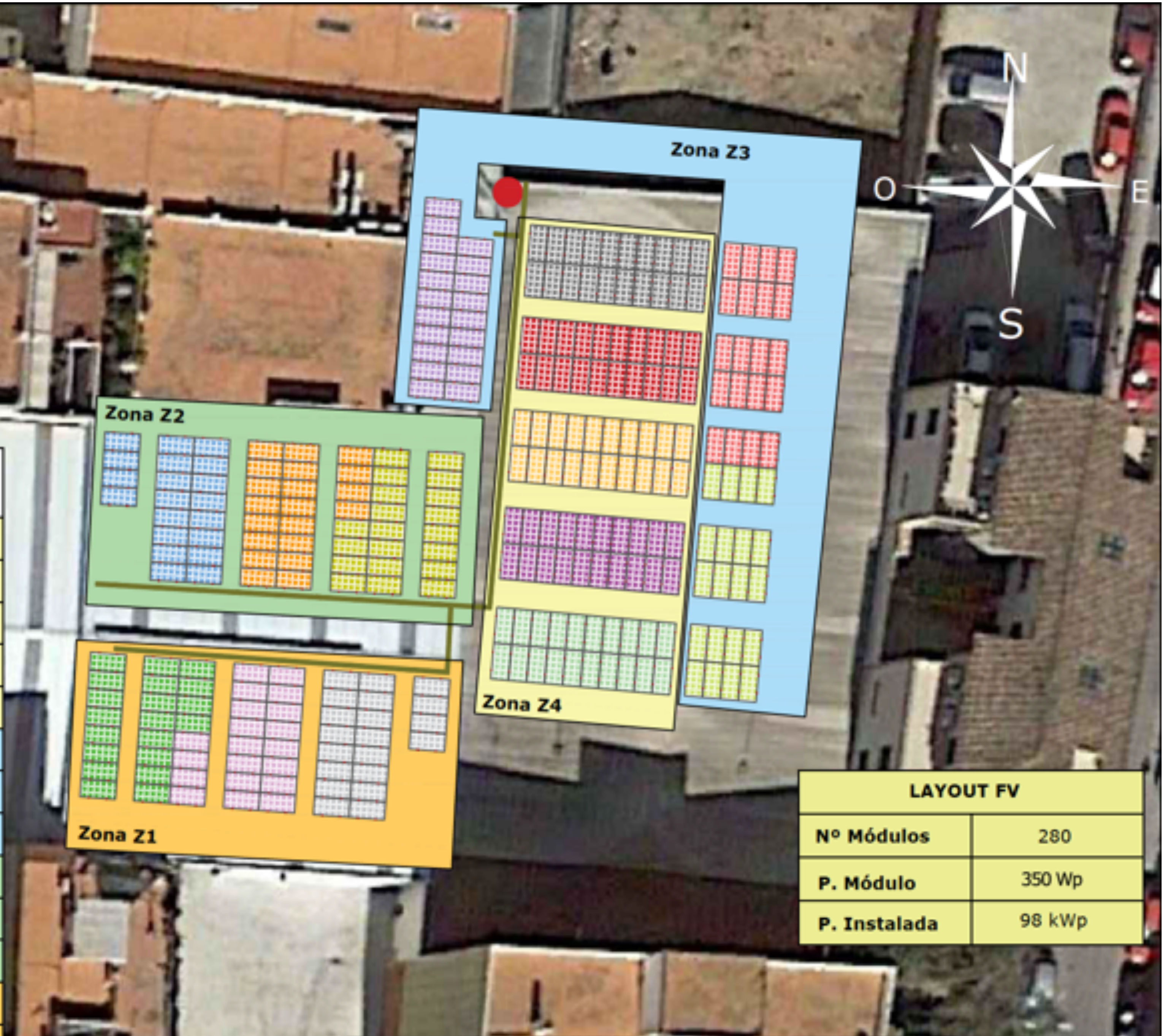
Dirección: [redacted] Tavernes Blanques (Comunidad Valenciana, España)



UNIVERSITAT POLITÈCNICA DE VALÈNCIA	**Proyecto:** Instalación fotovoltaica de autoconsumo de 96kW sobre cubierta de nave industrial			
	Título Plano: Ubicación y Emplazamiento	**NºPlano:** P01	Escala:	N/A
	Promotor: [redacted]		Cotas:	N/A
	Autor Proyectista: Diego Serrano Guardiola		Fecha: 22/08/2022	



N
O
E
S
LAYOUT FV
Nº Módulos 280
P. Módulo 350 Wp
P. Instalada 98 kWp
UDS SUJECIÓN
Endclamps 156
Interclamps 426
Trapezoidales 582
Leyenda
Módulo FV
Rejiband
Zona de inversores y cuadro de protecciones
UNIVERSITAT POLITÈCNICA DE VALÈNCIA
Proyecto: Instalación fotovoltaica de autoconsumo de 96kW sobre cubierta de nave industrial
Título Plano: Distribución en planta (Layout)
NºPlano: P02
Escala: 1:300
Promotor: [redacted]
Cotas: N/A
Autor Proyectista: Diego Serrano Guardiola
Fecha: 22/08/2022

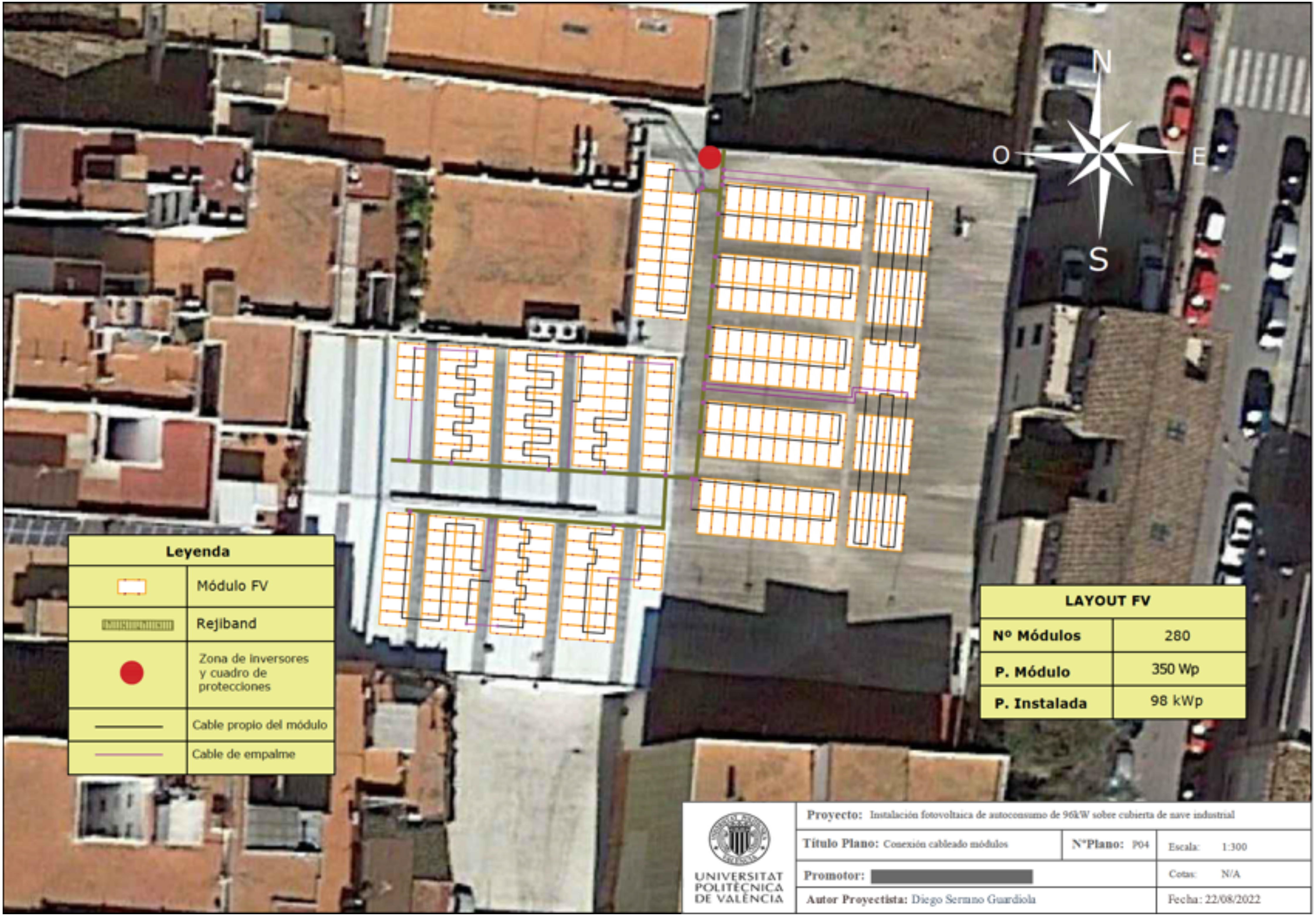


	Agrupación módulos	Zona	Entrada de inversor
	String 1	Z4	A-1
	String 2	Z4	A-2
	String 3	Z4	B-1
	String 4	Z4	B-2
	String 5	Z4	B-3
	String 6	Z3	A-3
	String 7	Z3	B-5
	String 8	Z3	B-6
	String 9	Z2	B-11
	String 10	Z2	A-5
	String 11	Z2	A-7
	String 12	Z1	B-7
	String 13	Z1	B-8
	String 14	Z1	B-9

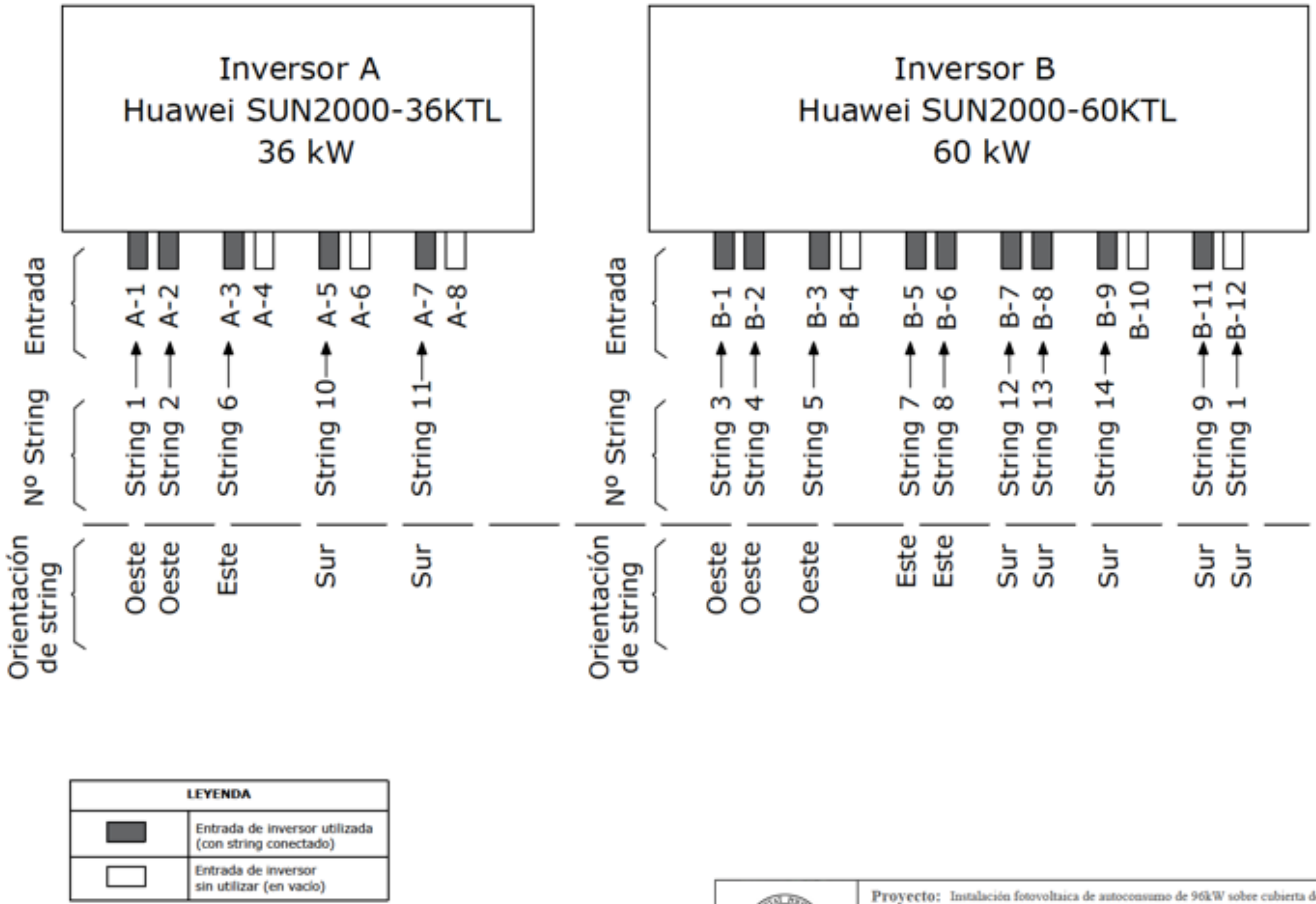
LAYOUT FV	
Nº Módulos	280
P. Módulo	350 Wp
P. Instalada	98 kWp

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

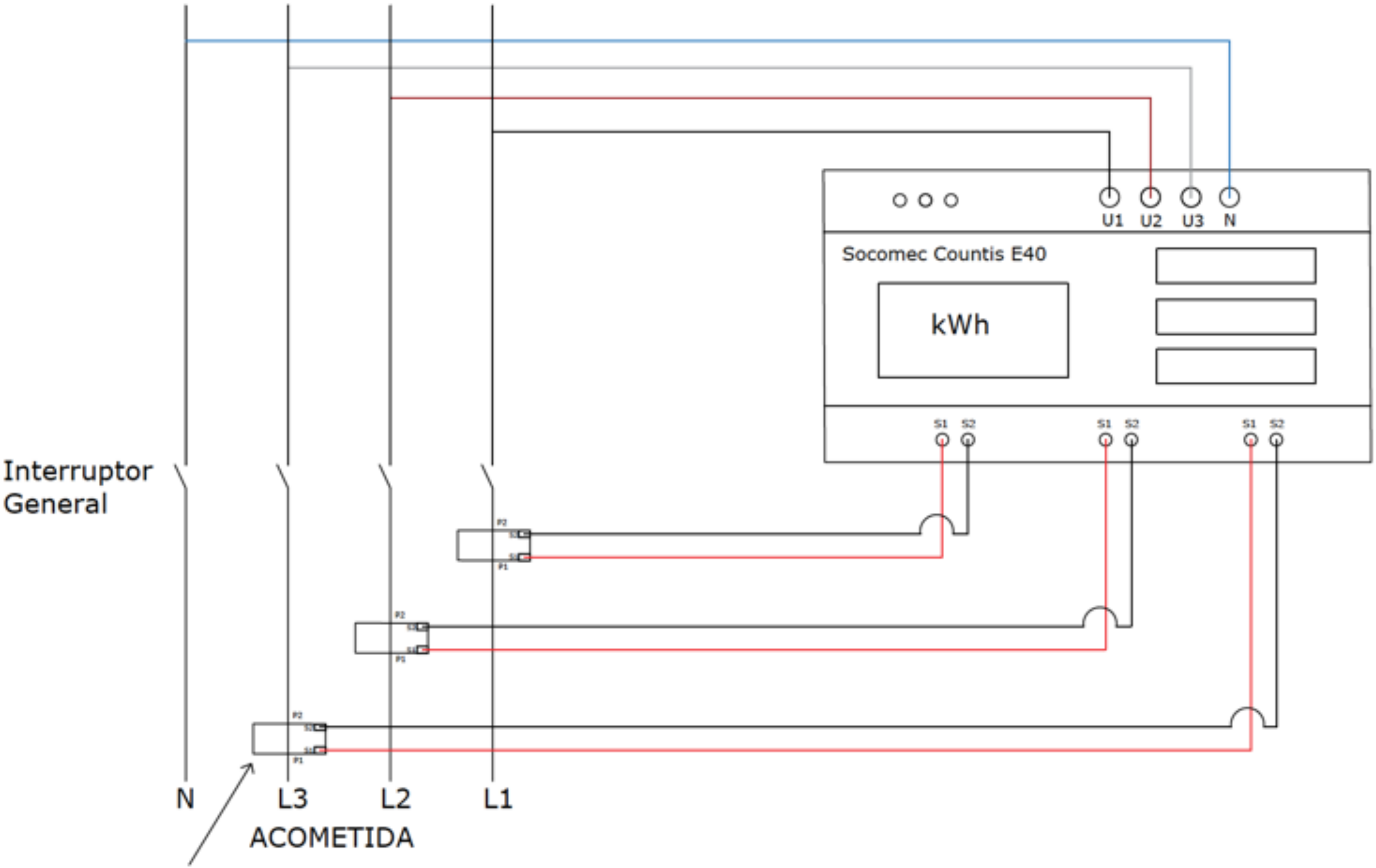
Proyecto: Instalación fotovoltaica de autoconsumo de 96kW sobre cubierta de nave industrial			
Título Plano: Distribución por strings	**NºPlano:** P03	Escala: 1:300	
Promotor: [redacted]		Cotas: N/A	
Autor Proyectista: Diego Serrano Guardiola		Fecha: 22/08/2022	



UNIVERSITAT POLITÈCNICA DE VALÈNCIA	**Proyecto:** Instalación fotovoltaica de autoconsumo de 96kW sobre cubierta de nave industrial	
	Título Plano: Conexión cableado módulos — **NºPlano:** P04	Escala: 1:300
	Promotor: [redacted]	Cotas: N/A
	Autor Proyectista: Diego Serrano Guardiola	Fecha: 22/08/2022



UNIVERSITAT POLITÈCNICA DE VALÈNCIA	**Proyecto:** Instalación fotovoltaica de autoconsumo de 96kW sobre cubierta de nave industrial		
	Título Plano: Conexión a inversores	**NºPlano:** P05	Escala: N/A
	Promotor: [redacted]		Cotas: N/A
	Autor Proyectista: Diego Serrano Guardiola		Fecha: 22/08/2022



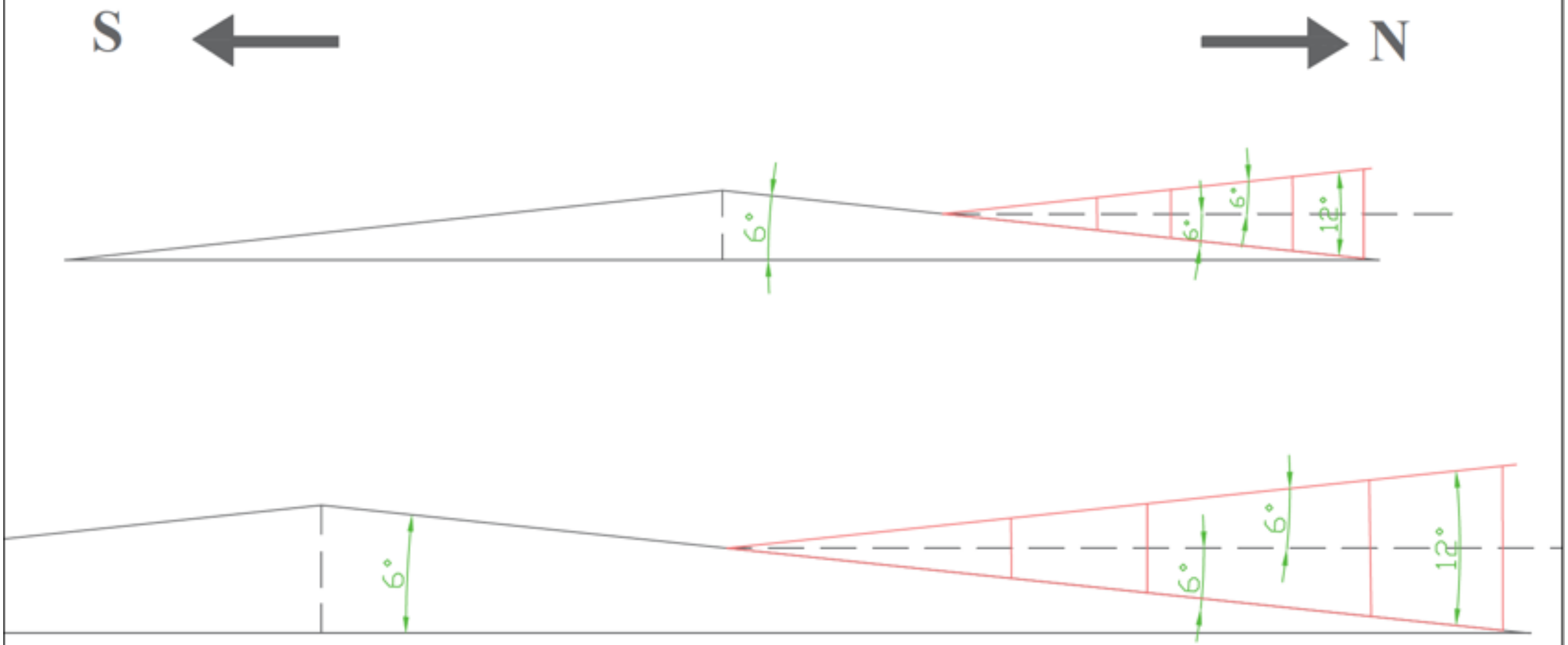
Transformadores de corriente toroidales 250/5A por cada fase.

P1: Cara inferior de la pinza toroidal
P2: Cara superior de la pinza toroidal

UNIVERSITAT POLITÈCNICA DE VALÈNCIA	**Proyecto:** Instalación fotovoltaica de autoconsumo de 96kW sobre cubierta de nave industrial		
	Título Plano: Conexión del medidor Socomec	**N°Plano:** P06	Escala: N/A
	Promotor: [redacted]		Cotas: N/A
	Autor Proyectista: Diego Serrano Guardiola		Fecha: 22/08/2022

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Proyecto: Instalación fotovoltaica de autoconsumo de 96kW sobre cubierta de nave industrial			
Título Plano: Distribución PRL		**NºPlano:** P07	Escala: 1:300
Promotor: [redacted]			Cotas: metros (m)
Autor Proyectista: Diego Serrano Guardiola			Fecha: 22/08/2022

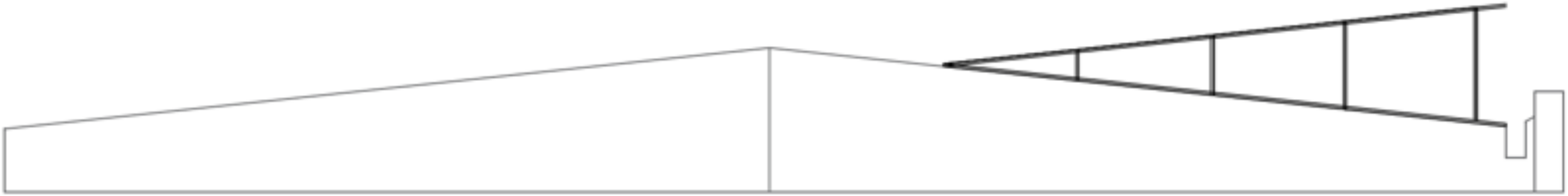


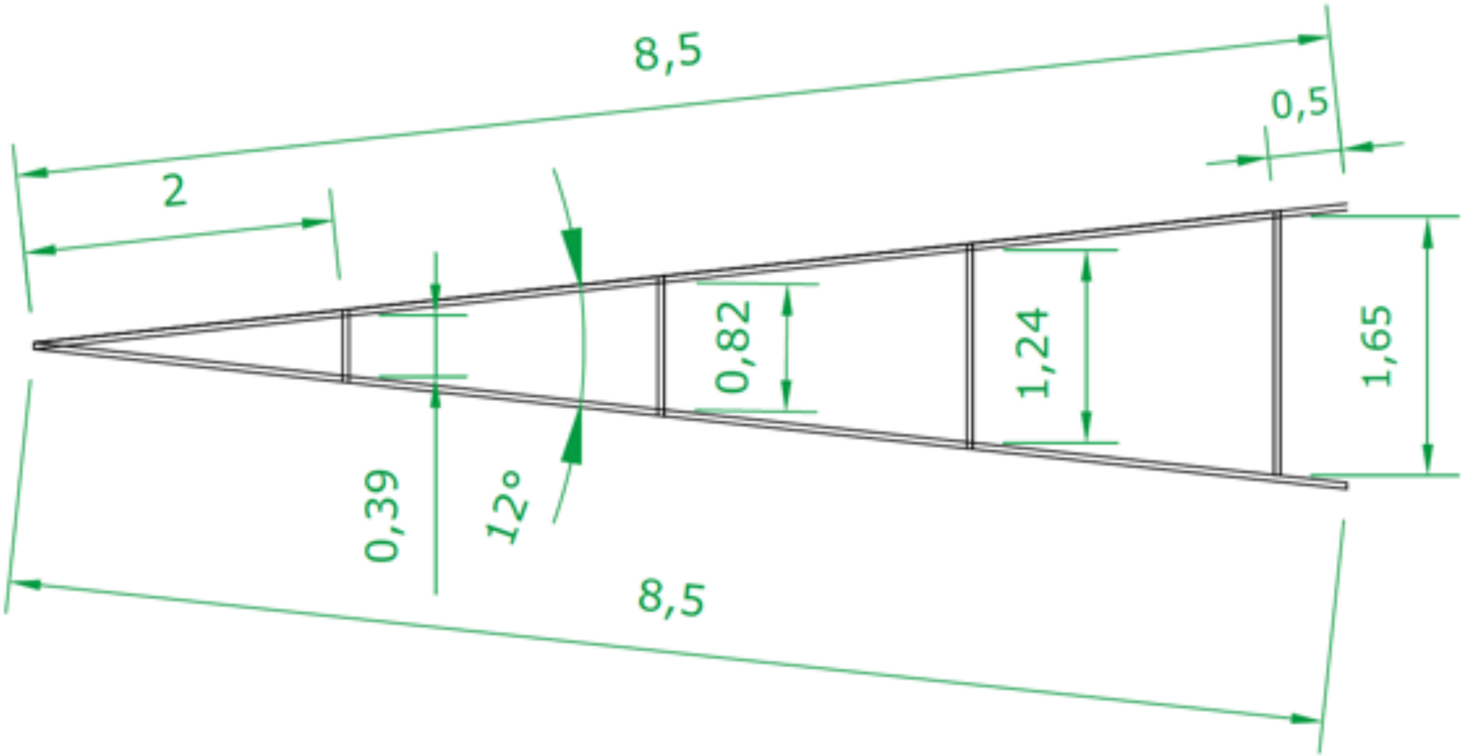
Nave de Aguas Norte-Sur

Escuadra triangular

Proyecto: Instalación fotovoltaica de autoconsumo de 96kW sobre cubierta de nave industrial	
Título Plano: Estructura Agua Norte	**NºPlano:** P08
Escala: N/A	Cotas: N/A
Promotor: [redacted]	
Autor Proyectista: Diego Serrano Guardiola	Fecha: 22/08/2022

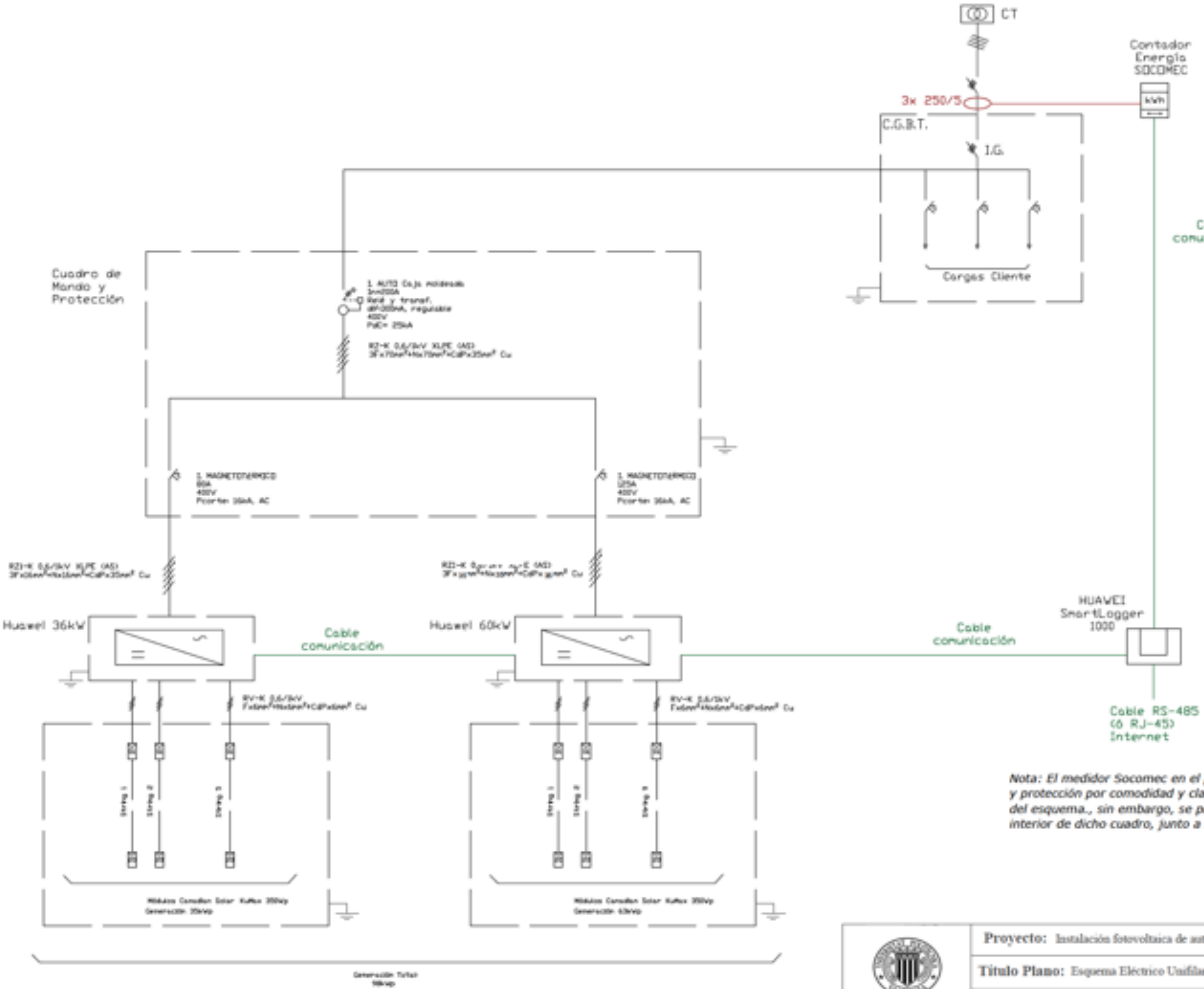
UNIVERSITAT POLITÈCNICA DE VALÈNCIA





Escuadra estrucutral Tipo 1	
Nº Uds	12

UNIVERSITAT POLITÈCNICA DE VALÈNCIA	**Proyecto:** Instalación fotovoltaica de autoconsumo de 96kW sobre cubierta de nave industrial			
	Título Plano: Escuadra estructural Tipo 1	**NºPlano:** P09	Escala: N/A	
	Promotor: [redacted]		Cotas: metros (m)	
	Autor Proyectista: Diego Serrano Guardiola		Fecha: 22/08/2022	



LEYENDA	
	Interruptor Magnetotérmico
	Módulo FV
	Interruptor General Automático con Relé diferencial, de caja moldeada
	Interruptor General (I.G.)
	Línea trifásica con neutro y conductor de protección (3F+N+CdP)
	Línea monofásica con conductor de protección (F+N+CdP)
	Puesta a Tierra (PaT)

Nota: El medidor Socomec en el plano se ha dibujado fuera del cuadro de mando y protección por comodidad y claridad de visualización del cableado del conjunto del esquema., sin embargo, se prevé para el proyecto que éste se incluya en el interior de dicho cuadro, junto a las protecciones y demás aparamenta eléctrica.

UNIVERSITAT POLITÈCNICA DE VALÈNCIA	**Proyecto:** Instalación fotovoltaica de autoconsumo de 96kW sobre cubierta de nave industrial		
	Título Plano: Esquema Eléctrico Unifilar	**NºPlano:** P11	Escala: N/A
	Promotor: [redacted]		Cotas: N/A
	Autor Proyectista: Diego Serrano Guardiola		Fecha: 22/08/2022