Universidad de
Oviedo

ESCUELA POLITÉCNICA DE INGENIERÍA DE GIJÓN.

GRADO EN INGENIERÍA ELECTRÓNICA INDUSTRIAL Y AUTOMÁTICA

ÁREA DE TECNOLOGÍA ELECTRÓNICA

DESIGN OF A PHOTOVOLTAIC SOLAR ENERGY SYSTEM FOR THE ELECTRICAL SUPPLY OF A HOUSE AND FEASIBILITY STUDY

D. BLANCO PÉREZ, Alejandro
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ADVISOR (Kütahya): Yılmaz Aslan

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<u>RESUMEN</u>

DISEÑO DE UN SISTEMA DE ENERGÍA SOLAR FOTOVOLTAICA PARA EL SUMINISTRO ELÉCTRICO DE UNA VIVIENDA Y ESTUDIO DE VIABILIDAD

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FECHA: Mayo 2019

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Introducción

El propósito de este proyecto es encontrar la solución más adecuada para el suministro de energía a un hogar a través de un sistema de energía solar fotovoltaica.

El primer paso es estudiar el consumo del hogar para tener en cuenta el sistema que se implementará, un objetivo importante porque calcular un consumo por debajo del necesario haría que nuestro sistema no proporcione suficiente energía para nuestras necesidades, mientras que el cálculo del consumo excesivo causaría que el precio del proyecto aumentara innecesariamente.

Debemos tener en cuenta la ubicación de la casa, ya que es esencial conocer los aspectos del clima que se encuentran en esa área para poder elegir los componentes correctos y su situación.

El sistema consta principalmente de los siguientes elementos: generador fotovoltaico, acumulador o baterías, regulador e inversor.

Para dimensionar adecuadamente estos elementos, debemos seguir el siguiente procedimiento: calcular el consumo, calcular la potencia necesaria del generador según la irradiación del área, calcular la capacidad de la batería, seleccionar el inversor que proporcionará CA a las cargas y elegir un regulador apropiado.

Sin embargo, las energías renovables son fuentes inagotables pero que aún presentan ciertas dificultades para su plena utilización, como por ejemplo la dificultad de almacenamiento, el elevado coste de su implementación y el hecho de que son menos eficientes que las energías tradicionales.

A pesar de ello, cada vez hay más consciencia al respecto, y empresas como Endesa aseguran que para el 2050 la economía estará totalmente ausente de carbón.

Una buena forma de apoyar la industria renovable es la aparición cada vez más común de viviendas energéticamente autosuficientes, como el proyecto que nos ocupa, y que debería convertirse en un estándar en nuestra sociedad si queremos evolucionar al respecto.

De entre los variados tipos de energías renovables que existen en la actualidad, vamos a centrar nuestro proyecto en la energía solar.

Energía solar

El sol emite energía a la tierra en forma de ondas electromagnéticas, y este fenómeno es comúnmente conocido como radiación. Llamamos energía solar a la que aprovecha la radiación procedente del sol para convertirla a calor o electricidad

Podemos obtener la energía solar de dos formas diferentes: energía térmica o energía solar fotovoltaica. Nuestro proyecto está centrado en la energía solar fotovoltaica.

La Energía solar fotovoltaica

Los paneles solares que encontramos en la energía solar fotovoltaica actual hacen que se produzca una diferencia de potencial eléctrico entre las dos caras de la placa (la radiación solar actúa sobre los electrones de un dispositivo semiconductor provocando una diferencia de potencial) y así podemos obtener energía eléctrica gracias al efecto fotovoltaico. La conexión en serie de estos dispositivos hace que la diferencia de potencial obtenida sea mayor.

Tradicionalmente este tipo de energía se utilizaba para el suministro de energía eléctrica en lugares donde no era rentable la instalación de líneas eléctricas. Con el tiempo su uso se ha ido diversificando hasta el punto que actualmente resultan de gran interés las instalaciones solares en conexión con la red eléctrica.

Beneficios de la energía fotovoltaica

La energía eléctrica generada mediante paneles solares fotovoltaicos es inagotable y limpia, no contamina (se trata de una energía renovable que no emite CO_2), por lo que contribuye al desarrollo sostenible, además de favorecer el desarrollo del empleo local. Asimismo, puede aprovecharse de dos formas diferentes: puede venderse a la red eléctrica o puede ser consumida en lugares aislados donde no existe una red eléctrica convencional.

El coste de instalación y mantenimiento de los paneles solares, cuya vida útil media es mayor a los 30 años, ha disminuido ostensiblemente en los últimos años, a medida que se desarrolla la tecnología fotovoltaica. Requiere de una inversión inicial y de pequeños gastos de operación, pero, una vez instalado el sistema fotovoltaico, el combustible es gratuito y de por vida, es decir, los gastos de mantenimiento y explotación son casi mínimos.

Es dimensionable desde grandes plantas a sistemas domiciliarios y además es modular: se pueden hacer grandes plantas en el suelo, o pequeños paneles para tejados, lo que permite fabricar desde pequeños paneles, útiles para los techos de las casas o hasta grandes plantas fotovoltaicas que pueden generar gran cantidad de energía.

Características del área

La vivienda en la que se implementará este sistema se encuentra en España, específicamente en una ciudad costera ubicada en el sur del país, en Chiclana de la Frontera, Cádiz. Cádiz tiene un clima subtropical suave que se corresponde con el clima mediterráneo.

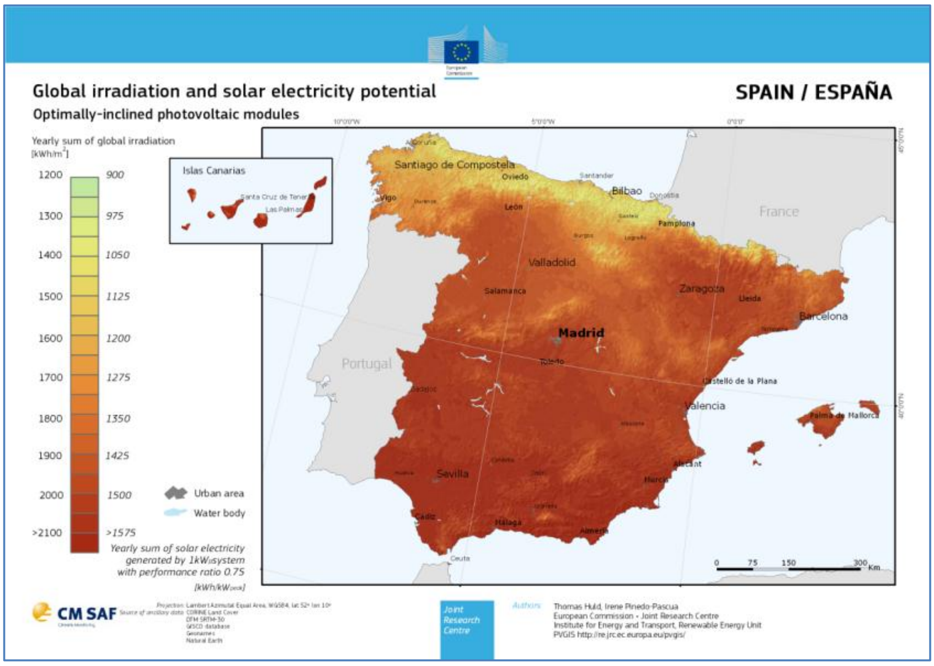

Figura 1.- Mapa de la irradiación en España.

Las coordenadas del lugar donde se implementará el sistema son las siguientes:

36,372 N(latitud) 6,175 W (longitud).

España es uno de los primeros países con más potencia fotovoltaica del mundo, con una potencia acumulada instalada de 3,523 MW. La venta de paneles fotovoltaicos ha crecido en el mundo al ritmo anual del 20% en la década de los noventa. .

En concreto Cádiz presenta características que hacen posible el éxito de las energías renovables en toda la extensión de la provincia.

Entre las tecnologías renovables, destaca la eólica que en Cádiz, supone el 88% de la potencia eléctrica renovable de esta provincia. La energía eólica producida por los parques gaditanos supone un ahorro de emisiones de CO_2 (dióxido de carbono) a la atmósfera que rozaría, aproximadamente, el millón de toneladas

En cuanto a la fotovoltaica parece que es en la última década cuando ha despertado el interés de instalaciones públicas y privadas, proliferando su instalación en tejados de edificios y equipamientos. Aunque hay que destacar la puesta en marcha de pequeñas centrales fotovoltaicas de 2 MW a 10 MW de potencia.

Irradiación

Para el correcto dimensionado del generador es conveniente realizar los cálculos con respecto al mes con menos irradiación. Ese mes es diciembre, con un promedio de 2,5 kWh/m^2. Para conocer estos valores es útil consultar ADRASE, la base de datos de radiación solar en España. También sabemos que el valor de irradiación anual promedio en el área es de: 5.3 kWh / m^2.

La base de datos PVGIS (Sistema de Información Geográfica Fotovoltaica), dependiente del Centro Común de Investigación de la Comisión Europea, también es muy útil para llevar a cabo este proyecto, donde accederemos a los datos de radiación solar según parámetros como la ubicación, la orientación de nuestros paneles o el mes del año que queramos consultar.

Para obtener los siguientes parámetros hemos accedido a dicha base de datos indicando que la inclinación deseada de nuestros paneles solares es de 46 grados. El motivo por el que escogemos dicha inclinación es simplemente porque los fabricantes recomiendan usar una inclinación de la longitud de la zona en grados, añadiéndole 10 grados más, es decir, en nuestro caso 36+10=46.

Sin embargo esta inclinación solo la usaremos para hacernos una idea previa de las características de la zona, pues más adelante se explicara el motivo por el que finalmente no se ha escogido esa inclinación, entre otros factores porque debemos tener en cuenta la importancia del mes crítico para hacer nuestros cálculos.

Una de las decisiones que hemos debido tomar es en relación a un sistema aislado o un sistema conectado a la red. A continuación se detallan ambos casos.

Fotovoltaica aislada

Un sistema fotovoltaico aislado es aquel que utiliza energía solar para transformarla en energía eléctrica sin conexión a la red. Requiere de baterías o acumuladores y permite usar dicha energía las 24 horas del día.

La instalación es sencilla y cómoda, y ofrece la posibilidad de consumir la energía gratuita del Sol, liberándonos del molesto ruido del generador y de los costes del gasóleo.

Es un sistema con muchas ventajas, podemos producir electricidad durante el día, almacenarla y consumirla posteriormente. La principal ventaja es hacerse independientes de la compañía eléctrica, aunque las circunstancias del mercado, los elevados costes y la comodidad de uso y el mantenimiento desaconsejan este tipo de instalación si ya se dispone de una conexión a la red.

Es especialmente útil en regiones donde la conexión a la red eléctrica no es posible, es decir zonas rurales o remotas donde la red eléctrica no es posible debido a los altos costes de desarrollo.

Para el correcto desarrollo del sistema será necesario hacer un cálculo del consumo detallado de cada electrodoméstico usado en la vivienda así como de la iluminación.

Elementos básicos de una instalación solar

Una instalación fotovoltaica está compuesta por un **grupo generador**, formado por una extensión de paneles solares fotovoltaicos, un regulador de carga, un grupo acumulador y un inversor.

Durante las horas de insolación, los paneles fotovoltaicos producen energía eléctrica en forma de corriente continua que es almacenada en los acumuladores. En los momentos de consumo energético, los **acumuladores** suministran a los receptores esta electricidad, que es transformada en corriente alterna por el **inversor.**

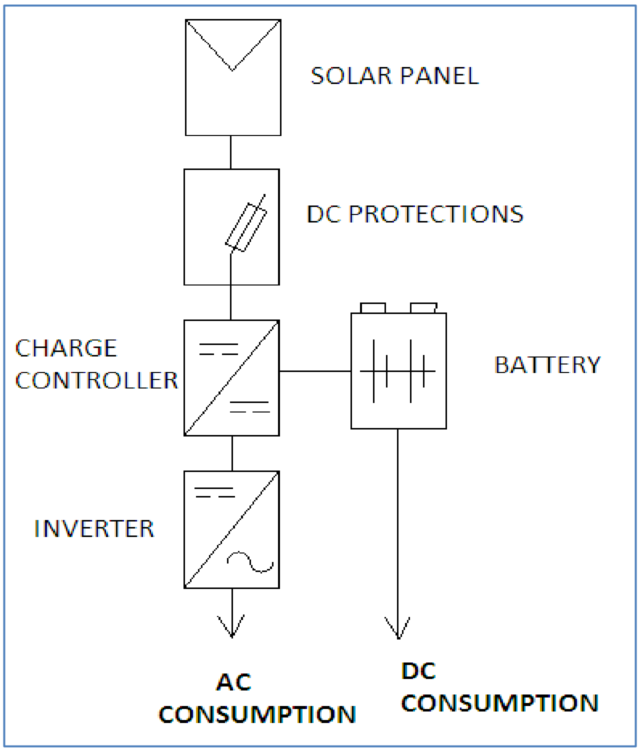

Figura 2.- Esquema de instalación fotovoltaica aislada

Descripción del sistema

Lo primero que debemos hacer antes de describir los componentes del sistema es calcular el consumo diario de la casa para hacernos una idea de nuestras necesidades

Consumo

Para el desarrollo del cálculo del consumo de la vivienda será necesario primero el número de vatios procedentes de la iluminación. Para ello hemos considerado adecuado calcular los vatios aplicables a cada luz teniendo en cuenta la superficie de cada zona a iluminar, de forma que para habitaciones, baños, cocina y comedor el valor usual es de $2W/m^2$, mientras que para los pasillos usaremos $1W/m^2$. Dado que la casa dispone de jardín y patio hemos considerado también un consumo de $2W/m^2$ para dichas zonas exteriores.

	Area(m^2)	Consumo(W/m^2)
Habitación 1	9.6	2
Habitación 2	12	2
Habitación 3	9.7	2
Cocina	7	2
Comedor	21.5	2
Baño 1	5.5	2
Baño 2	4	2
Luz exterior 1	8	2
Luz exterior 2	8	2
Luz exterior 3	12	2
Luz exterior 4	9.7	2
Pasillo	7	1

Tabla 1.- Consumo independiente de cada luz de la casa

Potencia total iluminación = 221W

Debemos tener en cuenta que las potencias que pertenecen a la iluminación tienen un factor de simultaneidad de 0,75. Por lo tanto el consumo para la iluminación total de la casa es:

221x0.75 = 165.7W

Para el cálculo debido a los electrodomésticos hay que considerar que no todos los dispositivos van a estar funcionando al mismo tiempo, ni al 100% de su demanda energética y por tanto el número de horas de uso diario que se han contemplado es una aproximación de lo que se cree que sería un uso razonable y habitual de cada dispositivo.

El objetivo del proyecto es que resulte lo más económico posible dentro de los límites de calidad mínimamente exigibles, y por tanto calcular un consumo excesivo haría que la elección de nuestros componentes resultara en un presupuesto demasiado elevado, cosa que no pretendemos.

	Potencia(W)	Horas/dia	Total(Wh/day)
Luces	165.7	3	497
Vitroceramica	1300	1	1300
lavadora	400	1	400
frigorifico	190	2	380
lavavajillas	800	1	800
Air acondicionado	600	2	1200
TV	200	2	400
Otros	200	2	400

Tabla 2.- Consumo diario de los electrodomésticos

Total=5377 Wh/día

Como se puede observar el consumo de aire acondicionado es elevado, puesto que aunque estamos teniendo en cuenta diciembre, el mes con menos irradiación, también usamos el aire acondicionado a modo de calefacción de la casa, y a pesar de ser una zona relativamente cálida, en ocasiones los meses de invierno requieren de un sistema de calefacción. Hemos supuesto un tiempo de dos horas diarias para el consumo del aire acondicionado de modo que hagamos un consumo responsable del mismo, puesto que precisamente el objetivo del proyecto es la utilización de las energías renovables de la forma más sensata posible, y dejando a un lado el mal aprovechamiento que se realiza habitualmente en la sociedad actual.

Ahora podemos calcular la potencia diaria promedio, para lo cual debemos tener en cuenta la eficiencia del inversor (0,94), la batería y el cableado, para los cuales asumiremos una eficiencia de 0,98.

Para calcular la eficiencia de la batería podemos acceder a tablas que relacionan eficiencia y temperatura. Teniendo en cuenta las condiciones del área podemos asumir una eficiencia aproximada de 0.85.

Potencia media diaria **(Pavd)** = $\frac{5377/0.94}{0.85 \cdot 0.98}$ = **7028Wh / día**

Consumo total anual (**Pt**) = Pavd· 365 = **2565220 Wh**

Generador

El generador fotovoltaico se encarga de recoger la energía de la radiación solar y transformarla en electricidad, obteniendo una corriente continua.

Las celdas fotovoltaicas son dispositivos formados por metales sensibles a la luz que desprenden electrones cuando los rayos de luz inciden sobre ellos, generando energía eléctrica. Los módulos fotovoltaicos admiten tanto radiación directa como difusa, pudiendo generar energía eléctrica incluso en días nublados.
Para el cálculo del generador fotovoltaico hay que tener en cuenta el consumo medio diario. Debemos elegir el número de paneles necesarios, así como su disposición en ramas.

Debemos calcular correctamente el consumo de nuestras necesidades, porque hacer los cálculos de manera excesiva causaría que la inversión se eleve más de lo necesario.

Inclinación óptima y orientación del generador

Para elegir la inclinación de los paneles solares tenemos varias opciones. La inclinación óptima en diciembre es la latitud + 10 °. Sin embargo, podemos observar en los datos ofrecidos por PVGIS varios parámetros que pueden ayudarnos a elegir la opción más apropiada.

Por un lado, recomendamos una inclinación de 33 °, pero estos datos se generan sin tener en cuenta nuestro criterio de uso del mes crítico (diciembre) como base, por lo que en principio lo rechazaremos.

PVGIS estima que la inclinación óptima para diciembre es de 64 °, y también sabemos que en este mes la irradiación para esta inclinación es de 4170 Wh/m^2/día. Elegimos esta opción.

En cuanto a la orientación, como regla general, los módulos deben estar orientados hacia el sur y se colocarán en el techo lateral de la casa, el lugar más apropiado, ya que es un techo adecuado sobre el que cae la luz del sol directamente, sin la presencia de paredes u objetos que puedan hacer sombra.

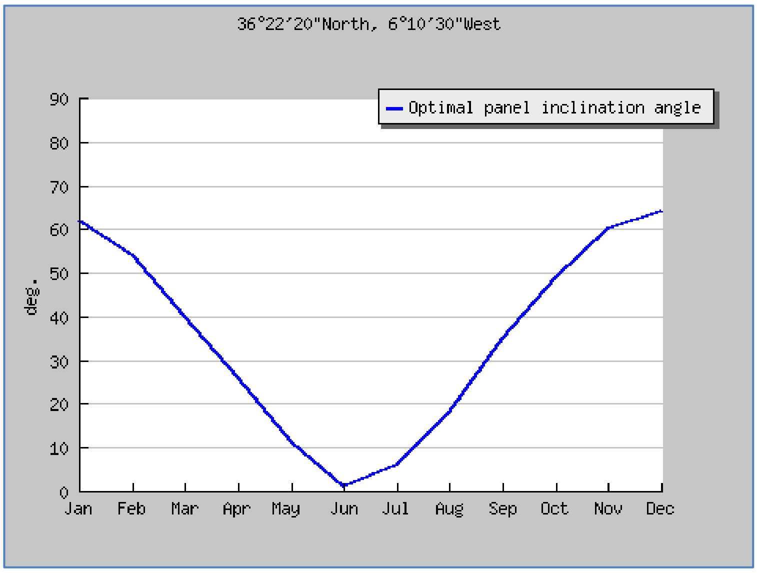

Figura 3.- Inclinación recomendada para la zona en función del mes del año

Dimensionado del generador

La fórmula necesaria para calcular la potencia del generador es la siguiente:

$$\text{Potencia mínima del generador} = \frac{\text{Pavd} \cdot \text{Gcem}}{\text{Gdm} \cdot \text{PR}}$$

-Gcem es una constante de valor 1000 W / m^2

-Hemos calculado Pavd anteriormente y, al examinar PVGIS, Gdm para el mes de diciembre, sabemos que la irradiación es de 4170 Wh /m^2/día.

El coeficiente de rendimiento se indica en porcentaje y expresa la relación entre el rendimiento real y el rendimiento nominal de la instalación fotovoltaica. Cuanto más cercano al 100 % sea el valor del coeficiente de rendimiento calculado para una instalación fotovoltaica, de forma más efectiva trabajará esta instalación fotovoltaica.

Como nuestro sistema tiene inversor y batería (sistema aislado), PR (relación de rendimiento) = 0,6.

$$\text{Potencia mínima del generador } (\textbf{Pmin}) = \frac{7028 \cdot 1000}{4170 \cdot 0.6} = \textbf{2809 Wp}$$

$$\text{Potencia máxima del generador } (\textbf{Pmax}) = \text{Pmin} \cdot 1.2 = \textbf{3370 Wp}$$

Nuestra elección será el panel solar SolarWorld SW 300 Mono Sunmodule Plus. Es un panel solar de 300W con una eficiencia del 18%, compuesto por 60 células Mono PERC.

Además, su precio es uno de los más baratos del mercado: unidad de 280,80 euros.

PERFORMANCE UNDER STANDARD TEST CONDITIONS (STC)*

		SW 290	SW 300
Maximum power	P_{max}	290 Wp	300 Wp
Open circuit voltage	U_{oc}	39.6 V	40.0 V
Maximum power point voltage	U_{mpp}	31.9 V	32.6 V
Short circuit current	I_{sc}	9.75 A	9.83 A
Maximum power point current	I_{mpp}	9.20 A	9.31 A
Module efficiency	η_m	17.30 %	17.89 %

Measuring tolerance (P_{max}) traceable to TUV Rheinland: +/- 2% (TUV Power controlled, ID 0000039351)

Figura 4.- Datos técnicos del generador

Para calcular la tensión nominal:

Potencia demandada (W)	Tensión del sistema(V)
< 1500 W	12 V
1500 W ÷ 5000 W	24 V, 48 V
>5000 W	120 V, 300 V

Tabla 3.- Tensión del sistema en función de la potencia demandada

Nuestra tensión nominal será de 48V.

También debemos calcular el número de módulos fotovoltaicos necesarios para la potencia demandada (dividiendo la potencia máxima entre la potencia del generador) y si están conectados en serie (tensión nominal entre la tensión máxima del punto de potencia) o en paralelo.

N = Pmin / Wp = 2809/300 = **10 módulos**

Nserie = Vsystem / Vmp = 48 / 32.6 = 1.46 = **2 módulos**

Nparalelo = N / Nserie =10/2= **5 módulos**

Cada panel mide 1001mm de ancho y 1675 de alto. Su espesor es relativamente despreciable con respecto al conjunto (33mm) y su peso es de 18 kg. Teniendo en cuenta que necesitamos diez paneles, sería necesaria una superficie de:

$$10 \cdot 1001 \cdot 1675 (mm^2) = 16.76 \ m^2$$

Con un soporte adecuado sería una superficie perfectamente asumible de colocar sobre el tejado de la vivienda.

Batería o acumulador

El acumulador es el dispositivo responsable de acumular la energía producida por los generadores y suministrarla a los receptores de la instalación.

La capacidad de una batería generalmente se expresa en términos del régimen de descarga, que suele ser 10 (C10), 20 (C20) o 100 horas (C100).

La capacidad de carga de una batería (cantidad de electricidad que puede suministrar) depende de factores como la temperatura, la tensión final de descarga, la intensidad de descarga o la velocidad de carga y descarga.

Cabe la posibilidad de que haya días cuya irradiación solar no sea suficiente, así que hemos estimado usar 4 días de autonomía en nuestros cálculos, es decir, suponemos que en el peor de los casos estaríamos cuatro días sin generar electricidad. Además, la función de las baterías también consiste en cubrir las demandas energéticas durante la noche.

Por lo tanto para calcular la capacidad nominal multiplicamos la potencia de las cargas por el número de días de autonomía que queremos y lo dividimos por el régimen de descarga deseado.

$$Cnbat = 7028 * 4/0.6 = 46853\ Wh$$

La explicación consiste en que necesitamos generar una energía diaria con nuestras baterías pero que podamos disponer de ella durante 4 días sin sol, sin permitir una descarga mayor del 60% y suponiendo un Factor de corrección de Temperatura (F CT = 1). Una vez sabida la energía en Wh de la batería, simplemente dividimos entre la tensión de la misma (24V en este caso) y ya tenemos la capacidad mínima que necesitamos para nuestro sistema de acumulación en función de los días de autonomía.

Para calcular la capacidad en Ah:

Cnbat= 46853 / 48 = **976 Ah**

Finalmente, nuestra mejor opción es la batería **24v 8 TOPZS 1000 (1300Ah c100)**

El precio es de 3.717,99 €, pero como la tensión de nuestro sistema es de 48 V, tendremos que comprar dos unidades (24 V), lo que hace un total de 7436 euros.

Si conectamos las baterías en serie conectaremos el polo positivo de la batería con el polo negativo de de la siguiente batería, así sucesivamente. De este modo lo que logramos es aumentar la tensión final del sistema de acumulación, que sería la suma de las tensiones de la baterías conectadas en serie, y mantenemos la capacidad, y tendremos una tensión de 48 V y 1300Ah

Regulador de carga

El regulador o controlador controla la carga de la batería, evitando cantidades excesivas. Es un elemento indispensable de los sistemas aislados. Entre sus funciones, está la de aislar los generadores fotovoltaicos si su tensión es menor a la tensión de carga de las baterías, o conectarlos si la tensión es superior a la de la batería debido a un aumento de la insolación. Además, deben proteger a las baterías frente a sobrecargas.

Para que cumpla todas estas funciones primero debemos calcular los parámetros necesarios.

Sabemos que la potencia del generador es igual a la potencia individual de cada módulo multiplicada por el número de módulos de los que dispongamos.

P generador = número de módulos · potencia generador= 10 · 300 **= 3000 W**

Para calcular las tensiones máxima del generador y la tensión de circuito abierto tendremos en cuenta el número de paneles conectados en serie.

Vmpgen = tensión máxima del generador · módulos serie = 2 · 32.6 = **65.2 V**

Vocgen = módulos serie · corriente de cortocircuito del generador= 2 · 40 = **80 V**

La corriente máxima del regulador la calcularemos teniendo en cuenta el número de módulos en paralelo, además de la corriente de cortocircuito de dichos módulos. También multiplicaremos dicho valor por 1.2, esto quiere decir que la corriente aconsejada para el regulador debe ser un 20% mayor a la de los módulos fotovoltaicos.

$$\mathbf{Imaxreg} = 1.2 \cdot \text{Nparalelo} \cdot \text{Isc} = 1.2 \cdot 5 \cdot 9.83 = \mathbf{58.98A}$$

Con estos datos podemos concluir que el controlador de carga solar 60A 3200W 48V MPPT satisface nuestras necesidades.

Modle	Solar Charge Controller		
	SCC1260	SCC2460	SCC4860
INPUT			
MPPT Range @Operating Voltage	15 ~115VDC	30 ~115VDC	60 ~115VDC
Maximum PV Array Open Circuit Voltage	145VDC		
Maximum PV Array Power	800W	1600W	3200W
Maximum Input Current	50A		

Figura 5.- Datos técnicos del regulador

Con un precio de 235 € / unidad, es la opción perfecta para nuestras necesidades.

Inversor / cargador

Los inversores se encargan de transformar la corriente continua obtenida por el sistema fotovoltaico en la corriente alterna necesaria para cualquier dispositivo convencional. Este dispositivo también hará la función de cargador, de manera que cuando las baterías se descarguen se podrá abastecer el sistema.

Los inversores trabajan con diferentes niveles de tensión, lo que será determinante a la hora de elegir nuestro modelo. Además de la tensión de entrada tendremos que buscar un inversor con la tensión de salida adecuada, en nuestro caso una tensión de alterna de 230 V.

También debemos tener en cuenta la potencia máxima del conjunto de las cargas. Consideramos que los inversores deben ser capaces de soportar las demandas eléctricas de electrodomésticos y aire acondicionado simultáneamente, debemos aplicar un factor de simultaneidad. En la mayoría de los casos encontramos que es 0.7 o 0.8. Para mayor seguridad, utilizaremos el coeficiente 0.8. Entonces:

Potencia del inversor = 0.8 · cargas = 0.8 · 3656 = **2940 W**

Además nuestro inversor debe tener una tensión nominal de 48 V. Por lo tanto se elegirá el modelo **Inversor de onda pura 48V 3000W TBB CPI3000S.**

Presupuesto

Hemos intentando mantener un equilibro entre calidad y precio que nos permitiera obtener productos de calidad, y cuya vida útil no se resintiese demasiado por la baja calidad de sus materiales u otros factores.

Aun así, realizar este proyecto unos años atrás habría resultado mucho más costoso. La tecnología avanza y cada vez que lo hace es más accesible para el usuario medio.

Además está comprobado que un panel solar de alta calidad, aunque va a ser más caro, a la larga es más rentable.

Para el presupuesto no hemos tenido en cuenta el precio del cableado, pues lo hemos considerado despreciable con respecto al precio del resto de instalación y mano de obra. El desglose más detallado está expuesto más adelante, pero el total es el siguiente:

Total material con IVA: 12259.81 €

Total montaje: 480€

Total montaje con IVA: 580.8€

Total: 12 840.61€

ESCUELA POLITÉCNICA DE INGENIERÍA DE GIJÓN.

GRADO EN INGENIERÍA ELECTRÓNICA INDUSTRIAL Y AUTOMÁTICA

ÁREA DE TECNOLOGÍA ELECTRÓNICA

MEMORY

DESIGN OF A PHOTOVOLTAIC SOLAR ENERGY SYSTEM FOR THE ELECTRICAL SUPPLY OF A HOUSE AND FEASIBILITY STUDY

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CONTENT

1.- OBJECTIVE

Figure 1.1.- Example of the implantation of solar energy in a house

The purpose of this project is to find the most appropriate solution for the supply of energy to a home through a photovoltaic solar energy system.

The first step is to study the consumption of the home to take into account the system to be implemented, an important goal because calculating a consumption below the necessary would make our system not provide enough energy for our needs, while calculating excessive consumption would cause the project price to rise too unnecessarily.
We must take into account the location of the house since it is essential to know the weather aspects that are in that area, to be able to choose the right components and their situation.

A study will be made of the different types of systems available for the generation of electricity, and will be assessed according to our needs if what is most convenient for us is an isolated system or a system connected to the network, listing the possible advantages and disadvantages (both economic type and in other areas) of each case.

The system consists mainly of the following elements: photovoltaic generator, accumulator or batteries, regulator and inverter.

To properly dimension these elements we must follow the following procedure: calculate the consumption, calculate the necessary power of the generator according to the irradiation of the area, calculate the capacity of the battery, select the inverter that will provide AC to the loads, and choose an appropriate regulator.

Once all the components have been selected, we will proceed to the elaboration of a budget of both labor and materials, which will give us a more approximate idea of whether the implementation of the method with respect to the current conventional electric power system is actually profitable.

The reason for this project is because the use of isolated systems of electricity generation is increasingly widespread, because in certain areas the lack of economic or structural resources can make it impossible to connect an urban core to the electricity grid.

2.- PRECEDENTS

2.1.- Renewable energies

The current energy system has a very low performance (ratio between energy consumed and primary energy used). For this reason, renewable energies are increasingly present today, the most common currently being wind energy, geothermal energy, biomass, hydraulics and solar energy.

We call renewable energies those capable of producing electricity from elements such as wind, sun and water. They are produced without exhausting the source of energy from which they come, since their rate of natural generation is much higher than consumption.

The renewable energies are a resource of great importance at present because conventional energies such as oil, coal or natural gas are more polluting and suppose a considerable deterioration of the environment (with adverse effects such as climate change, the greenhouse effect , acid rain etc), not to mention that there is a growing shortage of fossil fuels.

Figure 2.1.- Kinds of renewable energies.

There is a growing awareness on the part of both the public and the political class that it is necessary to adapt the different ways of obtaining energy to a more modern and less aggressive system for the environment. This is so because it is increasingly evident that we are facing a real problem with climate change. Temperatures have increased markedly throughout the Earth and sea level has risen. Many professionals of the sector assure that a change is necessary so that the situation does not become irreversible. An example of this is the Kyoto protocol.

2.1.1.- Kyoto Protocol

The Kyoto Protocol was created to reduce greenhouse gas emissions that cause global warming. Its destiny is to put into practice what was agreed in the United Nations Framework Convention on climate change.

It owes its name to that it was initially adopted in Kyoto on December 11, 1977, although it did not come into force until 2005.

The report concluded that the climate had already begun to change because of greenhouse gas emissions.

Governments agreed to more aggressive measures, in particular, legally binding commitments to reduce or limit emissions.

This protocol establishes, for the first time, objectives to reduce net emissions of greenhouse gases for the main developed countries and economies in transition, with a compliance calendar.

Greenhouse gas emissions from industrialized countries should be reduced by at least 5% below 1990 levels in the period 2008-2012, known as the first commitment period of the Kyoto Protocol.

The achievements of this pact are numerous: since the undersigned governments establish laws and policies to meet their environmental commitments; that companies take the environment into account when making investment decisions, to encourage the creation of the carbon market, whose purpose is to achieve the reduction of emissions at the lowest cost. In the following figure we can see the number of countries that are present in the Kyoto protocol. As we see, a large majority is collaborating on this.

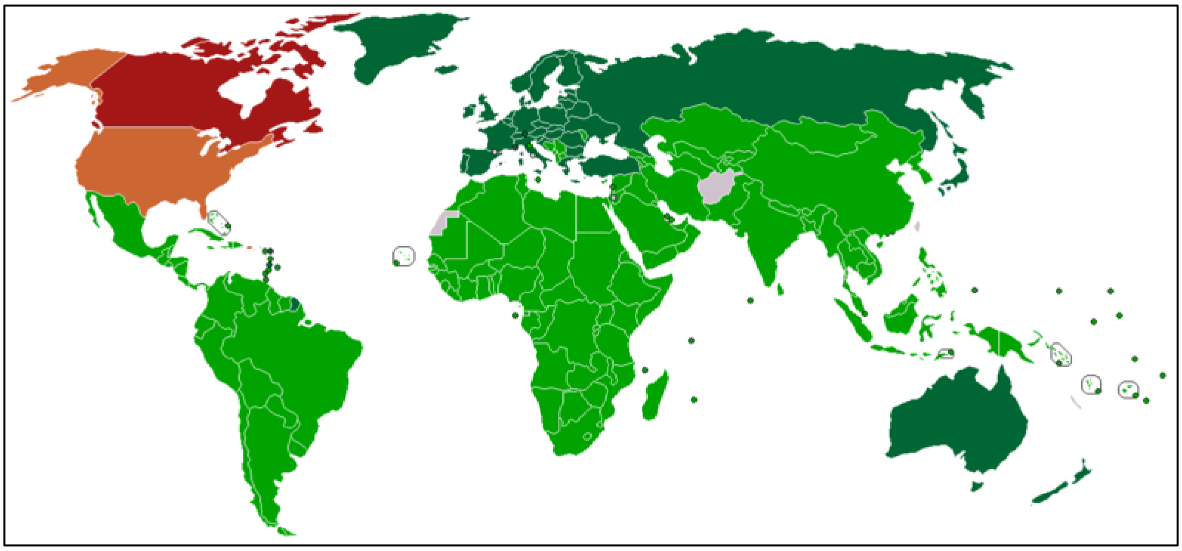
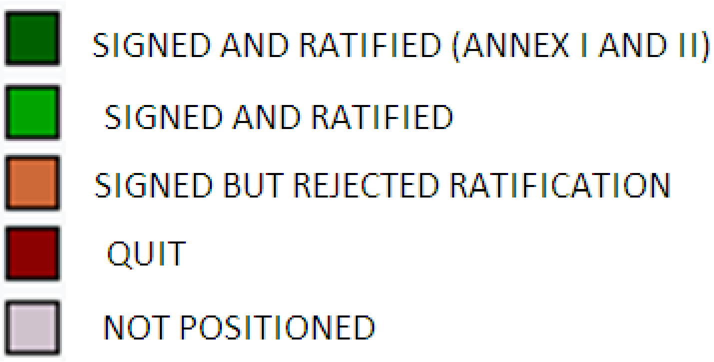


Figure 2.2.- Map about countries present in Kyoto Protocol.



However, renewable energies are inexhaustible sources but still present certain difficulties for their full use, such as the difficulty of storage, the high cost of their implementation and the fact that they are less efficient than traditional energies.

In spite of this, there is a growing awareness of this, and companies such as Endesa say that by 2050 the economy will be totally absent from coal.

A good way to support the renewable industry is the increasingly common appearance of energy self-sufficient housing, as the project that concerns us, and that should become a standard in our society if we want to evolve in this respect.

Among the various types of renewable energy that exist today, we will focus our project on solar energy.

2.1.2.- Solar energy

The sun emits energy to the earth in the form of electromagnetic waves, and this phenomenon is commonly known as radiation. We call solar energy that uses the radiation from the sun to convert it to heat or electricity

We can obtain solar energy in two different ways: by solar thermal energy or by photovoltaic solar energy.

Thermal solar energy:

It consists of the use of energy from the Sun to transfer it to a medium that carries heat, usually water or air.

The main component in charge of this task is the sensor, through whose interior there is a fluid that absorbs the irradiated energy. The thermal panels are installed in houses with direct sun reception.

Among the different applications of solar thermal energy there is the possibility of generating electrical energy. The current technology allows heating water with solar radiation to produce steam and then obtain electrical energy.

Although the principle of operation is very similar there are two main applications of solar thermal energy:

-Thermal single energy for use in homes and **small installations.**

-**Great central solar thermal energy**. In these plants the heat is concentrated in a point to generate steam, with the steam a turbine is driven to generate electric power. Once the heat is generated, the operation of a solar thermal power plant is very similar to that of a thermal power plant or a nuclear power plant. The difference lies in that a thermal power plant the heat to generate the steam comes from the combustion of fossil fuels, normally coal, and in a nuclear power plant, heat is obtained by fissuring the nucleus of uranium atoms.

Photovoltaic solar energy

It is the energy present in the project that concerns us. Although the photovoltaic effect was known since the nineteenth century, it was in the 50s when photovoltaic panels began to really enter the industry. Initially used to supply electricity to geostationary communication satellites, its use is now more widespread among the common population.

The solar panels that we find in the current photovoltaic solar energy cause a difference of electric potential between the two faces of the plate to be produced (the solar radiation acts on the electrons of a semiconductor device causing a potential difference) and thus we can obtain energy electrical thanks to the photovoltaic effect. The series connection of these devices means that the potential difference obtained is greater.

Traditionally this type of energy was used for the supply of electrical energy in rural areas where it was not possible to install power lines but over time its use has become popular.

Benefits of photovoltaic solar energy

The electrical energy generated by photovoltaic solar panels is inexhaustible and **clean**, it does not pollute (it is a renewable energy that does not emit CO_2), so it contributes to sustainable development, as well as favoring the development of local employment.

Likewise, it can be used in two different ways: **it can be sold** to the electricity grid or it can be consumed in isolated places where there is no conventional electricity grid.

For this reason, it is a particularly suitable system for **rural or isolated areas** where the power line does not reach or is difficult or expensive to install or for geographical areas whose climate allows many hours of sunshine per year.

The **cost** of installation and maintenance of solar panels, whose average useful life is greater than 30 years, has decreased significantly in recent years, as photovoltaic technology develops. It requires an initial investment and small operating expenses, but once the photovoltaic system is installed, the fuel is free and for life, that is, the maintenance and exploitation costs are almost minimal.

Another property is that it is **scalable** from large plants to domiciliary systems; and modular: large plants can be made in the ground, or small panels for roofs, which allows manufacturing from small panels, useful for the roofs of houses or even large photovoltaic plants that can generate a lot of energy.

2.2.- Characteristics of the area

The housing in which this system is going to be implemented is located in Spain, specifically in a coastal city located in the south of the country, in Chiclana de la Frontera, Cádiz. It is a city and municipality of Spain, capital of the homonymous province, in the autonomous community of Andalusia.

Figure 2.3.- House location

The city of Cádiz is located in what is called, geographically, a tómbolo. 66.91% of the land, between marshes (belonging to the Bahía de Cádiz natural park) and beaches, is not developable. The entire urbanizable land is occupied.

Cádiz has a mild subtropical climate that corresponds to the Mediterranean climate.

The average annual temperature in the observatory of Cádiz in the period 1981-2010 is 18.6 ° C. The average of the maximum temperatures in the warmest month (August) are 27.9 ° C while the average of the minimum temperatures in the coldest month (January) is 9.6 ° C. In 2007, Cádiz was fourth sunniest city in Spain, with 3016 hours of sunshine, according to the data available to the National Institute of Statistics, collected in its statistical yearbook.

2.2.1.- Location

The coordinates of the place where the system will be implemented are the following: 36,372 (latitude) 6,175 W (longitude).

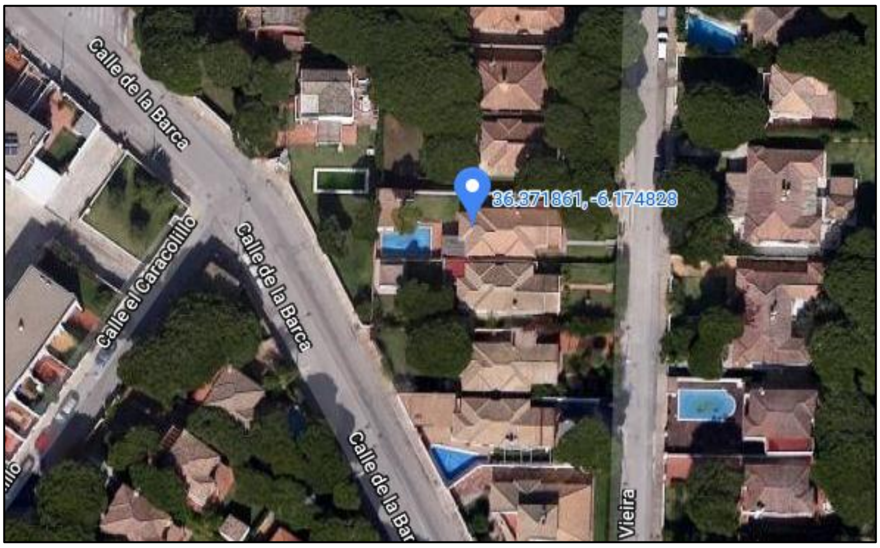


Figure 2.4.- Expanded satellite view of the housing position

In the following image we can see a graph of the average temperature of the area according to the months of the year. It can be seen that it is a relatively hot area, especially in the summer months, and the winter months are not too cold, which is an advantage for the system we are designing

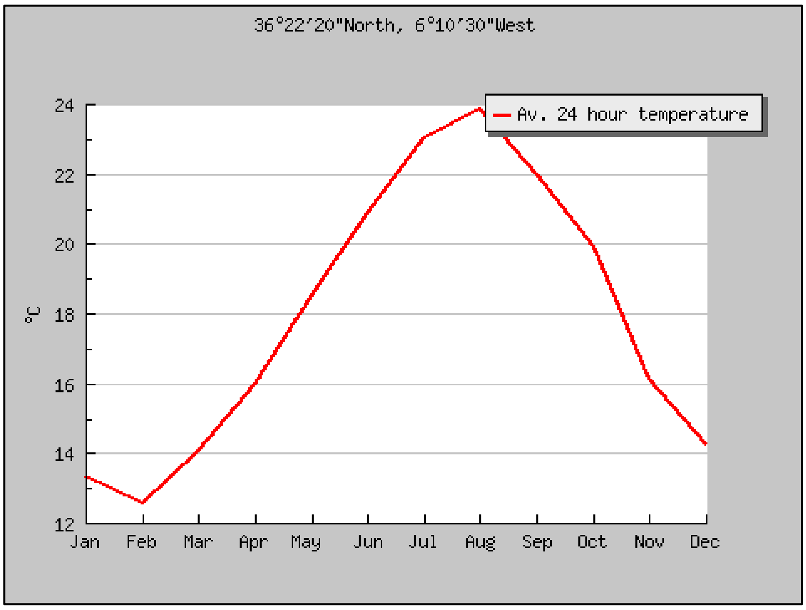


Figure 2.5.- Graph that shows average temperature of location in every month

2.2.2.- Renewable energies in the area

Spain is one of the first countries with more photovoltaic power in the world, with an accumulated installed capacity of 3,523 Megawatts (MW). Only in 2008 the installed capacity in Spain was about 2,500 MW. The sale of photovoltaic panels has been 20% higher each year, in the decade of the nineties.

With regard to **Andalusia**, in recent years the development of important energy infrastructures has been exploited, customized in: construction of gas pipelines, extension of the electric networks of transport and distribution, implantation of combined cycles or an increase of the installations of electrical generation with energies renewable.

Figure 2.6.- Situation of Andalusia in the map.

The province of **Cádiz** is characterized by having 41.5% of the installed electrical power of Andalusia, 49.7% referred to the power of non-renewable technologies.

Among the renewable technologies, wind power stands out, which in Cadiz accounts for 88% of the renewable electric power in this province.

Cádiz is the seventh province in surface in Andalusia and the third in population. It has an important industrial zone that generates a high per capita demand in relation to Andalusia. It has the largest generator park in Andalusia, concentrating 41.5% of installed capacity. Cádiz has been the Spanish province pioneer in wind energy, currently has 1310 MW (39.4% of the total installed wind power in Andalusia).

The province, both because of its **meteorological conditions** and because of the sensitization it must have to the consequences of pollution, is one of the greatest possibilities for the development of new sources of electrical power, and thus be able to reverse the trend towards climate change and avoid that the process is accelerated, since this fact would affect mainly a place like the one that occupies us.

In fact, Cádiz already stands out in the renewable energy sector since it generates 24% of the total produced in Andalusia. That is to say, a quarter of all the clean electricity that the Autonomous Community is able to put into use, is already supported by the province through its resources.

That is why it can be considered that Cádiz has a leading position in renewable energies. Among the technologies of this type, wind power stands out with its 67 wind farms and 1,307 megawatts (MW) installed in the province, which represents 39.3% of the wind power in Andalusia. It is the Andalusian Agency of Energy itself, an agency attached to the Ministry of Economy, which underlines that Cádiz has that leading position in electric power through renewable energy, with 1,493 MW installed.

The **wind energy** produced by the Cadiz parks means a saving of CO2 emissions (carbon dioxide) to the atmosphere that would touch, approximately, one million tons.
And the importance of this sector in Cádiz not only lies in this positioning within the business but also in the ability to generate employment. In the province there are already more than a hundred established companies that are dedicated to the production, installation or development of renewable energy. A sector that right now has approximately 3,000 workers (adding 702 direct jobs and some 2,325 indirect jobs). For a province hit by unemployment, renewable energy could open an important field of activity thanks to the weather.

The data confirm that wind energy is the one that gets the most out of it, since the sun is not yet sufficiently exploited. In fact, in terms of solar **thermal power** Cádiz only generates 100 MW (10% of what is produced in Andalusia), while photovoltaic only 73.28 MW is achieved (which does not even reach 9% of what is generated in Andalusia), according to data provided by the Andalusian Administration.
And it is that the immersion and use of the sun for the production of energy in Cádiz is relatively early, especially if it is referred to as solar thermal.

Regarding **photovoltaics**, it seems that it has been in the last decade when it has aroused the interest of public and private facilities, proliferating its installation on roofs of buildings and equipment. Although we must highlight the start-up of small photovoltaic power plants from 2 MW to 10 MW of power.

As for **other technologies**, Cádiz remains in line. In hydroelectric power plants, due to the need for consumption for irrigation and urban use, it does not even reach 2% of Andalusia; in biogas it is 7% regionally.

2.2.3.- Irradiation

For the correct dimensioning of the generator it is convenient to perform the calculations with respect to the month with less irradiation. That month is December, with an average of 2.5 kWh / m2. To know these values it is useful to consult ADRASE, the solar radiation database in Spain.

We also know that the average annual irradiation value in the area is: 5.3 kWh / m2

The PVGIS database (Photovoltaic Geographical Information System), dependent on the Joint Research Center of the European Commission, is also very useful for carrying out this project, where we will access solar radiation data according to parameters such as location, orientation of the our panels or the month of the year that we want to consult.

Monthly Solar Irradiation

PVGIS Estimates of long-term monthly averages

Location: 36�22'17" North, 6�10'29" West, Elevation: 24 m a.s.l.,

Solar radiation database used: PVGIS-CMSAF

Optimal inclination angle is: 33 degrees
Annual irradiation deficit due to shadowing (horizontal): 0.0 %

Month	H_h	H_{opt}	$H(46)$	I_{opt}	T_{24h}	N_{DD}
Jan	2650	4390	4760	62	13.3	144
Feb	3700	5410	5690	54	12.6	95
Mar	5190	6370	6380	40	14.1	32
Apr	6210	6600	6270	26	16.0	18
May	7260	6860	6220	11	18.5	1
Jun	8020	7150	6310	1	20.9	0
Jul	8010	7320	6520	6	23.1	0
Aug	7140	7220	6710	18	23.8	0
Sep	5590	6550	6440	35	22.0	1
Oct	4300	5900	6100	49	19.9	10
Nov	2980	4780	5150	60	16.1	103
Dec	2390	4170	4570	64	14.2	114
Year	5300	6060	5930	33	17.9	518

Table 2.1.- Irradiation features of the área according to PVGIS

H_h: Irradiation on horizontal plane (Wh/m^2/day)

H_{opt}: Irradiation on optimally inclined plane (Wh/m^2/day)

H(46): Irradiation on plane at angle: 46deg. (Wh/m^2/day)

I_{opt}: Optimal inclination (deg.)

T_{24h}: 24 hour average of temperature (�C)

N_{DD}: Number of heating degree-days (-)

To obtain the following parameters we have accessed said database indicating that the desired inclination of our solar panels is 46 degrees. The reason why we choose this inclination is simply because the manufacturers recommend using the length of the zone in degrees, adding 10 degrees more, that is, in our case 36 + 10 = 46.

However, this inclination will only be used to give us a previous idea of the characteristics of the area, because later we will explain the reason why this inclination has not been chosen, among other factors because we must take into account the importance of the critical month to do our calculations.

3.- ALTERNATIVES AND ADOPTED SOLUTION

One of the decisions we have had to make is in relation to an isolated system or a system connected to the network. Below are both cases.

3.1.- Isolated photovoltaic system

An isolated photovoltaic system is one that uses solar energy to transform it into electrical energy and that has **no connection** with the electric power grid of CFE.

The objective is to install a photovoltaic system to consume electricity without having to request a connection to the national electricity grid. The installation is easy and convenient, and offers the advantage of consuming the Sun's energy without any cost, dispensing with problems such as generator noise or diesel costs.

By means of an isolated photovoltaic installation we can produce electricity during the day, store it and consume it later.

In this way, we can supply electricity to country houses, mountain refuges, water pumping, livestock facilities, lighting systems or beacons and communication systems.

It is also advisable, as long as it is economically feasible and the terrain conditions permit, the combination of photovoltaic panels with wind turbines or a mini-hydraulic system, depending on the circumstances. The first case is especially recommended, since wind and photovoltaic energy complement each other because what are adverse weather conditions in one, are usually positive in another.

On the contrary, a non-autonomous photovoltaic installation (or **connected to the grid**) consists of generating electricity through photovoltaic solar panels and injecting it directly into the electrical distribution network, therefore it does not require batteries or accumulators.

Electricity distribution companies are obliged by law to buy the energy injected into their network by these photovoltaic power plants.

Advantages and disadvantages of an isolated installation

In fact, the electricity generated by solar PV can both be sold to the electricity grid and also feed **isolated areas** of the national grid, and is especially useful for agricultural uses, rural housing and even neighborhood communities or blocks of electricity. households.

The main advantage is to become **independent** of the electricity company, although it is also true that this type of installation is not advised if a connection to the network is already available due to market circumstances or high costs.

However, this is changing due to the cheapening of the components, especially when buying solar panels, and soon it will be more profitable photovoltaic self-consumption than the connection to the electricity grid.

3.2- Basic elements and operation

A photovoltaic installation consists of a photovoltaic generator, consisting of a group of photovoltaic solar panels, a charge regulator, an accumulator and an inverter.

During the hours of insolation, the photovoltaic panels produce electrical energy in the form of direct current that is stored in the accumulators or batteries. At times of energy consumption, the batteries supply the receivers with this electricity, which is converted into alternating current by the inverter.

Photovoltaic solar energy is based on the photoelectric effect to directly convert the energy of the sun's rays into electricity. To obtain an electric current, an electrical potential difference must be created. Conductive materials must be used since their electrons have a higher activity and allow to create electric flow easily.

In order for the photovoltaic cell to generate electricity, we must create a difference between the positive and negative charges by adding a small dose of contaminating atoms to a pure semiconductor, capable of yielding or accepting electrons.

Through charges we must generate a current exposing the photovoltaic cell to a light radiation to take advantage of the energy of the photons. The photon gives energy to an electron in the valence band and passes it to the conduction band. Thus, the absence of electrons is caused, which create charges and establish an electric current. We will obtain a potential difference by joining two semiconductors that contain different densities of positive or negative charges. This generates an electric field.

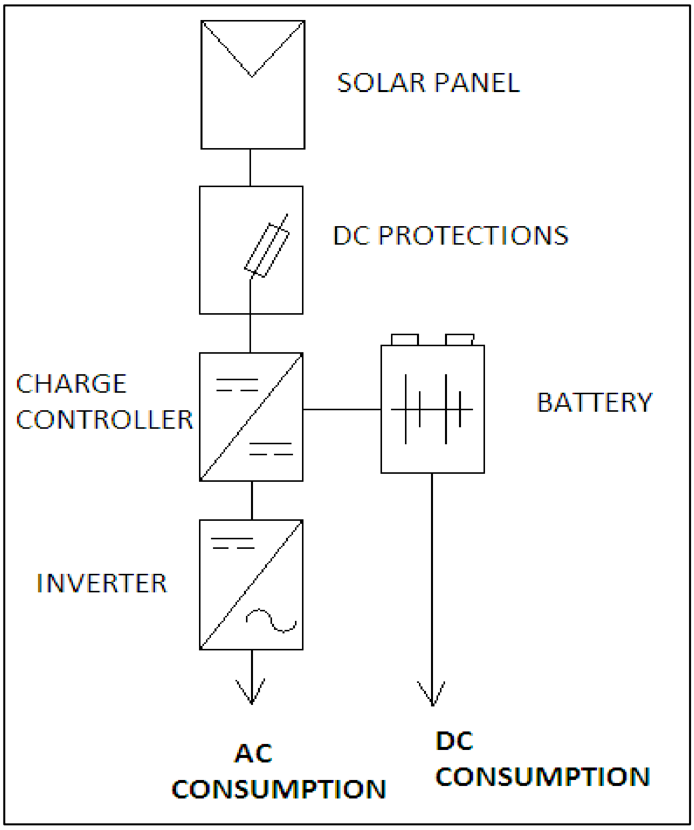


Figure 3.1.- Schematic system version

4.- SYSTEM DESCRIPTION

The installation requires a series of previous calculations necessary to know what type of devices and components are optimal for that particular project. The determining factor to take into account is the daily consumption xpected for the house (and the approximate time that each appliance is working per day) so it will be the first calculation to be made before describing the components.

4.1- Consumption

For the development of the calculation of the consumption of the house will be necessary first the number of watts from the lighting. For this we have considered adequate to calculate the watts applicable to each light taking into account the surface of each area to be illuminated, so that for rooms, bathrooms, kitchen and dining room the usual value is 2W /m2, while for the corridors we will use $1W/m^2$. Since the house has a garden and backyard, we have also considered a consumption of $2W/m^2$ for those outdoor areas.

	Area(m^2)	Consumption(W/m^2)
Room 1	9.6	2
Room 2	12	2
Room 3	9.7	2
Kitchen	7	2
Living room	21.5	2
Bathroom 1	5.5	2
Bathroom 2	4	2
Exterior light 1	8	2
Exterior light 2	8	2
Exterior light 3	12	2
Exterior light 4	9.7	2
Hall	7	1

Table 4.1.- Power of lighting

Total lights power= 221W

We must bear in mind that the powers belonging to enlightenment have a simultaneity factor of 0.75. Therefore the consumption for the total lighting of the house is:

221x0.75 = 165.7W

In addition, we can see in the following graph that we have accessed from the data offered by the website of the current electricity company in the house, which approximately makes a balanced use of lights and appliances, that is, choosing a random month we can see that electricity is consumed approximately the same number of hours during the hours that are the cheapest and during the most expensive hours.

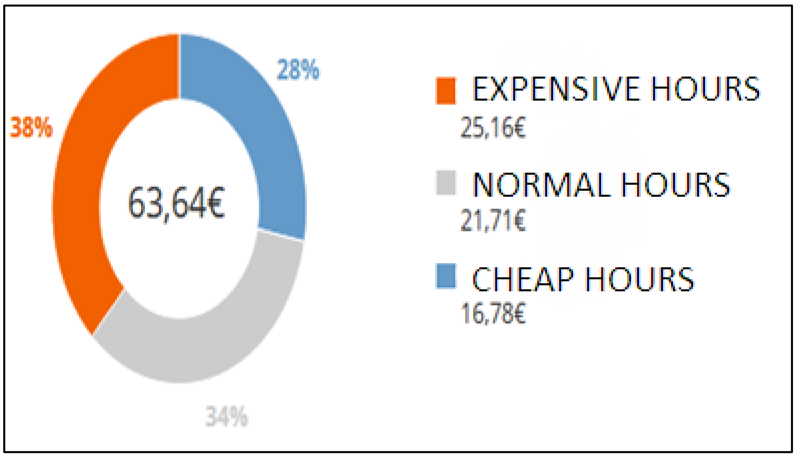


Figure 4.1.- Economic consumption depending to the type of hour

For the calculation due to the appliances, it is necessary to consider that not all the devices will be working at the same time, nor at 100% of their energy demand and therefore the number of hours of daily use that have been contemplated is an approximation of the which is believed to be a reasonable and usual use of each device.

The objective of the project is to be as economical as possible within the minimum quality limits, and therefore calculating excessive consumption would make the choice of our components result in a too high budget, which we do not intend.

	Power(W)	Hours/day	Total(Wh/day)
Lighting	165.7	3	497
Vitroceramic	1300	1	1300
Washing machine	400	1	400
Fridge	190	2	380
Dishwasher	800	1	800
Air conditioner	600	2	1200
TV	200	2	400
Others	200	2	400

Table 4.2.- Appliances consumption

Total=5377 Wh/day

As you can see the consumption of air conditioning is high, since although we are taking into account December, the month with less irradiation, we also use the air conditioning as heating of the house, and despite being a relatively warm area, in sometimes the winter months require a heating system. We have assumed a time of two hours a day for the consumption of air conditioning so that we make a responsible consumption of it, since precisely the objective of the project is the use of renewable energies in the most sensible way possible, and leaving aside the bad use that is usually made in today's society.

Now we can calculate the average daily potency, for which we must take into account the efficiency of the inverter (0.94), the battery and the cabling, for which we will assume a efficiency of 0.98.

To calculate the efficiency of the battery we can observe the following figure in which the efficiency is related to the temperature. Taking into account the conditions of the area we can assume an approximate efficiency of 0.85.

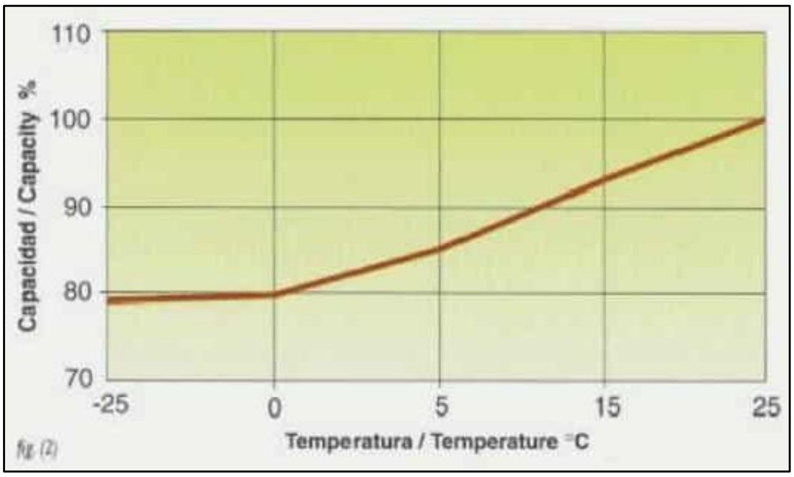


Figure4.2.- Efficiency/Temperature

$$\text{Average daily power } \mathbf{(Pavd)} = \frac{5377/0.94}{0.85 \cdot 0.98} = \mathbf{7028Wh / day} \qquad \mathbf{(4.1)}$$

$$\text{Total annual consumption } (\mathbf{Pt}) = \text{Pavd} \cdot 365 = \mathbf{2565220\ Wh} \qquad \mathbf{(4.2)}$$

4.2.- Generator

The photovoltaic generator is responsible for collecting the energy from the solar radiation and transforming it into electricity, obtaining a direct current.

Photovoltaic cells are devices made of light-sensitive metals that emit electrons when light rays fall on them, transforming light energy into electrical energy.

They are made up of cells made from a single silicon crystal or polycrystalline cells (formed by small crystallized particles), being able to generate each of 2 to 4 Amperes, at a voltage of 0.46 to 0.48 Volts.

These cells are placed together to achieve a greater electrical potential; panels capture solar energy, transforming it directly into electricity in the form of direct current, which is stored in accumulators, so that it can be used outside of daylight hours, being able to generate electric power even on cloudy days.

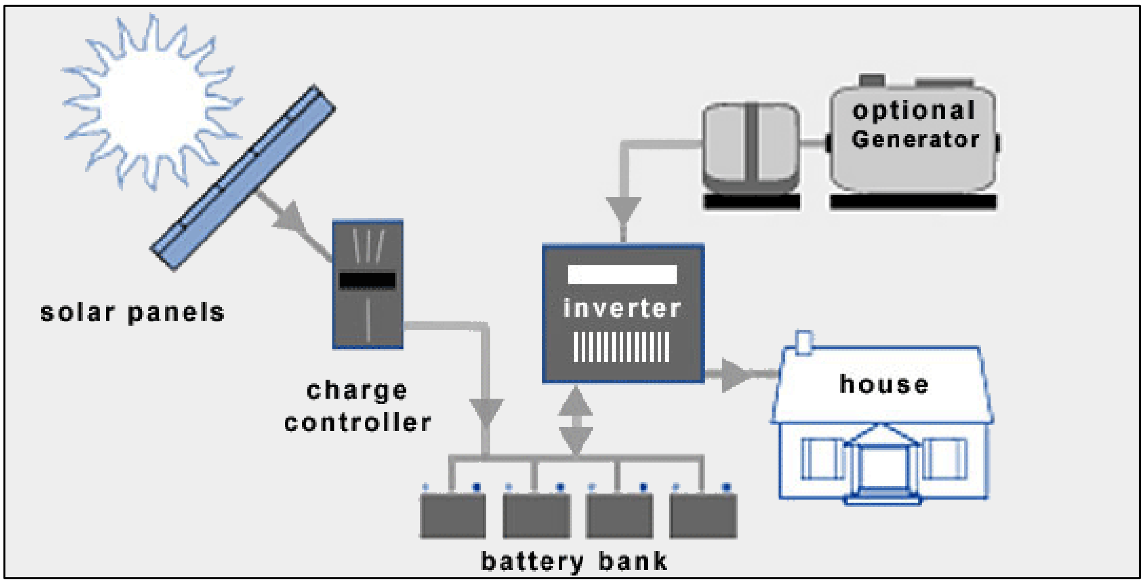


Figure 4.3.- Schematic view of the components of our system

Photovoltaic panels can now be obtained at moderate prices that are already totally competitive to generate energy in our homes at a price that is worth it, much lower than when the first models appeared. It is also estimated that the price of panels will continue to decline.

For the calculation of the photovoltaic generator we must take into account the average daily consumption. We must choose the number of panels needed, as well as their arrangement in branches and we must correctly calculate the consumption of our needs, because doing the calculations in an excessive way would cause the investment to be made more than necessary.

4.2.1.- Optimal inclination and orientation of the generator

To choose the inclination of the solar panels we have several options. The optimum inclination in December is the latitude + 10 °. However, we can observe in the data offered by PVGIS several parameters that can help us choose the most appropriate option.
On the one hand, it is recommend an inclination of 33 °, but this data is generated without taking into account our criterion of using the critical month (December) as a basis, so in principle we will reject it.

Performance of Grid-connected PV

NOTE: before using these calculations for anything serious, you should read [this]

PVGIS estimates of solar electricity generation

Location: 36�22'20" North, 6�10'30" West, Elevation: 22 m a.s.l.,

Solar radiation database used: PVGIS-CMSAF

Nominal power of the PV system: 3.0 kW (crystalline silicon)
Estimated losses due to temperature and low irradiance: 10.0% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 3.2%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 25.1%

Fixed system: inclination=64�, orientation=0�				
Month	E_d	E_m	H_d	H_m
Jan	11.30	352	4.92	153
Feb	13.10	366	5.66	158
Mar	13.50	419	5.95	185
Apr	12.10	364	5.38	161
May	10.90	339	4.94	153
Jun	10.40	311	4.76	143
Jul	10.80	335	4.99	155
Aug	12.00	373	5.54	172
Sep	12.80	384	5.82	175
Oct	13.20	409	5.93	184
Nov	12.00	360	5.27	158
Dec	10.90	338	4.76	148
Yearly average	**11.9**	**362**	**5.32**	**162**

Table 4.3.- Irradiation features according to our chosen inclination

E_d: Average daily electricity production from the given system (kWh)
E_m: Average monthly electricity production from the given system (kWh)
H_d: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)
H_m: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

PVGIS estimates the optimum inclination for December is 64°, and we also know that in this month the irradiation for this inclination is 4170 Wh /m^2/day. We choose this option.

As for the orientation, as a rule the modules must be oriented to the south and they will be placed on the side roof of the house, the most appropriate place, since it is a properly roof on which the sunlight falls directly, without the presence of walls or objects that can make shade.

In the PVGIS database we also have options such as the visualization of graphs that show us data such as Kwh / month depending on the month of the year.

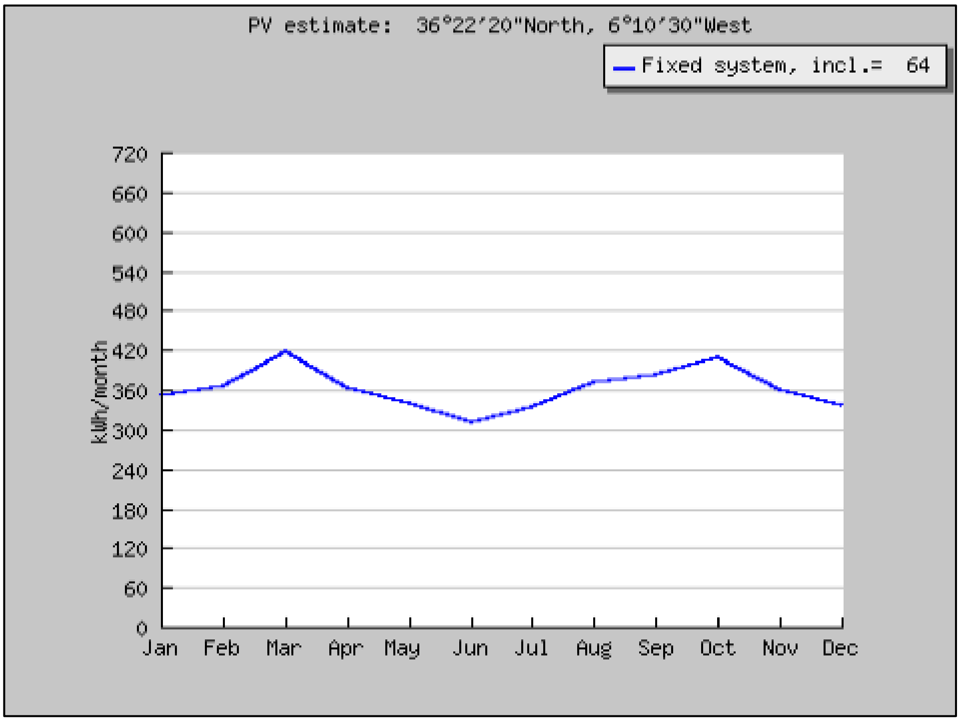


Figure 4.4.- Kwh/month (PVGIS)

Another option of the PVGIS allows us to compare the optimal inclination of the panels according to the month of the year. It is useful to observe how depending on the month we choose to perform our calculations, the position of the generator changes ostensibly.

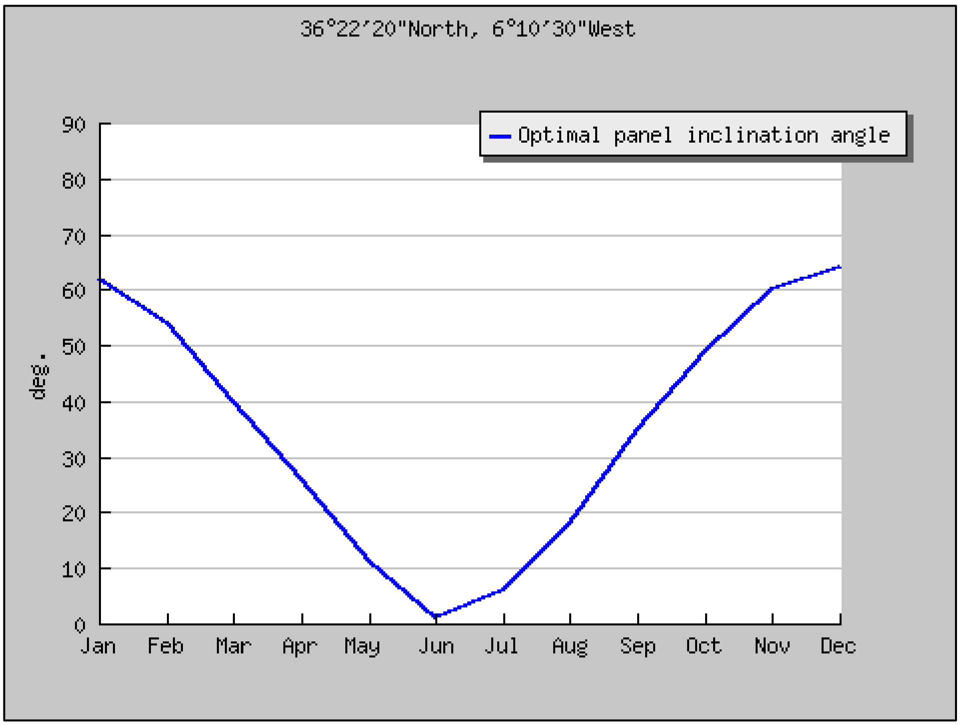


Figure 4.5.- Optimal panel inclination angle per month

4.2.2.- Generator sizing

$$P\ \text{minimum generator} = \frac{Pavd \cdot Gcem}{Gdm \cdot PR}$$

-Gcem is a constant of value 1000 W/m^2

-We have calculated Pavd previously and looking at PVGIS, Gdm for the month of December we know that the irradiation is 4170 Wh /m^2/day

The performance ratio expresses the relationship between the real performance and the nominal performance of the photovoltaic installation. Then, it indicates what proportion of the energy is actually available for the power supply after having deducted the energy losses that may be due to the wiring or the thermal effect and the own consumption for the operation.

The PR is a quantity expressed in percentage, regardless of the location or quality of a photovoltaic installation and therefore is often also a factor of quality, this means that the closest to 100% is the value of the coefficient of calculated performance for a photovoltaic installation, this photovoltaic installation will work more effectively. However, it is not possible to reach a real value of 100% since during the operation of the photovoltaic installation inevitable losses always occur. However, an efficient photovoltaic installation should have a coefficient of performance of up to 80%.

As our system has inverter and battery (isolated system), PR (performance ratio) = 0.6. Accordingly we have the following values of maximum and minimum power of the generator.

$$\text{P minimum generator } (\mathbf{Pmin}) = \frac{7028 \cdot 1000}{4170 \cdot 0.6} = \mathbf{2809\ Wp} \qquad \mathbf{(4.3)}$$

$$\mathbf{Pmax} = \text{Pmin} \cdot 1.2 = \mathbf{3370\ Wp} \qquad \mathbf{(4.4)}$$

Our choice will be the solar panel SolarWorld SW 300 Mono Sunmodule Plus. It is a solar panel of 300W of 18% efficiency, composed of 60 Mono PERC cells.

In addition, its price is one of the cheapest in the market: 280.80 euros unit

PERFORMANCE UNDER STANDARD TEST CONDITIONS (STC)*

		SW 290	SW 300
Maximum power	P_{max}	290 Wp	300 Wp
Open circuit voltage	U_{oc}	39.6 V	40.0 V
Maximum power point voltage	U_{mpp}	31.9 V	32.6 V
Short circuit current	I_{sc}	9.75 A	9.83 A
Maximum power point current	I_{mpp}	9.20 A	9.31 A
Module efficiency	η_m	17.30 %	17.89 %

Measuring tolerance (P_{max}) traceable to TUV Rheinland: +/- 2% (TUV Power controlled, ID 0000039351)

Table 4.4.- Features of SolarWorld SW 300 Mono Sunmodule Plus

To calculate the nominal voltage of the system we look at the following table:

Demanded power(W)	Voltage of system(V)
< 1500 W	12 V
1500 W ÷ 5000 W	24 V, 48 V
>5000 W	120 V, 300 V

Table 4.5.- Voltage of the system according to demanded power

Our nominal voltage will be 48V

We must also calculate the number of photovoltaic modules needed for the power demanded (dividing the maximum power between the power of the generator) and if these are connected in series (nominal voltage between maximum power point voltage) or in parallel.

$$\mathbf{N} = Pmin / Wp = 2809/300 = \mathbf{10\ modules} \quad \mathbf{(4.5)}$$

$$\mathbf{Nseries} = Vsystem / Vmp = 48 / 32.6 = 1.46 = \mathbf{2\ \ modules} \quad \mathbf{(4.6)}$$

$$\mathbf{Nparallel} = N / Nseries = 10/2 = \mathbf{5\ modules} \quad \mathbf{(4.7)}$$

Each panel measures 1001mm in width and 1675 in height. Its thickness is relatively negligible with respect to the set (33mm) and its weight is 18 kg. Taking into account that we need ten panels, the total surface will be:

$$10 \cdot 1001 \cdot 1675(mm) = 16.77\ m^2 \quad \mathbf{(4.8)}$$

With a suitable support it would be a perfectly acceptable surface to place on the roof of the house.

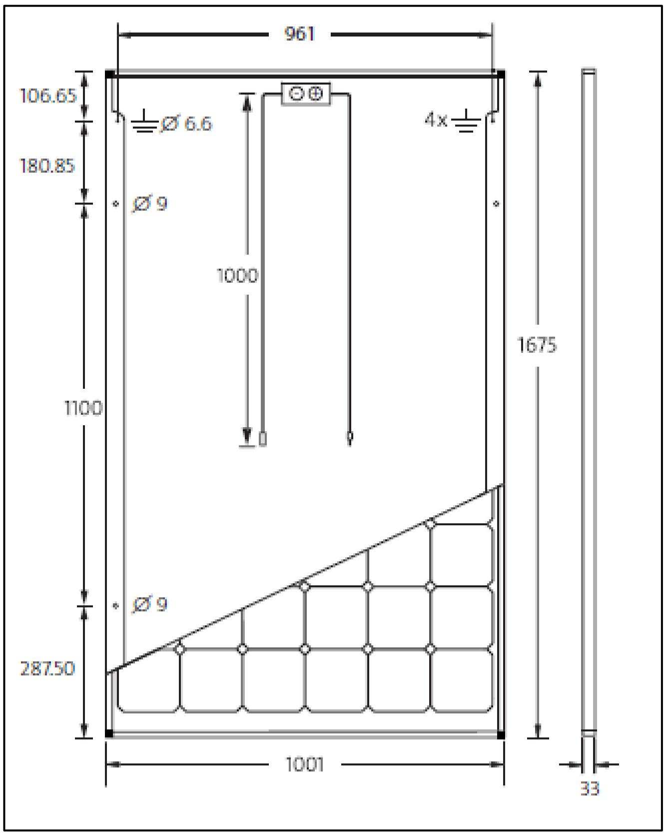


Figure 4.6.- Visual design of our solar panel.

DIMENSIONS / WEIGHT	
Length	1675 mm
Width	1001 mm
Height	33 mm
Weight	18.0 kg

Table 4.6.- Dimensions and weight of our solar panel.

4.3.- Battery or accumulator

The accumulator is the device responsible for accumulating the energy produced by the generators and supplying it to the receivers of the installation, that is, they provide the energy as it is demanded, regardless of whether the system is producing energy or not at that moment.

The capacity of a battery is usually expressed in terms of the discharge regime, which is usually 10 (C10), 20 (C20) or 100 hours (C100).

The value provided by the manufacturer is the nominal capacity (CN). To calculate the capacity of a battery for solar use, for chraging or discharging, we can use the following equation:

$$CN\ [Ah] = IN\ [A] * \text{Duration of charge / discharge } [h] \qquad \textbf{(4.9)}$$

Being IN the charge or discharge current.

4.3.1.- Useful data for the choice of batteries

The charge capacity of a battery (amount of electricity it can supply) depends on factors such as temperature, final discharge voltage, discharge intensity or charge and discharge speed.

In general, as there are slow discharge cycles in photovoltaic solar installations, the term discharge capacity C100 is usually used.

The depth of discharge of a battery is the percentage of the total capacity of the battery that is used during a charge cycle or discharge cycle. We can distinguish two possibilities: superficial (discharges of approximately 20% of nominal capacity) or deep discharges (discharges of 60-80% of nominal capacity).

In isolated solar energy installations, stationary batteries prepared for deep discharge are usually used, since in some installations they must support consumption for several days. We should also note that the greater the depth of discharge (DOD), the fewer cycles of use a battery will be able to give us, it is seen more clearly in the following graph:

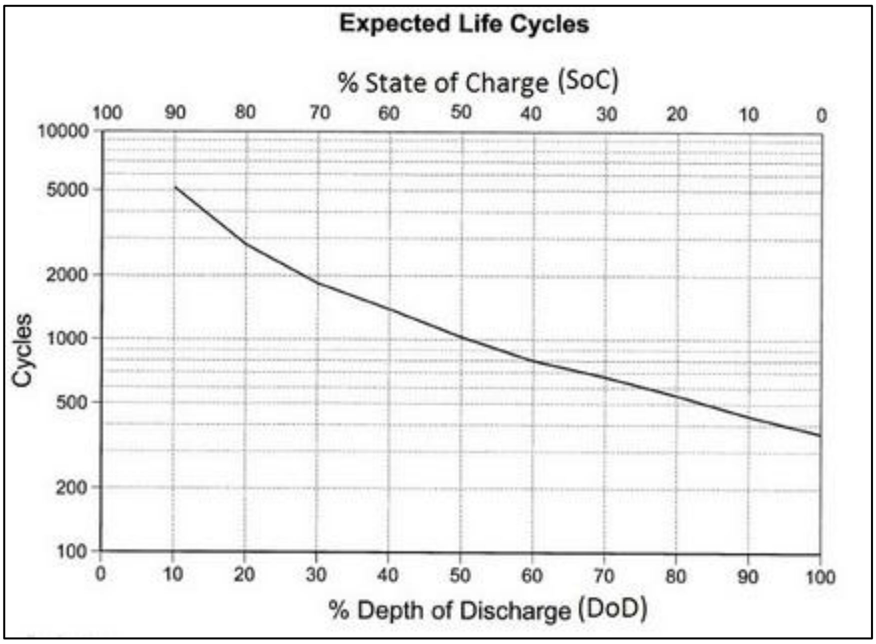


Figure 4.7.- Number of cycles/ %State of Charge / %Depth of Discharge

On the other hand, we must know that depending on the speed of discharge of the battery, we will have a final discharge voltage. The faster the discharge is made, the lower the final discharge voltage of the battery will be. We can see it with the following graph:

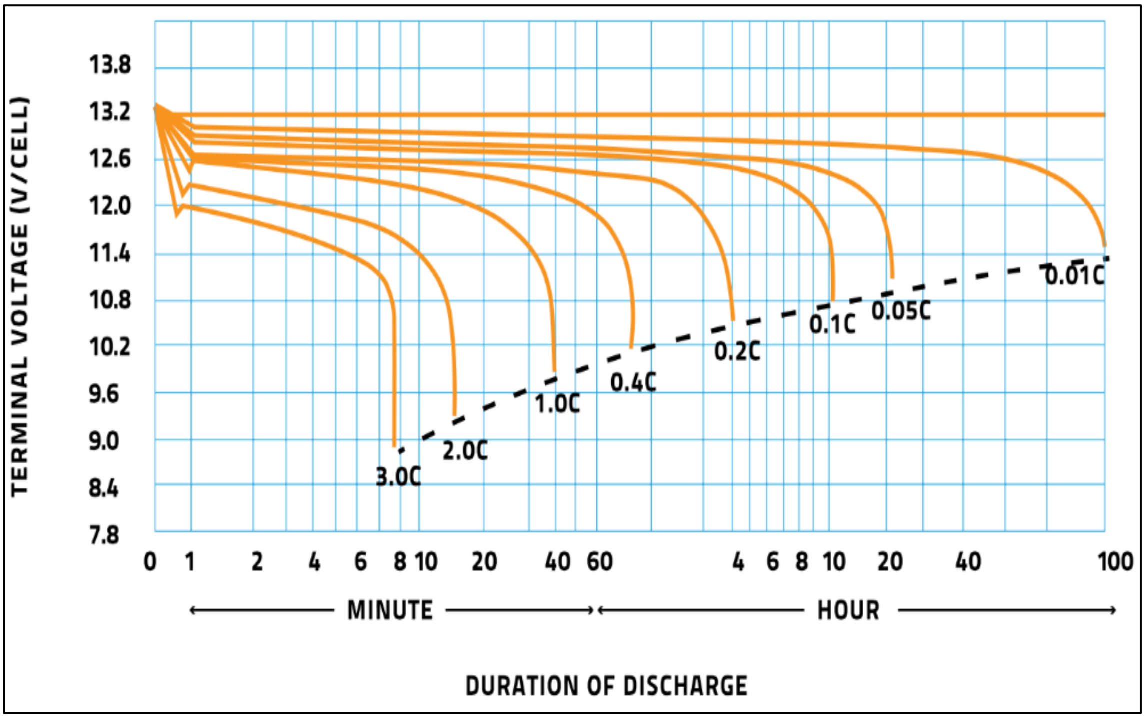


Figure 4.8.- Terminal Voltage / Duration of Discharge

In the graph we can see that a slow discharge regime is more suitable for a longer battery life.

We must also bear in mind that the more discharge cycles have occurred and the more numerous they are, the shorter the life of a battery will be.

We understand as the useful life of a battery as the number of charge and discharge cycles to which a battery can be subjected to a certain discharge capacity until its capacity falls below 80%. The life time of the batteries is directly proportional to the depth of discharge. The deeper your discharge, its life (measured in number of cycles) becomes smaller and comes to an end. We can see it clearly in the following graph:

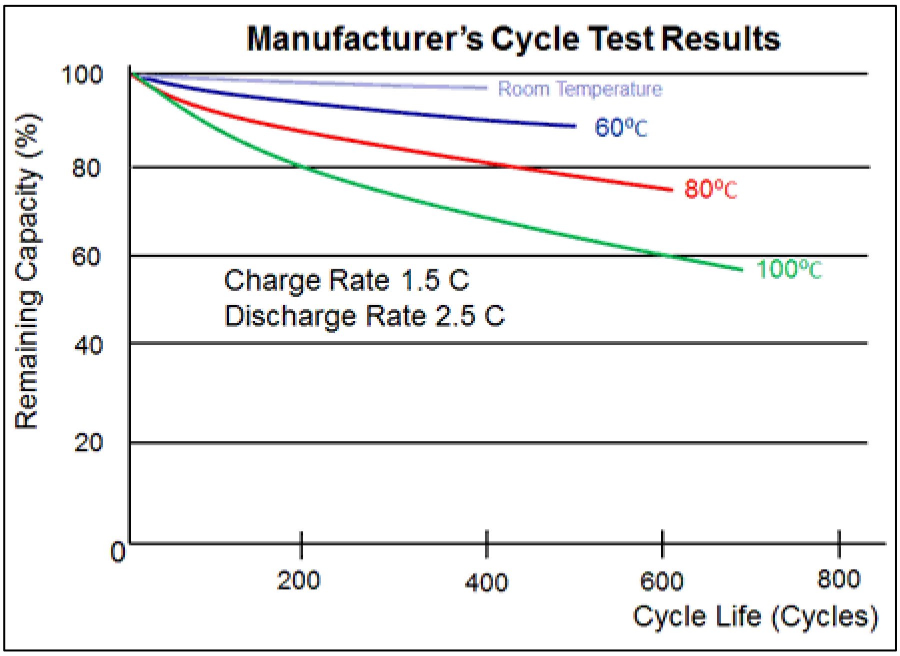


Figure 4.9.- Remaining Capacity / Cycles

4.3.2.- Batteries connection

We must know the necessary procedure for the connection of batteries because the batteries that we will use individually do not have the capacity and the tension that we want, so we will have to buy several units. The possibilities are to connect the batteries in series or in parallel. We will analyze the two options:

-Batteries connected in parallel: This way we can increase the final capacity of the accumulation system and maintain the same output voltage value of each battery. All positive poles are connected and, separately, all negative poles. The total capacity of the battery system will then be equal to the sum of all the capacities of each battery.

-Batteries connected in series: we managed to increase the final voltage of the accumulation system, which would be the sum of the voltages of the batteries connected in series, and maintain the capacity, which would be the same as the unit of the batteries that we are using. In this case, we will connect the positive pole of the battery with the negative pole of the next battery, so on.

4.3.3.- Choice of the battery

It is possible that there are days whose solar irradiation is not enough, so we have estimated using 4 days of autonomy in our calculations, that is, we assume that in the worst case we would be four days without generating electricity. In addition, the function of the batteries also consists of covering the energetic demands during the night.

Therefore, in order to calculate the nominal capacity of the battery that we need, we multiply the power of the loads by the number of days of autonomy that we want and we divide it by the desired discharge regime.

$$Cnbat = 7028 * 4/0.6 = 46853 \text{ Wh} \quad \textbf{(4.10)}$$

The explanation is that we need to generate a daily energy with our batteries but that we can have it for 4 days without sun, without allowing a discharge greater than 60% and assuming a Temperature Correction Factor (F CT = 1). Once the energy in Wh of the battery is known, we simply divide it between the voltage of the battery (48V in this case) and we already have the minimum capacity that we need for our accumulation system according to the days of autonomy.

In order to calculate the capacity in Ah:

Cnbat= 46853 / 48 = **976 Ah** **(4.11)**

Knowing all this, finally our best choice is the **Battery 24v 8 TOPZS 1000 (1300Ah c100).**

Figure 4.10.- Photograph of a model of Battery 24v 8 TOPZS 1000 (1300Ah c100)

The solar batteries type TOPZS are intended for use in solar installation to provide a large energy supply. Thanks to its low concentration of antimony we can highlight its low self-discharge and its long service life, the set includes all connection bridges and screws for assembly.

Accumulation capacity:
C10: 1000AH C100: 1300 AH

It stands out for its low price, since its less expensive container, more flexible and with less quantity of electrolyte but with the same final result. This type of solar batteries have a very high lifetime.

Characteristics:

-Durability of the elements.

-Reduced maintenance. Easy and fast control of the electrolyte level.

-Connections and terminals totally isolated.

-Maximum duration in cycles (approximately 1200 life cycles).

-High energy accumulation

-Higher voltage stability and discharge efficiency due to its great depth of discharge.

-Very low self-discharge.

The price is € 3,717.99, but as the tension of our system is 48 V, we will need to buy two units (24 V), making a total of 7436 euros.

If we connect the batteries in series we will have a voltage of 48 V and 1300Ah

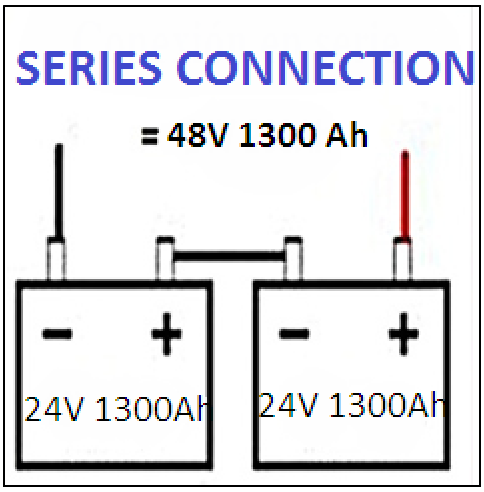


Figure 4.11.- Two batteries (48V, 1300 Ah) with series connection

4.4.- Charge regulator

The regulator or controller controls the charge of the battery, avoiding excessive amounts. It is an indispensable element of isolated systems.

Among its functions, is to isolate the photovoltaic generators if their voltage is lower than the battery charging voltage, or connect them if the voltage is higher than the battery due to an increase in insolation. In addition, they must protect the batteries against overloads.

To fulfill all these functions we must first calculate the necessary parameters.

We know that the power of the generator is equal to the individual power of each module multiplied by the number of modules that we have.

P generator = number of modules · generator power= 10 · 300 **= 3000 W** **(4.12)**

To calculate the maximum voltage of the generator and the open circuit voltage, we will take into account the number of panels connected in series.

Vmpgen = maximum generator power voltage · serial modules = 2 · 32.6 = **65.2 V** **(4.13)**

Vocgen = serial modules · open circuit voltage of the generator= 2 · 40 = **80 V** **(4.14)**

The maximum current of the regulator will be calculated taking into account the number of modules in parallel, in addition to the short-circuit current of said modules. We will also multiply this value by 1.2, this means that the recommended current for the regulator must be 20% greater than that of the photovoltaic modules.

Imaxreg = 1.2 · Nparallel · Isc = 1.2 · 5 · 9.83 = **58.98A** **(4.15)**

With these data we can conclude that 60A 3200W 48V MPPT Solar Charge Controller meets our needs, since all restrictions are met both in terms of voltages and currents and also has the right power.

Modle	Solar Charge Controller		
	SCC1260	SCC2460	SCC4860
INPUT			
MPPT Range @Operating Voltage	15 ~115VDC	30 ~115VDC	60 ~115VDC
Maximum PV Array Open Circuit Voltage	145VDC		
Maximum PV Array Power	800W	1600W	3200W
Maximum Input Current	50A		

Table 4.7.- Features of our charge regulator.

With a price of 235 €/unit it's the perfect choice for our needs, undoubtedly the cheapest component compared to the rest of the installation.

Figure 4.12.- Photograph of a model of 60A 3200W 48V MPPT Solar Charge Controller.

4.5.- Inverter-Charger

The inverters are in charge of transforming the direct current obtained by the photovoltaic system into the alternating current necessary for any conventional device.

This device will also function as a charger, so that when the batteries are discharged, the system can be supplied.

Inverters work with different voltage levels, which will be decisive when choosing our model. In addition to the input voltage we will have to find an inverter with the appropriate output voltage, in our case an alternating voltage of 230 V.

We must also take into account the maximum power of the set of loads.

We believe that investors must be able to support the electrical demands of appliances and air conditioning simultaneously, so we must apply a simultaneity factor.

In most cases we find that it is 0.7 or 0.8. For greater security, we will use the coefficient 0.8. Then:

$$\textbf{Inverter power} = 0.8 \cdot \text{loads} = 0.8 \cdot 3656 = \textbf{2940 W} \qquad \textbf{(4.16)}$$

The power of the chosen inverter should be slightly higher than 2940 W, since in addition to the active power, reactive power is also present in some domestic appliances, which makes consumption higher.

In addition, our inverter must have a nominal voltage of 48 V.

Consequently, to fulfill all the impositions previously exposed, the inverter used will be Inverter of pure wave 48V 3000W TBB CPI3000S.The TBB CPI3000S inverter is designed to work at 48V DC and a power of 3000W. Unlike other brands, the TBB solar inverters offer their nominal power up to 40ºC of ambient temperature.

In addition, these single-phase inverters can provide up to 80% of their rated power at temperatures of 60 ° C. Its houses electronic components with 94% performance and its forced air system will allow perfect cooling and almost silent operation.

This pure wave inverter is designed to withstand overloads of up to 125% for 1 minute and 150% for 20 seconds.

Thanks to its 3-position switch, the inverter can be switched on and off comfortably or even activate the energy-saving mode so that, when the loads are not connected, the inverter's own consumption is even lower.

Features:
Reference: TBB010
Brand: TBB
Power Cont. Output 40º (W): 3000 W
Battery voltage: 48 V
Performance: 94%
Output Voltage Range (VAC): 208-240 V
Dimensions: 527 x 228 x 180 mm
Degree Protection: IP20
Price: 1040.96 €

Figure 4.13.- Photograph of a model of Inverter of pure wave 48V 3000W TBB CPI3000S.

5.- BUDGET

The budget of our installation has not been excessively expensive, but the cheapest result has not been chosen either. We have tried to maintain a balance between quality and price that would allow us to obtain quality products, and whose useful life would not be too affected by the low quality of its materials or other factors.

Anyway, we can see in the following graph that carrying out this project a few years ago would have been much more expensive. On the vertical axis the average price (€/Wp) is shown. Technology advances and each time it does it is more accessible to the average user.

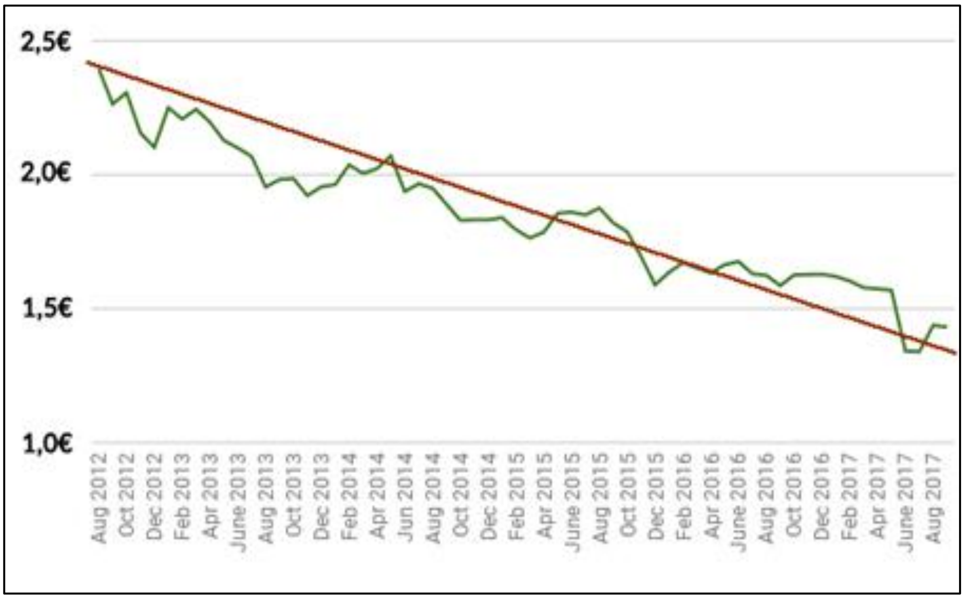


Figure 5.1.- Evolution of the prices of solar panel installations in recent years

We can see that in just 5 years its price has been divided by almost half.
Inquiring on the internet we can find user experiences that told us a lot of unpleasant surprises that we can find throughout the life of a photovoltaic installation made with poor quality solar panels.

It is also proven that a high quality solar panel, although it will be more expensive, in the long run is more profitable.

For the budget we did not take into account the price of the wiring, because we have considered it negligible with respect to the price of the rest of the installation and labor.

Element	Units	definition	Concept	Price/unit(€)	Units	Import(€)
Panels	unit	SolarWorld SW 300 Mono Sunmodule Plus	material	280.8	10	2808
Battery	unit	Battery 24v 8 TOPZS 1000 (1300Ah c100)	material	3718	2	7436
Inverter	unit	Inverter of pure wave 48V 3000W TBB CPI3000S	material	1040.96	1	1040.96
Regulator	unit	60A 3200W 48V MPPT Solar Charge Controller	material	235	1	235
Holder	unit	Support structure for solar installations, designed to install 2 photovoltaic modules (approx. 1650x1000)	material	147.97	5	739.85
Official 1º electrical technician	hour		assembly	40	6	240
Assistant 1	hour		assembly	20	6	120
Assistant 2	hour		assembly	20	6	120

Table 5.1.- Budget breakdown

In Spain the VAT (Value Added Tax) is 21%, therefore, and taking into account that the prices of the material are already considered including the VAT, the breakdown is as follows:

Total material with VAT: 12259.81 €

Total assembly: 480 €

Total assembly with VAT: 580.8 €

TOTAL: 12 840.61 €

6.- CONCLUSIONS

6.1.- Final results

We can conclude with certainty that the choice of a photovoltaic energy system for our house will be a **highly recommended option** not only in terms of economic savings, but taking into account that renewable energies are a perfect alternative for the polluting energy resources that predominate in daily life today.

Since in order to have an energy system like the one we are dealing with, we have to make a considerable investment, we have tried to choose the cheapest possible elements, of course always within the minimum quality limits, since simply choosing the cheapest option could cause problems in the future since the useful life of the components could be of a low quality.

Even so, we can always conclude that in the long term the investment will be **profitable**, since the electricity consumption of a standard electrical installation is currently a considerable expense.

In addition, the chosen area is perfect for our needs. The same project in a location whose atmospheric characteristics were more adverse would have less favorable results, but it is the case that the conditions in the area are perfect due to the excellent irradiation data. We could even have opted for a hybrid system with a wind mini-generator, since wind data in this area would also be adequate, however the necessary investment would increase considerably.

Definitely, it is proven that we can make our homes a model of energy that is respectful of the environment, relatively profitable, and without dispending any provision that traditional energy methods can offer.

6.2.- Solar photovoltaic energy in the future

We can also add as a conclusion the path that renewable energies seem to follow in the future. If we want to make a reflection of what these energies are going to assume on the planet in the coming years, we have only to observe the data.

Solar energy will become the **cheapest** source of electricity in many parts of the world in the next ten years, in a context of continued decline in the cost of photovoltaic panels, according to International Business Time, echoing an investigation.

Since the 1980s, panels to generate electricity from the sun have been cheapening by 10% per year. A trend that would enable this technology to meet 2027 of 20% of global energy needs.

Fortune, a reputable business magazine, collects a study that ensures that in a very short time solar energy will offer more jobs of new creation than the oil sector.

The global photovoltaic market should **increase** by around 20% in the next two years, adding at least 60 GW in 2016 and more than 70 GW in 2017, according to a study by the PV Market Alliance (PVMA). This same organization anticipates that the demand will remain bullish, mainly due to the emerging markets that we have as an example in countries like India, China or the United States.

In fact, according to PVMA - data grouped in the website renewable energies -, the integration of 51,000 MW made it exceed a new record of photovoltaic power installed in the world in 2015, with Asia as the first continent in photovoltaic installation that year (thanks to the bet of China and Japan).

According to the statistics of the company Red Eléctrica Española, the degree of growth of renewable energies has been intense.

If we take as an example the years 2007-2008, renewable energies have grown by 20.1%, while non-renewable energies have reached 12.2%.

Among the first, the one that has had the most relative increase has been the solar one, although in the case of wind, it has had the highest development in quantitative terms, it has grown by 15.3%, a clearly higher percentage to any of the non-renewable.

	2004	2005	2006	2007	2008	% 08/07
RENEWABLES	**23.386**	**28.143**	**30.782**	**35.798**	**42.991**	**20,1**
HIDRAULIC	4.596	3.652	4.001	3.980	4.416	10,9
EOLIC	15.753	20.520	22.736	27.221	31.393	15,3
OTHER RENEWABLES	3.038	3.970	4.045	4.597	7.183	56,02
BIOMASS	1.639	2.120	2.194	2.272	2.437	7,2
INDUSTRIAL WASTES	725	783	786	854	771	-9,7
URBAN WASTES	657	1.028	966	997	1.163	16,6
SOLAR	17	39	99	473	2.812	494,1
NON RENEWABLES	**22.482**	**21.824**	**19.236**	**20.767**	**23.308**	**12,2**
RESIDUAL HEAT	201	293	262	254	233	-8,4
CARBON	716	693	748	735	651	-11,4
FUEL-GASOIL	3.280	2.481	1.808	2.626	2.856	8,8
REFINARY GAS	592	310	294	299	308	3,0
NATURAL GAS	17.692	18.047	16.124	16.853	19.260	14,3
Total	**45.868**	**49.967**	**50.017**	**56.565**	**66.298**	**17,2**

Table 6.1.- Structure and evolution of the energy obtained in GWh

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Universidad de Oviedo

ESCUELA POLITÉCNICA DE INGENIERÍA DE GIJÓN.

GRADO EN INGENIERÍA ELECTRÓNICA INDUSTRIAL Y AUTOMÁTICA

ÁREA DE TECNOLOGÍA ELECTRÓNICA

PLANS

DESIGN OF A PHOTOVOLTAIC SOLAR ENERGY SYSTEM FOR THE ELECTRICAL SUPPLY OF A HOUSE AND FEASIBILITY STUDY

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ADVISOR (Gijón): Inés Peñuelas Sánchez
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DATE: May 2019

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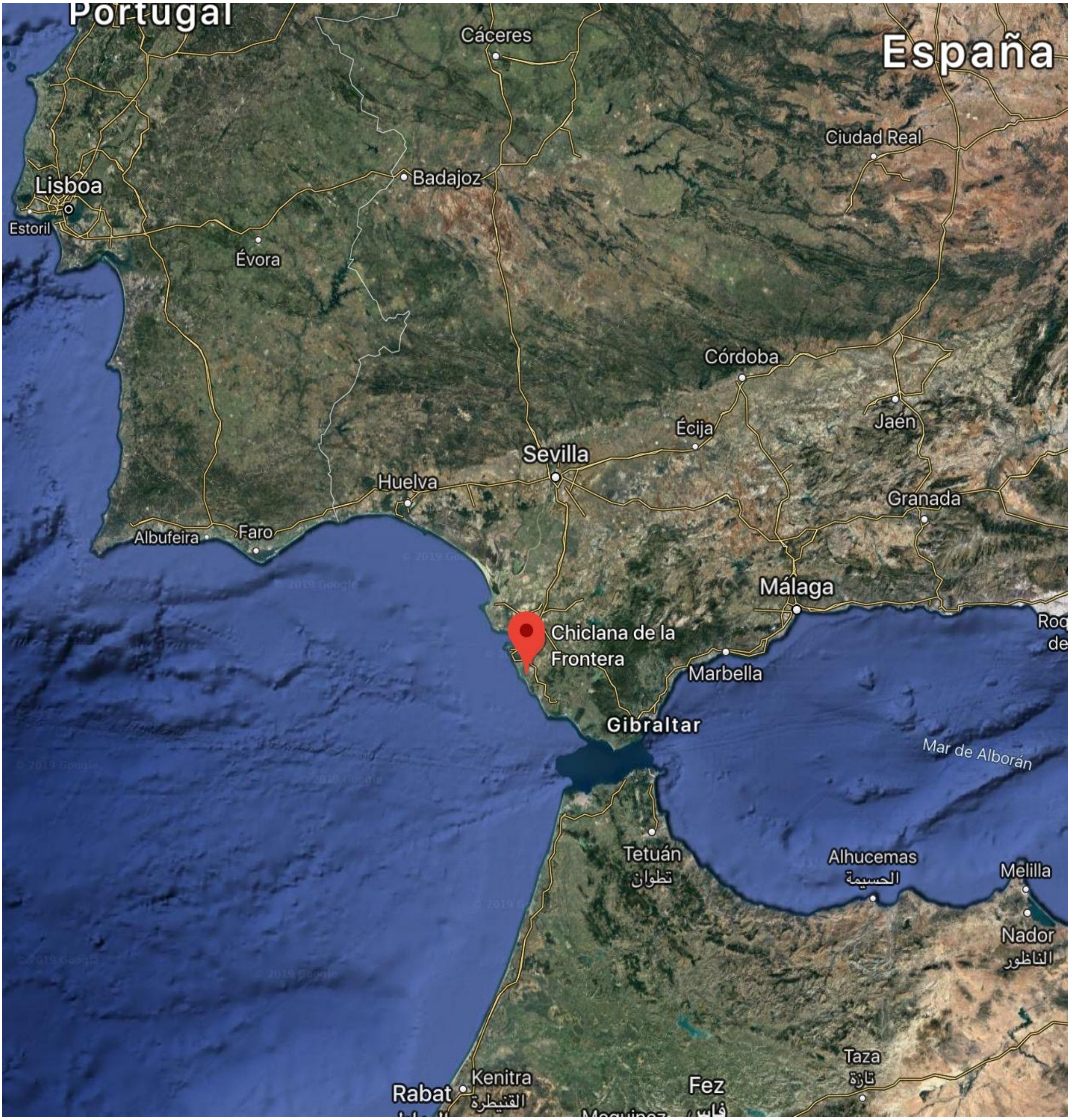

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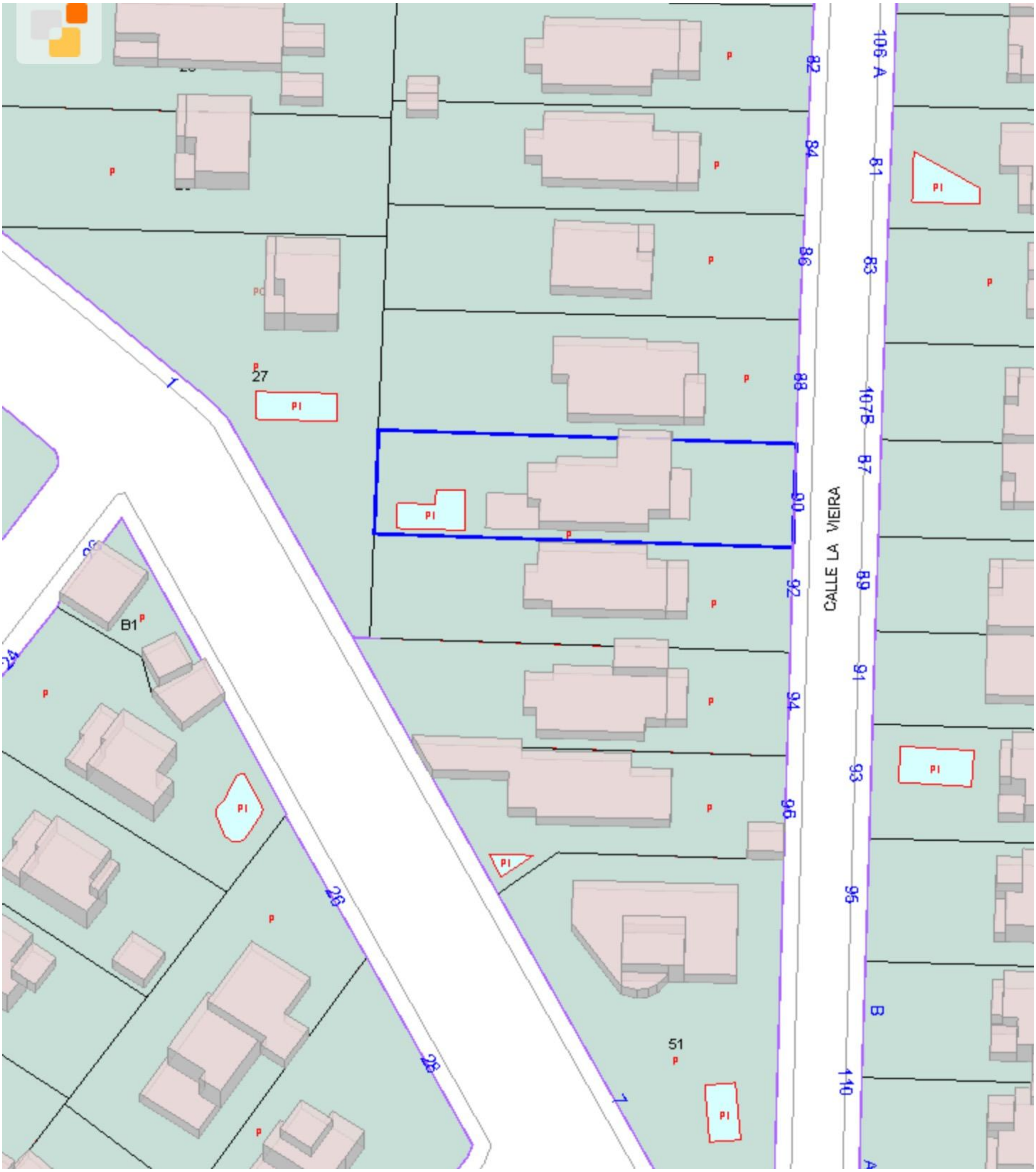
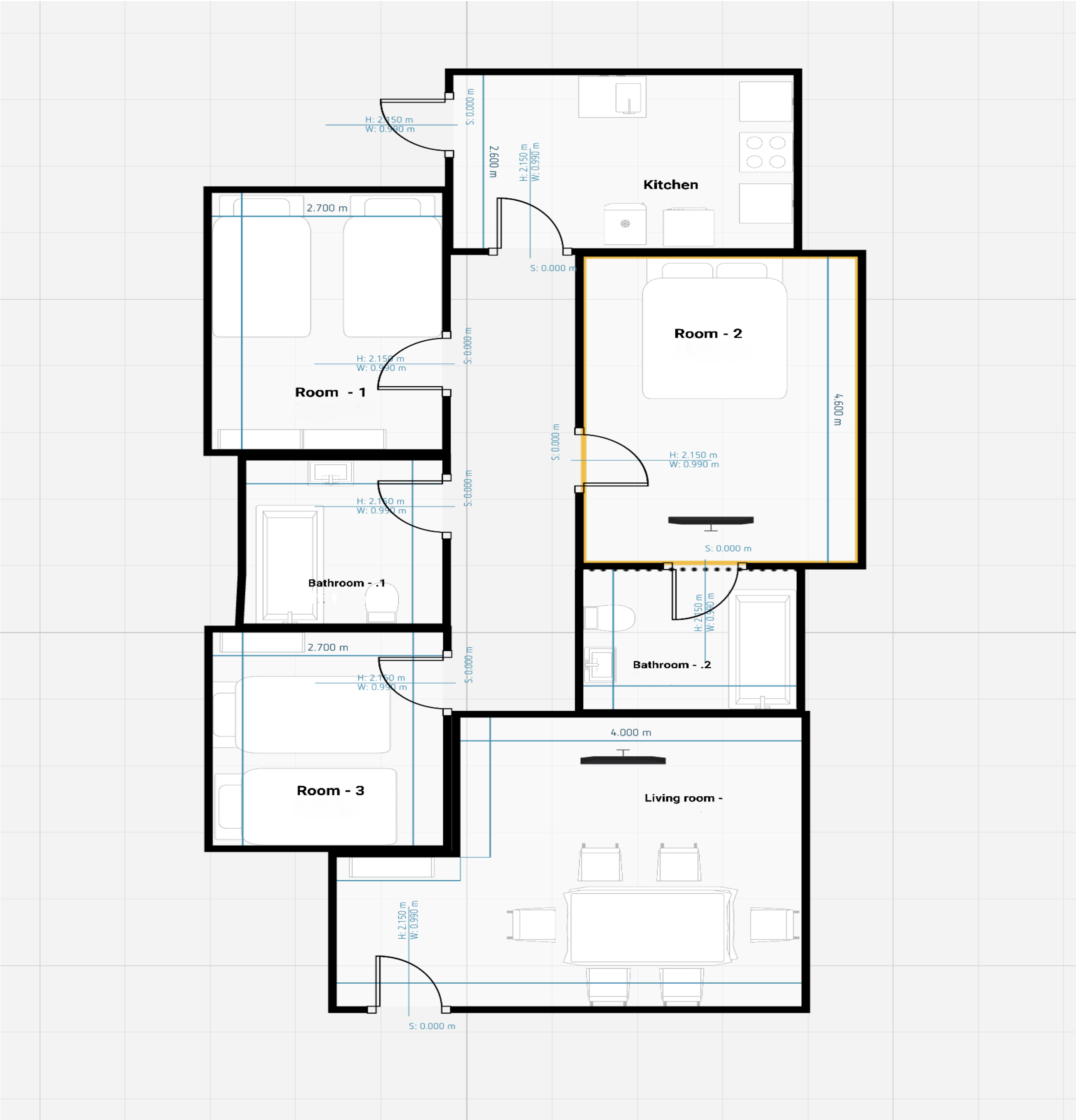
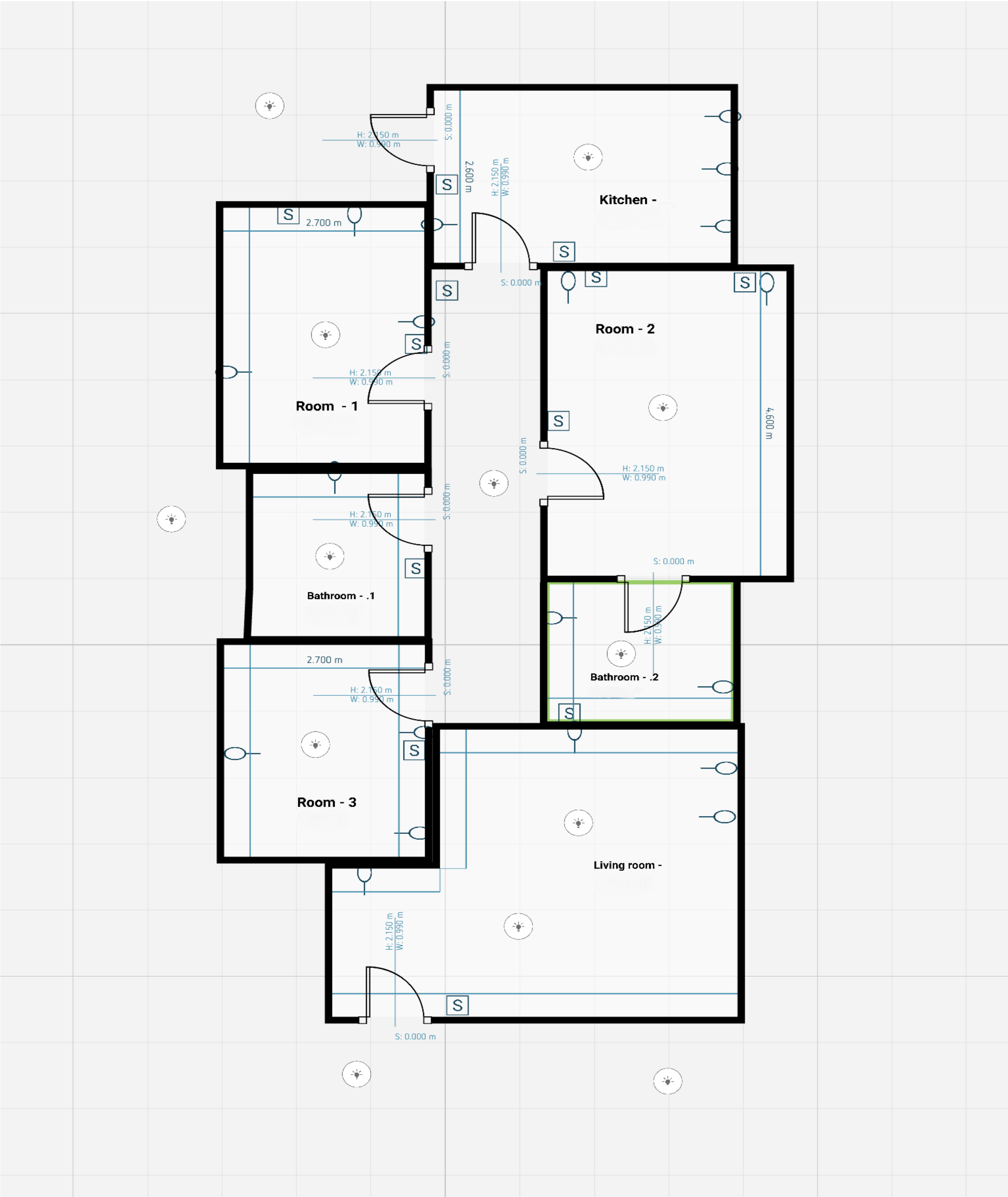
1st Surname	Blanco		
2º Surname	Pérez		
Nº1	Zoom out location		Photovoltaic solar energy system for the electrical supply of a house



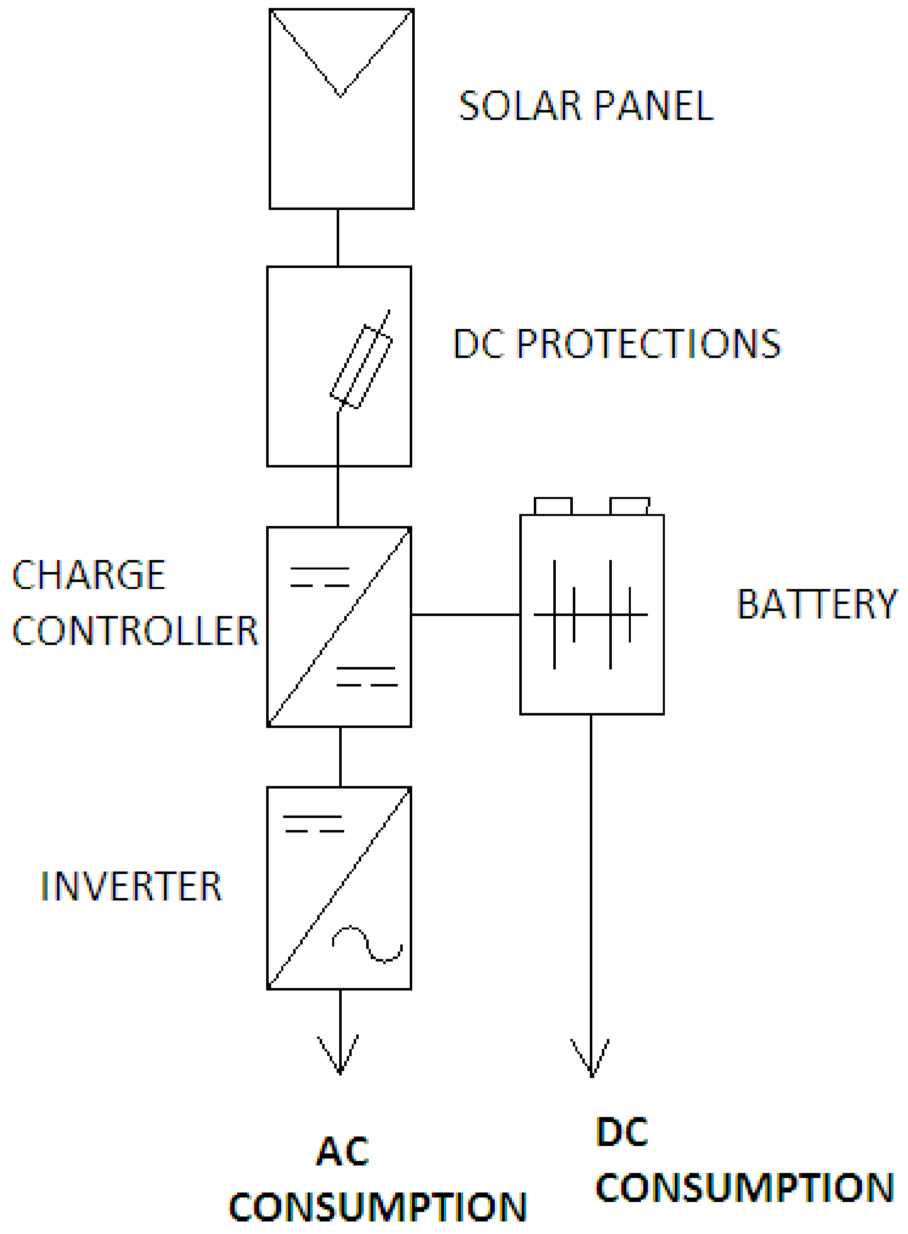
Name	Alejandro	2018/2019	EPIG
1st Surname	Blanco		
2º Surname	Pérez		
Nº2	Plan from satellite		Photovoltaic solar energy system for the electrical supply of a house



Name	Alejandro	2018/2019	EPIG
1st Surname	Blanco		
2º Surname	Pérez		
Nº 3	House plan		Photovoltaic solar energy system for the electrical supply of a house



Name	Alejandro	2018/2019	EPIG
1st Surname	Blanco		
2º Surname	Pérez		
Nº 4	Electricity plan		Photovoltaic solar energy system for the electrical supply of a house



Name	Alejandro	2018/2019	EPIG
1st Surname	Blanco		
2º Surname	Pérez		
Nº 5	Schematic version of the isolated installation		Photovoltaic solar energy system for the electrical supply of a house

Universidad de Oviedo

ESCUELA POLITÉCNICA DE INGENIERÍA DE GIJÓN.

GRADO EN INGENIERÍA ELECTRÓNICA INDUSTRIAL Y AUTOMÁTICA

ÁREA DE TECNOLOGÍA ELECTRÓNICA

ANNEX : DATA SHEET

DESIGN OF A PHOTOVOLTAIC SOLAR ENERGY SYSTEM FOR THE ELECTRICAL SUPPLY OF A HOUSE AND FEASIBILITY STUDY

D. BLANCO PÉREZ, Alejandro
ADVISOR (Gijón): Inés Peñuelas Sánchez
ADVISOR (Kütahya): Yılmaz Aslan

DATE: May 2019

DATA SHEET INDEX

Sunmodule® Plus
SW 290 / 300 MONO

SOLARWORLD
REAL VALUE

Data sheet

HIGH QUALITY ENGINEERING BY SOLARWORLD

More than 40 years of technology expertise, ongoing innovation and continuous optimization create the foundation for the performance of Solarworld‘s high-quality modules. All production steps, from silicon to module, are established at our production sites, ensuring the highest quality for our customers every step of the way. Our modules are extremely flexible when it comes to their application and provide optimal solutions for installation and non-stop performance – worldwide.

- Especially stable, despite its low weight mechanical resilience of up to 8.5 kN/m²
- Tested in extreme weather conditions – resistance to salt spray, frost and hail-proof, resistance to ammonia, dust and sand
- PID-resistant and proven hotspot guarantee
- Highly-efficient cells (mono PERC) for the highest possible yields
- Harmonized components such as mounting systems, connector cables, inverters and energy storage systems can be delivered as complete system
- Patented drainage corners for optimized self-cleaning
- Front glass with an anti-reflective coating
- Long-term safety and guaranteed top performance – At least 97% of nominal power in the first year – 25-year linear performance warranty 20-year product warranty

High Quality Engineering by SolarWorld

VDE Quality Tested ID. 40045046

www.solarworld.com

Sunmodule® Plus
SW 290 / 300 MONO

SOLARWORLD
REAL VALUE

PERFORMANCE UNDER STANDARD TEST CONDITIONS (STC)*

		SW 290	SW 300
Maximum power	P_{max}	290 Wp	300 Wp
Open circuit voltage	U_{oc}	39.6 V	40.0 V
Maximum power point voltage	U_{mpp}	31.9 V	32.6 V
Short circuit current	I_{sc}	9.75 A	9.83 A
Maximum power point current	I_{mpp}	9.20 A	9.31 A
Module efficiency	η_m	17.30 %	17.89 %

Measuring tolerance (P_{max}) traceable to TUV Rheinland: +/- 2% (TUV Power controlled, ID 0000039351)

*STC: 1000W/m², 25°C, AM 1.5

PERFORMANCE AT 800 W/m², NOCT, AM 1.5

		SW 290	SW 300
Maximum power	P_{max}	219.6 Wp	226.7 Wp
Open circuit voltage	U_{oc}	36.7 V	37.0 V
Maximum power point voltage	U_{mpp}	29.5 V	30.2 V
Short circuit current	I_{sc}	7.99 A	8.06 A
Maximum power point current	I_{mpp}	7.43 A	7.52 A

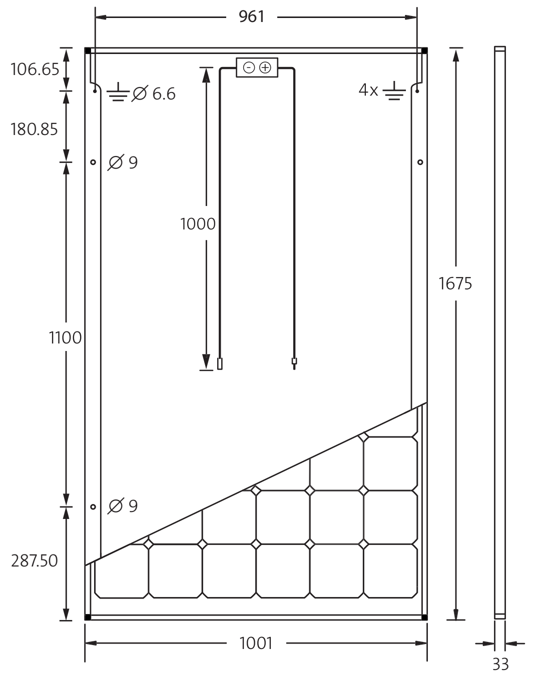
Minor reduction in efficiency under partial load conditions at 25°C: at 200 W/m², 97% (+/-3%) of the STC efficiency (1000 W/m²) is achieved.

PARAMETERS FOR OPTIMAL SYSTEM INTEGRATION

Power sorting	-0 Wp / +10 Wp
Maximum system voltage IEC	1000 V
Maximum reverse current	25 A
Number of bypass diodes	3
Operating range	-40°C - +85°C
*Maximum Design Loads (Two rail system)**	+5.4 kN/m² / -3.1 kN/m²
*Maximum Design Loads (Three rail system)**	+8.5 kN/m² / -3.1 kN/m²

*Please refer to the Sunmodule Installation instructions for the details associated with these load cases.

ISO 9001
ISO 14001
Certified



COMPONENT MATERIALS

Cells per module	60
Cell type	Mono crystalline PERC
Cell dimensions	156 mm x 156 mm
Front	Tempered safety glass (EN 12150)
Back	Film, white
Frame	Black anodized aluminum
J-Box	IP65
Connector	Amphenol H4 UTX

DIMENSIONS / WEIGHT

Length	1675 mm
Width	1001 mm
Height	33 mm
Weight	18.0 kg

THERMAL CHARACTERISTICS

NOCT	46 °C
TK I_{sc}	0.070 %/K
TK U_{oc}	-0.29 %/K
TK P_{mpp}	-0.39 %/K

ORDERING INFORMATION

Order number	*Description*
82000482	Sunmodule Plus SW 290 mono
82000432	Sunmodule Plus SW 300 mono

CERTIFICATES AND WARRANTIES

Certificates	IEC 61730	IEC 61215	UL 1703
	IEC 62716	IEC 60068-2-68	IEC 61701
Warranties	Product Warranty		20 years
	Linear Performance Guarantee		25 years

Europe SunFields

OFFICIAL DISTRIBUTOR

SunFields Europe | info@sfe-solar.com | www.sfe-solar.com

VESNA TOPzS
Solar Batteries

BATERIAS ESTACIONARIAS VESNA TOPzS DE BAJO MANTENIMIENTO

Las baterías estacionarias topzs se fabrican de acuerdo a la normativa din 40736, en 60896 y iec 896-1. Los acumuladores individuales (2v) están fabricados en recipientes de polipropileno translúcido. Las baterías estacionarias del tipo topzs están especialmente diseñadas para instalaciones solares. Debido a su extremada baja descarga las placas positivas tubulares son adecuadas para sistemas solares off-grid (aislados).

Diseño

ELECTRODO POSITIVO
- Placa Tubular con baja aleación de antimonio (<2%)

ELECTRODO NEGATIVO
- Placa plana con expansor de larga duración

SEPARACIÓN
- Separador microporoso

ELECTRÓLITO
- Ácido sulfúrico peso específico de 1,24 g/cm3

RECIPIENTE
- Polipropileno Transparente

TAPA
- Polipropileno en color verde

SELLADO DEL BORNE
- Estanqueidad al 100% de gas y electrolito, junta de goma de alta densidad

TERMINALES
- Terminal hembra (M10) tratado. Perfecto contacto y baja resistencia con cables de conexión flexibles.

CONEXIÓN
- Cable de cobre flexible y aislado, con una sección transversal de 35, 50, o 70 mm^2

BORNE ATORNILLADO
- M10, acero, aislado

Carga

IU - CARACTERÍSTICAS
- Imax sin límite

CARGA DE FLOTACIÓN
- U = 2,23 V / celda ± 1%,

CARGA INICIAL
- U = 2,35 a 2,40 V / celda

Características de descarga

TEMPERATURA DE REFERENCIA
- 20°C en el C10 (1,80 V / celda) y 25°C en C100 (1,85 V / celda)

CAPACIDAD INICIAL
- 100 %

INTENSIDAD DE DESCARGA
- Normalmente hasta el 80%
- Más del 80% POD o descargas mas allá de las tensiones de descarga final (independientes de la corriente de descarga) tienen que ser evitadas

Datos operativos

VIDA ÚTIL
- Hasta 15 años

AUTODESCARGA
- Aprox. 3% por mes a 20°C

TEMPERATURA DE FUNCIONAMIENTO
- -20°C a 55°C, se recomienda su uso entre 10°C a 30°C

NORMATIVAS
- IEC 896-1, EN 60896-1, EN 61427

NORMA DE SEGURIDAD, VENTILACIÓN
- EN 50272-2

TRANSPORTE
- Estas mercancías NO SE CONSIDERAN MERCANCIAS PELIGROSAS durante el transporte por carretera

3 AÑOS DE GARANTÍA AL 100%

- Stock inmediato de todas las referencias.
- 5 almacenes logísticos (Madrid, Barcelona, Valencia, Mallorca y Canarias).
- Línea de producción independiente y preferente.

Tipo de celda	VOLTAJE (V)	LxWxH (mm)	Peso (Kg) vacía / lleno	C10 (Ah) Uf=1,80V at 20°C	C100 (Ah) Uf=1,85V at 25°C
3 TOPzS 265	2	198×83×472	12,4/18,4	265	345
4 TOPzS 353	2	198×101×472	16/23,3	353	458
5 TOPzS 442	2	198×119×472	20,2/29	442	575
4 TOPzS 500	2	198×101×720	24,3/35,2	500	650
5 TOPzS 625	2	198×119×720	30,3/43,2	625	812
6 TOPzS 750	2	198×137×720	38,0/53,5	750	975
7 TOPzS 875	2	198×173×720	44,0/64,2	875	1137
8 TOPzS 1000	2	198×191×720	50,2/72,5	1000	1300

Las baterías estacionarias del tipo TOPzS se fabrican según norma DIN 40736, EN 60896, EN 61427 y IEC 896-1 y sus reglamentos.

La densidad del ácido en una celda con carga eléctrica es 1,24 ± 0,1 kg / l a 293° K (20°C +). Los ciclos no deben superar el 80% de la capacidad nominal. Una descarga profunda puede reducir el tiempo de vida de la batería.

MANTENIMIENTO

CADA 6 MESES
- Revise el voltaje y la densidad de la batería así como su temperatura en cada elemento (vaso)

CADA 12 MESES
- Descargar completamente la batería y revise la densidad así como su temperatura en cada elemento (vaso)

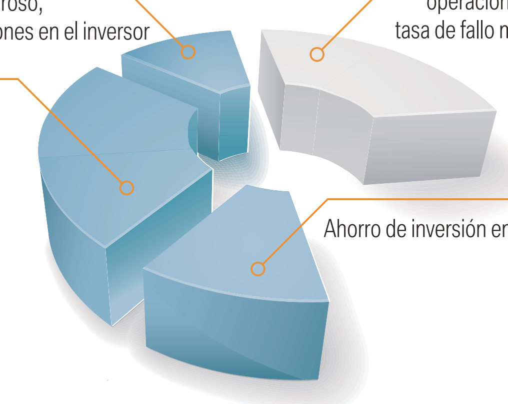
Solar Max

Inversor de Onda Sinusoidal Pura
1 kw-6 kw

El inversor solar de Solar Max está especialmente diseñado para la aplicación solar fuera de la red eléctrica que se caracteriza por la alta eficiencia, el consumo de potencia en estado extremadamente bajo, así como la confiabilidad sobresaliente. Puede proporcionar una potencia nominal continua en 40°C y 80% incluso en una temperatura abrasadora hasta 60°C. Combinado con una capacidad de sobrecarga sobresaliente, este inversor puede encender de forma cómoda las cargas grandes tales como acondicionador de aire, refrigeradores y bombas de agua en regiones trópicas.

- Salida de onda sinusoidal pura
- Diseño de alta temperatura ambiental
- Eficiencia máxima hasta 94%
- Consumo de potencia de estado extremadamente baja
- Potencia de pico sobresaliente, adaptable para todos los aparatos de hogar
- Contacto auxiliar construido
- Operación casi silenciosa
- Diseño a prueba de insectos

La instalación del inversor de Solar Max en su sistema solar puede ayudarle actualmente para ahorrar sus costos en el sistema solar fuera de la red eléctrica.



RCI
Pantalla LED Remota Simple

DCB
Con Disyuntor Principal DC

Nº de modelo							
	12 VDC	CPI700L		CPI1000L	CPI1200L	CPI1500L	CPI1800L
	24 VDC	CPI700M	CPI1000M		CPI1200M	CPI1500M	CPI1800M

Eléctrico

Voltaje nominal		12 VDC/24 VDC	24 VDC	12 VDC	12 VDC/24 VDC		
Potencia cont. @25 °C (W)		700 W	1000 W	1000 W	1200 W	1500 W	1800 W
Potencia cont. @40 °C (W)		600 W	800 W	1000 W	1200 W	1500 W	1800 W
cos Φ		0.9-1					
Capacidad de Sobrecarga	>150%	20 s					
	>125%	1 min					
	>110%	15 minutos					
Sobretensiones		300%					
Voltaje de salida		240 VAC,230 VAC, 220 VAC,208 VAC ± 2% o 127 VAC, 120 VAC, 110 VAC, 100 VAC+ 2% (ajustable) [1]					
Frecuencia de salida		50 Hz o 60 Hz± 0.5%					
Eficiencia (max)	12 VDC	89%					
	24 VDC	92%					
Factor de cresta		3:1					
THD		<3%					
Potencia de cero carga		7.4 W	15 W	12.5 W	13 W	14 W	14.5 W
Potencia de cero carga (modo de ahorro de energía).		2 W	4 W	3 W	3.5 W	3.5 W	3.6 W
Disyuntor de salida		/	/	10 A	10 A	10 A	15 A
Protección de sobrecarga		Desconexión automática con 3 veces de intento de reinicio					
Protección de acceso directo		desconexión automática					

Otros Datos

Conector de batería	M6 x 2		M8 x 2			
Cercado	Acero con pintura de polvo					
Dimensiones (mm)	400x236x89		492.5x240x134.5		527x228x180	
Peso Neto (kgs)	9	10.6	15	16	19	21
Enfriamiento	Ventilador forzado					
Protección	IP20					
Conector AC	Panel de ranura		/			
Contacto seco	/	/	Batería baja			

Estándar

Seguridad	EN60950-1
EMC	EN55022,EN55024,EN61000-3-2,EN61000-3-3

Nº de modelo						
	12 VDC	CPI2000L				
	24 VDC	CPI2000M	CPI3000M	CPI4000M		
	48 VDC	CPI2000S	CPI3000S	CPI4000S	CPI5000S	CPI6000S

Eléctrico

Voltaje nominal		12 VDC / 24 VDC / 48 VDC				
Potencia cont. @40 °C (W)		2000 W	3000 W	4000 W	5000 W	6000 W
cos Φ		0.9-1				
Capacidad de Sobrecarga	>150%	20 s				
	>125%	1 min				
	>110%	15 minutos	1 min			
Sobretensiones		300%				
Voltaje de salida		[1]	40 VAC, 230 VAC, 220 VAC, 208 VAC ± 2% (ajustable)			
Frecuencia de salida		50 Hz o 60 Hz± 0.1%				
Eficiencia (max)	12 VDC	89%				
	24 VDC	92%				
	48 VDC	94%				
Factor de cresta		3:1				
THD		<3%				
Potencia de cero carga		15 W	18 W	26 W	32 W	36 W
Potencia de cero carga (modo de ahorro de energía).		3.75 W	4.5 W	6 W	8 W	9 W
Disyuntor de salida		15 A	30 A	30 A	30 A	40 A
Protección de sobrecarga		Desconexión automática con 3 veces de intento de reinicio				
Protección de acceso directo		desconexión automática				

Otros Datos

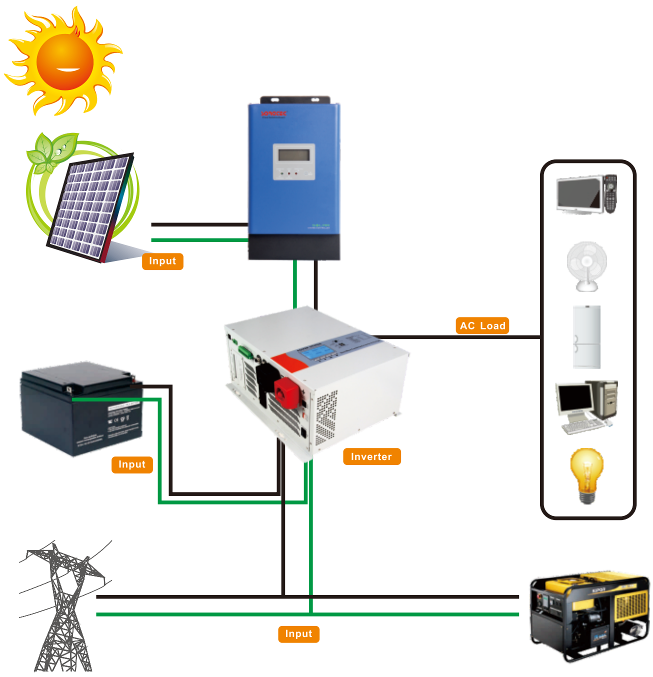
Conector de batería	M8 x 2				
Cercado	Acero con pintura de polvo				
Dimensiones (mm) (max)	527x228x180		527x396x180.5		
Peso Neto (kgs)	22	25	35	40	46
Enfriamiento	Ventilador forzado				
Protección	IP20				
Contacto seco	Batería baja				

Estándar

Seguridad	EN60950-1
EMC	EN55022,EN55024,EN61000-3-2,EN61000-3-3

Solar Charge Controller

With advanced maximum-power-tracking technology, SCC-MPPT series ensures maximum performance from your solar array at all times and in all weather conditions. It's compatible to 3 different battery types, sealed lead acid, vented gel and NiCd.



Key Features:

■Intelligent Maximum Power Point Tracking technology increases efficiency 25%~30%

■Compatible for PV systems in 12V, 24V or 48V

■Three-stage charging optimizes battery performance

■Maximum charging current up to 60A

■Maximum efficiency up to 98%

■Battery temperature sensor (BTS) automatically provides temperature compensation

■Support wide range of lead-acid batteries including wet, AGM, and gel batteries

■Multifunction LCD displays detailed information

Application

Solar charge controller is mainly used for solar power station, solar power system for household, solar street light control system, mobile solar power system,DC wind solar generating systems.

Solar Charge Controller

Modle	Solar Charge Controller		
	SCC1260	SCC2460	SCC4860
INPUT			
MPPT Range @Operating Voltage	15 ~115VDC	30 ~115VDC	60 ~115VDC
Maximum PV Array Open Circuit Voltage	145VDC		
Maximum PV Array Power	800W	1600W	3200W
Maximum Input Current	50A		
OUTPUT			
Nominal Battery Voltage	12VDC	24VDC	48VDC
Connected Battery Type	Sealed lead acid, NiCd or Gel		
Maximum Charge Current	60A		
Maximum Efficiency	98%		
Charging Method	Three stages: bulk, absorption and floating		
PROTECTION			
Overload Protection	> 110% : audible alarm		
Overcharge Protection	Yes		
Polarity Reversal Protection @ Solar Cell & Battery	Yes		
INDICATORS			
LCD Panel	LCD panel indicating solar power, load level, battery voltage/capacity, charging current, and fault conditions		
LED Display	Three indicators for solar, charging, and load status		
PHYSICAL			
Dimension, D x W x H (mm)	315 x 165 x 128		
Net Weight (kgs)	4.5		
Type of Mechanical Protection	IP 31		
ENVIRONMENT			
Humidity	0 ~ 100% RH (No condensing)		
Temperature	0°C to 55°C		
Storage Temperature	-15°C to 75°C		
Altitude	0 ~ 3000 m		

STANDARD:EN 62040-1:2008+A1:2013 EN 60420-2

Note: Product specifications are subject to change without further notice.