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MÁSTER UNIVERSITARIO EN INGENIERÍA INDUSTRIAL

TRABAJO FIN DE MÁSTER

BLOCKCHAIN APPLICATION TO ENABLE THE FINANCING OF SOLAR POWER PLANTS

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Madrid

Julio de 2019

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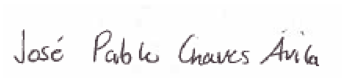

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Madrid

Julio de 2019

APLICACIÓN DE BLOCKCHAIN PARA PERMITIR LA FINANCIACIÓN DE PLANTAS DE ENERGÍA SOLAR

Autor: Oliveros Rubio, Patricia.

Directores: Chaves Ávila, José Pablo; Fernández Lestón, Daniel y Diez García, Daniel.

Entidad Colaboradora: ICAI – Universidad Pontificia Comillas.

RESUMEN DEL PROYECTO

Introducción

En la última década, el sector eléctrico en Europa ha acometido grandes cambios con el fin de reducir las emisiones de gases de efecto invernadero y aumentar el uso de las energías renovables.

La Unión Europea ha establecido unos objetivos en los que los distintos países deben alcanzar niveles concretos de generación de energía procedente de fuentes renovables. Para conseguir estos objetivos, en Europa se está tendiendo de manera muy notable hacia la descentralización, es decir, en lugar de haber unas pocas plantas de generación que alimenten a toda la población a través de redes de distribución y transporte, lo que se está instalando son muchas plantas individuales pequeñas, de forma que un consumidor se convierte en productor de su propia energía.

Sin embargo, por una parte, en las zonas habitadas de España lo más común es que los edificios sean bloques con varias plantas o comunidades de propietarios. Por otra parte, España es uno de los países de Europa con más radiación solar, y, además, tiene una superficie deshabitada muy grande. Por estas razones se ha decidido desarrollar este proyecto, que lo que fomenta es la construcción de nuevas instalaciones fotovoltaicas a gran escala, de forma que, no sólo las personas que disponen de espacio útil para instalar placas solares en sus viviendas o edificios se pueden beneficiar del consumo de energía renovable, sino que también pueden consumir energía verde aquellas que no dispongan de estas instalaciones privadas, a través plantas de generación de gran escala que son más eficientes y que se conectan directamente a la red.

Por otra parte, la tecnología Blockchain, que nació en 2009 para soportar a la moneda virtual Bitcoin, permite el registro de una transacción o cualquier acción en internet de manera descentralizada, fiable e infalsificable sin necesidad de la verificación de la misma por un tercero. En su lugar, existen varios nodos que compiten entre sí con el fin de verificar las transacciones a cambio de unas determinadas comisiones.

Desde 2016, la mayoría de las nuevas instalaciones renovables en España se construyen tras la celebración de una subasta, por la que las empresas compiten por que sus proyectos sean los elegidos y así obtener un precio mínimo en la venta de su electricidad. Otra opción, que ya han llevado a cabo algunas empresas, es la construcción de la instalación de forma privada, de forma que se arriesgan a una remuneración dependiente del precio del mercado o del precio acordado en un contrato bilateral firmado directamente con un consumidor o una comercializadora, llamado Power Purchase Agreement (PPA). La tecnología Blockchain tiene

potencial en este sector, ya que las empresas podrían construir estas instalaciones de forma privada, pero con una inversión en la que participasen distintos inversores a través de un concepto parecido al crowdfunding haciendo uso del asset tokenization. El asset tokenization consiste en la división de la instalación en participaciones, que se podrían considerar como acciones, de forma que los inversores, que serán entidades legales, las adquieran y se les remunere de acuerdo al porcentaje de la instalación que ellos posean.

Además, en la plataforma, estos inversores pueden invertir directamente en el proyecto concreto, diversificando su capital en los proyectos que ellos consideren. Actualmente se puede invertir en instalaciones renovables aportando dinero a un fondo de inversión o a empresas concretas, sin embargo, con este proyecto, los inversores pueden elegir las instalaciones concretas en las que invertir su dinero.

Además de invertir en el proyecto, a estos inversores se les ofrece la posibilidad de obtener un Certificado como el Certificado de Energía Verde, que les ofrece la posibilidad de rastrear el origen de la energía que consumen, de forma que la cantidad de energía que ellos consumen en los puntos de consumo final debe ser la misma que la energía generada en esta instalación. Es decir, no consumen directamente de la instalación, ya que, al estar conectada a red, la energía final que llega a los consumidores es la misma independientemente de su origen, sin embargo, estos consumidores tendrán la certeza de que, con estos certificados, garantizan que el pago por la energía consumida contribuye a la financiación de esta planta, y que toda o una parte de la energía que consumen procede de esta fuente renovable.

Metodología

Para llevar a cabo este proyecto lo primero que se ha hecho es decidir el tipo de monedas con las que va a funcionar esta plataforma. Para que los usuarios puedan hacer uso de la plataforma se ha creado el EC coin (Energy Community coin), que es el utility token del sistema. Los usuarios pueden cambiar dinero Fiat y otras criptomonedas para obtener la cantidad correspondiente en EC coins, de forma que puedan realizar pagos o transacciones a través de la plataforma. El EC coin es un stablecoin respaldada por el Euro, de forma que el cambio EC coin – Euro se realiza con la relación 1:1. Esto permite evitar las fluctuaciones de la criptomoneda y darle estabilidad al sistema. Las participaciones en las que se divide el proyecto mencionadas en el apartado anterior son las PGP (Photovoltaic Generation Participation), que son security tokens emitidos por la empresa que lleva a cabo el proyecto con el fin de financiar el proyecto.

Estas participaciones se comprarán en el mercado primario y se podrán comercializar en el mercado secundario que ofrecerá una mayor liquidez, ya que éstas se podrán vender siempre y cuando haya otro inversor interesado en comprarla, independientemente del estado en el que se encuentre el proyecto.

El esquema por el cual funciona este sistema de inversión se muestra en Figura I. Como se puede observar, son los inversores los que aportan la inversión necesaria para cubrir los costes. Una vez que el generador dispone de esa inversión, se puede empezar a construir la planta y cuando la planta esté construida, recibirá ingresos por la venta de la energía y de la SolarCoin Foundation, por la generación de energía solar. Posteriormente, estos beneficios se devuelven a los inversores, de forma que éstos puedan recuperar su inversión.

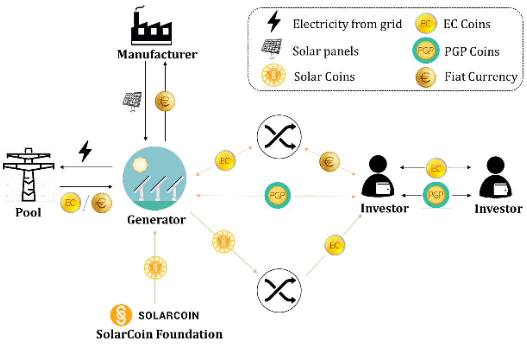

***Figura I**: Flujo de valor en la plataforma global*

Para obtener la inversión que van a tener que cubrir los inversores, se han estimado los costes con el Microsoft Project para una planta de 42MW de capacidad, teniendo en cuenta los costes de los elementos individualmente, el coste de la mano de obra y materiales, y el coste de los diferentes permisos necesarios para llevar a cabo la construcción de la instalación. La inversión total obtenida de esta estimación ha sido de 40.529.405 €, que equivale a la misma cantidad en EC coins. Como la inversión se hará por medio de la compra de participaciones, se ha hecho la siguiente conversión entre EC coins y participaciones:

$$1\mathbf{PGP} \rightarrow 100\mathbf{EC} \rightarrow 100€$$

Por lo tanto, para cubrir esta inversión, es necesario la emisión de 519.932 PGP.

Posteriormente, estos costes se han incluido en el modelo financiero junto a los ingresos que tendrá la instalación a lo largo de su vida útil, que serán debidos a la generación de energía y a la remuneración de SolarCoins (SLR) por parte de la SolarCoin Foundation.

Con respecto a los ingresos por venta de energía, se ha asumido que el precio de la energía va a ir disminuyendo debido al creciente número de instalaciones de generación renovable en funcionamiento [37]. La tendencia de precios se muestra en la Figura II.

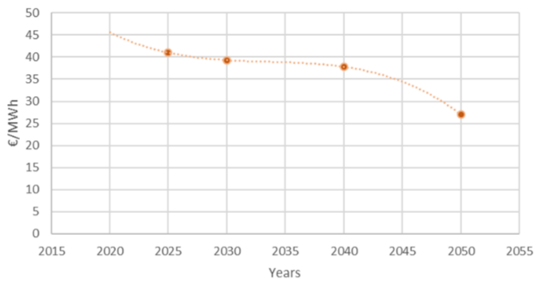

***Figura II**: Evolución del precio medio de la energía*

Con estos datos se ha realizado un caso de referencia con la finalidad de ver si el proyecto es rentable y calcular, en caso de que no lo sea, la subvención del gobierno necesaria para que sí lo sea.

Finalmente se han propuesto varios escenarios, explicados en la Tabla I, para ver la influencia de diferentes parámetros en el modelo.

Tabla I. Escenarios

Escenarios	Descripción
Caso de referencia	-
1.1	Menos generación de energía de la esperada
1.2	Más generación de energía de la esperada
2	Menor crecimiento del SolarCoin del esperado
3	Mayor vida útil de la planta
4	Vender energía a través de un PPA en lugar de a través del mercado
5	Diferente tasa libre de riesgo
6	Combinación del escenario 3 y 4

Resultados

Todos los casos tienen una estructura de ingresos como la que se muestra en la Figura III. Es decir, tienen una parte que corresponde a la venta de generación de energía (azul), otra correspondiente a los ingresos de SolarCoin (verde) y otra correspondiente a la subvención del gobierno (naranja).

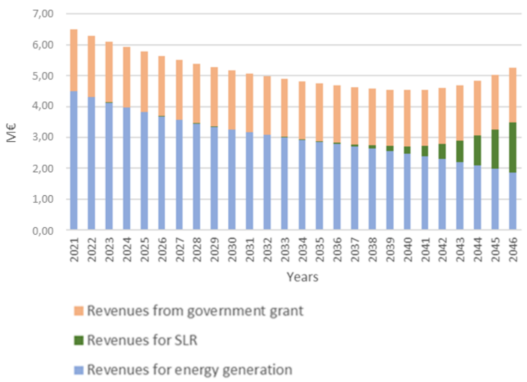

Figura III: Estructura de los ingresos

Se ha resuelto el modelo financiero para cada uno de los escenarios explicados anteriormente, y finalmente, las subvenciones necesarias para que el proyecto sea rentable en cada uno de ellos han resultado las mostradas en la Tabla II.

Tabla II. Subvención necesaria en cada escenario

Escenarios	Subvención (€/ MWh)
Caso de referencia	20,97
1.1	23,15
1.2	19,18
2	22,86
3	15,92
4	17,7
5	22,14
6	12,45

Conclusiones

El proyecto implementado es la financiación de una planta fotovoltaica de 42MW usando la tecnología Blockchain, con el fin de cambiar el método de construcción de las nuevas instalaciones y hacer del sistema una plataforma mucho más líquida para los inversores, y mucho más accesible para la inversión en proyectos concretos.

Se ha concluido que este método de financiación es posible siempre y cuando el gobierno aporte una subvención, menor que el precio mínimo de las últimas subastas, 32 €/MWh, para que el proyecto resulte rentable para los inversores. Estas subvenciones serían necesarias ya que el gobierno se ha comprometido a cumplir con unas cuotas de renovables y sin esta remuneración adicional no se llegaría a cumplir.

Como se puede ver en la Tabla II, el escenario más favorable en el que se necesita una menor subvención del gobierno es el 6, que es una combinación entre los escenarios 3 y 4. En este escenario combinado, la vida útil de la planta se alarga, de forma que genere ingresos durante más tiempo, y la energía se vende por medio de un PPA en lugar de a través del mercado. Para este caso, la subvención necesaria para que sea rentable es de 12,45 €/MWh, que es un 41% menor a la necesaria en el caso base.

Como trabajo futuro, para que el modelo sea más realista, se propone hacer una predicción de los costes en el tiempo, para todos los escenarios, de los elementos y de la mano de obra necesaria, ya que, además, cada año los precios de los componentes de la instalación disminuyen por el desarrollo de la tecnología.

Además, con la tecnología Blockchain emergiendo en todo el mundo y, concretamente, en algunos países de Europa, en los que se están realizando proyectos innovadores piloto con el fin de ver su funcionamiento en el mundo real, la legislación de esta tecnología también irá evolucionando en España, donde actualmente se permite la implementación de algunos proyectos innovadores a través de un espacio controlado llamado “sandbox”.

También se propone la implementación de esta plataforma en Ethereum, con el fin de simular las transacciones y el funcionamiento del sistema, de forma que, eventualmente, se pueda convertir en un modelo comercial.

BLOCKCHAIN APPLICATION TO ENABLE THE FINANCING OF SOLAR POWER PLANTS

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Entity in Collaboration: ICAI – Universidad Pontificia Comillas.

SUMMARY OF THE PROJECT

Introduction

In the last decade, the electricity sector in Europe has undergone major changes in order to reduce greenhouse gas emissions and increase the use of renewable energy.

The European Union has established objectives in which individual countries must achieve specific levels of energy generation from renewable sources. In order to achieve these objectives, in Europe, decentralization is moving very significantly, that is, instead of having a few generation plants that feed the entire population through distribution and transmission networks, what is being installed are many small individual plants, so that consumers become producers of their own energy consumption.

However, on the one hand, in inhabited areas of Spain it is common that the buildings are blocks with several floors or community of owners. On the other hand, Spain is one of the countries in Europe with more solar radiation, and, in addition, it has a very large uninhabited area. For these reasons it has been decided to develop this project, which encourages the construction of large-scale photovoltaic installations, so that not only people who have space to install solar panels in their buildings can benefit from renewable energy consumption, but also those who do not have these private installations can consume green energy through large-scale generation plants that are more efficient and that are connected directly to the grid.

In addition, Blockchain technology, which was born in 2009 to support the Bitcoin, allows the registration of a transaction or any action on the internet in a decentralized, reliable and unforgeable way without the need of verification by a third party. Instead, there are several nodes that compete with each other in order to verify transactions in exchange for certain commissions.

Since 2016, most of the new renewable installations in Spain are built through auctions, whereby companies compete to have their projects chosen so that they can obtain a minimum sale price for their electricity. Another option, which has already been used by some companies, is the construction of the installation privately, so that they assume the risk of a dependent remuneration from the price of the market or the agreed price in a bilateral contract signed directly with a consumer or retail company, called Power Purchase Agreement (PPA). Blockchain technology has potential in this sector, since companies could build these installations privately, with an investment in which different investors can participate through a concept similar to crowdfunding using asset tokenization. The asset tokenization consists in the division of the installation into shares, so that investors, who will be

legal entities, acquire them and are remunerated according to the percentage of the installation they own.

In addition, in the platform these investors can invest directly in a specific project, diversifying their capital in the project they consider. Currently investors can invest in renewable facilities through an investment fund or through specific companies, however, with the platform of this project, investors can choose the specific installations in which to invest their money.

Besides investing in the project, these investors are offered the possibility of obtaining a Certificate such as the Green Energy Certificate, which offers them the possibility to track the origin of the energy they consume, so that the amount of energy they consume must be the same as the energy generated in this installation. That is, they do not consume directly from this photovoltaic installation, since, as it is connected to the grid, the energy that reaches the final consumer is the same regardless of its origin, however, these consumers will have the certainty that with these Certificates, they guarantee that the payment for the energy consumed contributes to the financing of this plant, and that all or just a part of the energy they consume comes from renewable sources.

Methodology

To accomplish this project, it is decided the type of coins with which this platform will work. In order for users to use the platform, the EC coin (Energy Community coin) has been created, which is the utility token of the system. Users can exchange Fiat money and other cryptocurrencies to obtain the corresponding amount in EC coins, so that they can make payments or transactions through the platform. The EC coin is a stablecoin backed by the Euro, so the exchange EC coin-Euro is made with the ratio 1:1. This allows to avoid the fluctuations of the cryptocurrency and to give stability to the system. The participations in which the project is divided, as explained in the previous section, are the PGP (Photovoltaic Generation Participation), which are security tokens issued by the company that implements the project, in order to finance it.

These participations will be purchased in the primary market and may be traded in the secondary market, that will offer great liquidity, since these participations can be sold as long as there is another investor interested in buying it, regardless of the stage of the project.

The diagram by which this investment system works is shown in Figure I. As it can be seen, the investors are the ones who provide the necessary investment to cover the costs. Once the generator makes these funds available, it can start to build the installation, and when the installation is built, it will receive revenues from both the sale of energy and from the SolarCoin Foundation, for the generation of solar energy. Subsequently, these profits are returned to investors after the payment of the costs such as Operation and Maintenance, so that they can recover their investments.

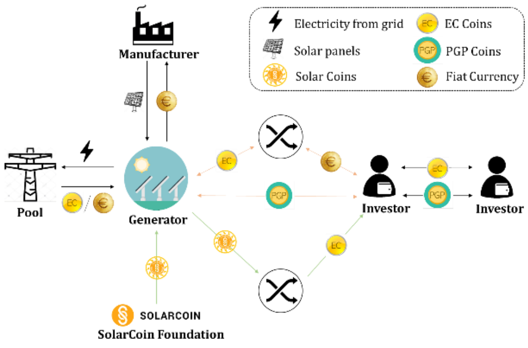


Figure I. *Flow of value in the global platform*

To obtain the investment that the investors will have to cover, costs have been estimated with the Microsoft Project for a 42MW capacity plant, taking into account the costs of the elements individually, the labor and material costs and the cost of the different permits needed to conduct the construction of the installation. The total investment obtained from this estimation is 40.529.405 €, equivalent to the same amount in EC coins. As the investment will be made through the purchase of participations, the following exchange has been made between EC coins and PGP:

$$1\mathbf{PGP} \rightarrow 100\mathbf{EC} \rightarrow 100€$$

Therefore, to cover this investment, it is necessary to issue 519.932 PGP.

Subsequently, these costs have been included in the financial model together with the revenues that the installation will have throughout its lifespan, which will be due to the selling of energy generation and the remuneration of SolarCoins (SLR) by the SolarCoin Foundation.

Regarding revenues from the sale of energy, it has been assumed that the price of energy will decrease due to the growing number of renewable generation installation in operation [37]. The price trend is shown in Figure II.

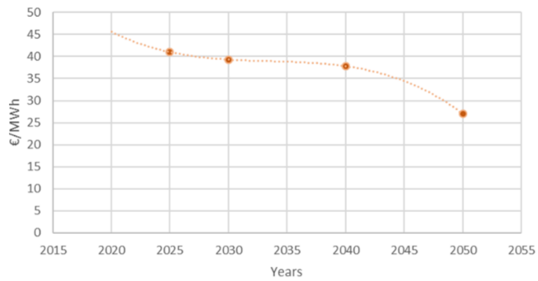


Figure II: *Energy average price evolution*

With this data, a reference case has been implemented in order to know if the project is profitable and to calculate, if it is not, the government subsidy necessary for it to be profitable.

Finally, several scenarios have been proposed, explained in Table I, to see the influence of different parameters in the model.

Table I. *Scenarios*

Scenarios	**Description**
Reference case	-
1.1	Less energy generation than expected
1.2	More energy generation than expected
2	Less growth in SolarCoin than expected
3	Longer lifespan
4	Selling energy through PPA instead of through the market
5	Different risk-free rate
6	Combination scenario 3 and 4

Results

All the scenarios have a revenue structure similar to the one shown in Figure III.That is to say, they have a part that corresponds to the sale of energy (blue), another that corresponds to SolarCoin revenues (green), and another part that corresponds to the government subsidy (orange).

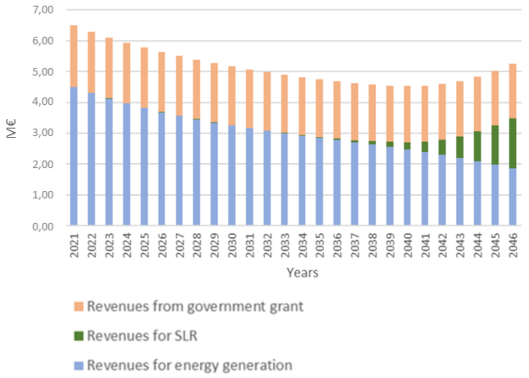


***Figure III**: Revenues structure*

The financial model has been solved for each scenario explained previously, and finally, the subsidies needed for the project to be profitable in each of them are shown in Table II.

***Table II**. Subsidy necessary in each scenario*

Scenarios	Subsidy (€/ MWh)
Reference case	20,97
1.1	23,15
1.2	19,18
2	22,86
3	15,92
4	17,7
5	22,14
6	12,45

Conclusions

The project implemented is the financing of a 42MW photovoltaic plant using Blockchain technology, in order to change the method of construction of new installations and to make the system a much more liquid platform for investors, and to make it much more accessible for the investment in specific projects.

It has been concluded that this financing method is feasible as long as the government provides a subsidy, lower than the minimum price of the last auctions, 32€/MWh, so that the project is profitable for investors. These subsidies would be necessary since the government has committed to comply with renewable quotas and without this additional remuneration, the quotas would not be met.

As it can be seen in Table II, the most favorable scenario in which the lower government subsidy is needed is the last one, which is a combination between scenarios 3 and 4. In this combined scenario, the lifespan of the installation will be longer, so that it generates revenues for a longer time, and the energy is sold through a PPA instead of through the market. For this case, the subsidy necessary to make it profitable is 12,45 €/MWh, which is 41% lower than the one needed in the base case.

As future work, in order to make the model more realistic, it is proposed to make a prediction of the costs over time, for all the scenarios, of the elements and the labor required, since, in addition, each year the prices of the components of the installation decrease due to the development of the technology.

In addition, with Blockchain technology emerging all over the world and, specifically, in some European countries, where innovative pilot projects are being carried out in order to see how they work in the real world, the legislation of this technology will also evolve in Spain, where currently the implementation of some innovative project is allowed through a controlled space called “sandbox”.

It is also proposed the implementation of this platform in Ethereum, in order to simulate the transactions and the operation of the system, so that, eventually it can become a commercial model.

INDEX

TABLE OF FIGURES

TABLE OF TABLES

TABLE OF EQUATIONS

1. INTRODUCTION

Until recently, electric energy production has been characterized by a centralized, fossil-fuel based and one-way generation scheme, complemented with incentive and control measures over the demand performance [1]. Since the signature of the Paris Treaty in 2016 [2], the electricity system is evolving to a decarbonized system, where renewables are playing an increasingly major role. In addition, since the European Parliament approved the new policies to increase the use of renewable energy [3], the system is moving from a centralized system to a more distributed system where generation is being connected also close to the demand.

The European Union has stablished energy objectives including the ones related to renewable energy. Among these objectives, it can be found that the 32% of the energy consumed in Europe in 2030 will have to come from renewable energies [3]. Regarding Spain, this percentage is at 20% in 2020 [4], and at around 42% in 2030 [5]. Due to this need of increasing renewable generation, in Spain it is intended to install more than 87 GW of renewable generation, including solar, wind and other renewable sources. At the moment, about half of these installations have already the license granted by Red Eléctrica de España [6].

This evolution towards a reduction of the dependency on carbon-based fuels, and an increase of renewable energy consumption, could be performed in several ways. The first one is the self-consumption, fostering distributed generation, so that people would cease their electricity consumption from the grid and would start to consume their own electricity that would come from their own photovoltaic installation. This way, people would have to invest in their own solar plant or at least in a shared one, where all the neighbors from the same community could consume from. The second one is consuming electricity from renewable energies through the grid, fostering renewable energy projects at large scale. This means that, instead of investing in your own solar plant at your house, you invest in large-scale plants, in order to increase the amount of clean electricity that goes through the grid, so that as a final consumer, you can consume that clean energy at your house. In addition to the clean energy that the consumer receives, the investment in these installations means rewards or remuneration depending both on the percentage of participations the consumer has on the financing of the generation, and the performance of the plant.

This project is focused on the second alternative, because although self-consumption is an awaited concept, it is believed that larger scale projects may benefit from economies of scale and are more economic than self-generation. In addition, although self-consumption in Spain is predicted feasible in the future, due to the configuration and layout of the houses along the country, and taking into account that the majority of the houses are not individual houses but buildings, it could be very difficult for these communities, in terms of space, to share one solar installation for all of them or to install one small solar plant for each house.

In comparison with other European countries, Spain has a bigger amount of km^2 of surface than others, 505.000 km^2, and only a 13% of the surface is inhabited [7], which means that Spain has a greater "active population density" than other countries. The population density in Spain is shown in Figure 1.

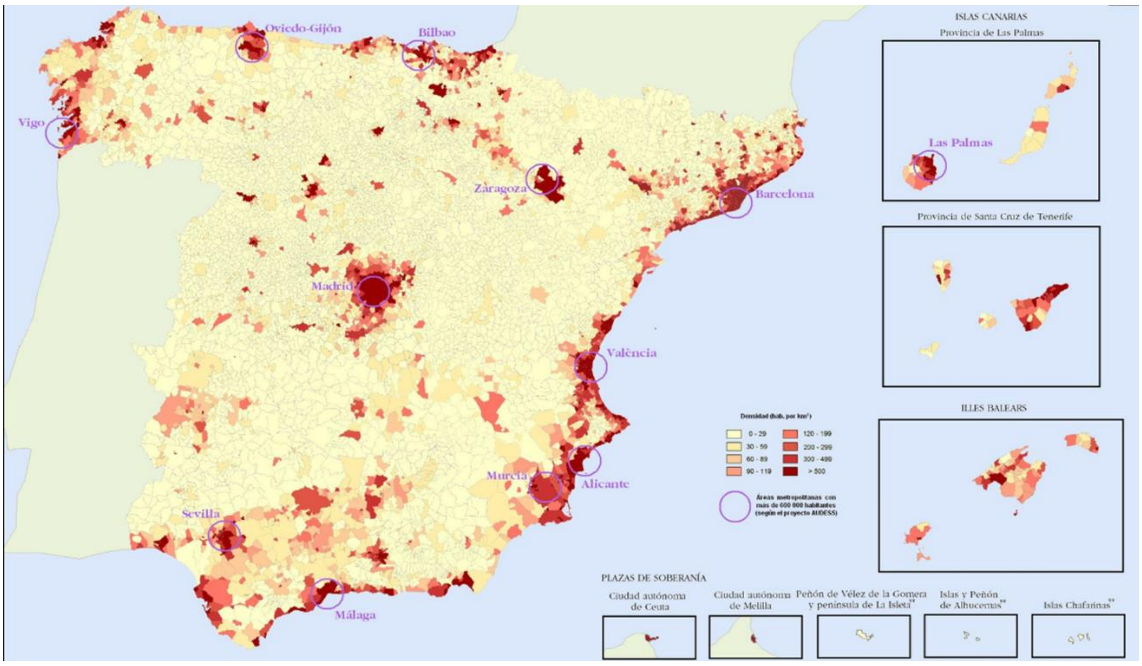


***Figure 1**: Density population in Spain*

As it can be seen, Spain has a lot of uninhabited surface that could be used for generation of collective renewable energy.

In addition to all of this data, and as it can be seen in the Figure 2 below, Spain has a much higher solar radiation than many of other European countries, and its renewable energy installed capacity is not higher than the rest of the countries, such as France, Germany, Italy and United Kingdom [8].

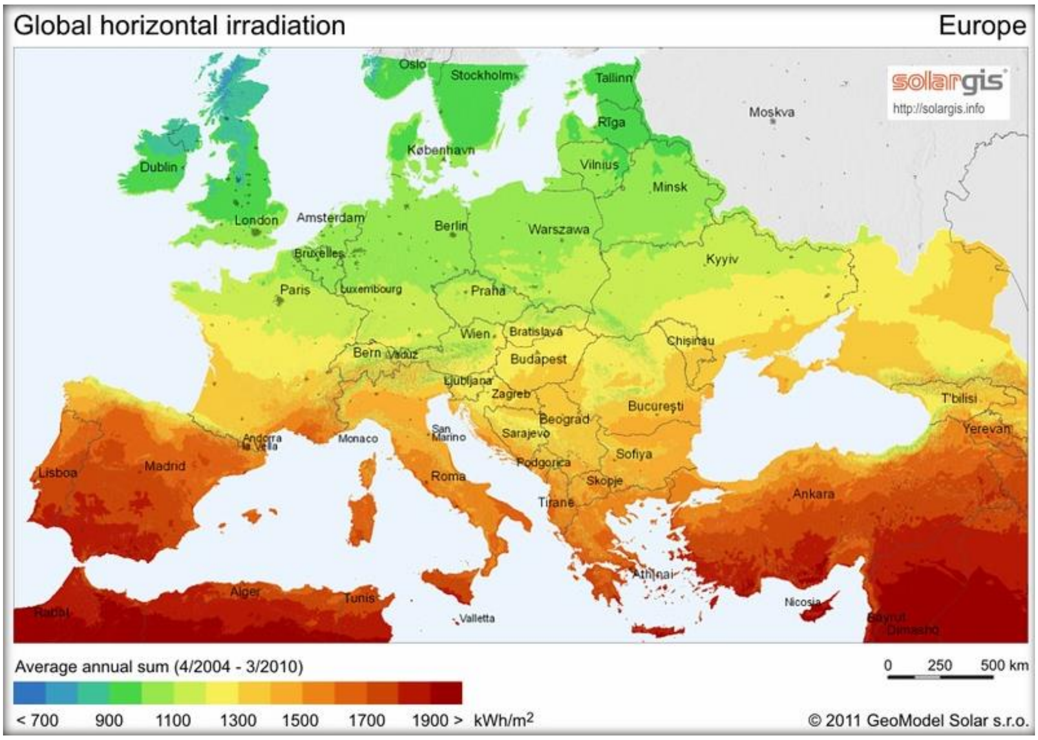


***Figure 2**: Level of radiation in European countries*

Source: [9]

Therefore, due to the privilege situation of Spain in terms of radiation, as well as to its demographic situation and its extension, this project is proposed to foster the consumption of renewable energy at large scale.

2. EVOLUTION OF THE SPANISH ELECTRIC SYSTEM

Currently, the Spanish electricity system distinguishes four clearly differentiated activities: generation, transport, distribution and retail.

The electrical generation installations produce energy at a certain voltage, which is later transformed to a higher voltage so that it can be transported. This increase in voltage is done to reduce losses in the network, since the energy has to travel long distances, and the greater voltage, the lower energy losses. Then, in order to distribute the energy to the final users, the voltage is reduced again, so electricity can be used for final purposes. As a matter of fact, distribution networks are not as long as transmission ones, so the distribution networks operate at lower levels. Finally, retail consists in the sale of energy to the final consumer.

Transmission and distribution activities are natural monopolies, while generation and retail have more freedom to act within the market, that is to say, free competition in these two sectors is permitted. However, this has not been always the same, since the concept of ownership over the transmission network has been modified [10], going from the consideration as exclusive property of the vertically integrated companies, that are the ones that made the four activities on their own (generation, transport, distribution and retail), to be property of one single company.

Regarding generation and retail, they have also been liberalized, allowing the privatization of government-owned companies and the entry of other companies to favor competition. Nowadays, any retail company or generator can start its activity acquiring the corresponding license. Furthermore, the government does not fix the price of electricity anymore, but it ensures perfect competition. The market price is obtained based on the market model that replaces the initial traditional model. This new model consists in a system of marginal prices called the wholesale market or "pool".

Figure 3 shows a general outline that synthesizes what has been explained above. The outline shows an ideal situation of liberalization of the system, since currently the liberalization turns out to be "incomplete" because there are some distribution companies that continue to be vertically integrated, operating more than one activity, generation, distribution and retail.

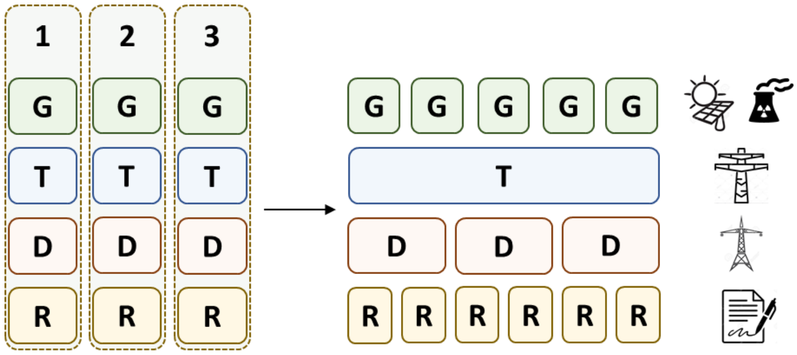


***Figure 3**: System ideally liberalized*

Source: own elaboration

This change in structure in the electricity system occurred in 1997, with Law 54/1997, in order to achieve an improvement in the efficiency of the sector and in the quality of the service offered to customers. This liberalization consists in the separation of free competition activities (generation and retail) from those regulated (transmission and distribution), for the purpose of ensuring free access to the transmission and distribution networks, and to offer customers the freedom to choose the retail company they desire. In addition, the remuneration of transport and distribution continues to be set administratively, avoiding potential abuse of domain positions determined by the existence of a single network [11]. This Law was subsequently extended successive amendments, from which one of the most relevant ones is the Law 24/2013, which also includes social bonds for vulnerable customers and the expansion of consumer rights, among other aspects [12].

Therefore, with the restructuring of the electricity system, there is now free access for generation and demand in which two markets can be differentiated: the wholesale market, in which generators sell electricity to the retail companies or qualified consumers for the price obtained by the pool market, and the retail market, where retail companies sell electricity to their clients.

In the Iberian wholesale pool market (OMIE), there are also two types of markets, the daily and the intra-day market [13].

In the daily market, all available production units that are not subject to a physical bilateral contract have the obligation to submit bids for this market, this is to say, that they have to communicate at which price they want to sell electricity in the market the following day. Retail companies acquire the electricity they need to supply their customers. Direct consumers can acquire energy in the market by signing a physical bilateral contract with a generator, a situation in which the generator would no longer offer electric power in the market but would sell it to that specific consumer.

After the daily market, agents can buy and sell electricity continuously in the intra-day market. This intra-day market usually yields similar prices to those resulting in the daily market and allow buyers and sellers to readjust their commitments up to four hours before real time. From that moment on, there are other markets managed by the System Operator in which the balance of production and consumption is always ensured.

Up to this point, the evolution of the Spanish electrical system has been explained. Hereunder, it will be explained the evolution of generation technologies and the different trends to which the Spanish electrical system can evolve.

2.1 Evolution of generation technologies

The history of the electricity sector is marked by two fundamental aspects: the global growth of demand and the great technological advances [14].

In the 60s, nuclear generation began to be fostered in order to obtain cheaper electric power. In addition, in the 60s there was also a cheap energy from the use of fuel-oil, that moved the sector towards the installation of conventional thermal power plants with more efficient and smaller equipment compared to those of conventional thermal coal plants. Larger plants started to be built to take advantage of economies of scale.

In the 70s the first oil crisis took place, and with it the standstill of the growth of the demand, the increase of the prices of fuels, the increase of the nuclear investment costs and their greater social rejection. The result was a situation of over-equipment and expensive indebtedness for companies in the sector.

The successive oil crises further aggravate the situation, so that companies in the electricity sector have no choice but to act on more important aspects such as energy efficiency, energy savings and the diversification of energy sources.

In the 80s the only investments that were made were for environmental adaptation. Apart from that, in this decade a law that encourages mini-hydraulic, Law 82/1980, to face the oil crisis begins to be developed.

From the 90s, new investments in generation stopped to be made and the lives of those that already existed were extended [15]. On the contrary, investment in renewable technologies such as wind and solar photovoltaic increased due to the laws and regulations of the European Union. Specifically, Law 40/1994 consolidates the concepts of special regime, which includes hydraulic or cogeneration installations.

From 2007 until 2011, when the construction of renewable plants was very expensive, the installed renewable power expanded, however, until 2017 it only added 1.000MW due to the suspension of the premiums for new renewable plants and strict regulation on self-generation [16]. This issue will be explained in more depth in section 2.3.

In 2017, however, the construction of renewable plants began to be mobilized through government auctions. Finally, a total of 5.037MW was allocated resulting in no additional remuneration to the expected market prices evolution and a guaranteed price floor.

Figure 4 shows the evolution of the type of generation between 1980 and 2014 in Spain. It can be seen that the generation of renewable energy has been increasing, displacing those that pollute more.

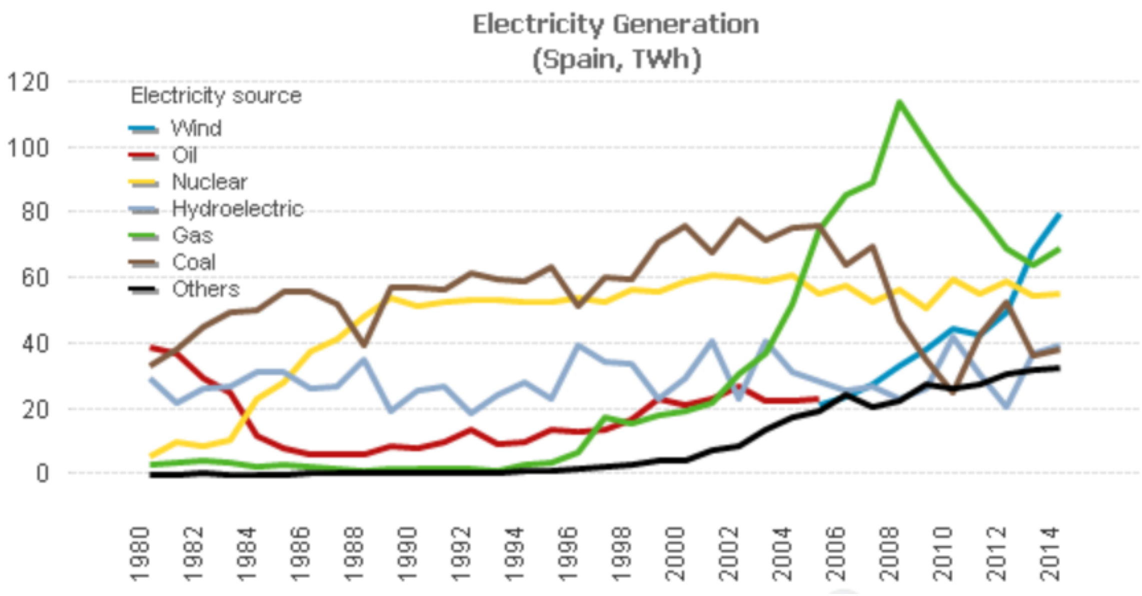


***Figure 4**: Electricity Generation in Spain (TWh)*

Source: [17]

The trend towards decarbonization and toward innovation and construction of renewable energies has occurred for the following reasons that will be explained below: climate change, digitalization and other benefits.

2.1.1 Climate change

It is generally believed that the CO_2, that is a greenhouse gas (GHG), increases the global warming. The NASA predicts the following scenarios for this century:

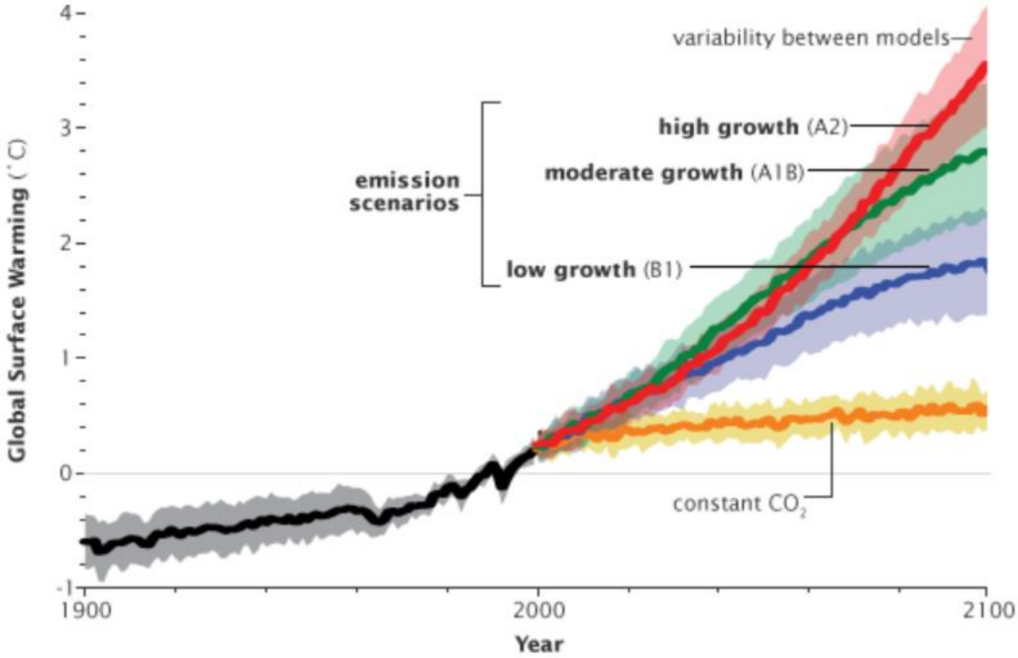


***Figure 5**: Future temperature scenarios due to Global Warming*

Source: [18]

With the Kyoto Protocol, adopted in 1997, the industrialized countries were committed, in general, to reduce their GHG emissions [19]. In some cases, the commitment was the reduction of GHGs, as in Japan, in others the stabilization of their emissions, as in Russia, and in others, a limited increase of emissions, as in Australia.

Subsequently, with the Paris Agreement, adopted in 2015 by 195 countries of the United Nations Framework Convention, the objective stablished was to maintain the world average temperature in this century below 2ºC with respect to pre-industrial levels, committing to carry out the needed efforts to limit that increase to 1,5ºC. In Figure 5, this objective would be the first emission scenario, low growth.

2.1.2 Digitalization

Since the technological revolution 4.0 began, there has been thinking about other options and initiatives to increase generation with renewable energies.

This technological revolution is a concept that describes a vision of the manufacturing with all its processes interconnected by Internet of Things (IoT). This revolution includes:

- Artificial Intelligence. This consist in the simulation of human intelligence processes by machines that include learning and reasoning.

- Blockchain. This technology consists in a distributed record book that maintains a permanent registration of transactions and that works as a decentralized data base.
- Cryptocurrency. It is a virtual currency that is used in Peer to Peer networks. It bases its security using cryptography and there is not any central authority that governs it.
- Data storage in the cloud. It is a service model where data is stored and administered remotely. This data is available to users through Internet.
- Electric and autonomous cars. These are cars that do not need a person to control them. They imitate human abilities in the control of the automobile.

In addition, for being able to use some of these advances for the improvement of electrical systems, there will be required a high consumption of electricity, so a large volume of renewable generation will be needed to cope with this change.

Due to both the energetic and the financial nature of this project, firstly it is going to be analyzed the digitalization in the electrical system and then the digitalization in the financial system.

Regarding the digitalization in the electrical system, it has been extended the adoption of digital technologies in the system under the so-called Smart Grids. Smart sensors and meters are being installed throughout the electrical system to reduce costs thanks to the control and forecasting of consumption.

Precisely because of the increase of renewable energies, due to their intermittent production, a real-time measurement and prediction is needed to adjust generation and consumption, since these have to match perfectly. Information Communication Technologies (ICT) can help to foster this consumption that is currently based on estimations because the lack of real information [20].

In addition, the increased use of distributed generation, which would allow consumers to produce their own energy and sell the surplus to the network, makes the use of information technology more necessary in order to connect all the nodes correctly [20].

Regarding the digitalization in the financial system, the way of operating it is also evolving towards a more digitalized system with the use of blockchain, technology that will be explained throughout the next section and that is modifying the way in which the investments are made.

Currently the most common way to invest is in government instruments, in investment funds, in shares of a company or in Startups. This means that the investor owns a portion of the financial instrument in which he has invested and, depending on the performance of that instrument, the investor will receive a certain dividend or compensation in case of selling it. However, the so-called Crowdfunding is currently being fostered, that is a way of collective financing through online platforms without financial intervention, and which is used to finance a specific project [21]. The different Crowdfunding types that currently exist are the following:

- Crowdfunding: it is expected to receive a reward that can be in the form of product or service.
- Crowdinvesting: the consideration is through company shares.
- Crowdlending: the contribution is made in exchange for an interest on the borrowed money, which will change based on the amount borrowed and the return period.
- Crowdonation: contributions are made in a disinterested way and no type of reward is expected.

2.1.3 General benefits of energy transition

In addition to climate change and digitalization, the promotion of renewable energies would make it possible to bring electricity to isolated areas, being able to build small photovoltaic installations near isolated cities and thus allow the consumption of electricity throughout the world. This is one of the objectives established by the United Nations, since there is still 17% of the world population that does not have access to electricity [22].

In addition, the transition to an energy system based on renewable technologies will have very positive economic effects. According to the International Renewable Energy Agency (IRENA), doubling the share of renewable energy in the global energy mix to reach 36% in 2030 would mean an additional global growth of 1.1%, an increase in welfare of 3.7% and the increase in employment in the sector to more than 24 million people, compared to the current 9.2 million [22].

2.2 Evolution of energy prices depending on the mechanism of remuneration

In this section it is explained the origin of energy prices depending on the evolution of the mechanisms of remuneration. In Figure 6 it is shown the different mechanisms along the time.

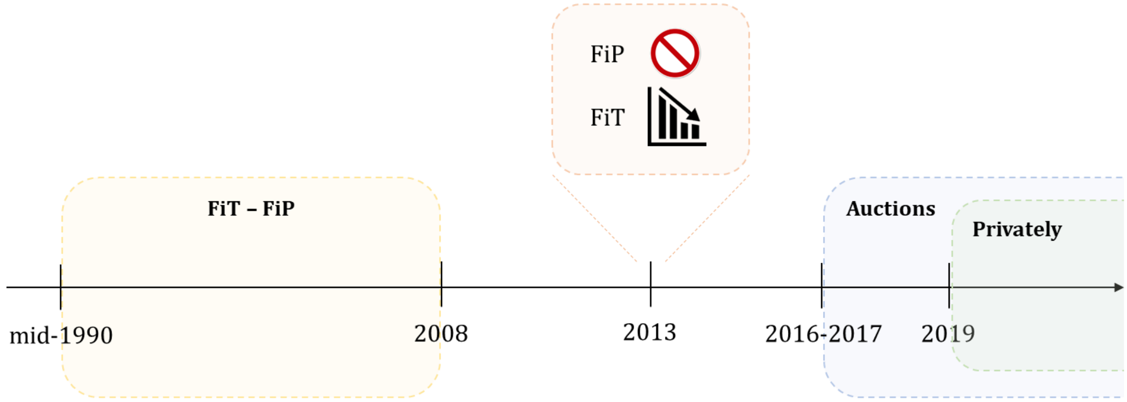


Figure 6*: Renewable Energy selling price evolution*

Source: own elaboration

From mid-1990 to 2008, the policy of renewables in Spain was characterized by continuous innovation. It was the first country to introduce the "Feed in Premium" (FIP) for wind energy, the "Feed in Tariff" (FIT) for concentrated solar energy, and bonuses for systems capable of providing reactive power to the grid.

The FIT is an economic policy created to promote investments and the production of renewable energy. This tariff guaranteed access to the network, offering long-term contracts that set the price of the energy that will be produced in the future [23].

The FIP was a remuneration in addition to the market price that could be fix or variable, and it was applied to all renewables except for solar generation. This market premium was calculated once a month.

The fix system had the risk of overcompensating generators in case the market price was too high, and of undercompensating them in case the market price was too low. For this reason, the fix system was combined with floor and cap prices, that are the maximum and minimum quantity that the government would pay the generators, and it was determined by the Real Decreto 661/2007. In Spain, the system used was the fix one. The possible scenarios are explained below, each one illustrated with its corresponding graph.

- Case 1. If the market price plus the premium is in between the floor price and the cap price, the generator received the FIP.

$$floor < (market\ price + FIP) < cap \rightarrow premium = FIP$$

Equation 1*: Premium if market price plus FIP is between floor and cap values*

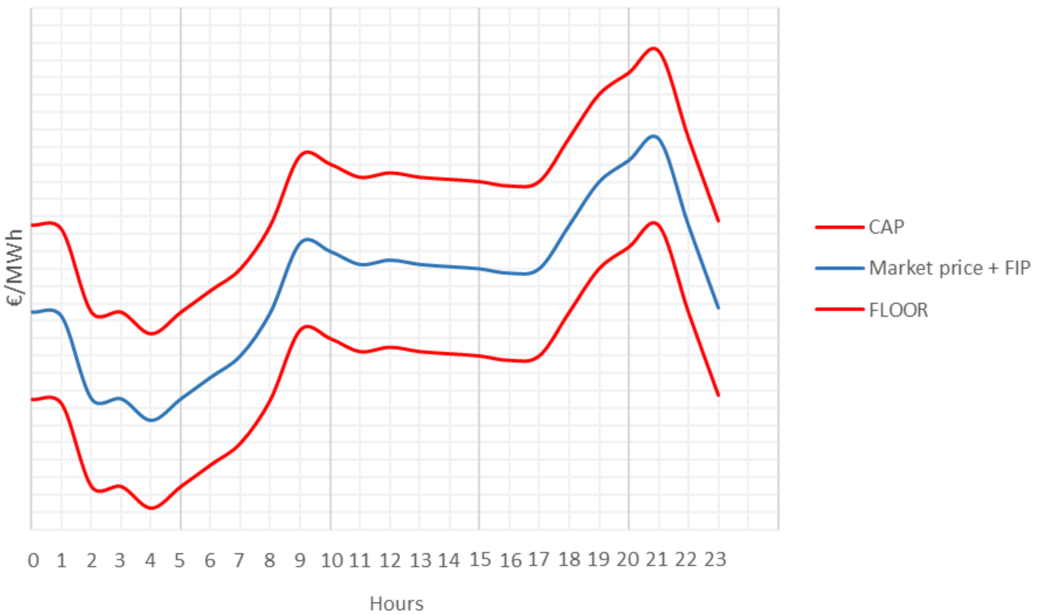


***Figure 7**: Case 1 fix FIP*

Source: own elaboration

- Case 2. If the market price plus the premium is below the floor price, then the premium received is the floor price minus the market price.

$$(market\ price + FIP) \leq floor \rightarrow premium = floor - market\ price$$

***Equation 2**: Premium if market price plus FIP is below floor value*

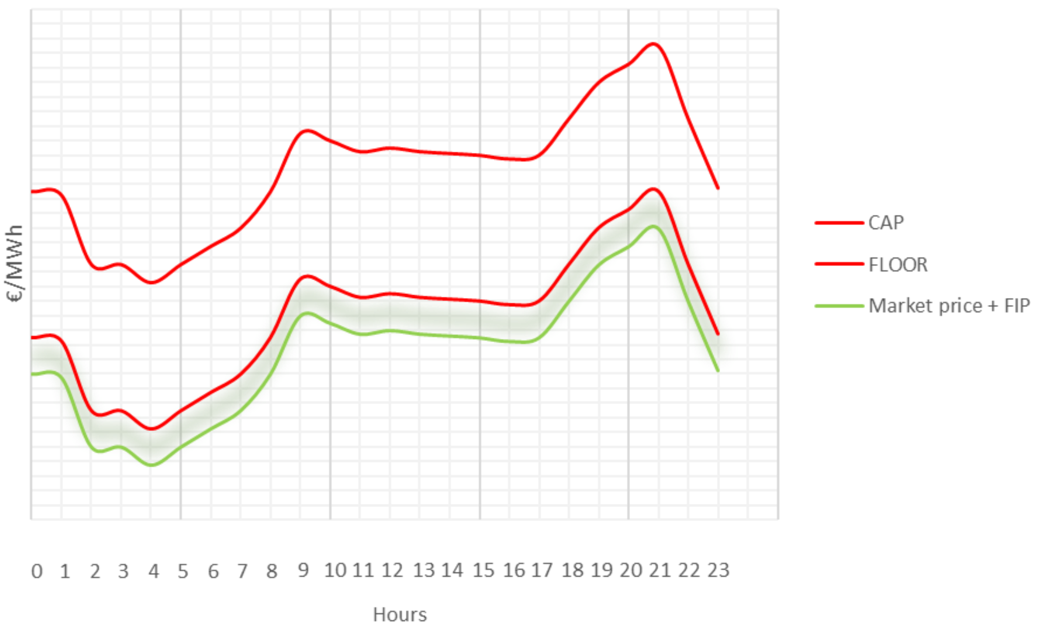


***Figure 8**: Case 2 fix FIP*

Source: own elaboration

- Case 3. If the market price is higher than the cap price, then there is no additional remuneration.

$$market\ price \geq cap \rightarrow premium = 0$$

***Equation 3**: Premium if market price is above cap value*

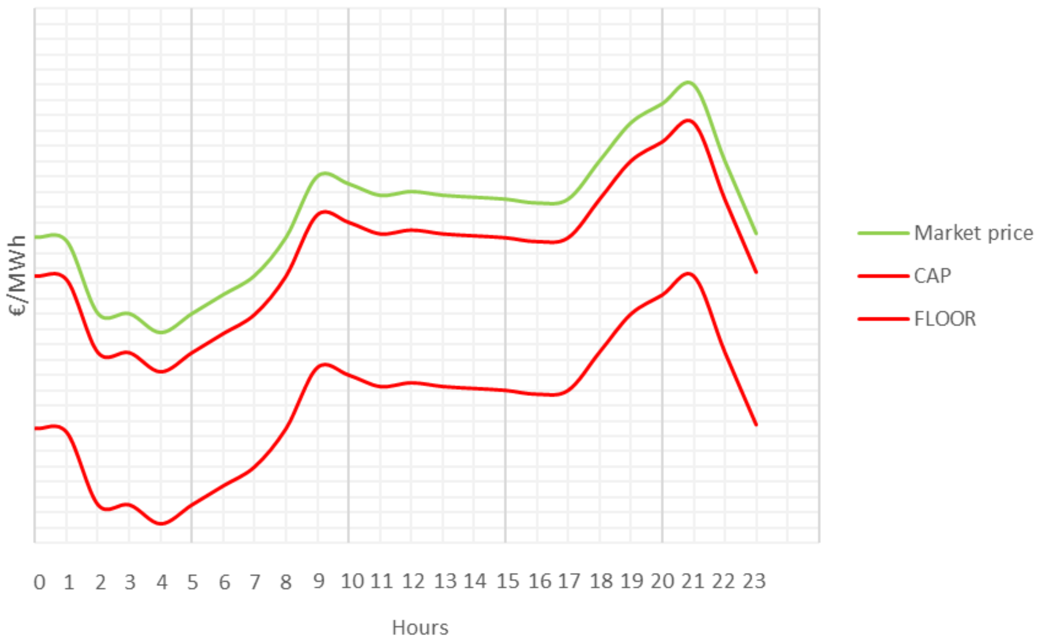


***Figure 9**: Case 3 fix FIP*

Source: own elaboration

Regarding the variable system, there is a reference value, so that if the market price is above this reference value, no additional remuneration was given, and if the market price was lower, FIP was paid. These two scenarios can be seen in Figure 10.

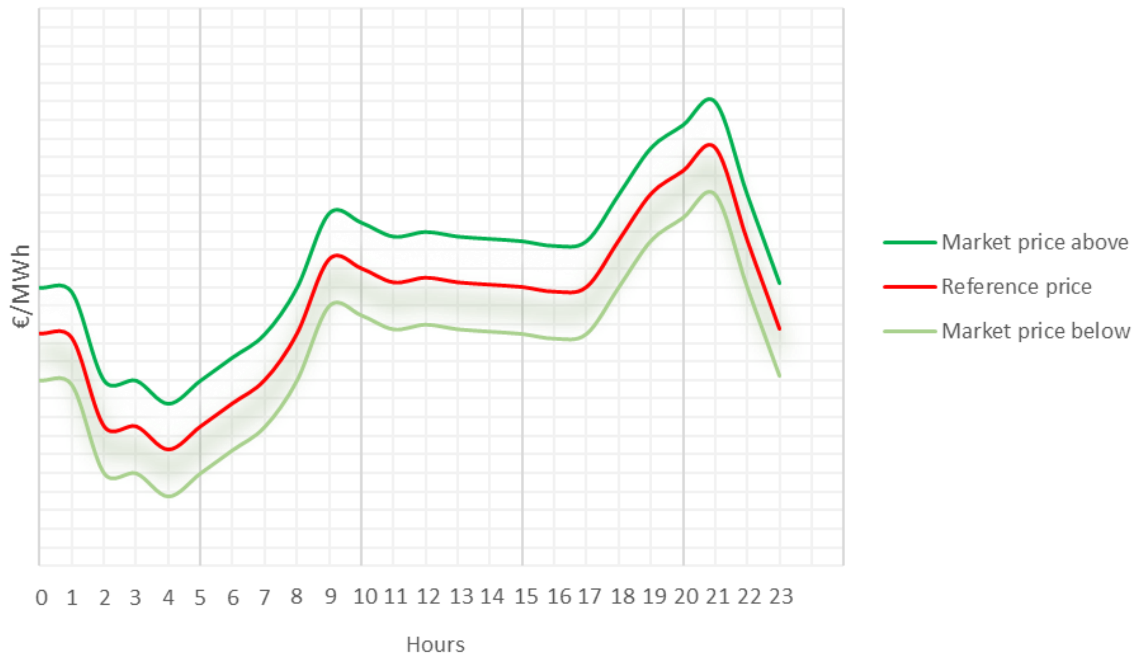


Figure 10*: Variable FIP*

Source: own elaboration

Subsequently, due to the large investments in solar generation, there was an energy crisis in Spain and in 2008 an auction mechanism was proposed to decide the amount of solar power that would be installed, so that there could be more control over the amount of renewables that were introduced in the system. As of 2013, all FIP were reduced to zero and the mechanism was abolished. As for the FIT, it was also reduced to 7,5% retroactively [24], [25].

The first auctions that were held were in 2016 and in 2017, in order to comply with the agreement with the European Union to reach 20% of renewable energy in 2020. By the fact of building an installation through an auction, a floor price is guaranteed. In the case of the last auction this base price was 32€/MWh [26], although energy is currently being sold at almost twice this value. The projects that are chosen in the auction are those that offer a lower sale price of the energy in addition to the base price offered by the government.

In 2019 some companies have begun to build renewable facilities without the need of doing it through an auction, so that the generating company is the one that assumes the risk in case the market price decreases. This happens because in these cases, the government does not commit to subsidize the facilities or guarantee a floor price to be received by the generator.

2.3 Trends in the electricity sector

There are two types of trends towards this situation can evolve. The first one is the decentralization, as many countries are already implementing, and the second one is the renewable generation at large scale. Both tendencies are not opposite and can coexist.

2.3.1 Decentralization

Decentralization consists in building various small generation facilities, for a particular property or for rural areas, so that what is produced in that facility can be consumed by the inhabitants of that same area.

In addition, thanks to decentralization, access to electricity in currently isolated areas is expected to increase considerably.

However, the extension of electrification networks fed with large-scale generation is also of great importance, as in the case of India, where renewable energies of new access accounted for around 20% of decentralized energy, while the general network represented around 75% [27].

2.3.2 Large-scale renewable generation

Large-scale renewable generation consists in building collective renewable energy generation facilities that can be financed by many citizens so that everyone can consume from the grid.

The objective of this trend would be to replace the current power plants with other more environmentally friendly, so that citizens can continue to consume from the grid, as they do at the present, and avoid them to invest in a self-generation installation.

In this project this trend is developed, and a method is proposed to carry out these installations without prior intervention of government auctions.

3. FRAMEWORK AND ASSET TOKENIZATION

In this section it is explained Blockchain Technology, Asset Tokenization and some of the relevant developments that must be taken into account to conduct this financing system, such as SolarCoins or Green Energy Certificates.

3.1 Blockchain technology

Blockchain was born as the technology that made Bitcoin works. It is a codification system of the information that is behind the virtual currency. Shortly after, it was discovered the potential it had for itself and the amount of applications it allows in other areas beyond financial transactions [28].

Blockchain is a technology that allows the transfer of digital data with a very sophisticated coding and in a completely secure way and without the need of a centralized intermediary that identifies and certifies the information. Figure 11 shows a scheme that shows how the system traditionally works. Many times, this intermediary can be hacked and here is when blockchain becomes important.

Figure 11*: Operation of traditional system of transfers*

Source: own elaboration

Blockchain allows distributed consensus where each transaction is registered and validated in multiple independent nodes, so that the intermediary is eliminated, and the owners of the origin and destination accounts are the ones who have control over their transaction. This is done without compromising the privacy of the parties involved, that is, the users are anonymous and only the origin account and the destination account are known.

Once the origin account sends the transaction, the order is stored in a block of transactions that is not yet part of the final database. As more transactions are executed and passing to that block, once the block reaches its capacity limit, it is validated though mining. This mining requires time and electricity, but when it ends, these transactions are permanently registered in the blockchain and they cannot be modified.

In addition, the blocks are linked with an encoded pointer called hash, which links one block to the previous one, plus a timestamp and the transaction data. All this information is public, so that it permits the control of the traceability of the transactions [29].

Figure 12 shows an explanatory diagram of the Blockchain's operation explained above:

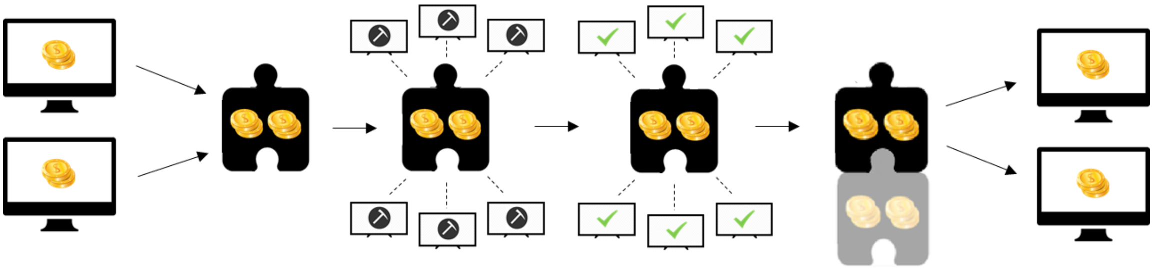


Figure 12*: Operation of blockchain technology*

Source: own elaboration

This technology has several advantages [30]:

- It is **incorruptible.** With various data verification mechanisms, the alteration of the information contained is practically impossible, since if you want to change any data of a block, it is necessary to redo all the **Proof-of-Work** (PoW) associated with the blocks, for which you would need to control more than 50% of Peer to Peer (P2P) network. There are two different ways to accept a transaction:
    - The PoW is the consensus algorithm of the blockchain network, which the miners, competing among others, solve to confirm transactions and to produce new blocks in the chain. This information remains stored in each of the computers that have done the mining.
    - Sometimes **Proof of Stake** (PoS) is used instead PoW. This PoS is still an algorithm, but the process is different. Unlike PoW, in which all the miners solve the puzzle and the one that solves it first gets the reward, in PoS there is no problem to solve, so no rewards are given for it; instead, the miner gets a fee for every transaction it makes. So as not everybody is competing to solve every puzzle, there is no massive energy required [31].

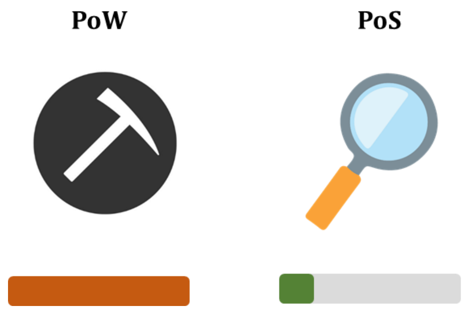


Figure 13: Energy required by Proof of Work and Proof of Stake

Source: own elaboration

- **Free from errors**. As the miners are constantly checking the data, and as the information has to be agreed by all of them, the results are always verified and correct. Moreover, the information is not lost since each one has a copy of the blockchain.
- Reduced **transaction costs**. Since there are no intermediaries in the transaction process, there are no cost associated with third parties. However, by adding a commission to the transaction, it is assured that its resolution will be more attractive to the miners and they will give it a high priority, so that the first miner in solving the PoW can take the commission.
- **Faster process**. Traditionally we depend on an intermediary who does not work continuously, but since the P2P system operates 24 hours a day, 7 days a week, the information is transmitted more quickly. In order to execute these transactions, Blockchain uses programs that run automatically as if it were a contract, these are called Smart Contracts and they will be explained in the next section.

3.2 Asset Tokenization

Constantly new cryptocurrencies appear that improve Bitcoin, or that have different characteristics. In 2014 the public platform Ethereum was developed, and it created what is called “the internet of value”, which goes beyond the “internet of information” that exists today [32].

This platform extends the concept of Blockchain not only to the money, but to any asset, allowing its transfer. Thus, the token is introduced as a representative element of the digitalized property, so that the acquires of these tokens may have liquidity over part or the entire asset.

Tokenization of all types of assets is linked to the so-called Smart Contracts, that are programs that reflect agreements between parties, so that the transfer can be executed if a series of specific conditions reflected in the program are met.

Hereafter the use of Asset Tokenization is explained as a form of financing a specific asset, photovoltaic installations.

3.2.1 Asset Tokenization for Renewable Energy installations

Nowadays, the Spanish system for the building of renewable energy installations consists in the implementation of auctions proposed by the government, that is, a public system. This means that the Ministry sets a certain number of megawatts available for the power companies, and the projects that win the auction will be the ones that will be built. It can happen that the auction is finally at price zero, like in the auctions held in 2016 and 2017, that is to say, that the companies will not receive any financial contribution from the Ministry for the installed capacity in addition to the market remuneration. However, the fact of building the solar plant through an auction supposes that the Ministry guarantees to the company a floor price, so that it guarantees a minimum price to charge for the energy sold in the Market when the price of the wholesale market or pool decreases [33].

The system proposed on this project is a private system. Its operation consists on an investment on the part of an electrical company for the building of the photovoltaic installation. If it is compared to an auction, and it is assumed that the final price of the auction will be zero, so far both procedures are identical. The difference is that with this private system, the ministry does not guarantee you the floor price explained above. So as to compensate this effect, this project proposes to use what is called, Asset Tokenization.

Asset tokenization consists in dividing a tangible asset into small units or pieces, so its liquidity increases, at the same time as it enables a bigger number of participants or investors [34]. Subsequently, these small pieces will be sold in the Primary market to certain investors, and afterwards, they will be traded in a Secondary market.

In order to study the behavior of the investors and their rewards in a better way in later sections, it will be analyzed different scenarios and hypothesis about the future prices of the market, from a technical report developed by the ICAI IIT and Iberdrola [35] so that the marginal prices for future years can be calculated.

First, it is assumed that there is a minimum penetration of renewable energy per year, to comply with the European objectives explained in previous paragraphs. It is not assumed that more Megawatts than those required will be installed, just that the new installations made, will be financed with this new asset tokenization system with Blockchain.

Second, it is assumed that nuclear closures will be made progressively [36]. Although this closure is done in an orderly manner, there is a need to increase the generation of firm additional support, since renewables offer a very volatile and discontinuous energy. In order to have this support of firm capacity, an additional investment in these technologies is necessary. In addition, these technologies would become the most expensive in the market, which would require a remuneration to these facilities when the marginal cost is lower, so that they can recover their investment and maintenance.

With this scenario of nuclear closures and opening of renewable facilities, with an increase of 2% in demand and keeping all other parameters relatively constant, the marginal price over the years evolves as shown in the graph below. As it can be seen, the marginal price decreases over time due to the increase of renewable generation, although it does not decrease sharply, since, when the nuclear power plants are eliminated, an investment in other types of technologies with a higher marginal cost should be made.

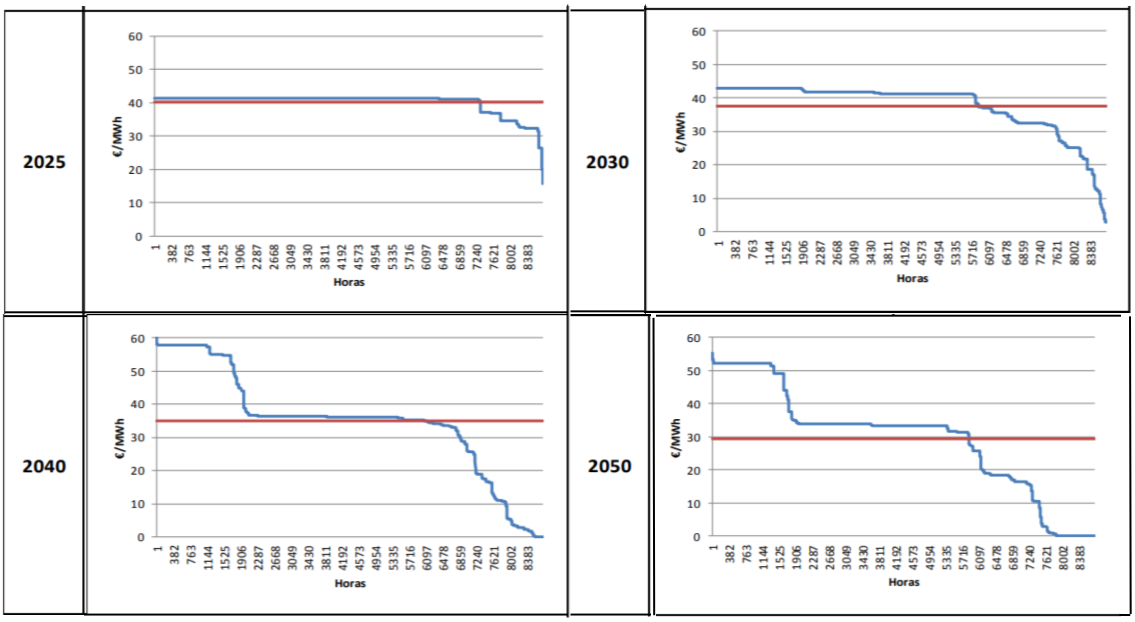


__Figure 14__: Monotonous curves of marginal generation costs (blue) and arithmetic average marginal cost (red)

Source: [37]

Third, in order to achieve the objective of renewable energy it is necessary to force their entry, and this is what is intended with this project. As it has been observed in recent months, it is intended to eliminate the incentive of the minimum price for renewables taken at auction, so that building an installation publicly through an auction would be the same as doing it privately, because if the pool price collapses, the investment would not be recovered so easily in that period of time [38]. However, with this project, the construction company of the renewable installation would recover its investment thanks to the asset tokenization of the installation, through the injection of money from other investors.

As it can be deduced, now the investors are the ones who are assuming the risk, since if the price collapses because of the greater amount of renewable facilities, the installation will receive low marginal prices and investors could not be remunerated enough to cover all the costs. So investors may have economic losses or others would not want to invest in these facilities, and therefore there will not be companies interested in building them. To ensure that this does not occur, a public support system is necessary so that when the marginal price is low or even zero, investors can continue earning profits to recover the costs.

Moreover, as it already happens nowadays, there may be people or companies that are willing to pay a higher amount for consuming renewable energy, which would imply an additional income for these renewable generation facilities.

All this is discussed in more depth in the Market Operation section.

3.3 Green Energy Certificates

Green Energy Certificates serve to trace the origin of the energy and promote the use of renewable energy [39].

When a consumer buys electrical energy from the retailer, since the energy that is transmitted through the network and that finally reach final consumers is the same regardless of its origin, there is no exact way to know if the energy comes from a renewable source or not.

As some energy distributors can commit fraud by allegedly offering green energy, Green Energy Certificates have been created to track and endorse that the electricity that is received, actually comes from renewable sources. These certificates are issued by the retailers to the consumers, that are the purchasers of energy in the wholesale market.

Analogous to this, it is proposed the creation of a new certificate, which expedition would be optional for the consumer, that shows that the energy received by the investors of the photovoltaic installation at the points of their consumptions, comes from that particular installation. These investors would be receiving energy from the grid and a common electricity bill with an extra that will be explained below; however, they could also be receiving a certificate that would authenticate the maximum amount of renewable energy that they could be receiving from one specific installation.

As each investor can have their investment diversified in several plants, this certificate will include all the renewable energy that the investor can receive from all the installations. In the same way, when the investor sells participations of any of the installations, this certificate will have to be updated.

The certificate will be unique for each investor, and will show that, at most, the investor can receive as much renewable energy as the percentage of participations the investor has on each installation multiplied by the maximum generation that each installation has every hour, and this calculated for every installation that the investor has invested in. This is calculated assuming that the installation generates at maximum power in all hours of sunshine, not considering little sun or rainy scenarios:

$$Certified\ Energy = \sum_{j=1}^{j=24} \sum_{i=1}^{i} Maximum\ plant\ generation\ i, j \cdot \%\ Participations_i$$

***Equation 4**: Certified Energy for investors*

Being:

j = day hours.

i = number of installations in which the investor has participations.

Regarding the electricity bill, if the amount of energy received each hour is greater than the consumption of the investor during all days of the month, the electricity bill may state that the consumption of this investor that month comes entirely from renewable sources. Conversely, if it is less, the exact figure will be shown based on the participations that this investor has in the different facilities:

$$Actual\ Energy\ Received = \sum_{j=1}^{j=24} \sum_{i=1}^{i} Plant\ generation\ i, j \cdot \%\ Participations_i$$

***Equation 5**: Actual Energy Received by Investors*

It should be noted that the energy received each month will not be constant, since the generation is assumed not constant during all months and, therefore, in the most unfavorable scenario in which the installation does not generate, the investor would not be receiving renewable energy from that particular source, and in the electricity remuneration that term would be zero.

3.4 SolarCoin

SolarCoin is a reward to incentivize solar generation, in order to accelerate to global transformation towards renewable energies [40].

The SolarCoin Foundation gives to solar energy generators tokens based on blockchain at a ratio of 1 SolarCoin (SLR) per Megawatt-Hour (MWh) of solar energy produced.

The SolarCoin is given for free to generators of solar energy by the SolarCoin Foundation, it is an additional reward for solar energy producers, and has nothing to do with government subsidies. SolarCoin is global, decentralized and independent of any government, and it is designed to last forty years from 2010.

SolarCoin can be spent at businesses that accept them and can be traded like any other cryptocurrency. In addition, it can be collected, redeemed or traded for any other currency on cryptocurrency exchanges. This means that it is a hybrid cryptocurrency, because it can be traded like any other cryptocurrency, but in addition, it is a reward for solar generation. Below is a diagram of the general operation of SolarCoin.

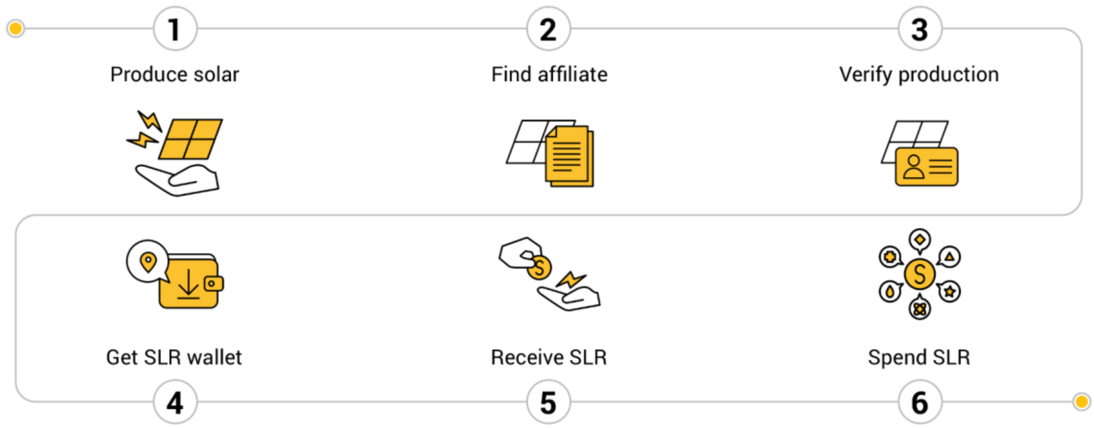


Figure 15: Operation of SolarCoin

Source: [41]

Currently, each SolarCoin can be exchanged for 0,04032USD, which equals approximately 0,036392€. It has to be taken into account that these changes fluctuate permanently, so these values are indicative.

The evolution of the SolarCoin value in USD is shown in the following graph. As it can be seen, between 2014 and 2019, this value fluctuated between 0,01USD and 2,88USD, value that took place in 2018.

***Figure 16**: Evolution of the value of SolarCoin in reference to USD*

Source: [42]

The concept of SolarCoin is very interesting, since the objective of this project is precisely to promote renewable energy at large scale.

At present, there is no scenario in which all the energy demanded is satisfied only with renewable energy, however, in a scenario in which all demand is satisfied only by renewables, the marginal price would fall to zero and the generators would not be remunerated.

This scenario can occur due to the following reasons:

- The penetration of renewable energy increases greatly, so that the entirely consumption can be done from these renewable sources, and the consumption of fossil sources is avoided.
- Democratization of the system. This means that everyone has access to energy and that this energy is also green. The combination of renewables with storage, the electric vehicle, microgrids, networks and smart meters would provide sufficient flexibility and demand management to balance variable generation, so that consumption could be concentrated in the hours of solar and wind energy production thanks to smart meters, and the energy that is not consumed could be stored for its use in another moment of demand.

Therefore, in this scenario, renewable energy generator would not be remunerated because, as it has been explained before, the marginal price would be zero; and here is where the concept of SolarCoin becomes interesting, because generator will continue receiving an income to generate.

In addition to the remuneration with SolarCoins, the following sections will study the possibility of introducing a minimum price, paid by the state or by the citizens directly, for energy in case the pool price collapses.

4. INITIAL COIN OFFERING (ICO)

An Initial Coin Offering (ICO) is a method of financing a project. This is very similar to crowdfunding or crowdlending, as it will be explained later, since it is a community of users who finance a project without any intermediary.

This is very important, since what is precisely pursued with the use of blockchain technology in this project, is to eliminate any intermediary in the financing of a photovoltaic project. This way, it will be a community of investors who will invest directly in the installation, and the generator will not be the one looking for financing through other means. These means are explained later in the next section.

The operation of this form of financing is explained below.

4.1 Operation of the Initial Coin Offering

Whenever it is decided to use blockchain technology for special use, there must be an associated currency so that an ICO can be created. This ICO consists in doing a pre-mining under closed doors and offering the new virtual currency in exchange for other currencies that already circulate, as Bitcoin or Ether, and that are also interchangeable for fiat money. Therefore, an ICO consists in offering to the initial investors the new currencies in exchange of money [43].

This method displaces the traditional venture capital, so that these companies no longer have to go to a venture capital company to provide funding.

The advantages and disadvantages of ICOs are shown below:

Advantages:

- Companies do not have to sell part of their companies to provide funding.
- Investors can finance very innovative companies directly, and this method provides them with liquidity since, unlike startups in which the money is immobilized until dividends are distributed or until the company is sold, investors in an ICO can sell their tokens whenever to another user who wants it.
- ICOs give better returns on the investment to the investors.
- Cryptocurrencies rise rapidly in price, because there are a limited number of tokens and increasingly more people willing to buy them, so the initial participants have greater chances of high profits.

Disadvantages:

- The project might not success and the coins issued in exchange of money are worthless. This is a risk that exists in all startups since it is never guaranteed the success of the project.

- The security of the platform is not secure, that is, that the Smart Contract code has errors or gaps.

There are two types of tokens that can be created to finance a project:

- **Utility token**: many ICOs have issued Utility tokens to raise funds, but it is not considered a financial investment, so they will not have to comply with the applicable regulations. These tokens only allow future access to the products or services offered by the company, and therefore, Utility tokens have not been created to be an investment. Also, for them to have value, the company behind them also has to have value.
- **Security token**: they are supported by something more tangible that are assets or benefits of the company, and they are considered investments for legal purposes. It is a digital asset that derives its value from an external asset that can be commercialized; therefore, those who buy them have the right to have dividends or compensations in the form of additional cryptocurrencies as long as the company has benefits in the market. Holders of Security tokens also get ownership of the company. In addition, Blockchain offers a platform to create a voting system that allows investors to exercise control in the company's decision making.
  Hence, these tokens are subject of federal laws that govern securities. Security token issuers have to comply with legal requirements applicable to securities where the tokens are being issued and actively commercialized.

Therefore, an ICO is a process through which a company sells a series of tokens that can be, as explained before, utility or security tokens. If the company sells Utility tokens, it is called Initial Coin Offering (ICO), and if it sells security tokens, it is called Security Token Offering (STO). Below, it is explained the characteristics of each one:

- **ICO**: investor simply buy the tokens in order to be able to use them in the platform. This way of raising funds would resemble to crowdfunding.
- **STO**: the tokens represent participation or economic rights over a company. The security tokens give different rights for its holders, according to the programmed smart contract that gives them life. This way of raising funds would resemble to crowdlending or crowdinvesting, which is regulated by the Spanish Law 5/2015, which regulates participative investment and loan financing.
  Anyone who wants to issue any form of securities have to register their investment contract with Securities and Exchange Commission (SEC).

Spanish legislation does not currently regulate the ICO, however, they can be subjected to certain regulations, particularly the Real Decreto Legislativo 4/2015 (Securities Market Law) and Real Decreto 217/2018 (Investment Services Law).

Below there is explained a brief legislative framework through which the ICOs would be governed.

4.1.1 Legislation of the Initial Coin Offering

The Spanish regulator of financial markets, Comisión Nacional de Mercado de Valores in Spain (CNMV), published a document that includes the preliminary criteria applied to the Initial Coin Offering. The document emphasizes the issue about when a token offered through an ICO should be considered a negotiable value. The new criteria "exclude from this category those cases in which the yield of the token does not keep a reasonable correlation with the evolution of the project that issues it". However, it is not clear what exactly this correlation is, if it must be statistical or on the contrary, if it must be considered from a subjective point of view [44].

This implies that negotiable values will be those tokens that grant the investor the right to access to the product or service with an expectation of remuneration, that are, security tokens [44].

One possibility is what is being developed in France, where this method of financing has begun to be promoted, since it attracts very innovative projects. It has been approved a project that foresees the authorization of ICOs by the Autorité des marchés financiers (AMF) (the equivalent to the Spanish CNMV). Promoters, that have to be French companies, will present the documentation of the project and the offer and the system they will follow to guarantee the safety of the funds raised. If the authority considers the information and the guarantees enough, it will grant the issuance of a "visa" that facilitates access to banking services for fund raising [45].

In Spain, it does not exist any project like this one, but it is allowed to use a controlled testing space or "sandbox". A project already exists under the name "Proposed bill of measures for the digital transformation of the financial system", which allows the implementation of innovative financial activities under a specific regime and supervision, but without having to comply with the requirements they usually demand for this type of activity.

This preliminary project is designed for the provision of financial services to consumers and not for ICOs, however, the ICOs could fit into this Law because they meet a series of articles defined in it [46].

"Sandbox" will be coordinated by the General Secretariat of the Treasury in collaboration with the Bank of Spain the National Securities Market Commission (CNMV) and the Directorate General of Insurance [47].

The tests will be performed in a close setting, and the projects accepted will have to be beneficial for the users.

4.2 Initial coin offering of photovoltaic installations

For this project it has been decided to make a dual issue of tokens, so that both utility tokens and security tokens will be issued. The usage of each currency in this project is explained below:

- Utility token is going to be used as the useful coin, so that dividends and other forms of compensation to investors, as well as all the operations on the platform, will be made with this coin. This currency is called Energy Community Coin (**EC Coin**).
- A security token is a representation of a participation in a specific project, so that each installation will have a different security token. In this case, the token to this installation is called Photovoltaic Generation Participation token. In this project there will be 2 types of investors, as it will be explained along the project, and each type will have their own type of security token. The first type are those who have a fix rate of return and therefore are exposed to a lower risk; these investors are the ones that will be playing the role of the bank and they could buy Photovoltaic Generation Participation Fix (**PGPF token).** The second ones are those who are exposed to higher risks, and therefore they have a variable rate of return; these investors will play the role of social capital and they could buy Photovoltaic Generation Participation Variable (**PGPV token).** In the diagrams shown, these 2 types of tokens are both simplified as PGP.

Hereunder it is explained the global operation of this platform, followed by a diagram where it can be visualized the flows among all the participants:

- The construction company purchase the panels and all the materials needed to build the installation.
- The company issues some PGP tokens to finance the installation. That is, it implements a STO. Investors can buy these shares in the primary market with EC Coins.
- Investors, as well as the generator and all the participants of the platform, will obtain these EC Coins through an exchange of fiat money on cryptocurrency exchanges.
- Investors can buy and sell the PGP tokens among them in the secondary market using EC Coins. The generator can also buy its PGP tokens to be an additional investor, so that it can also benefit from the operation of the installation. As there are two types of security tokens, there will also be two secondary markets, where users can trade the participations depending on the interest rate of the PGP.
- In addition, when Solar Coins are received from the SolarCoin Foundation, they are distributed among all the investors of the installation. SolarCoins are exchanged for EC Coins on cryptocurrency exchanges, so that investors finally receive EC Coins.

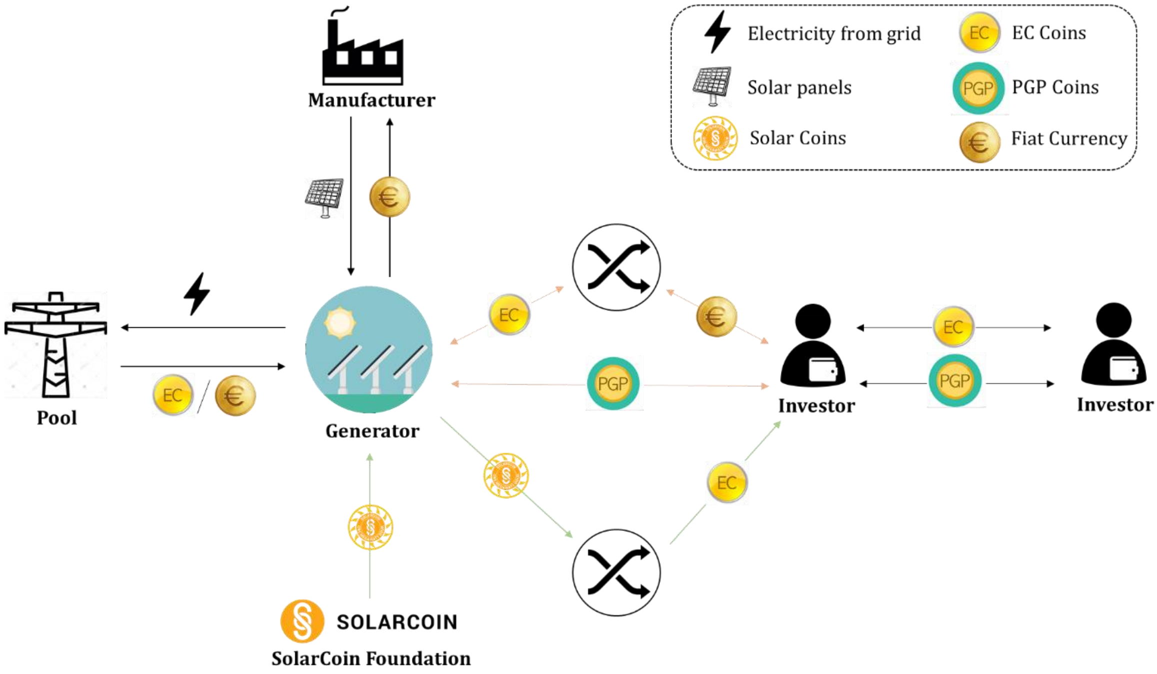


***Figure 17**: Flow of value in the global platform*

Source: own elaboration

As explained above, to be able to buy tokens of this project it is necessary to exchange fiat currency, in this case the EURO, into a cryptocurrency. This is going to be explained in the next section, where it will be analyzed the type of cryptocurrency that will be used in the platform.

4.2.1 Stablecoins

The cryptocurrency chosen for its use in the platform of this project is a stablecoin.

The stablecoin of this platform, the EC coin, is a currency based on Ether, and will be a currency issued as an ERC20 token, which is an interface that guarantees interoperability between tokens. The ERC20 tokens are a subset of Ethereum tokens that conform to certain parameters, and to fully comply with the ERC20 standards, the developer must incorporate a specific set of functions in the smart contract. This way, if the developers know in advance how the token will work, they can easily integrate it into their projects without the fear of making mistakes [48].

There are three types of stablecoins [49]:

- Stablecoins backed by Fiat currency or products. The price of this cryptocurrency is linked to a Fiat currency, so that the users of the platform are guaranteed to exchange their token for the stable value of the Fiat currency, set at a ratio of 1:1.

- Stablecoins backed by other cryptocurrencies. The objective of these cryptocurrencies is to decentralize the stablecoins backed by Fiat money, although supporting them by a more volatile cryptocurrency. In this case, the relationship established between the two cryptocurrencies is 1:2, so if the cryptocurrency quotes at 1€, the backup must be double that amount.
- Stablecoins that do not have backup guarantee. The price stability of these cryptocurrencies is achieved through a reserve bank operated by the network that allows to increase and decrease the supply of money within the blockchain.

In this project it is chosen a stablecoin backed by a Fiat currency, to avoid fluctuations and volatility. Therefore, the relationship between the chosen Fiat cureency, the Euro, and the EC coin results:

$$1\textbf{€} \rightarrow 1\textbf{EC}$$

***Equation 6**: Relation € - EC coins*

In order to study a specific case, we choose to finance a hypothetical installation of 42MW, reference value based on the installation built by Enel in Extremadura, which cost has been approximately 33 million EUR [50]. In the case of this project, as it will be explained and calculated in next sections, the investment has a value of 40.529.405 €.

To cover the investment of this project, the financing structure of the project should be known previously. As it will be explained in the financing model, the financing structure will be divided in 30% social capital, with PGPV, and 70% debt, with PGPF. Therefore, from the 405.294 PGP tokens that will be issued, each with a value of 100 EC Coins, that are 100€ each, 30% of these PGP will have a variable interest rate, and the other 70% a fix interest rate.

$$1\textbf{PGP} \rightarrow 100\ \textbf{EC} \rightarrow 100€$$

***Equation 7**: Relation PGP - EC coins*

5. CONDITIONS FOR THE INVESTMENT AND INTEGRATION WITH ELECTRIC COMPANIES

In this section it is explained the conditions for the investment for this specific project. However, in order to fully understand the usefulness of this new method of financing, traditional methods of financing used by many companies nowadays are also explained.

Currently there are several methods to finance a photovoltaic installation:

1. **Power Purchase Agreement** (PPA). It is a purchasing contract between a generator and a buyer, usually for a long period of time. Buyers are electricity retail companies, which in turn will resell the energy purchased through the PPA to their final customers, fixing their long-term electricity supply costs [51].
   Energy generators seek to close PPAs because it ensures a stable sale price over a long period of time, and thereby generators can guarantee income with which to finance their projects.
   As for the buyers of this energy, these PPAs allow retailers to offer their customers electricity with favorable economic conditions in comparison with the prices of the wholesale market, since it reduces future risk against fluctuations in the volatile market price.
   Regarding final consumers of this energy, this type of agreements offers them a more attractive and stable price for their electricity consumption, in addition to a green certification for consuming renewable energy if the facility is a renewable installation.
2. **Green Credits or Energy Bonds**. These Green Credits give investors the opportunity to support low carbon emission projects, especially small projects, since their funding sources are generally expensive and limited [52]. This way, these credits allow companies to obtain better financing conditions and more adequate maturities that respond to the specific needs of each project. Thus, these Green Credits allow interest rates to be reduced according to the degree of sustainability of the project, and in addition they support the technological innovation of the companies that carry them out.
3. Financing using **blockchain technology** applied to **asset tokenization** of the installation. With this method, as it has been explained along the project, investors can contribute buying participations and thus providing funding for the construction of the installation. This way, the generator would not have to request any loan, nor would it need to make any PPA with a retail company, since the project would be financed thanks to external investors. Below it is explained the characteristics of the possible investors to this project.

Like in Project Finance, this method of investment will only allow the investment to legal entities, that is, those by which a person, entity, association or company with sufficient capacity to contract obligations is recognized, and with capacity to implement activities that generate full legal responsibility, both with respect to themselves and to others. In any case the participation of natural persons will not be allowed.

There is an **owner** of the installation, the generation company or a developer, who is in charge of pre-mining the coins so that investors, who must register on a website by entering their data, can buy them in the primary market by transferring their coins to the owner's address.

Once the generator company has sold all the participations at a base price, investors can start trading them in the secondary market. As it happens in the stock market, the seller places an order to sell participations, this order can be a "market order", in which the seller communicates the number of participations that will be sold at market price. Another option is to place a market order to sell an action between a range of prices, so that if at any time the sale price range of user 1 coincides with the purchase range of user 2, then the participation will go from one wallet to another, and the coins will be transferred from one wallet to the other as well.

Blockchain, as explained before, is a technology that respects the anonymity of users among them, so neither user 1 nor 2 know who are buying or selling the participation to.

In Figure 18, it is shown a diagram with the operation explained above:

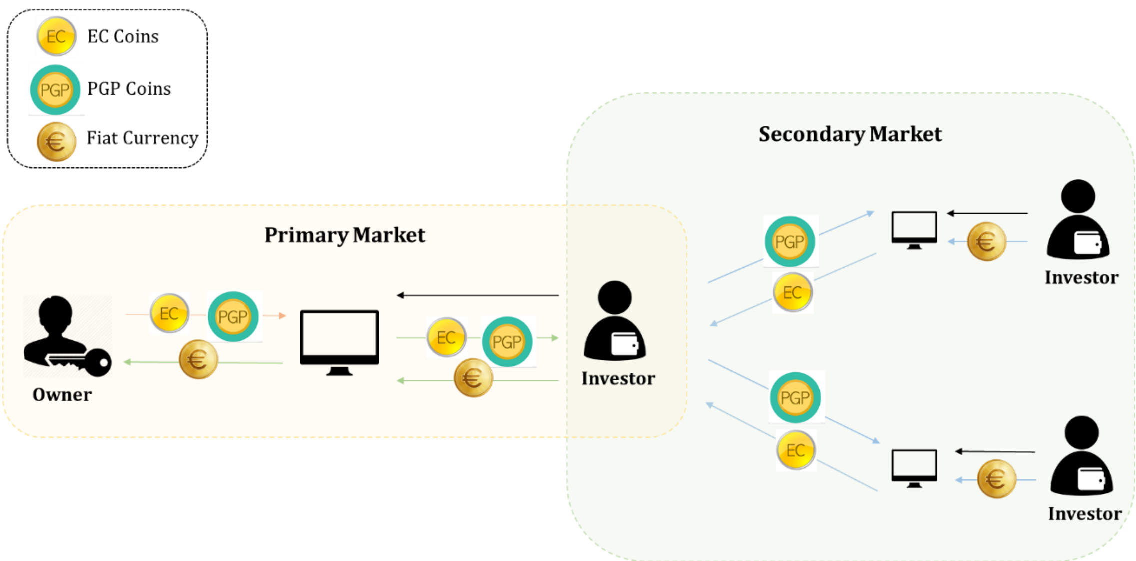


***Figure 18**: Primary and Secondary market operation diagram*

Source: own elaboration

In order to invest in this project, previously it has to be known the entity that is participating, so that the generating company can verify that this person or entity has sufficient capacity to contract obligations, and then if it is a client of the construction company of the installation. This will be done with an automatic process that consists of 2 steps: first, the user will register on a web page and it will be assigned a unique wallet direction, where they can receive the virtual coins that they buy. This wallet direction will be visible but anonymous for the other users of the platform; and second, it will be asked if the user is a client of the retail company that is building the installation. In Figure 19, it can be seen the diagram of this process.

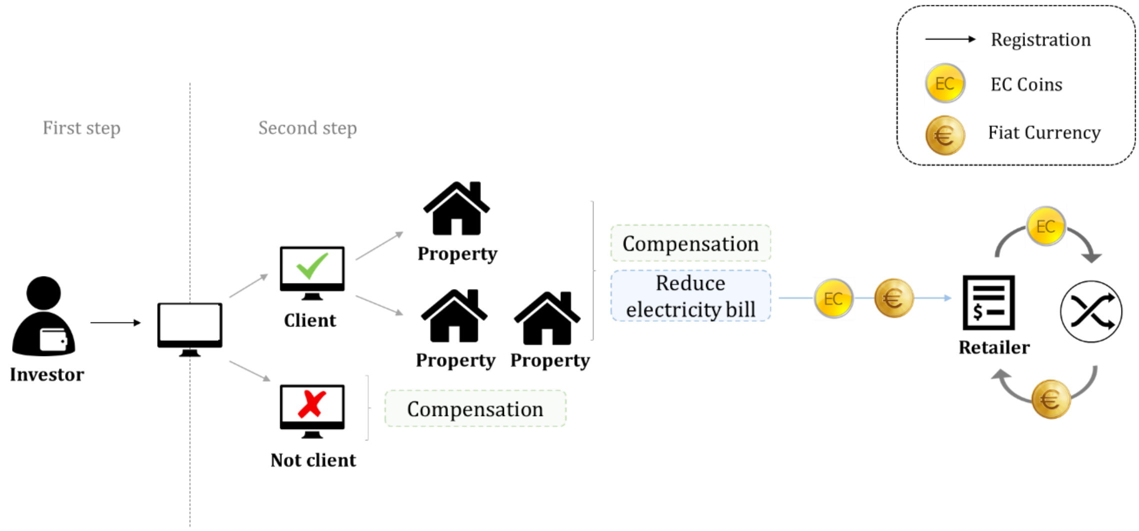


***Figure 19**: Investors automatic process diagram and compensation*

Source: own elaboration

<u>First Step</u>

In the first step, once the users have the address of their wallets, they can go to a currency exchange house, which in this case is the company itself, and buy EC Coins and SCP Coins in exchange for FIAT currency.

For the company the investor is not anonymous, since it has been verified previously that the investor meets the conditions to be able to invest in the project. However, for all the users of the platform, each investor is a wallet address, and there is no way to link those addresses to particular entities, so for all of them, the rest of investors are anonymous. The diagram of this first step is shown in Figure 20.

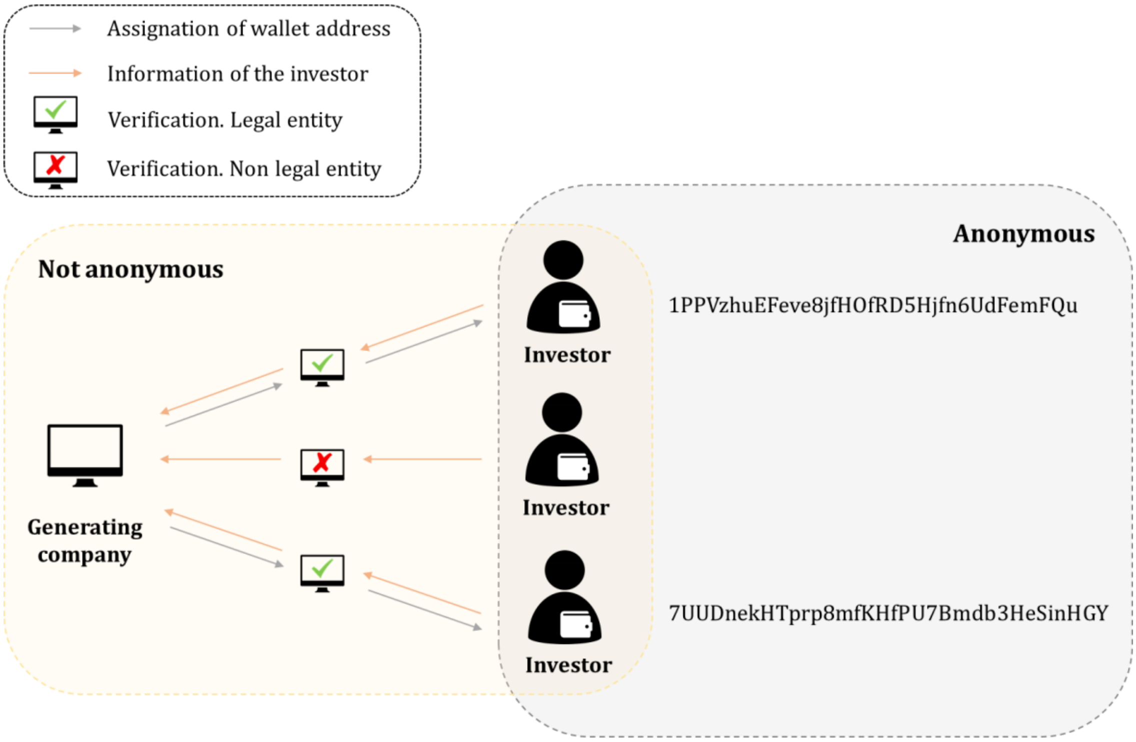


***Figure 20**: First step of the automatic process*

Source: own elaboration

<u>Second Step</u>

The second step is done for those retail companies that want to build a renewable installation to become a generator, or to increase the generation power they already have. On the contrary, if the generator has nothing to do with a retail company, this second step of the process will be ignored.

If the user is a client of the retail company, then the web page will match the customer's business name with the database of the retailer's customers to identify the property or properties the user has, as it can be seen in Figure 19. Hereunder it is shown the three possible options:

- If the user is a client of the retailer and only has one property, the client will be given the option to receive compensation each month for its participations or to reduce the electricity bill in that property.
- If the user is a client of the retailer and has more than one property, the client will be given the option to receive compensation each month for its participations or to reduce the electricity bill in one of the properties.
- If the user is not a client of the retailer, it will only have the option to receive compensation for its participations.

In case of being a client of the retailer and to want a reduction in the electricity bill, the retailer will send the user the electricity bill with its value in euros, so that if this user prefers to pay in EC Coins, it will be able to do so through the web page or application, at the exchange of that moment. Immediately after the transaction in EC Coins, the retailer will make the change to euros if it wishes, to be able to receive the entire amount without worrying about the fluctuations of the currency.

Thus, when a user wants to send money to another user, whether they are investors or not, they simply have to enter the destination wallet's address and the number of coins.

In addition, in case of making a payment to pay the electricity bill, the only way for the retail company to know that a specific user is the one paying a specific invoice, is entering, in addition to the address of the retail company and the amount of EC Coins, the invoice number.

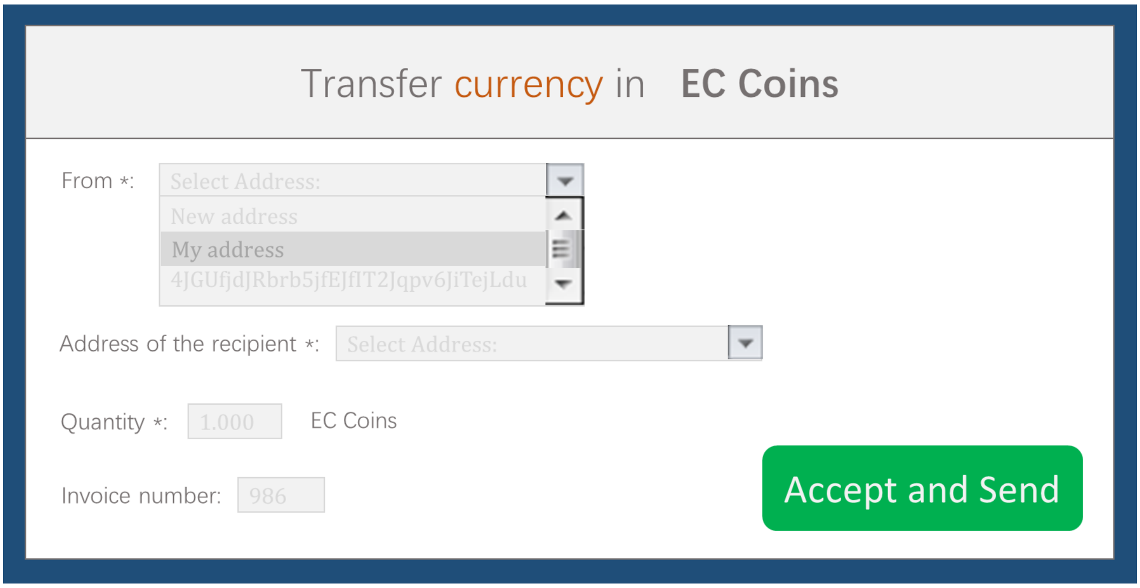


Figure 21: Example of the transfer interface in the second step

Source: own elaboration

At this time, if the retail company tracks the transactions of the user's address on the public account book of the blockchain, it will be able to see all the movements that have been made, and the details of the user will no longer be anonymous to it. This public account book can be seen by anyone inside the platform, so that everyone can see the movements made by each address, but no one knows who corresponds each address. Therefore, from the moment a user knows this information, all the transactions made in the past and the ones that will be made in the future by an entity, will no longer be anonymous to this user. If the entity prefers to remain anonymous in order to maintain its privacy, that is a right everyone has, or to maintain its competitive advantage for the rest of the users of the platform, because that way no one else will know its trading strategy, for example, it can make a second address only to pay the bills, so even if the retail company has the address with which the user has paid the invoice, and even if the retail company tracks the transactions made by that address, it will not find any movement different from the payment of the bills [53].

In this particular investment process, implemented with project finance, there are two options for financing the debt. The first one is to finance it through a bank, with green credits, which have low interest rates, and the second one is to offer this debt to investors with the same interest rate as the green credit, so that they will have to face lower risk because their debt will be the first that would be satisfied; after this debt is returned each year, the investors that play the role of social capital, could have their compensation too. Since these investors will have to face a higher risk, they will have a higher rate of return. For this project, it is going to be assumed that the project has a part of debt of 70%, financed with money of investors with the same interest rate as green credits, and a 30% of social capital.

5.1 Legislation of cryptocurrencies

The operations of cryptocurrency trading can result in a capital gain or loss, to the extent that when they are carried out, an alteration in the composition of the patrimony is generated. These changes occur in three cases [54]:

- The exchange of cryptocurrency for legal currency, because currencies are goods of different nature and there is a variation between the book value of the cryptocurrency and the value of the money.
- The exchange of cryptocurrency for goods or services. They are goods of different nature and there is also a variation between the book value of the cryptocurrency and the fair value of the cryptocurrency that is equivalent to the acquired good.
- The exchange of cryptocurrency for another cryptocurrency. There is a variation between the book value of the cryptocurrency at the delivered price, and the fair value of the cryptocurrency at the acquisition price.

If the operation is made by a company, the profits obtained with cryptocurrencies are declared in the Corporation Tax.

Moreover, VAT does not apply in the transmission of virtual currencies, only in the purchase of goods or services. No VAT is applied to the income obtained when exchanging cryptocurrencies into FIAT currency [55].

When it comes to paying services in virtual currency, it is not illegal as long as the process is completely transparent. Currently it can be found businesses in Spain that accept payments in Bitcoin [56].

Likewise, in some countries in South America there are systems such as enBlockchain that allows users to pay bills with Bitcoin [57].

In Japan this system also exists, and it is called Coincheck [58].

6. MARKET OPERATION

In this section it will be explained the market operation taking into account the different elements analyzed so far: the global operation, the operation of the primary and secondary market, and the remuneration of investors. This process is presented in Figure 22.

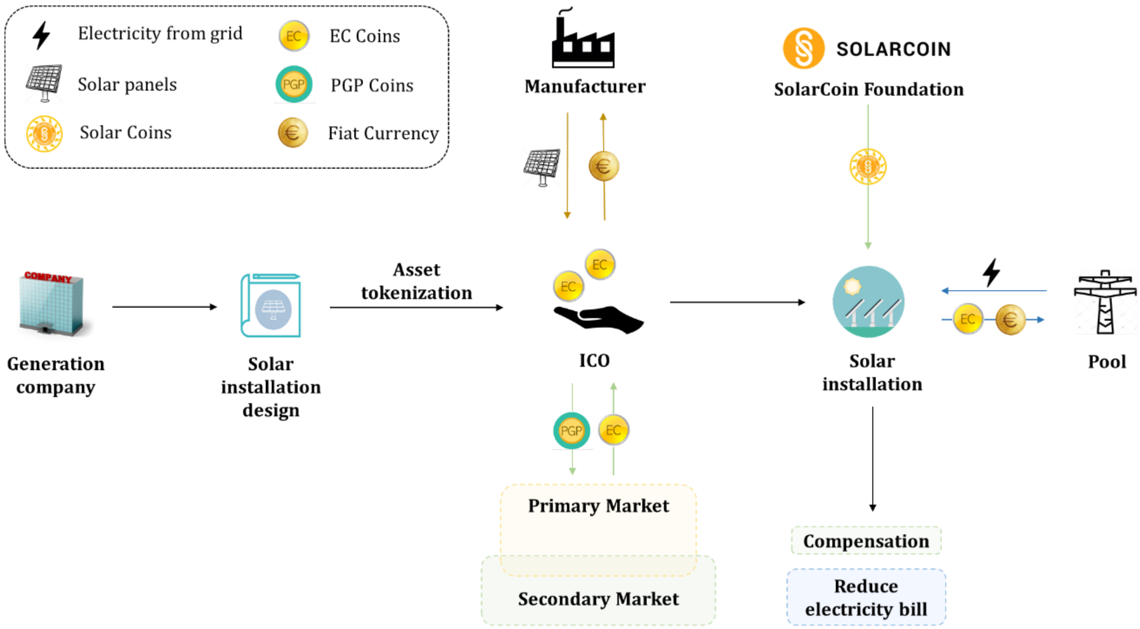


***Figure 22**: Market Operation*

Source: own elaboration

The process begins with the design of a photovoltaic installation by a generating company, which will include all the construction costs of the plant. This generating company can be a business or corporation, or an association of consumers. In order to collect all the money needed for its construction, the generating company will digitalize the plant and will convert it into an asset through the asset tokenization, so that the installation costs will be covered by the investors that invest in the plant, buying EC coins, currency of the blockchain platform, to then buy PGP, participations in which the asset is divided.

In order to implement this, and as explained in previous sections, the generating company will perform an ICO, a pre-mining under closed doors with the investment value, that is, the cost of the installation, the CAPEX. In this pre-mining both utility token, which is the currency of the platform that allows operating in it and buying participations, and security token, which is the participation itself, and which is purchased with EC coins, will be offered. All the EC coins and the PGP will have a fix price, so at this first point in the primary market, there will not be any problem regarding the fluctuation of the virtual currency.

Thus, the investors can enter the platform through a web page where they can register and buy PGP by exchanging fiat currency into EC coins.

Once the investment has been satisfied, that is, when the investors have purchased all the PGP directly from the generating company in the primary market, the generating company will dispose of the necessary money in fiat currency to pay all the materials and labor force needed to build the installation.

As of this moment, the primary market closes, because the generating company no longer sells PGP, and the secondary market begins to operate. In this secondary market, investors can buy and sell their PGP whenever they want, so that they provide liquidity to the system. The more demand, the higher the price of the participations, and the less demand, the more its price will fall. Its operation is very similar to the trading of a stock in the stock market. Until the actual entry of the installation into the energy market, these prices will be purely speculative.

Once the installation is built and in operation, this energy will be injected into the network and sold in the pool market, so that it is this pool market the one that decides the price of the energy at all times.

When the marginal price is above zero, the installation will have a positive income. This income will be distributed among all the investors, so that each one will receive the quantity proportional to the number of participations they have. Additionally, maintenance will be a fix expense, and until that expense is covered every month, investors will not be able to receive their benefits. That is to say, benefits will be distributed with the percentages mentioned above after covering previously all the costs.

Besides, it is also important to remark that the installation will only receive compensation when it is in operation, in the hours when there is no sun, investors will not receive anything.

The remuneration will be distributed at the end of the month, that is, the value corresponding to each one will be stored in their wallets and they will be able to cash out their EC coins at the end of the month. This way, in case the investor does not want to receive compensation and prefers a reduction in the electricity bill, both methods are compatible.

Moreover, there is the value of the PGP. The better the installation works, that is, the more energy sold to the pool, the more remuneration will be received from both the wholesale market and the SolarCoin Foundation. This means that investors will receive higher compensations, and the more money investors receive, the more investors will be interested in buying participations. As there are no shares in the primary market, investors will have to buy them in the secondary market, and the more demand of participations, the higher its price, so that initial investors could earn money in case they sell the PGP.

In the financial analysis, different hypotheses will be made depending on whether the plant goes bad, regular, good or very good.

In Figure 22, it is shown an explanatory diagram with the process of the market operation.

This project also contemplates the situation in which many renewable facilities will be built in the long-term, so that the price would collapse, and it would be needed a different system that provides a remuneration so that the electricity system could continue having the same percentage of renewables. It is assumed that SolarCoins will also be received because of the fact of being a generator of solar energy, but it is also required that the energy is remunerated.

Currently, the Ministry of Ecological Transition has presented a preliminary draft that aims to restore regulatory stability in the remuneration of some renewable facilities. These renewable facilities are the ones affected by the premium cut in 2013, and it is proposed a compensation of 7,09% [59].

In addition, the remuneration for new renewable facilities will be based on two terms. On the one hand, a term per unit of installed power, which will have to cover the investment costs for each installation, and on the other hand, a term of the operation, that covers the difference between the operating costs and the operating income of the installation.

Currently, the new installations built, will not have any remuneration regarding the term per unit of installed power [60]. Regarding the term of the operation of the plant, as this project is not entering the system through an auction, there will not be any remuneration from the government to cover these costs, but the project will be the one taking the risk of covering its costs.

Therefore, in the financing model it will be assumed that no remuneration is received by the generator, but afterwards it will be calculated the minimum compensation that the government should pay it in order the project to be profitable.

With all this information, it is deducted that this system will be more profitable in the short-term, when there are still technologies in operation with a considerable marginal cost, that in the long-term, when the marginal price is not the one that gives price to the consumed energy, but the floor price established by the state in each case, which will be lower than the marginal prices of traditional technologies. This gives this project an advantage to start and an incentive for the initial investors.

7. COST OF THE PHOTOVOLTAIC INSTALLATION

In order to conduct a financial model to analyze the behavior of the investments made by the users, it is necessary to estimate previously the overall cost of the installation.

For this purpose, in this section it will be analyzed on the one hand, the elements that constitute the photovoltaic installation, and on the other hand, the labor force and additional elements that will be needed for its construction.

This way, it will be obtained the approximate cost which the investors of this project will have to face.

At the end of the section a comparative of prices is shown between those calculated manually based on figures of individual elements, and the reference prices of the National Renewable Energy Laboratory (NREL).

7.1 Elements of the photovoltaic installation

In this section it will be estimated the cost of the solar installation. For this aim, it will not be executed an exhaustive study of all its elements, but the purpose is to obtain an approximate cost of each of them.

The elements that compose the photovoltaic installation are the following:

- **Photovoltaic modules**. They are a set of photovoltaic cells that produce electricity from the light that falls on them through the photoelectric effect.
- **Structure** on which the modules are placed.
- **Inverters**. Converter that transforms Direct Current (DC) power into Alternating Current (AC) power for its subsequent transportation and consumption.
- **Transformers**. Electric machine that allows to increase the low voltage in AC, coming from the inverter, into higher voltage for its later injection in the distribution network.
- **Connection and Balance of System (BoS)**. Cost of the evacuation infrastructure needed to connect the installation with the general grid, and the cost of the rest of the components and infrastructure needed, such as electrical cabling.

In Figure 23 an outline of the plant is shown, as well as all the elements that compose it, that will be explained and chosen throughout this section. In addition, at the end of the section, a summary of the costs associated with all these elements will be shown

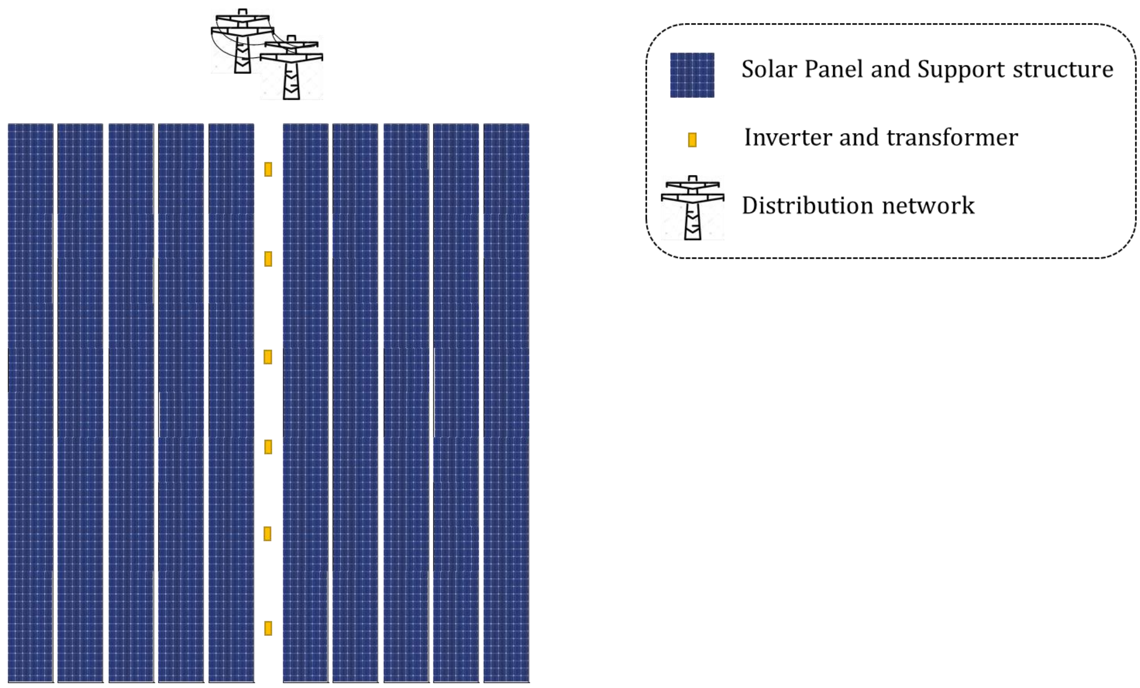


Figure 23: Photovoltaic Installation outline

Source: own elaboration

7.1.1 Types of solar panels

In this section it will be explained the types of solar panels that exist in the market [61], [62]:

1º generation panels

This type of panels are formed by silicon or polysilicon and are the most commonly used. Two different types of panels can be distinguished:

- **Monocrystalline** (Mono-Si): these are the purest panels and their efficiency ratio is greater than 20,1%, which makes them one of the most efficient panels in the market. However, they are also among the most expensive. They offer great power output; they take up little space and have a long lifespan.
- **Polycrystalline** (Poly-Si): they have a cheaper final price than monocrystalline ones because the manufacturing process is simpler, however, they also have a lower efficiency ratio, from 13% to 16%, approximately. Its lifespan is also shorter than the monocrystalline ones, since they are more affected by high temperatures.

2º generation panels

They are more used for installations in buildings or small installations. There exist different types:

- **Thin-Film Solar Cells** (TFSC): they are cheap and the easiest to produce, their large-scale production greatly decreases their price. They have efficiencies of 7% to 13%, they are flexible, and they are little affected by high temperatures. The problem is that their guarantees are the lowest since their lifespan is shorter than the 1º generation panels.
- **Amorphous Silicon Solar Cell** (A-Si): this is commonly used in solar calculators. They have efficiency ratios of 7% and if several layers of amorphous silicon solar cells are combined, its efficiency can increase up to 8%. It is a relatively cheap module in cost.

<u>3º generation panels</u>

Many of these panels are still under development, and they generate energy from organic materials and inorganic substances. The different models that exist are the following:

- **Biohybrid Solar Cell**: this module is still being developed. The concept behind this technology is to simulate the process of photosynthesis with the solar panel, which would have an efficiency ratio of 100%.
- **Cadmium Telluride Solar Cell** (CdTe): these materials allow the manufacture of solar panels with efficiency ratios from 9% to 11% at a very low cost. The problem with this material is that its inhalation or intake is toxic.
- **Copper Indium Gallium Selenide** (CIS/CIGS): this type of panels contains less toxic material than the previous ones and it is still under development. It has efficiency ratios from 10% to 12%, approximately.
- **Concentrated PV Cells** (CVP and HCVP): this type of solar panels reaches an efficiency up to 41%, the highest in the market, however, its price is also the highest in the market. Their shape is cylindric-parabolic and they produce maximum power only if they have a certain angle with respect to the sun, a position that they achieve thanks to a solar tracker they have integrated, which is responsible for following the path of the sun to continuously maximize their output.

Below, in Table 1 it is shown a summary of the analyzed modules and a diagram that compares their price versus their efficiency.

***Table 1**. Characteristics of Solar Panels*

Generation	Solar Panel	Maximum Efficiency rate	Cost
1ª	Monocrystalline Solar Panel	20,1%	High
	Polycrystalline Solar Panel	16%	Medium – Low (large – scale)
2ª	Thin Film Solar Cells	13%	Medium
	Amorphous Silicon Solar Cell	7%	Low
3ª	Bio-Hybrid Solar Cell	100%	Developing
	Cadmium Telluride Solar Cell	11%	Very Low
	Copper indium Gallium Selenide Solar Cell	12%	Developing
	Concentrated PV Cell	41%	Very High

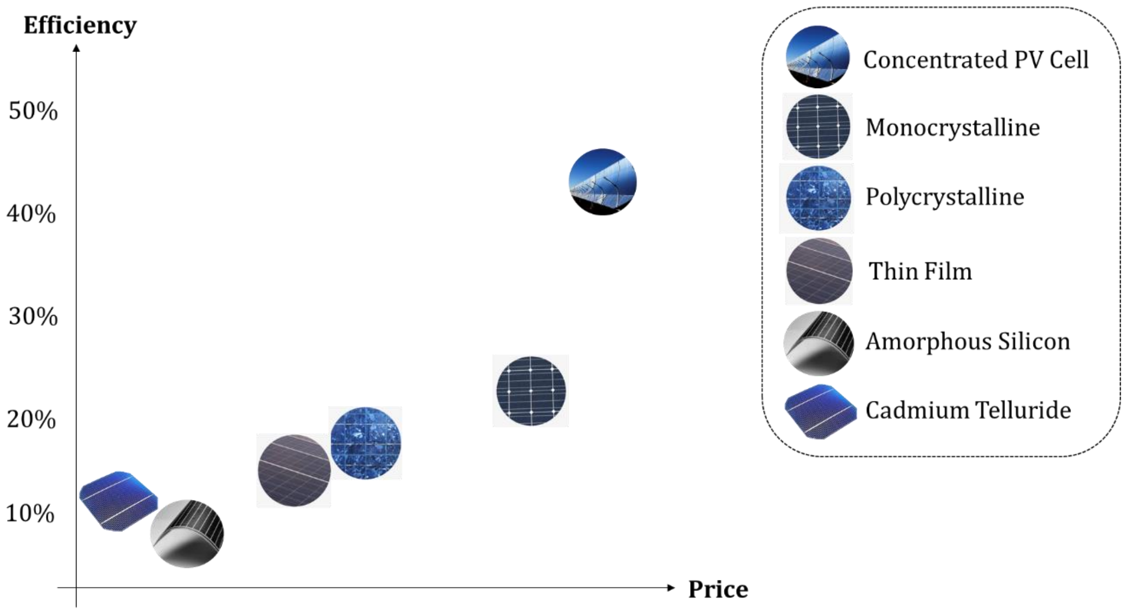


***Figure 24**: Solar Panels. Efficiency Vs. Price*

Source: own elaboration

In view of Figure 24, for this project it is desired a solar panel with medium-high efficiency, a price not too high and a relatively long lifespan. The most efficient modules are the Concentrated PV, however, its price is very high too, so it will be considered the next panel in efficiency, that is the monocrystalline, which have a relatively high efficiency and a more affordable price.

Below is a list of the most reliable solar panel manufacturers on the market, based on their manufacturing history, quality and actual results [63]:

- LG Energy
- SunPower
- Winaico
- REC
- Hanwha Q cells
- Canadian Solar
- JinkoSolar
- Trina Solar

In Figure 25 it can be seen the range of efficiencies of the panels manufactures by each company.

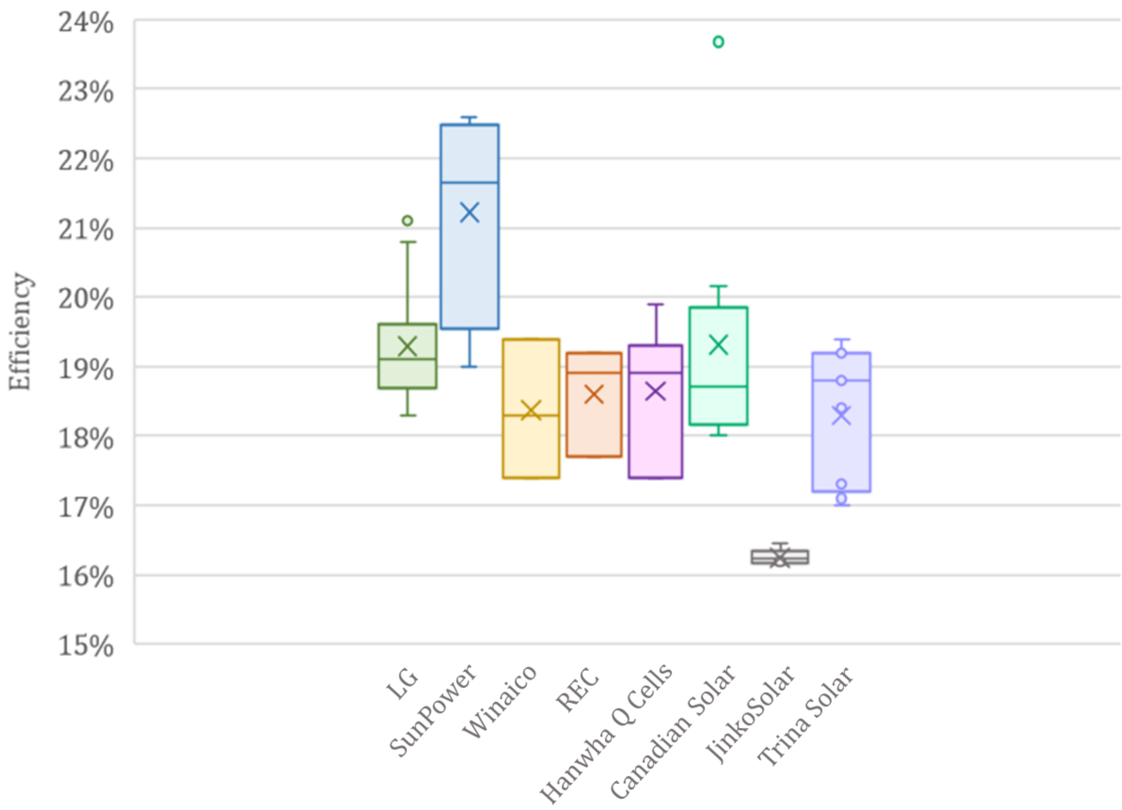


***Figure 25**: Efficiency of Solar Panels of the different companies*

Source: own elaboration

In Figure 26, the production volume of the best panel manufacturers is shown [64].

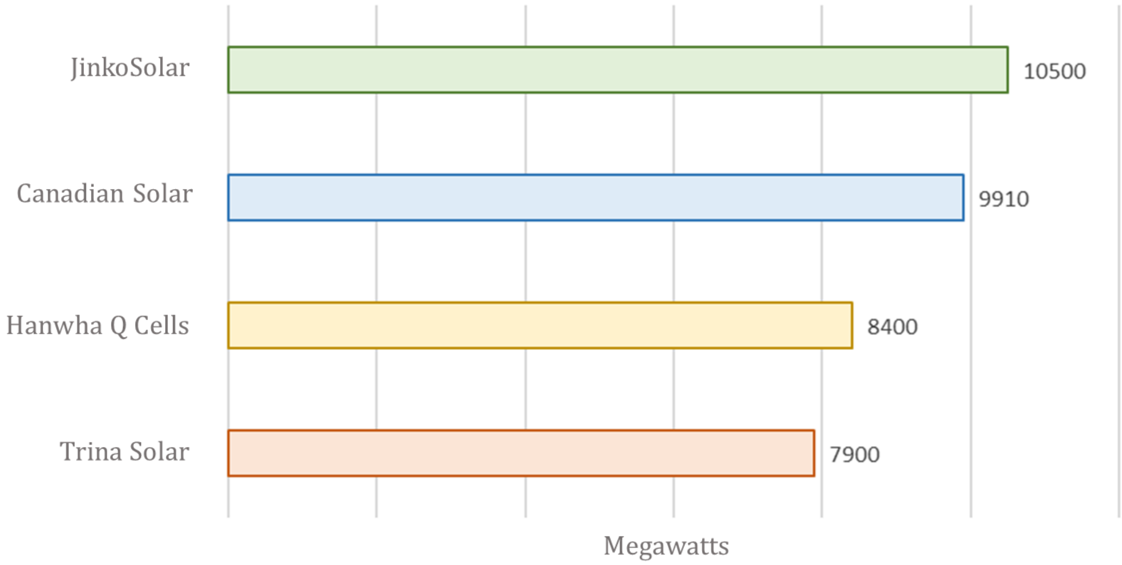


***Figure 26**: Top solar module manufacturers in 2018*

Source: own elaboration

In view of the data presented above, a monocrystalline panel of the company Canadian Solar is chosen, since its panels have high efficiencies and are among the most reliable and of good quality of the market.

The specific model that has been chosen to calculate an approximate cost for this project is the HiDm, High Density Mono perc module, CS1U 420MS, of 420MW and an efficiency ratio of 20,27 % [65].

***Figure 27**: HiDm, Cs1U 420MS. Canadian Solar*

As the plant of the project has 42MW of capacity, 100.000 photovoltaic modules will be needed. Each solar panel costs 230€ [66], however, in this project the modules will be bought directly to the supplier, which makes them cheaper. In addition, as this project needs 100.000, it is assumed that the supplier will include a discount in the purchase order. With these facts, the discount assumed is of 30%, so the total cost results on **16.100.000€**.

7.1.2 Structure supports

For this project, a tracker support has been chosen to follow the path of the sun, so as to maximize the energy generated during the entire solar period, that is, to maximize the area under the orange line shown in Figure 28:

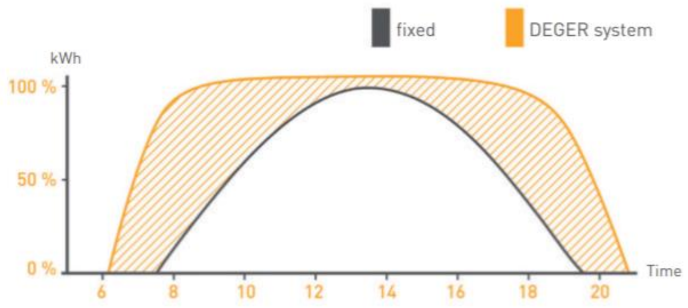


***Figure 28**: Performance advantage of the DEGERtracker*

A specific support has been chosen in order to obtain an approximate cost for this element. This support is from the company DEGER Iberica, called DEGERtracker S100-PF-SR [67]. Its dimensions are 63,2m x 2m, so there will only be one row of solar panels in each support, since each solar panel has a height of 2,078m and a width of 0,992m. This way, 63 panels can be placed along the entire support.

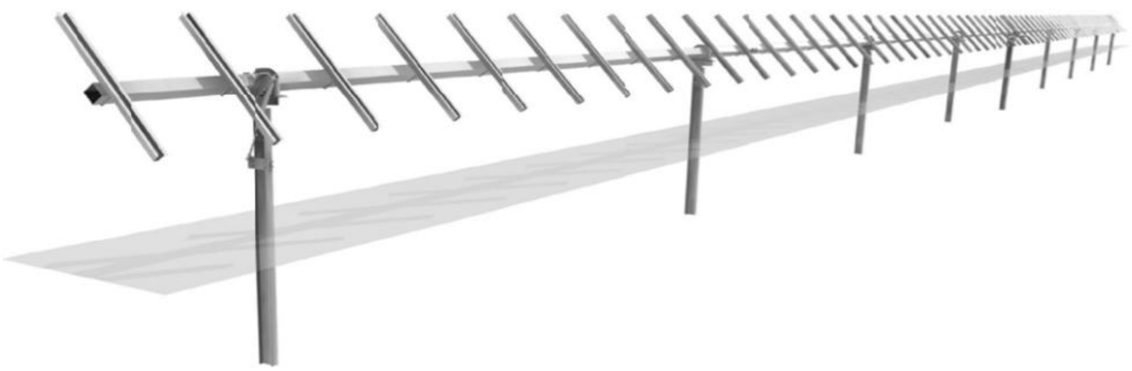


***Figure 29**: DEGERtracker S100-PF-SR*

Since 100.000 solar panels are needed, and each structure supports 63 panels, 1.588 structures are needed.

The price is 3.300€ per unit, information provided by direct contact with the company Deger Iberica. However, it is assumed that the supplier will offer a discount in the purchase order of 20%. Therefore, the final cost of the structures is **4.192.160€**.

7.1.3 Inverter and transformer

For this project it is assumed that the inverter installed is an inverter connected to the network, that is, that the inverter station will come fully equipped with all the elements already integrated: the photovoltaic inverters, the MV cubicles, the LV/MV transformer and the switchboard low voltage. This inverter station will have a capacity of 7,2MW, therefore, as the capacity of this installation is 42MW, 6 inverters will be necessary.

The approximate price of an investor station of these characteristics has been obtained by direct contact with the company Ingeteam, and is 355.000€ per unit. As 6 inverter stations will be needed, the total price results **2.130.000€**.

7.1.4 Connection and Balance of System

The cost values shown below respond to real offers from different manufacturers and EPC companies and they have been based on a Project of the Polytechnic University of Madrid (Universidad Politécnica de Madrid) [68].

- Connection costs: 0,13 €/Wn. The nominal power in this case is 42MW, so the total cost of the connection results **5.460.000€**.
- BoS costs: 0,20 €/Wp. An overload of 10% is assumed for the calculations, that is, an overload up to 46,2MW, resulting in a total cost of **9.240.000€**.

7.1.5 Cost summary

A summary of the costs of all the elements necessary for the construction of the installation is shown in Table 2:

***Table 2**. Costs of all elements of the photovoltaic installation*

Element	Quantity	Unit Price	Discount	Final Cost (€)
Solar Modules	100.000	230 €	30%	16.100.000
Structure Supports	1.588	3.300 €	20%	4.192.160
Inverter and transformer	5	355.000 €	-	2.130.000
Connection	-	0,13 €/Wn	-	5.460.000
BoS	-	0,20 €/Wp	-	9.240.000
TOTAL	-	-	-	**37.122.160**

7.2 Costs associated to the construction of the installation

In this section it will be simulated a real project in Microsoft Project in order to obtain the approximate costs associated with the needed workforce and activities related to the project. This will reflect an approximate CAPEX (Capital Expenditure) of the project, that is the amount of money that the investors will have to cover.

In the software with which the estimation of the CAPEX has been calculated, the costs of the components calculated in the previous section have also been included.

The list of activities that have been used in Microsoft Project, as well as the time it takes to perform each one reflected in a Gantt chart, is shown in Annex I.

In Annex II, the resources used in each activity are specified.

In order to set the cost of certain activities, it has been taken into account the following assumptions [69]:

- As for the activity of Land Expropriation, it has been assumed that the m^2 of rustic land has a value of 3,5€. Taking into account, according to the scheme of Figure 23, that the surface of the plant is approximately 571.605 m^2, the total cost of the expropriation of the land would be 2.006.217,5€.
- Regarding the Geotechnical survey, an average cost of 2.500€ has been assumed.
- The cost of the permits needed, such as the transport permit, has been set at 3.000€.

In terms of the resources needed to build the installation, the workers listed in Table 3 is proposed, with their respective standard rate:

***Table 3**. Resources used in the simulation*

Resource	Quantity	Standard rate (€/h)
General Project Manager	1	150
Mechanical Project Manager	1	130
Mechanical Engineer	2	90
Civil Project Manager	1	130
Civil Engineer	4	90
Electrical Project Manager	1	130
Electrical Engineer	2	90
Site Manager	1	80
Workforce	1	630

For the construction of the plant, the machines listed in Table 4 have been used in the simulation, also considered as resources:

***Table 4**. Machines used in the simulation*

Resource	Quantity	Standard rate (€/h)
Feather crane	1	60
Excavator	1	52
Transport machine	1	45

In order for resources not to overlap in the execution of the activities, it has been necessary to make some changes in the allocation of resources and in the sequence of the tasks.

Finally, with all this information, the total cost of the project is 40.529.405€.

Here below it is shown how the cost is divided among the different resources named above:

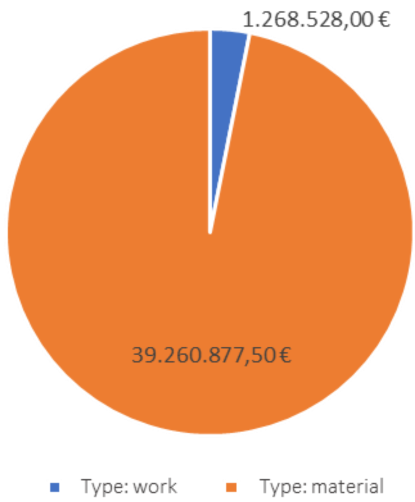


***Figure 30**: Resources. Cost distribution*

Source: own elaboration

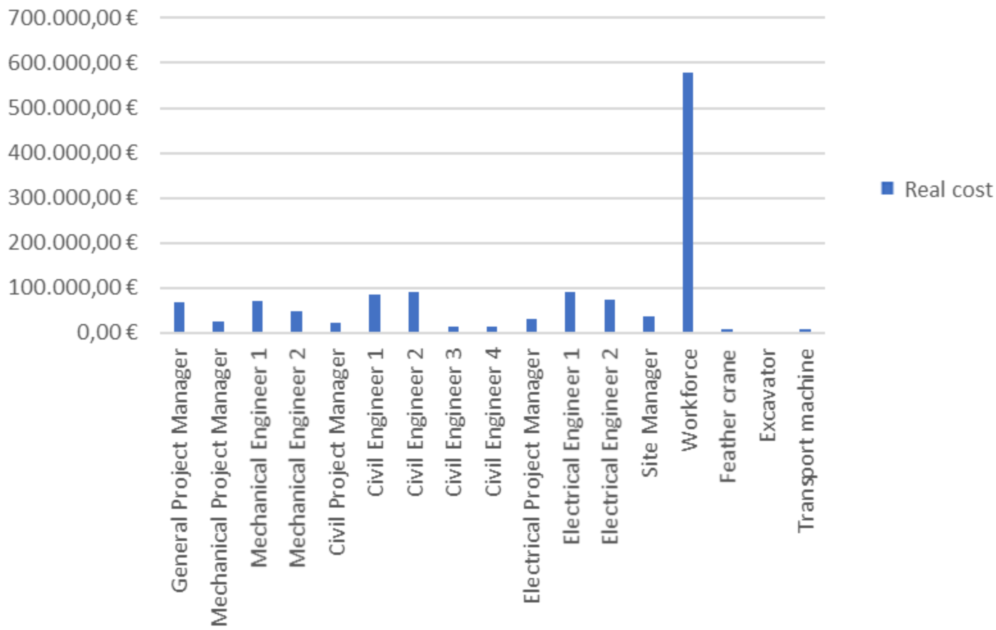


***Figure 31**: Resources. Cost status*

Source: own elaboration

***Table 5**. Resources. Details of costs*

Name	Real work	Real cost	Standard rate
General Project Manager	456 hours	68.400,00 €	150,00 €/hour
Mechanical Project Manager	200 hours	26.000,00 €	130,00 €/hour
Mechanical Engineer 1	776 hours	69.840,00 €	90,00 €/hour
Mechanical Engineer 2	520 hours	46.800,00 €	90,00 €/hour
Civil Project Manager	168 hours	21.840,00 €	130,00 €/hour
Civil Engineer 1	936 hours	84.240,00 €	90,00 €/hour
Civil Engineer 2	1.000 hours	90.000,00 €	90,00 €/hour
Civil Engineer 3	160 hours	14.400,00 €	90,00 €/hour
Civil Engineer 4	160 hours	14.400,00 €	90,00 €/hour
Electrical Project Manager	232 hours	30.160,00 €	130,00 €/hour
Electrical Engineer 1	1.008 hours	90.720,00 €	90,00 €/hour
Electrical Engineer 2	832 hours	74.880,00 €	90,00 €/hour
Site Manager	464 hours	37.120,00 €	80,00 €/hour
Workforce	920 hours	579.600,00 €	630,00 €/hour
Feather crane	160 hours	9.600,00 €	60,00 €/hour
Excavator	64 hours	3.328,00 €	52,00 €/hour
Transport machine	160 hours	7.200,00 €	45,00 €/hour

In Figure 32, it is shown the division of the costs among the quarters:

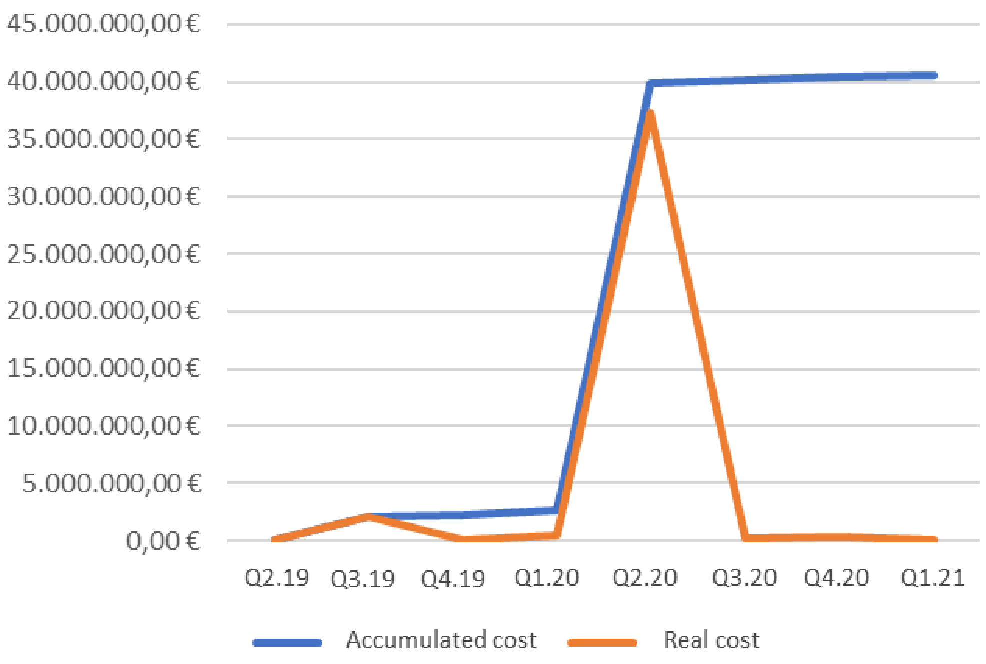


***Figure 32**: Cost per term*

Source: own elaboration

The division of the cost among the different phases is shown in Table 6 and Figure 33:

***Table 6**. Cost distribution in the phases*

Name	Real cost
Initiation Phase	41.760,00 €
Planning Phase	2.540.205,50 €
Execution Phase	37.726.320,00 €
Connection and Testing Phase	175.840,00 €
Closure Phase	45.280,00 €

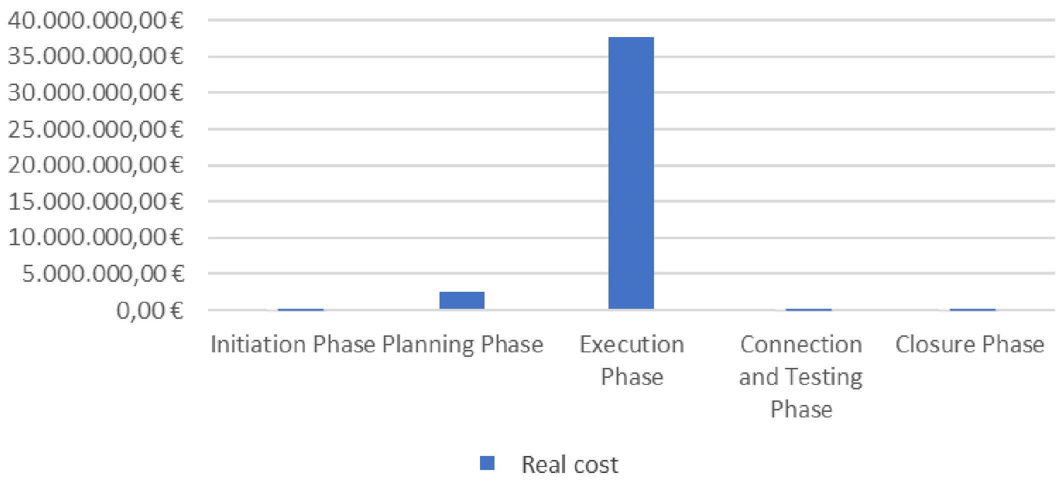


***Figure 33**: Cost distribution in the phases*

Source: own elaboration

7.3 Costs comparison

This section shows the value of the investment of this project in comparison with real projects that are currently being implemented in Spain and refer to reference values of the National Energy Renewable Laboratory (NREL).

Table 7 shows the investment of three photovoltaic installations of two different companies:

***Table 7.** Cost of real projects*

Project	Capacity (MW)	Cost (€)	€/MW
This project	42	40.529.405,5	**964.985,85**
Francisco Pizarro – Iberdrola [70]	500	300.000.000	**600.000**
Augusto – Enel [71]	49,86	40.000.000	**802.246,29**
Baylio – Enel [72]	42	33.333.333	**793.650,79**

As it can be seen, the estimated costs for this plant, although they are a little higher, they are reasonable.

The cost of certain elements of the installation have also been compared with the reference values of the NREL. In Table 8 it is shown the disaggregated costs for these elements according to the NREL on the left [73], and according to this project on the right.

Table 8. Cost in Spain

<table>
<tr><th></th><th>$/W</th><th>€/W</th><th>Power (W)</th><th>Cost NREL (€)</th><th>Quantity</th><th>Cost in the project(€)</th></tr>
<tr><td>Modules</td><td>0,29</td><td>0,26</td><td>42.000.000,00</td><td>10.875.000,00</td><td>100.000,00</td><td>16.100.000,00</td></tr>
<tr><td>Inverter</td><td>0,08</td><td>0,07</td><td>611.100,00</td><td>43.650,00</td><td rowspan="2">6,00</td><td rowspan="2">2.130.000,00</td></tr>
<tr><td>Transformer</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Optimize inverter</td><td>0,25</td><td>0,22</td><td>1.909.687,50</td><td>1.909.687,50</td><td>-</td><td>-</td></tr>
<tr><td>TOTAL</td><td></td><td></td><td></td><td>12.828.337,50</td><td></td><td>18.230.000,00</td></tr>
</table>

It can be seen that the cost of the elements of this project is almost double than the one offered by NREL. This difference in cost is explained because in this project, it has been considered that the inverter and the transformer are combined, and NREL takes into account only the cost of the inverter.

8. FINANCIAL MODEL

In this section, the financial model is implemented, all the inputs are explained, and the results obtained in the reference case are analyzed. Afterwards, the different risks of the project are explained, and the different scenarios are implemented, starting from the reference case and changing a single parameter each time.

8.1 Project Finance

This project will be developed with Project Finance (PF), that consists in financing an asset through the creation of an independent legal company, called Special Purpose Vehicle (SPV).

Financing a project through PF offers it stability and safe cash flows. Unlike Corporate Finance (CF), where the project is financed by a enterprise and not by an independent company, in PF, if the project goes wrong or fails to recover its costs, the only thing that is lost is the investment, and in case of default to the bank, the bank would go against the independent company and not against the parent company, so that in the worst case, it would be the independent company the one that would bust and not the parent company.

8.2 Reference case

In this reference case, the income statement with the cash flows of all years is implemented to, finally, estimate the Net Present Value (NPV) and the Internal Rate of Return (IRR), in order to know if the project is profitable or not.

For this, the structure shown in Figure 34 will be followed. The origin of all the data is explained throughout the section.

The detail of the financial model obtained, is shown in Annex III.

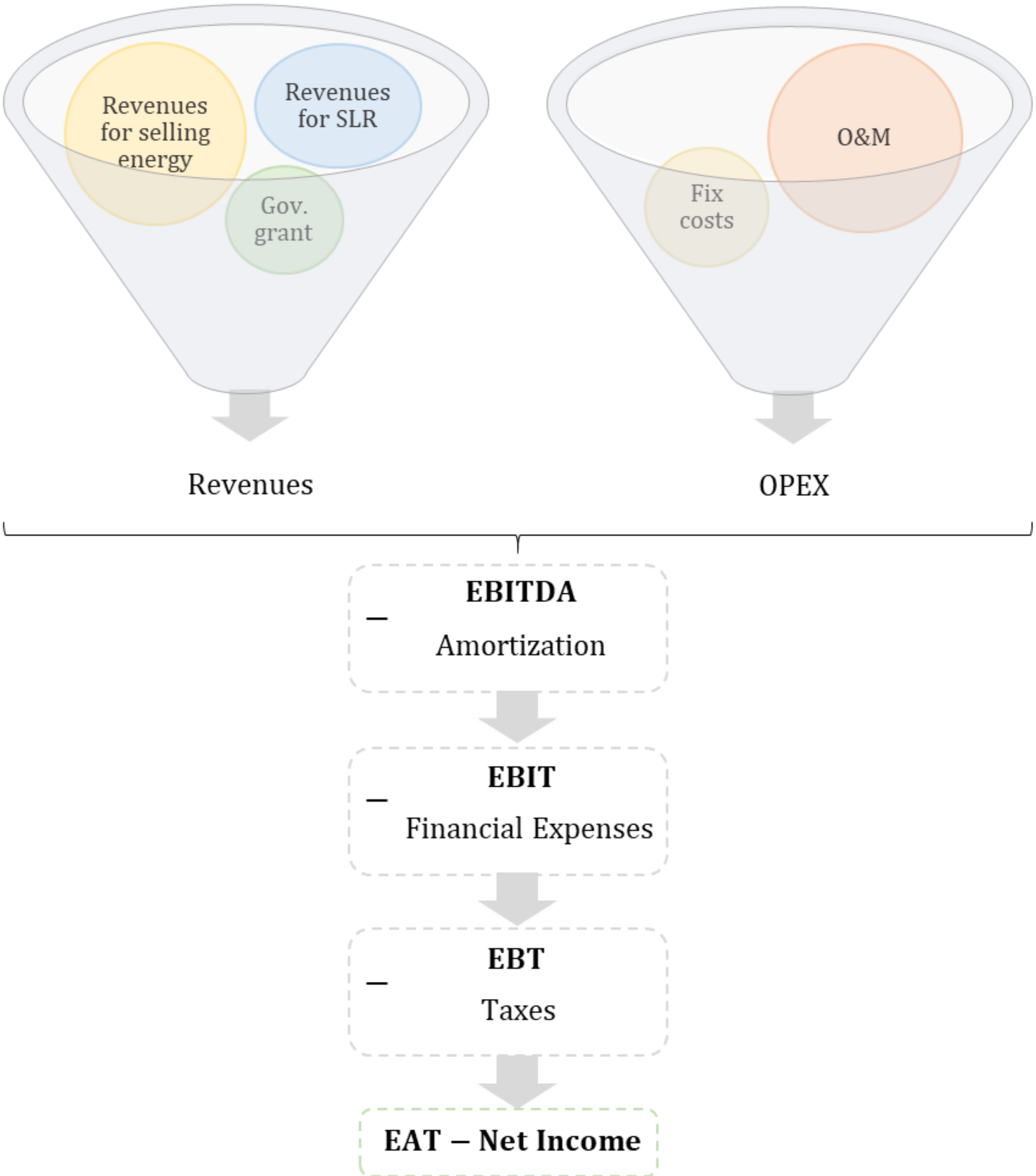


***Figure 34**: Income statement structure*

Source: own elaboration

8.2.1 Revenues

The value of the investment, estimated in the previous section and calculated with Microsoft Project, resulted of 40.529.405 €, and the lifespan of the installation is set at 25 years.

***Table 9**. Investment and time horizon of the project*

Investment	**40.529.405** €
Time horizon	**25** years
Amortization period	**20** years

The project is divided into two phases, the construction phase and the exploitation phase. The period of each phase is shown in Table 10:

***Table 10**. Phases of the project*

Construction phase	Operation phase
2019 – 2020	2021 – 2046

To calculate the energy generated by the installation after the first year, the solar generation data of 2018 published by Red Eléctrica de España (REE) has been used, which shows the amount of energy generated each hour within a year, according to a total installed power of 4.714 MW. With these data, a scaling has been made to estimate how much this 42 MW installation would generate in each hour of the year.

However, in Spain, there are many facilities already installed that are not in operation. In addition, the installation of this project has trackers, that is, since the structure of the modules follows the trajectory of the sun, the module will generate a greater power that a facility with no trackers, and this supposes a 30% more production [74]. Taking these two facts into account, a correction factor of 1,45 has been considered, that is, the generation is considered 45% greater in comparison with the reference profile data of current installations published by REE.

Finally, the energy generated in the first year of operation has resulted in 95,343 MWh.

In order to estimate the energy generated during the rest of the lifespan years, it has been taken into account that each year the energy generated decreases due to the deterioration of the modules. It is assumed that each year production decreases by 0,5% [75], so that at the end of the lifespan of the installation, 88,22% of its initial capacity will be generated. In Figure 35, it can be seen production decreasing over time.

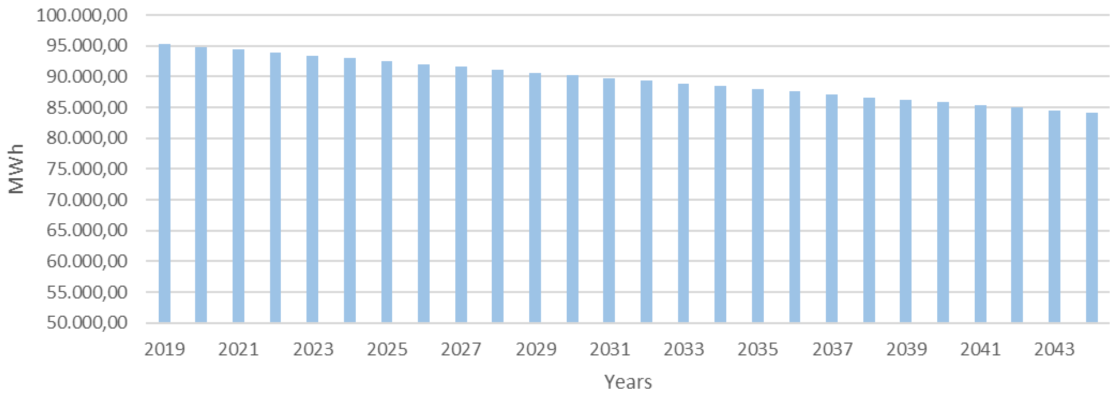


***Figure 35**: Energy generation*

Source: own elaboration

To obtain the benefits that result from selling this generated energy, in this base case it is assumed that the energy will be traded in the pool and sold to the market as the energy of any other generator. The hourly prices of the market from the beginning of the operation of the plant, in 2021, until its closure, in 2045, have been obtained from a technical report developed by the ICAI IIT and Iberdrola [37], where the prices of the years 2025, 2030, 2040 and 2050 are specified, according to the hypothesis explained in section 3.2.1.

With these prices and the hourly generation, hourly and later annual revenues are calculated. These revenues imply the sale of the energy previously calculated for these four years. To obtain the income of all the intermediate years, from 2021 to 2046, the trend line of these four annual revenues has been obtained. The curve obtained is shown in Figure 36 and, as explained in section 3.2.1, it has a negative trend due to the continuous closure of the oldest non-renewable technologies, which are those that have a higher marginal price and are, therefore, the ones that set the price every day in the pool.

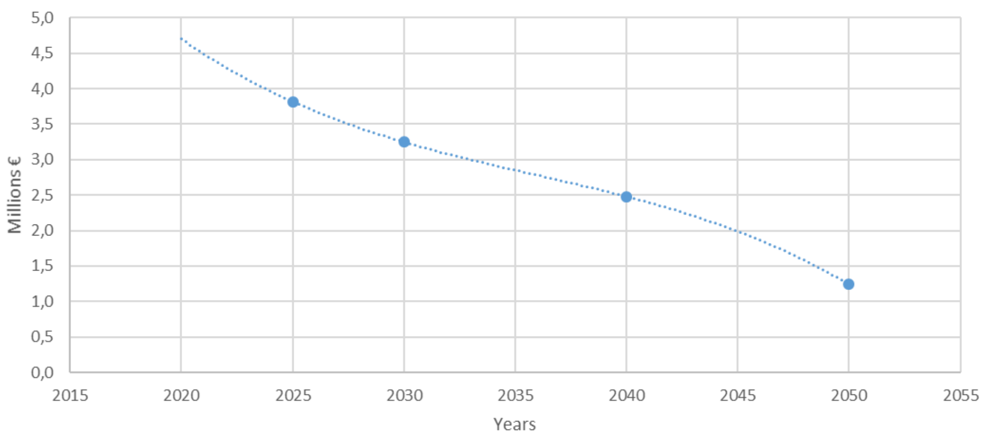


***Figure 36**: Revenues from energy generation tendency line*

Source: own elaboration

Finally, the income obtained from energy generation is shown in Figure 37:

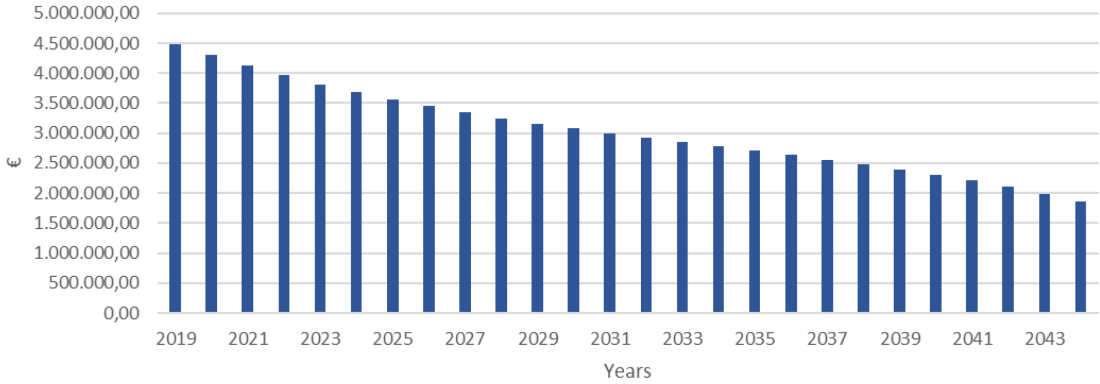


Figure 37*: Revenues for energy generation*

Source: own elaboration

In addition to the benefits obtained from the sale of energy in the market, this installation will also obtain revenues from the SolarCoin Foundation for the generation of solar energy, as already explained in section 3.4. To obtain the value of the SolarCoin each year, it has been assumed that its price in 2021 is equal to the average of the values it had from January to June 2019. This value is 0,03639194 €/SLR [76].

SolaCoin has had large fluctuations until the end of 2018, however, since June 2018, no significant fluctuations of the cryptocurrency have been seen. In the financial model, increasing SLR values have been proposed, since it is said that the SLR will take values between 20€ and 30€ at the end of its life cycle that ends in 2050 [77]. Following this premise, the growth and value proposed of the SLR throughout the lifespan of the solar installation are shown in Figure 38 and Figure 39. Both figures are future predictions based on the previous premises explained.

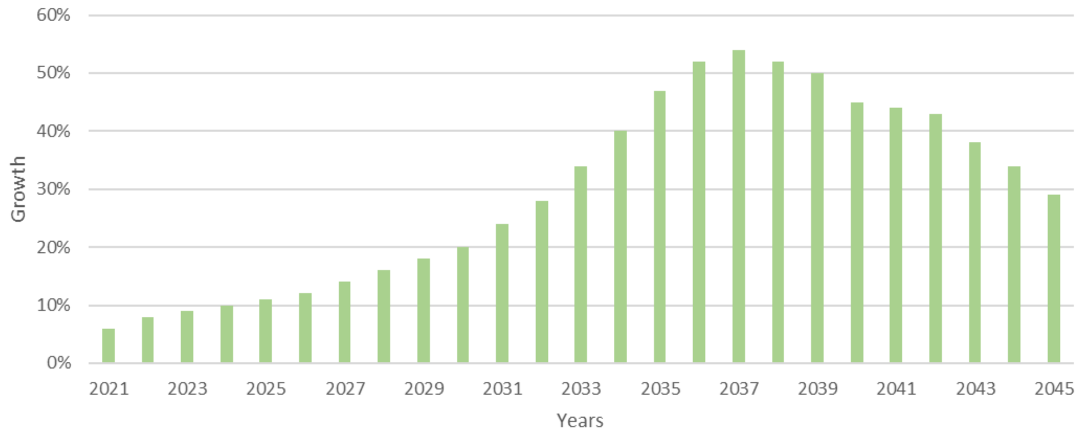


***Figure 38**: Growth of SolarCoin*

Source: own elaboration

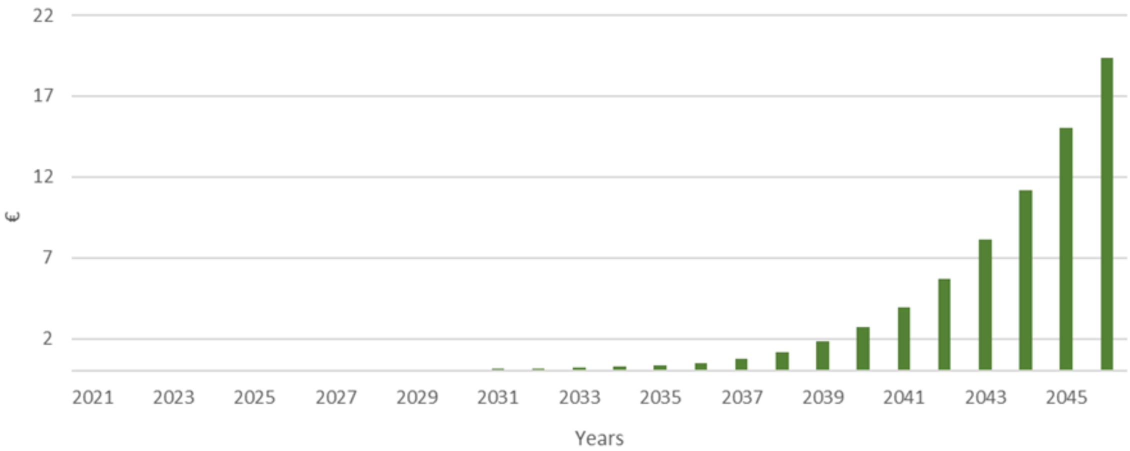


***Figure 39**: Value of SolarCoin*

Source: own elaboration

Finally, the revenues due to these two sources are shown in Figure 40:

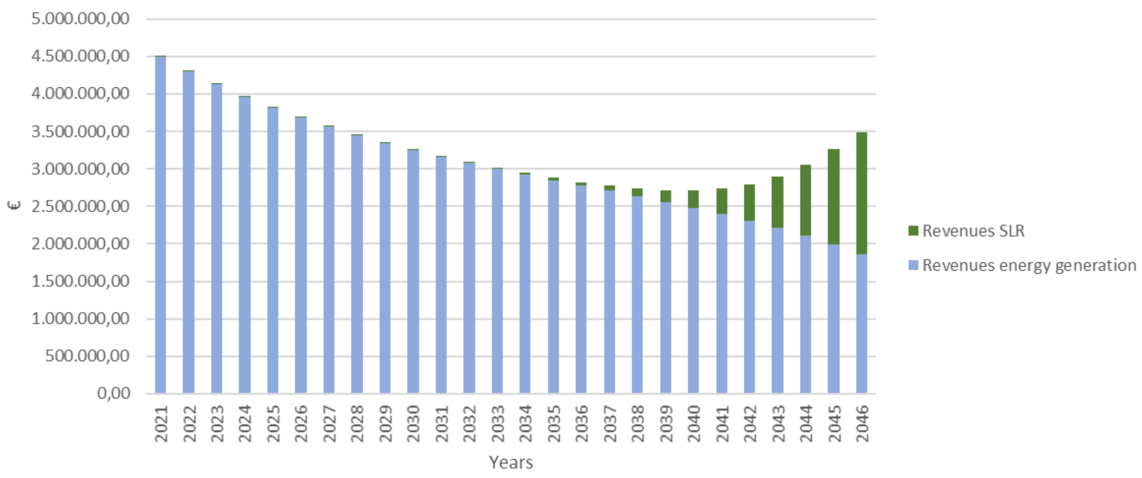


***Figure 40**: Revenues for energy generation and SLR*

Source: own elaboration

The objective of this project is to make a positive NPV and a IRR greater than the WACC, so that, on the one hand, the project has value, and on the other hand, the investors obtain the greater return as possible, and greater than the one they initially expected.

For this, a government grant that the project will receive each year will be added to the revenues. This subsidy will be calculated at the end of the model and its value will depend on the profitability of the project without subsidy.

8.2.2 OPEX

In this section it can be found operating and maintenance costs, (O&M) that reflect the costs of the continuous supervision on the installation and the preventive and corrective maintenance when necessary. The value of operation and maintenance cost is usually between 0,5% and 1,5% of the investment of the installation [78], for this project a value of 3,4 €/MWh is used, which is approximately 0,6% of the value of the investment.

Within the OPEX, it can also be found management costs and an insurance cost in order to cover possible disasters in the installation. In Table 11 it can be seen the value assigned to each cost.

***Table 11**. OPEX*

O&M [79]	**3,4** €/MWh
Management cost	**52.000**€/year
Insurance	**11.000** €/year

8.2.3 Amortization

The amortization period of the installation is considered to be 20 years from the beginning of the operation phase. Therefore, the value of the amortization each years results 2.599.656,53€.

8.2.4 Financial expenses

In order to cover this investment, the following financing structure is proposed, in which equity finance refers to the percentage invested by the users, and debt finance to the debt requested from other investors, with less risk, and financed with a lower interest rate.

***Table 12**. Financing structure*

	% project	Amount (€)	Amount (EC coins)
Equity finance	**30**	**12.158.821,65**	**12.158.821,65**
Debt finance	**70**	**28.370.583,85**	**28.370.583,85**

Since the debt is financed with money of investors that take less interest rate, the interest rate is assumed to be 2%. This debt will be paid in 2030, that is, 10 years after the beginning of the operation phase.

As the loan from the investors who face low risk is received before the operation phase, there is a period of time in which the SPV has no income and, therefore, it is not obliged to pay interest during that period. However, interest accrues, and it increases the financial cost of the project [80].

8.2.5 Taxes

As the project is going to be implemented with PF, as it has been explained previously, it is considered that the tax that must be paid by the SPV is the general corporation tax, valid since 2016, with a value of 25% [81].

8.2.6 Earnings after taxes

Finally, in order to obtain the net income of the project each year, a legal reserve must be taken into account, as set forth in the Spanish Ley de Sociedades de Capital of July 2, 2010, which will allocate 10% of the net income each year to this legal reserve until reaching 20% of the value of the equity capital [80]. However, it does not matter that it never reaches the 20% of the equity capital [82], while that 10% is allocated to the legal reserve, as is the case with this project.

8.2.7 NPV and IRR

Once the income of the project has been obtained, the Net Present Value (NPV) will be calculated by discounting the cash flows with the Weighted Average Cost of Capital (WACC), which represents the minimum return that the investment must provide to be acceptable, that is, to equal or exceed the opportunity cost of the capital invested.

For the calculation of the WACC, the Equation 8 following is used.

$$WACC = K_e \frac{E}{E + D} + K_d\,(1 - t)\frac{D}{E + D}$$

***Equation 8**: WACC*

Where:

K_e: profitability demanded by investors. Cost of equity

K_d: cost of debt

E: part of the capital structure that comes from the investors

D: part of the capital structure that comes from the debt

The profitability rate required by the investors, K_e, is calculated by the Capital Asset Pricing Model (CAPM) method:

$$K_e = R_f + \beta(R_m - R_f)$$

***Equation 9**: Rate of return required by the investors*

Where:

R_f: risk-free rate. Rate of return of the asset without risk of the country in which the project is developed. The 30-year Treasury Bond yield is considered in this project.

$(R_m - R_f)$: market risk premium, that is the difference between the expected return on a market portfolio and the risk-free rate.

β: coefficient that measures the volatility of an asset in relation to the variability of the market in which it is listed.

To obtain the beta, as it is an SPV which is usually not quoted, it cannot be calculated in a traditional way, so an estimation is made taking as reference other betas from companies of the same sector that do quote [80]. In this case, Siemens Gamesa Renewable Energy has been taken as the reference company.

This beta is the beta of the unlevered company, leveraged again with the SPV debt, as Equation 10 shows.

$$\beta_L = \beta_U \cdot \left[1 + (1 - t) \cdot \frac{D}{RP}\right]$$

***Equation 10**: Beta leveraged*

Where:

β_L: beta leveraged

β_U: beta unleveraged

$\frac{D}{RP}$: ratio debt – equity capital of the SPV

In Table 13 it is shown the values of these known data, and in Table 14, the results obtained from these calculations.

***Table 13**. Known data needed for the calculation of WACC*

Cost of debt (K_d)	**2**%
Equity (E)	**12.158.821,65** €
Debt (D)	**28.370.583,85** €
Risk-free rate (R_f)	**0,90**%
Market premium ($R_m - R_f$)	**90** basis points
Beta unleveraged (β_U)	**1,1**

***Table 14**. Results WACC*

Cost of equity (K_e)	**3,62**%
Beta leveraged (β_L)	**3,03**
WACC	**2,14**%

Then, cash flows can be already discounted with the WACC for the calculation of the NPV, which results -24.730.310,68€, and it has been calculated with the Equation 11.

$$NPV = -Investment + \sum_{i=1}^{n} \frac{CF_i}{(1+r)^i}$$

***Equation 11**: Net Present Value*

Where:

n: number of years of the lifespan of the installation

As the NPV is negative, another source of income is necessary for the project to be profitable. As explained at the end of the section 8.2.1, a subsidy will be considered from the government, and in order the project to be profitable, that is to say, in order the NPV to be positive, the amount of this subsidy should be on average, 20,97 €/MWh. With this amount, the revenues profile results as shown in Figure 41.

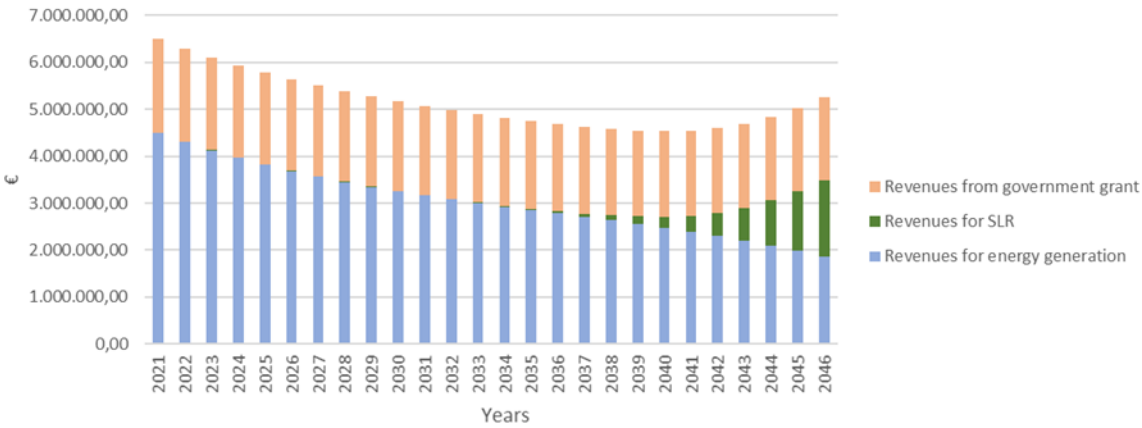


***Figure 41**: Revenues of the project*

Source: own elaboration

With this subsidy, the IRR, that is calculated with Equation 12, equals the WACC

$$-Investment + \sum_{i=1}^{n} \frac{CF_i}{(1+IRR)^i} = 0$$

***Equation 12**: Internal Rate of Return*

Figure 42 shows the Cash Flow Waterfall that allows to see how the money is distributed each year between the different parties. As it can be seen, the sum of all the components equals the revenues of Figure 41.

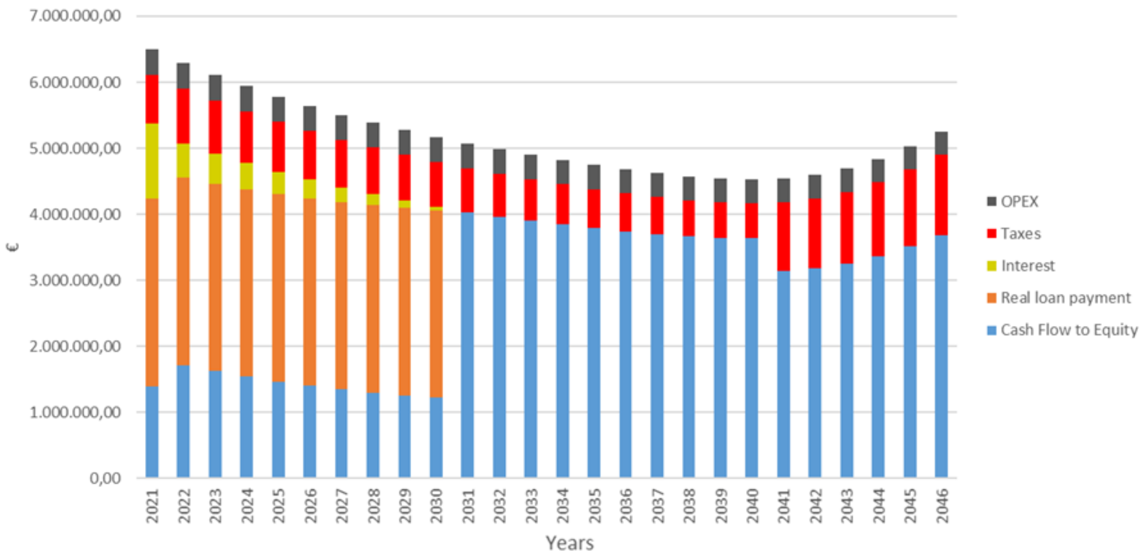


***Figure 42**: Cash Flow Waterfall*

Source: own elaboration

Although the financial model that has been implemented is in Euros, as the conversion of EC coins to Euros is 1:1 because it is a stablecoin backed by the Euro, as already explained in section 4.2, investors will receive an amount equal to the one in Euros, and therefore, no additional conversion is necessary.

8.3 Risks and scenarios

In this section it will be analyzed the different risks that exist in this project and it will be implemented different possible scenarios. In addition, more scenarios are proposed to see the influence of other factors on the reference case.

As previously mentioned, in each scenario, a single parameter will be modified to see the influence of each risk on the reference case.

The risks that are going to be considered are the following:

- Risk related to the solar generation. It may happen that there is not as much sun as initially expected and the hours of sunshine per day decrease. If this happens, the generation of the solar modules will decrease and less income from energy generation, less SolarCoins and less subsidy will be received. However, it can also happen the opposite, so both scenarios will be analyzed afterwards.

- Risk related to the growth of the SLR. The growth of the SLT has been assumed permanent throughout the life of the installation. However, a more unfavorable scenario will be considered in which the SLT price is not as high as the one proposed in the reference case.

In addition, as explained at the beginning of the section, other parameters will also be modified to analyze their influence on the base case. The proposed scenarios are the following:

- Lifespan of the project of 30 years instead of 25. The photovoltaic installations have a lifespan of 25 to 30 years, with this increase in the lifespan, the installation would be generating for 4 more years, and therefore, would be receiving more benefits.
- Selling energy through a PPA and not through the market. In the reference case, the project depends on the price of the energy in the market, however, if a contract is signed with a retailer, this price would be fixed and known from the beginning.
- Modify the parameters of the WACC calculation. In this scenario, the risk-free rate is modified, since it is currently below the levels reached in previous years.

8.4. Scenarios

Next, the previously introduced scenarios will be explained in more depth, and the results obtained will be shown.

8.4.1 Scenario 1. Different energy generation than expected

In the first part of this scenario, it will be assumed that the energy generated by the installation is 10% less than in the reference case. Therefore, the revenues from solar generation are also 10% lower than in the reference case, so the government subsidy necessary for the project to be profitable increases, approximately, by 10%, reaching 23,15 €/MWh.

In the second part of the scenario, it will be assumed that the energy generated by the installation is 10% higher than in the base case. Therefore, the revenues from solar generation are also 10% higher than in the reference case, so the government subsidy necessary for the project to be profitable decreases, approximately, by 9%, reaching 19,18 €/MWh.

8.4.2 Scenario 2. Less growth in SolarCoin than expected

The value of the SolarCoin has been assumed to increase due to the beliefs that exist today regarding the subject. However, in this scenario, it is going to be assumed that it grows half of what it was initially expected. In Figure 43 and Figure 44 it can be seen the growth and the value of the SLR with respect to the reference case.

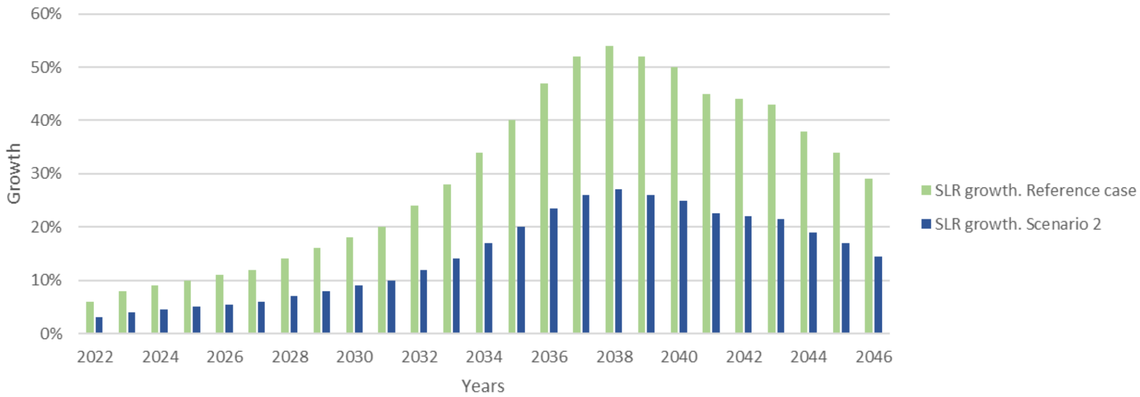


***Figure 43**: SLR growth - Scenario 2*

Source: own elaboration

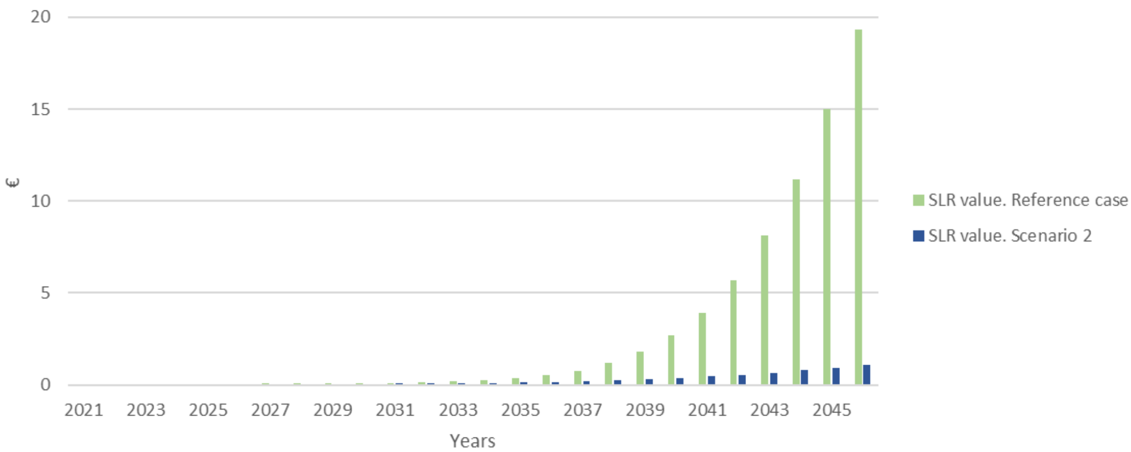


***Figure 44**: SLR value - Scenario 2*

Source: own elaboration

Figure 45 shows the revenues for SLR in this scenario.

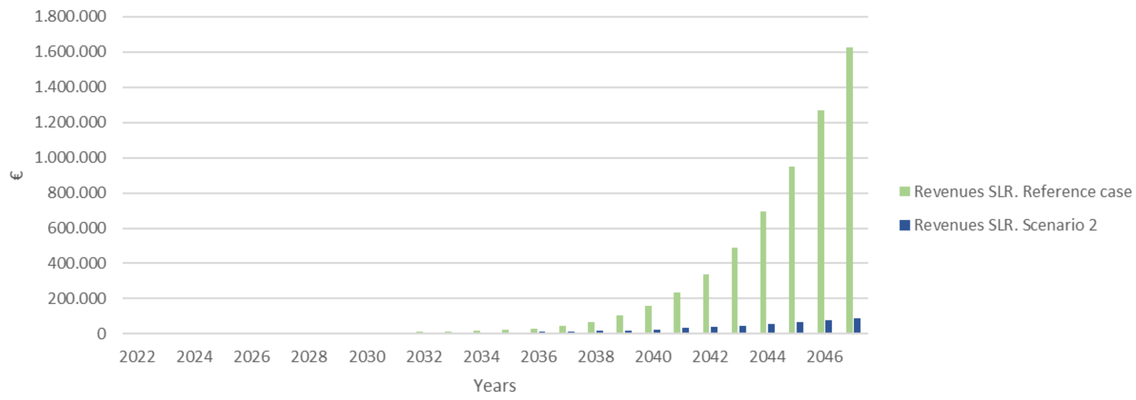


Figure 45*: SLR revenues - Scenario 2*

Source: own elaboration

Again, as revenues decrease, the government subsidy must be higher than the one of the reference case. This value is 22,86 €/MWh, that is, approximately 9% higher than the base case.

8.4.3 Scenario 3. Longer lifespan

In this scenario it is assumed that the lifespan of the installation lasts until 2050, that is to say, four more years generating energy and revenues. However, a higher value in O&M will be necessary in order to maintain the installation working another four years. This aspect should be taken into account in future developments.

The growth of the SLR is assumed to be 1% each year until 2050. The growth and the value of the SLR with respect to the reference case is shown in Figure 46 and Figure 47.

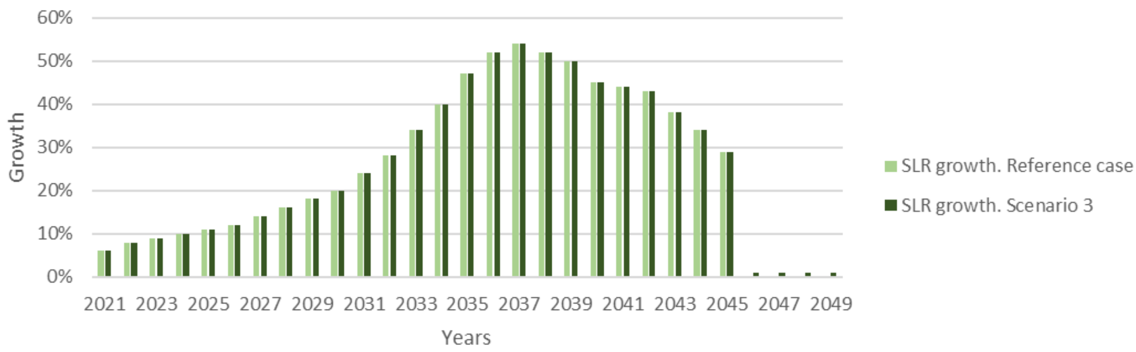


Figure 46*: SLR growth - Scenario 3*

Source: own elaboration

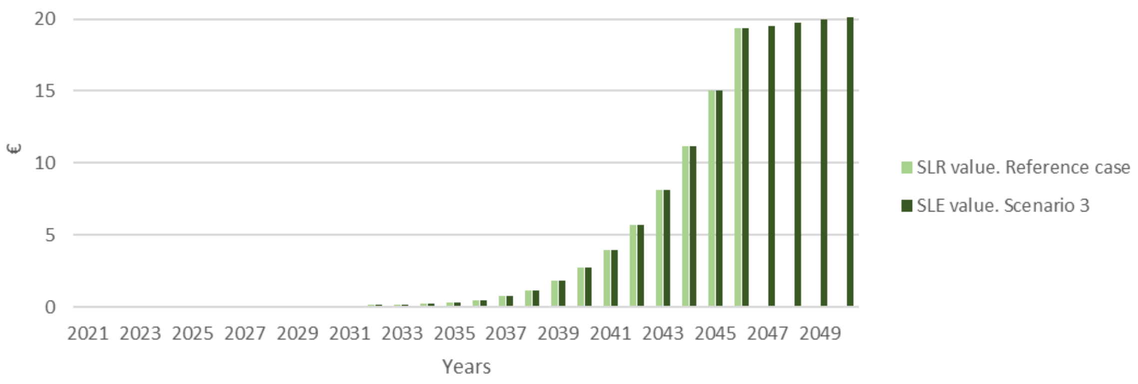


***Figure 47**: SLR value - Scenario 3*

Source: own elaboration

Figure 48 shows the energy generated along the lifespan of the installation in comparison with the reference case.

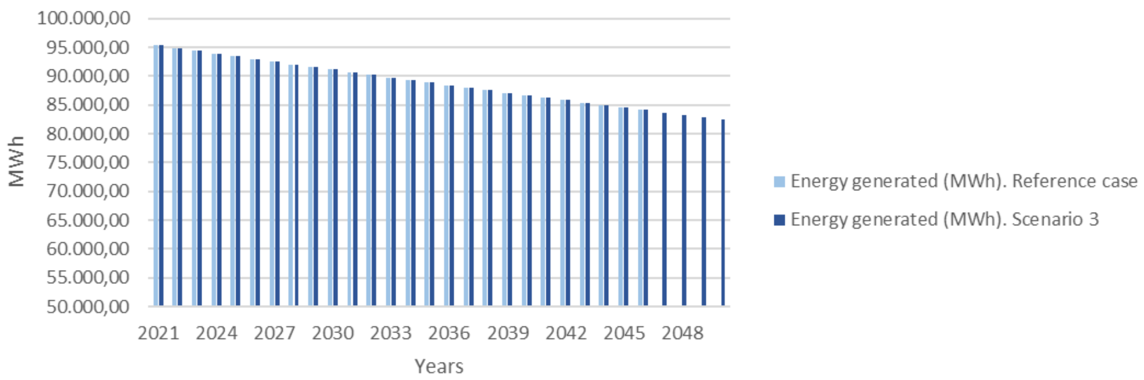


***Figure 48**: Energy generation - Scenario 3*

Source: own elaboration

Finally, as it can be seen in Figure 49, the installation generates revenues for a longer time.

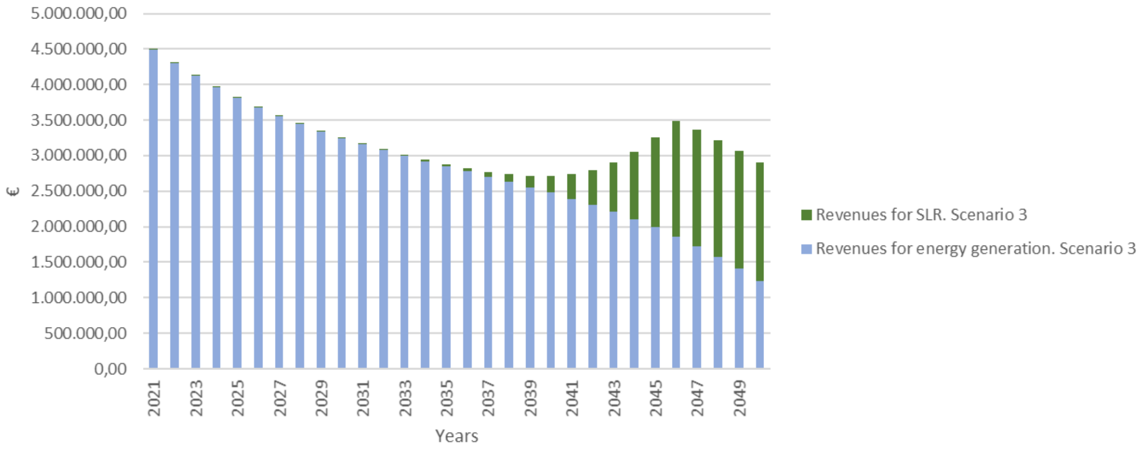


***Figure 49**: Revenues - Scenario 3*

Source: own elaboration

As the installation has revenues for a longer period of time, the government subsidy will have a lower value than that of the reference case, but it will be paid for a longer period of time. The value of this subsidy is 15,92 €/MWh, that is approximately 24% lower than the one of the reference case.

8.4.4 Scenario 4. Selling energy through PPA

In this section it is shown the results of the project in case the energy, instead of being sold in the market, is sold directly to a consumer or retailer through a financial PPA. This way, the consumer and the generator would know from the beginning the price of energy they will pay for a specific time horizon.

As explained in previous sections, the PPA allows the retailer to have a forecast of costs over the long-term, and not depend on market fluctuations. As for the generator, the PPA allows it to guarantee stable long-term income.

In the financial PPA, the rwo parties agree to pay the difference between the agreed price and the market price, so that, on the one hand, if the market price is below the PPA price, the consumer will have to pay the different to the generator, green zone of Figure 50, so the generator perceives the agreed price. On the other hand, in case the market price is above the agreed price, it will be the generator the one who has to pay the difference to the consumer, red zone of Figure 50, so that the consumer finally pays the price agreed in the PPA.

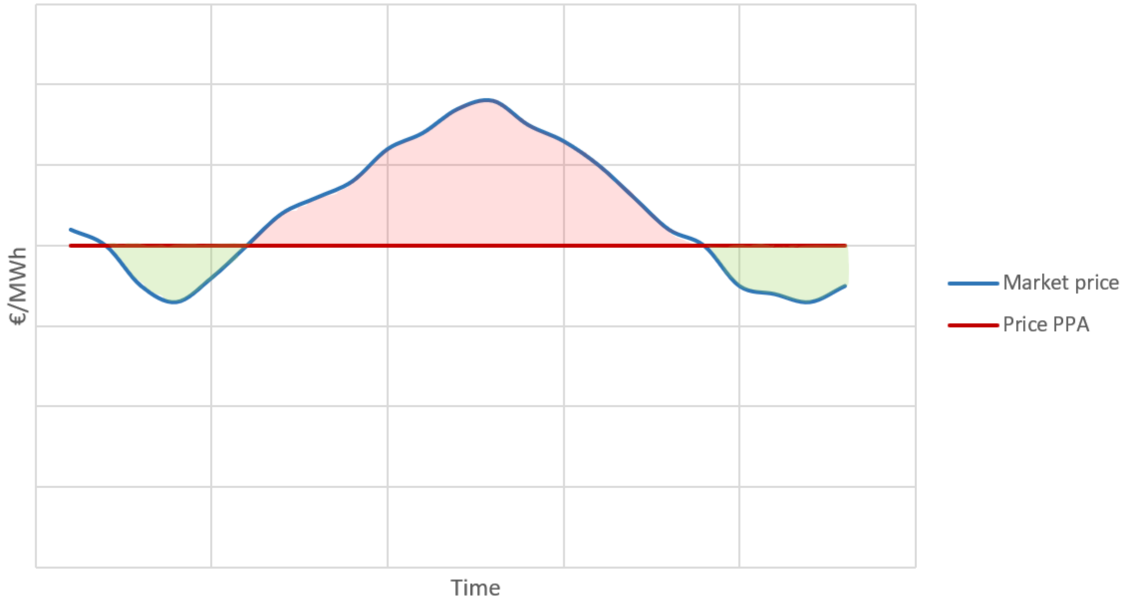


***Figure 50**: PPA operation*

Source: own elaboration

To choose this PPA price, it is necessary to know the average annual price of the market. In Figure 51 the following data is shown in 2018:

- The curve of 24 hours of solar generation. In this curve it can be seen that the solar generation is only produced in the hours of sun light, while over the rest of the hours it is zero.
- The market price each hour.
- The average market price throughout the day.
- The average market price during the hours of sun.

As it can be seen, the average market price during the sun hours is slightly lower than the average market price throughout the day.

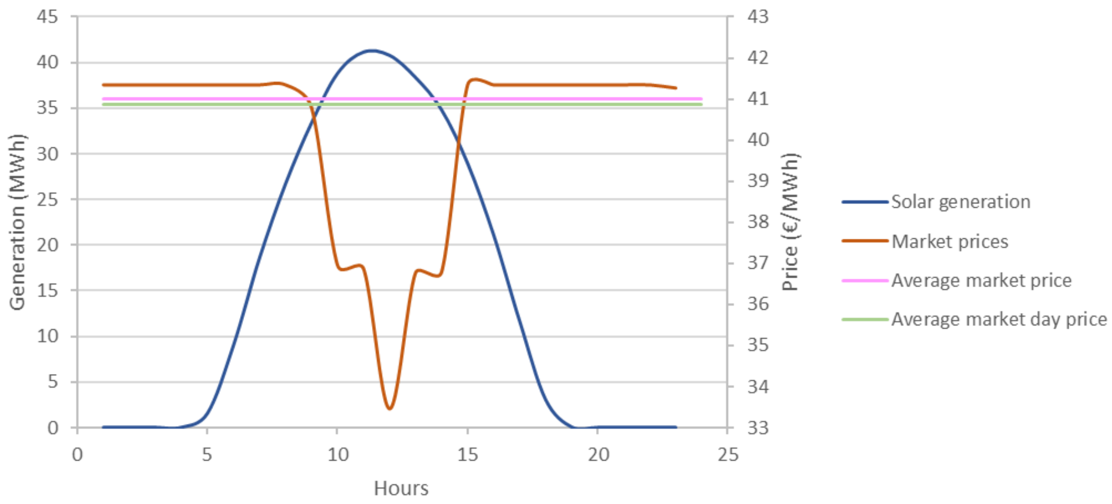


Figure 51*: Market price curve and energy profile*

Source: own elaboration

Moreover, the price of energy is going to decrease every year due to the increase of renewable sources [37], as it can be seen in Figure 52. Since PPAs are usually signed for a period of 10 or 15 years, for this project two PPA are proposed; the first one from 2021 to 2034, with a price of 40,8 €/MWh, and the second one from 2035 until 2046, with a price of 36,4 €/MWh.

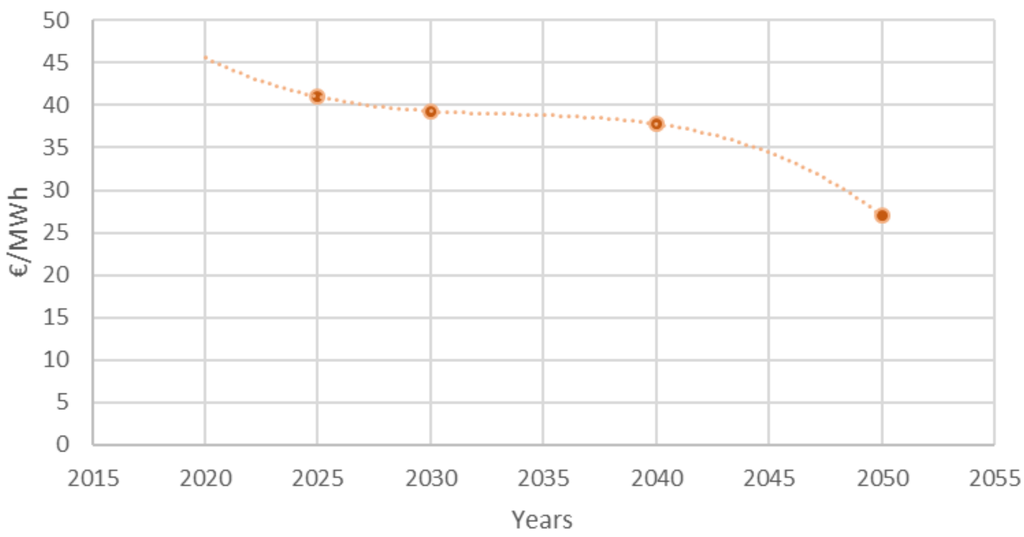


Figure 52*: Market price evolution*

Source: own elaboration

Assuming that the market prices remain as in the reference case, in both PPA, for a period of time it would be the generator the one who would be paying to the consumer, but during the next period, it would be the consumer who would have to pay the difference to the generator. Figure 53 shows what this payment sequence would look like, according to the color code used in Figure 50.

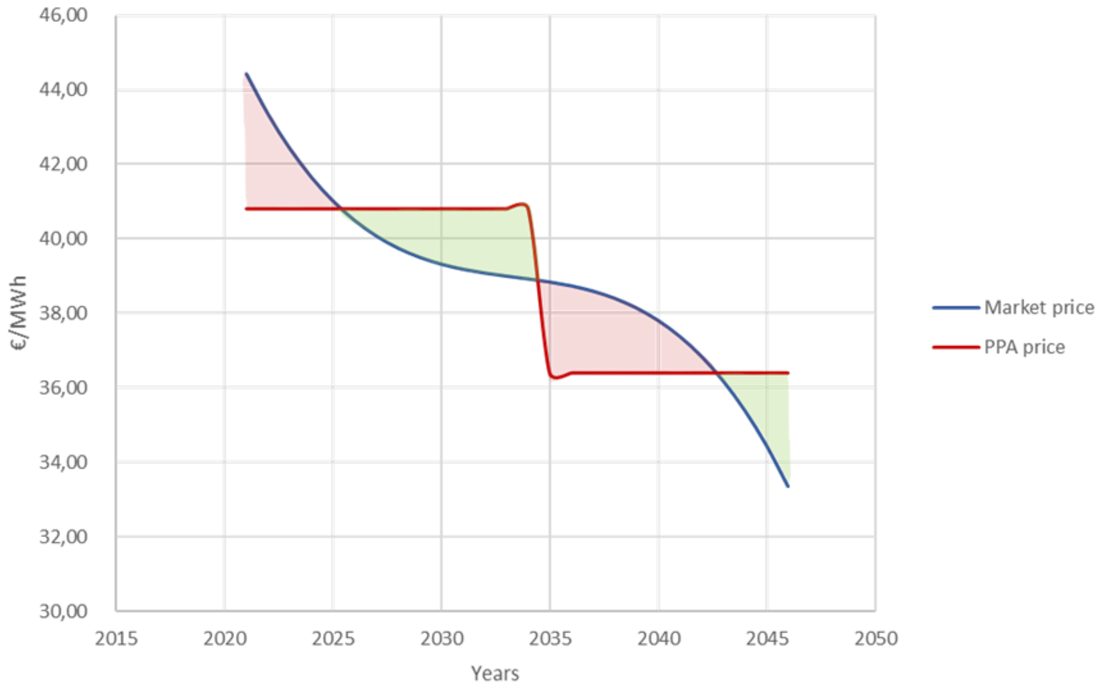


***Figure 53**: Market price Vs. PPA price*

Source: own elaboration

The revenues of this scenario in comparison with the reference case are shown in Figure 54, where it can be seen that the PPA offers much more stable income than the reference case, in which the energy was sold directly in the market.

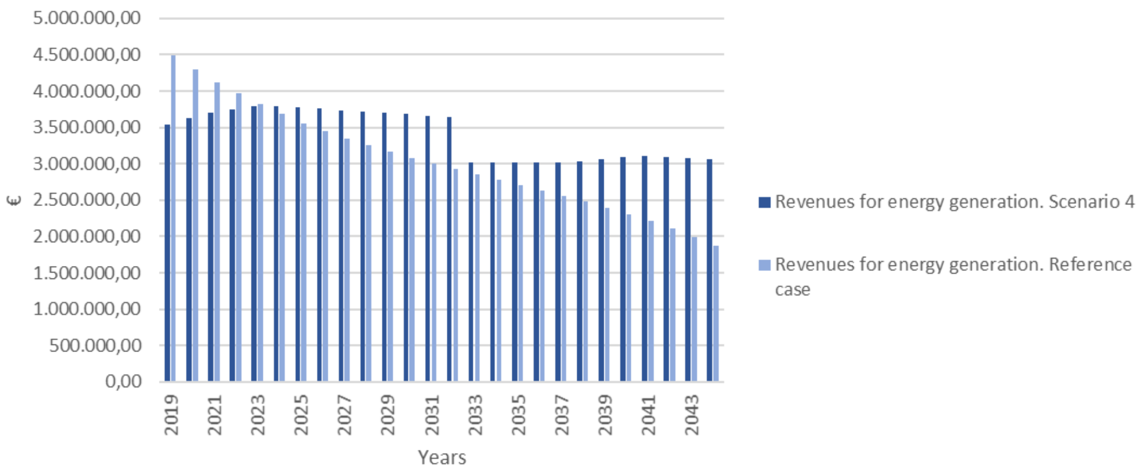


***Figure 54**: Revenues for energy generation - Scenario 4*

Source: own elaboration

Regarding the consumers of this energy, they will be paying the price they negotiate with the retail company. The previous prices are the ones negotiated between the generation and the retail company, not between the retail company and the demand.

Assuming that the energy generated is the same as in the reference case, the minimum subsidy that the government would have to pay for the project to be profitable is 17,70 €/MWh, that is approximately 16% less than in the reference case.

8.4.5 Scenario 5. Different risk-free rate

Analyzing the data of the Spanish bond yield at 20 years, it can be observed that, since 2015, it has varied in a range from 2,9% to 0,89% [83], being the latter the value that it currently has.

In this scenario, a value within this range will be assumed, so that the project can be seen in a less profitable context. The value of the risk-free rate is considered 1,8%, and for this value, the minimum cost of capital, that is to say, the minimum profitability requested by investors is 4,52%, higher than the one of the reference case, with a value of 3,62%.

In this case, the NPV is very negative, so the subsidy needed for the project to be profitable is 22,14 €/MWh, which is approximately 6% higher than in the reference case.

8.4.6 Scenario 6. Combination of scenario 3 and 4

As it has been analyzed, the scenarios in which the government subsidy is lower are the third one, in which the lifespan of the installation is extended, and the fourth one, in which the energy is sold through a PPA with previously fixed prices, and not through the market.

This scenario combines these two in order to achieve an optimal scenario to obtain a government subsidy even lower.

For this scenario, it is necessary a readjustment of the second PPA price, since is the plant works for a longer period of time, the PPA price should decrease according to the market prices. This price is set at 34,7 €/MWh.

Figure 55 shows the revenues of this scenario.

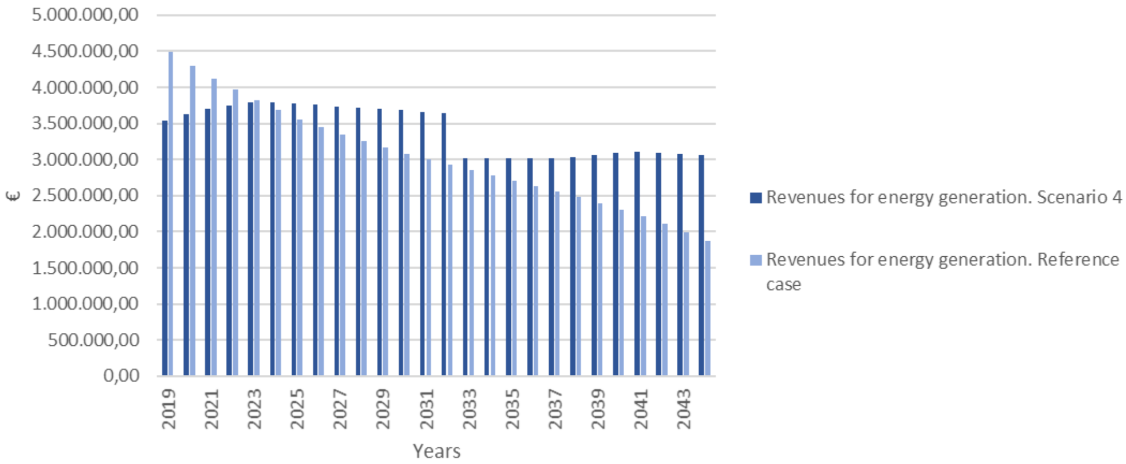


***Figure 55**: Revenues for energy generation - Combined scenario*

Source: own elaboration

Assuming that the energy generated is the same as in the reference case, the minimum subsidy that the government would have to pay to the project would be 12,45 €/MWh, that is, approximately 41% lower than in the reference case.

8.4.7 Comparison of the different scenarios

This section shows a comparison of the analyzed scenarios where the subsidies needed are shown in each scenario, and those that need a lower subsidy will be the most favorable for this project.

***Table 15**. Comparison of the different scenarios*

Scenarios	Description	Subsidy (€/MWh)	Subsidy (%)
Reference case	-	20,97	-
1.1	Less solar generation	23,15	+10%
1.2	More solar generation	19,18	-9%
2	Lower SLR growth	22,86	9%
3	Longer lifespan	15,92	-24%
4	PPA	17,7	-16%
5	Higher risk-free rate	22,14	+6%
6	Combined scenarios 3 and 4	12,45	-41%

Next, Figure 56 visually shows the scenarios according to the subsidy the different scenarios, besides the revenues received from energy generation and SolarCoin, need.

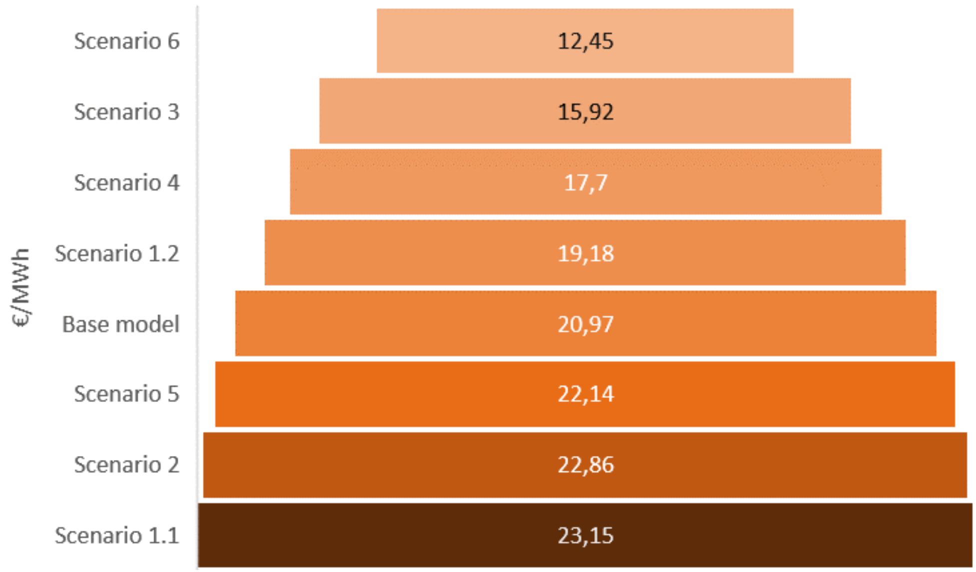


***Figure 56**: Scenarios according to its subsidy*

Source: own elaboration

9. CONCLUSIONS AND RECOMMENDATIONS

Throughout the project, many of the blockchain technology concepts have been explained and analyzed in order to, finally, implement a financial model based on new tokens, in order to find an alternative to government auctions, and to traditional financing of photovoltaic installations.

Subsequently, the type of tokens to be used for this project has been decided; the Energy Community coins (EC coins) as the cryptocurrency to use in the platform, the Photovoltaic Generation Participation Fix (PGPF) as the participations of the investors with a fixed interest rate and the Photovoltaic Generation Participation Variable (PGPV) as the participations of the investors with a variable interest rate.

Afterwards, the cost of the installation has been estimated with Microsoft Project, according to the cost of the elements individually, the manpower and material costs, and the cost of different permits needed to build the installation. Then, the revenues of the reference case have been estimated according to the data of the hourly generation published by REE, and the energy prices published by the IIT [37]. Subsequently, several scenarios have been proposed in order to obtain the model in which the needed government subsidy was as low as possible, since, based on the results obtained in the previous section, the project is not profitable without a government subsidy, if the renewables quota need to be met and the technology costs are the ones expected by [37]. Moreover, these subsidies are necessary since the government has committed to comply with specific renewable quotes, and without this remuneration, these quotes would not be met.

The most favorable scenario, that is, the one in which a lower government subsidy is needed, is the scenario 6, that is the one in which the lifespan of the plant is extended, and the sale of the energy is made through a PPA. However, it is needed to further investigate if there are costs associated to the lifetime extension of the installation.

Moreover, the return required by the investors with variable rate of return, that is, those who have to assume the risk, is assumed to be at least 6%, since otherwise, not many investors would be willing to invest in this project. Following this premise, the necessary subsidies for the reference case, the scenario 6, which is the most favorable, and the scenario 1.1, which is the most unfavorable, have been obtained.

For the base case, the minimum subsidy that the government should pay is 38,9 €/MWh; for the scenario 6, 33,44 €/MWh, and for the scenario 1.1, 43,22 €/MWh. The range of subsidies needed, according to the scenarios analyzed, in order the project to be interesting for investors and profitable, is shown in Figure 57.

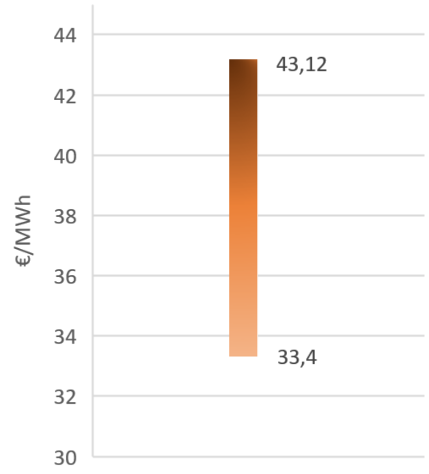


***Figure 57**: Subsidy range*

Source: own elaboration

Next, the advantages of this type of financing in the context of renewable energies are explained:

- It allows the financing of a project without any intermediary. Investors, who invest money in return for a certain profitability, do not need the intervention of any bank or investment fund to inject money in the project.
- With this type of projects, investors can diversify their investments as they desire, and obtain return in their investments, while promoting the improvement of the environment and encouraging the achievement of the objectives imposed by the European Union with respect to renewable energy.
- In addition, the participations bought by the investors, that are the portions in which the investment of the installation is divided, are purchased in the primary market and may be traded in the secondary market, that will offer great liquidity, since these participations can be sold as long as there is another investor interested in buying it, regardless of the stage of the project.
- Regarding the consumers of this energy, the implementation of these projects allows them to consume from renewable sources and to decrease the sale price of the energy in the pool and, therefore, in their electricity bill.
- In addition, in case the users of the platform are also consumers of this energy, this platform allows them to make payments faster in EC coins directly to the trader, in case it accepts payments in cryptocurrencies.
- Transactions between users are anonymous and do not need an intermediary either. This type of transaction gives the project liquidity, since investors can sell their shares as long as there is a buyer, regardless of the circumstances of the project.
- These transactions require little commission and are done at a higher speed than conventional transactions through banks and platforms.

- The technology on which this project is based, the blockchain, is a very secure system that allows reliable and irreversible transactions between two nodes. In addition, these data cannot be falsified or deleted once they are in the blockchain.
- Depending on different factors considered in this project, the government may need to provide subsidy to make the investments profitable, otherwise there is a risk that investors may lose money and some of them go bankrupt. This project provides a trustable system in which the government can check the energy generated and the payments received by the installations and quantify the additional financial support.

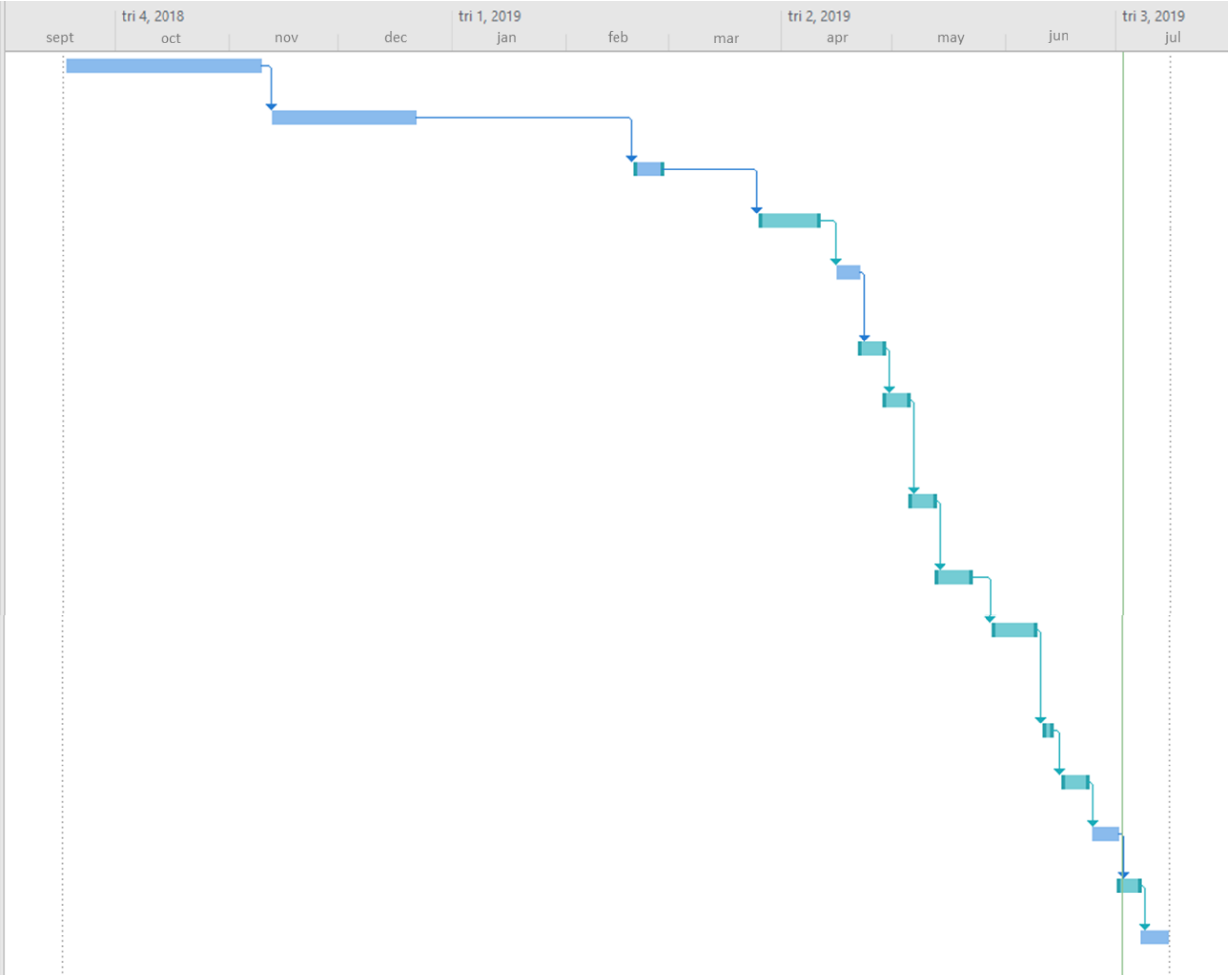
As future work, in order to make the model more realistic, it is proposed to make a prediction of the costs over time, for all the scenarios, of the elements and the labor required, since, in addition, each year the prices of the components of the installation decrease due to the development of the technology.

In addition, with Blockchain technology emerging all over the world and, specifically, in some European countries, where innovative pilot projects are being carried out in order to see how they work in the real world, the legislation of this technology will also evolve in Spain, where currently the implementation of some innovative project is allowed through a controlled space called “sandbox”.

As future work it is also proposed the implementation of this platform in Ethereum, in order to simulate the transactions and the operation of the system, so that, eventually it can become a commercial model.

GANTT CHART

Task mode	Name of the task	Duration	Start	End
	Research of the State of the Art	50 days	mon 17/09/18	fri 09/11/18
	Learn and program Smart Contracts	37 days	mon 12/11/18	fri 21/12/18
	Annex B reconsideration	7 days	wed 20/02/19	wed 27/02/19
	Analysis of Spanish Electric System	15 days	tue 26/03/19	wed 10/04/19
	Research and Analysis of Asset Tokenization	6 days	mon 15/04/19	sun 21/04/19
	ICO	7 days	mon 22/04/19	sun 28/04/19
	Conditions for the investment and integration with the electric companies	7 days	mon 29/04/19	sun 05/05/19
	Elements of the photovoltaic installation	7 days	mon 06/05/19	sun 12/05/19
	Market Operation	9 days	mon 13/05/19	wed 22/05/19
	Costs associated with the photovoltaic installation	11 days	wed 29/05/19	sun 09/06/19
	Evolution of energy prices	2 days	wed 12/06/19	thu 13/06/19
	Design a Financing Model	7 days	mon 17/06/19	sun 23/06/19
	Propose scenarios	7 days	mon 24/06/19	mon 01/07/19
	Conslusions and abstract	6 days	tue 02/07/19	sun 07/07/19
	Presentation	7 days	mon 08/07/19	mon 15/07/19



BIBLIOGRPAHY

[1] «Boletín Oficial del Estado,» 2015. [En línea]. Available: https://www.boe.es/buscar/act.php?id=BOE-A-2015-10927.

[2] «Comisión Europea,» [En línea]. Available: https://ec.europa.eu/clima/policies/international/negotiations/paris_es.

[3] «Parlamento Europeo,» 7 November 2018. [En línea]. Available: http://www.europarl.europa.eu/news/es/headlines/economy/20181031STO18175/la-ue-afronta-el-cambio-climatico-mas-renovables-mejor-eficiencia-energetica.

[4] «Energías Renovables,» 3 July 2018. [En línea]. Available: https://www.energias-renovables.com/panorama/espana-es-ahora-el-mercado-renovable-20180703.

[5] «Borrador del plan nacional integrado de energía y clima 2021 - 2030,» Febrero 2019.

[6] L. Ojea, «El periódico de la energía,» 31 January 2019. [En línea]. Available: https://elperiodicodelaenergia.com/locura-renovable-en-espana-quieren-instalarse-mas-de-87-gw-la-mitad-ya-con-el-permiso-de-acceso-concedido-por-ree/.

[7] «The Diplomat In Spain,» 4 Marzo 2018. [En línea]. Available: https://thediplomatinspain.com/2018/03/espana-es-el-pais-europeo-con-mas-poblacion-por-superficie-habitada/.

[8] E.B, «El Boletín,» 5 Febrero 2019. [En línea]. Available: https://www.elboletin.com/noticia/169880/economia/que-paises-son-los-mayores-productores-de-energia-solar.html.

[9] «Raley,» [En línea]. Available: http://raleyestudioscosteros.blogspot.com/2012/06/21-de-junio-dia-internacional-del-sol.html.

[10] «Punto Crítico Editorial,» 7 Feb 2017. [En línea]. Available: http://puntocritico.com/2017/02/07/historia-del-sistema-electrico-espanol-parte-i/ .

[11] «Boletín Oficial del Estado,» 1997. [En línea]. Available: https://www.boe.es/boe/dias/1997/11/28/pdfs/A35097-35126.pdf.

[12] «Boletín Oficial del Estado,» 2013. [En línea]. Available: http://www.energiaysociedad.es/wp-content/uploads/pdf/documentos/regulacion_tarifas/regulacion_nacional/PPTLey24_2013.pdf.

[13] «OMIE,» [En línea]. Available: http://www.omie.es/inicio/mercados-y-productos/mercado-electricidad/nuestros-mercados-de-electricidad/diario-e-intradia.

[14] «Techno Industria,» [En línea]. Available: https://technoindustria.wordpress.com/2015/02/22/evolucion-del-sector-electrico-en-espana/.

[15] J. L. G. Ortega, «Ambienta,» [En línea]. Available: http://www.revistaambienta.es/WebAmbienta/marm/Dinamicas/secciones/articulos/Revolucion.htm.

[16] «El Diario,» [En línea]. Available: https://www.eldiario.es/tribunaabierta/Renovables-Espana-tecnologico-retroceso-regulatorio_6_644695545.html.

[17] «The Shift Project Data Portal,» [En línea]. Available: http://www.tsp-data-portal.org/Historical-Electricity-Generation-Statistics#tspQvChart.

[18] «Earth Obervatory NASA,» [En línea]. Available: https://earthobservatory.nasa.gov/features/GlobalWarming.

[19] «Energía y Sociedad,» [En línea]. Available: http://www.energiaysociedad.es/manenergia/3-1-el-cambio-climatico-y-los-acuerdos-internacionales/.

[20] I. T. I. Council, «Benefits of Information Communications Technology to Energy Infrastructure».

[21] «123Dinero,» [En línea]. Available: https://www.123dinero.com/donde-invertir-dinero/.

[22] «Acciona,» [En línea]. Available: https://www.acciona.com/es/energias-renovables/.

[23] W. Kenton, «Investopedia,» 2019. [En línea]. Available: https://www.investopedia.com/terms/f/feed-in-tariff.asp.

[24] «Energypedia,» 2019. [En línea]. Available: https://energypedia.info/wiki/Feed-in_Premiums_(FIP).

[25] D. M. Bechberger, «Renewable Energy World,» 2013. [En línea]. Available: https://www.renewableenergyworld.com/articles/2013/04/pain-in-spain-new-retroactive-changes-hinders-renewable-energy.html.

[26] A. Rodriguez Centeno, «Suelo Solar,» 2018. [En línea]. Available: https://suelosolar.com/newsolares/newsol.asp?id=12254.

[27] «El Periódico de la Energía,» 2017. [En línea]. Available: https://elperiodicodelaenergia.com/la-descentralizacion-es-la-forma-mas-barata-de-ampliar-el-acceso-a-la-electricidad/.

[28] «Acciona,» [En línea]. Available: https://www.imnovation-hub.com/es/transformacion-digital/que-es-blockchain-y-como-funciona-esta-tecnologia/.

[30] «Emprendices,» [En línea]. Available: https://www.emprendices.co/blockchain-cuales-ventajas-desventajas/.

[31] «Block Geeks,» [En línea]. Available: https://blockgeeks.com/guides/proof-of-work-vs-proof-of-stake/.

[32] «Cremades & Calvo - Sotelo,» [En línea]. Available: https://www.cremadescalvosotelo.com/noticias-legales/cambiara-blockchain-el-sistema-financiero-0.

[33] «Diario Renovables,» [En línea]. Available: https://www.diariorenovables.com/2017/05/como-funciona-la-subasta-renovable-de-espana.html.

[34] M. Wachal, «Software Mill,» 22 October 2018. [En línea]. Available: https://blog.softwaremill.com/asset-tokenization-on-blockchain-will-disrupt-the-asset-management-landscape-befbd71639b1.

[35] T. Gómez, M. Rivier, J. P. Chaves, F. Martin y T. Gerres, «Señales de precio a la inversión en un mercado eléctrico con elevada penetración de renovables,» 2018.

[36] E. Parra, Noviembre 2018. [En línea]. Available: https://www.europapress.es/economia/energia-00341/noticia-gobierno-no-preve-alargar-vida-util-nucleares-mas-40-anos-obligando-cerrar-antes-2030-20181115104517.html.

[37] M. Rivier, T. Gómez, J. P. Chaves, R. Cossent, Á. Sánchez, F. Martín y T. Gerres, «Análisis de escenarios futuros para el sector eléctrico en España para el período 2025-2050,» Instituto de Investigación Tecnológica, Madrid, 2018.

[38] V. Martínez y C. Urrutia, 2017. [En línea]. Available: https://www.elmundo.es/economia/2017/05/26/59272e3622601d4b708b45f0.html.

[39] «D Force Solar,» [En línea]. Available: http://www.dforcesolar.com/energia-solar/que-es-un-certificado-energia-verde/.

[40] SolarCoin.org, «Solar Coin, a blockchain-based solar energy incentive».

[41] «Solar Coin,» [En línea]. Available: https://solarcoin.org/.

[42] «Coin Gecko,» [En línea]. Available: https://www.coingecko.com/en/coins/solarcoin.

[43] C. Domingo, «Xataka,» [En línea]. Available: https://www.xataka.com/especiales/que-es-blockchain-la-explicacion-definitiva-para-la-tecnologia-mas-de-moda.

[44] «Cripto Noticias,» 2018. [En línea]. Available: https://www.criptonoticias.com/gobierno/regulacion/cnmv-publico-nuevos-criterios-realizar-ico-espana/.

[45] «Expansión,» [En línea]. Available: https://hayderecho.expansion.com/2018/10/08/las-icos-como-forma-de-financiacion-regulacion-especifica-o-utilizacion-del-sandbox/.

[46] «Expansión,» 2018. [En línea]. Available: https://hayderecho.expansion.com/2018/10/08/las-icos-como-forma-de-financiacion-regulacion-especifica-o-utilizacion-del-sandbox/.

[47] «Europa Press,» 2019. [En línea]. Available: https://www.europapress.es/economia/finanzas-00340/noticia-gobierno-aprueba-sandbox-impulsar-transformacion-digital-sector-financiero-20190222140603.html.

[48] J. Surga, «Criptonoticias ERC20,» 2019. [En línea]. Available: https://www.criptonoticias.com/colecciones/tokens-erc20-ethereum-como-funcionan/.

[49] G. González, «Criptonoticias,» 2019. [En línea]. Available: https://www.criptonoticias.com/colecciones/conoce-los-stablecoins-los-criptoactivos-de-precio-estable/.

[50] «Enel Green Power,» [En línea]. Available: https://www.enelgreenpower.com/es/medios/press/d/2018/10/Enel_Green_Power_Espana_inicia_la_construccion_de_sus_primeras_plantas_fotovoltaicas_en_Extremadura.

[51] «Factor Energía,» [En línea]. Available: https://www.factorenergia.com/es/blog/noticias/que-es-un-ppa-de-energia/.

[52] «BID,» [En línea]. Available: https://blogs.iadb.org/sostenibilidad/es/bonos-verdes-solucion-al-deficit-de-financiamiento-para-proyectos-de-energia-limpia-y-eficiencia-energetica/.

[53] «Bits of Proof,» 2019. [En línea]. Available: https://bitsofproof.com/es/bitcoin/anonimo.

[54] L. Parrondo Tort, «Contabilización de las criptomonedas como medio de pago en la compraventa de bienes o servicios,» Barcelona, 2018.

[55] «Afiris,» 2019. [En línea]. Available: https://www.afiris.es/fiscalidad-de-las-criptomonedas/.

[56] «Casasempere Abogados,» 20 Octubre 2018. [En línea]. Available: https://casasempereabogados.com/puedo-cobrar-mis-productos-servicios-bitcoin/.

[57] «El Capitalista Infiel,» 2017. [En línea]. Available: https://www.elcapitalistainfiel.com.es/2017/09/como-pagar-la-factura-de-la-luz-o-el.html.

[58] «wwwhat's new,» [En línea]. Available: https://wwwhatsnew.com/2016/09/26/en-japon-aprueban-solucion-para-pagar-cuentas-de-luz-con-bitcoins/.

[59] «La Vanguardia,» [En línea]. Available: https://www.lavanguardia.com/vida/20181228/453790450482/gobierno-ofrece-retribuir-al-75--a-afectados-recorte-renovables-hasta-2031.html.

[60] «Legalium,» [En línea]. Available: http://www.legalium.com/novedades-introducidas-por-el-real-decreto-ley-92013/.

[61] «Green Match,» [En línea]. Available: https://www.greenmatch.co.uk/blog/2015/09/types-of-solar-panels.

[62] «Energy Informative,» [En línea]. Available: https://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/.

[63] «Monsolar,» 2018. [En línea]. Available: https://www.monsolar.com/blog/mejores-fabricantes-paneles-solares-2018/.

[64] «El Periódico de la Energía,» [En línea]. Available: https://elperiodicodelaenergia.com/los-10-principales-fabricantes-de-paneles-fotovoltaicos-del-mundo-en-2017/.

[65] «Canadian Solar,» [En línea]. Available: https://www.canadiansolar.com/upload/bdc8ee14469947a9/66e7289dd6e786e0.pdf.

[66] «Civic Solar,» [En línea]. Available: https://www.civicsolar.com/manufacturers/canadian-solar.

[67] «Deger Iberica,» [En línea]. Available: https://degeriberica.com/wp-content/uploads/2018/07/180101-Ficha-t%C3%A9cnica-DEGERtracker-S100-PF-SR-ES.pdf.

[68] J. d. l. P. Carrascosa, «Estudio y desarrollo de una planta solar fotovoltaica,» Madrid.

[69] Project Management - ICAI, 2018 .

[70] «Europa Press,» 2019. [En línea]. Available: https://www.europapress.es/economia/noticia-iberdrola-inicia-extremadura-planta-fotovoltaica-mas-grande-europa-inversion-300-millones-20190606100930.html.

[71] «Hoy,» 2019. [En línea]. Available: https://www.hoy.es/badajoz/sale-informacion-publica-20190409135608-nt.html.

[72] «Europa Press,» 2019. [En línea]. Available: https://www.europapress.es/economia/noticia-enel-green-power-espana-inicia-construccion-primeras-plantas-fotovoltaicas-extremadura-20181023162922.html.

[73] D. Feldman y R. Margolis, «NREL,» November 2018. [En línea]. Available: https://www.nrel.gov/docs/fy19osti/72810.pdf.

[74] «Instituto Enerxético de Galicia,» [En línea]. Available: http://www.inega.gal/informacion/preguntas_frecuentes/enerxia_solar_fotovoltaica.html?idioma=es.

[75] F. Blanco Silva, «Estudio de viabilidad de una instalación fotovoltaica de coste 50.000 euros en España,» Santiago de Compostela, 2010.

[76] «Coin Gecko,» [En línea]. Available: https://www.coingecko.com/en/coins/solarcoin/eur.

[77] «Diario Renovables,» [En línea]. Available: https://www.diariorenovables.com/2018/01/solarcoin--energia-solar-criptomoneda-blockchain.html.

[78] «Pontificia Universidad Católica de Chile,» [En línea]. Available: http://hrudnick.sitios.ing.uc.cl/alumno12/costosernc/C._Foto.html.

[79] «Energías Renovables,» 2018. [En línea]. Available: https://www.energias-renovables.com/fotovoltaica/el-precio-de-la-electricidad-va-a-20180517.

[80] L. Garvia Vega y A. Solsona Durán, «Análisis de la viabilidad económica de un parque eólico a través de un Project Finance,» Madrid, 2017.

[81] «El economista,» 2018. [En línea]. Available: https://infoautonomos.eleconomista.es/fiscalidad/impuesto-de-sociedades/.

[82] «Reviso,» [En línea]. Available: https://www.reviso.com/es/que-es-la-reserva-legal.

[83] «Investing,» [En línea]. Available: https://es.investing.com/rates-bonds/spain-20-year-bond-yield.

ANNEX I. Activities and Gantt Diagram

***Table 16**. Activities I*

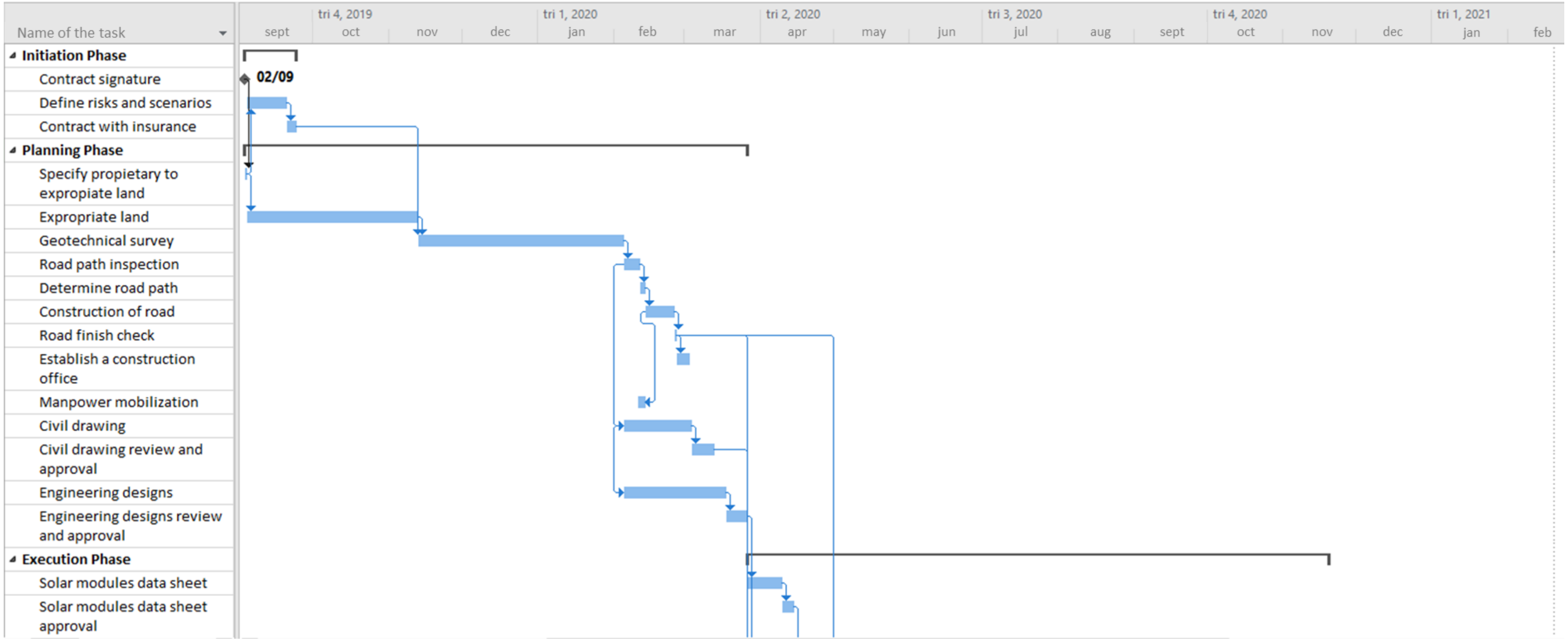


Table 17*. Activities II*

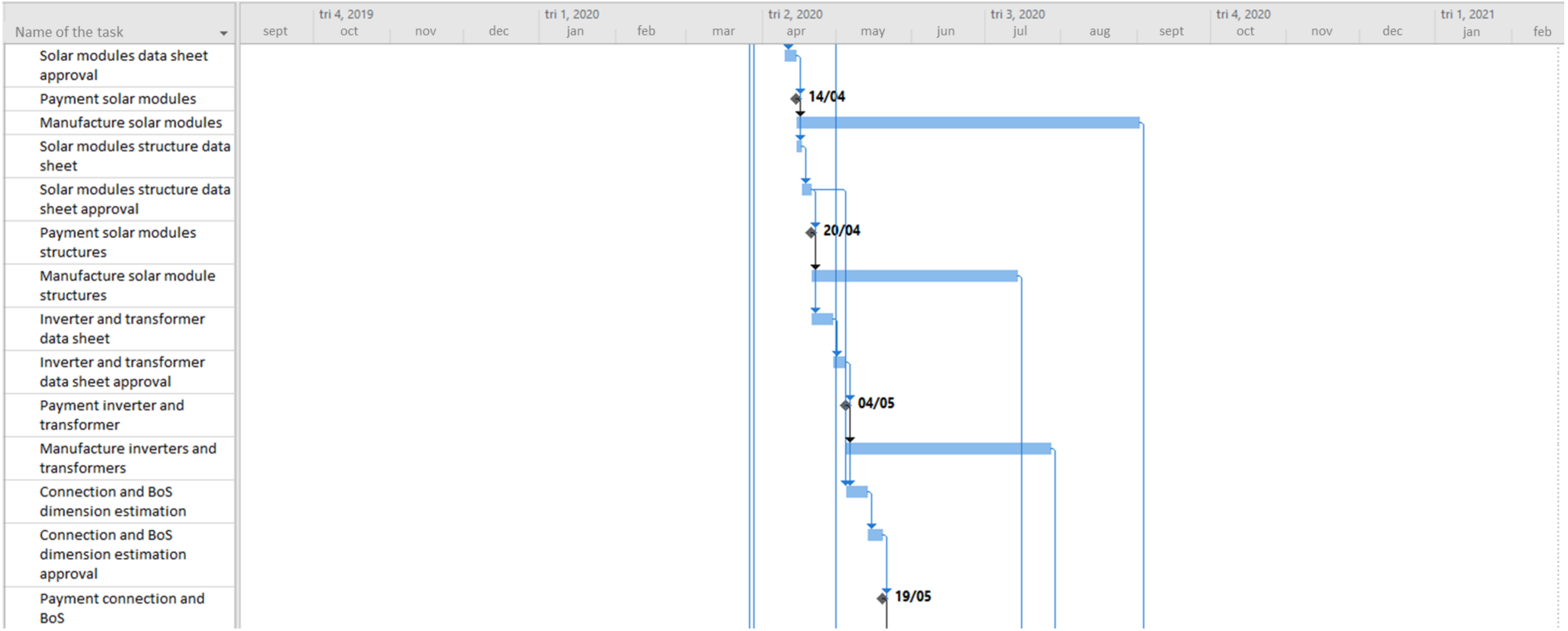


***Table 18**. Activities III*

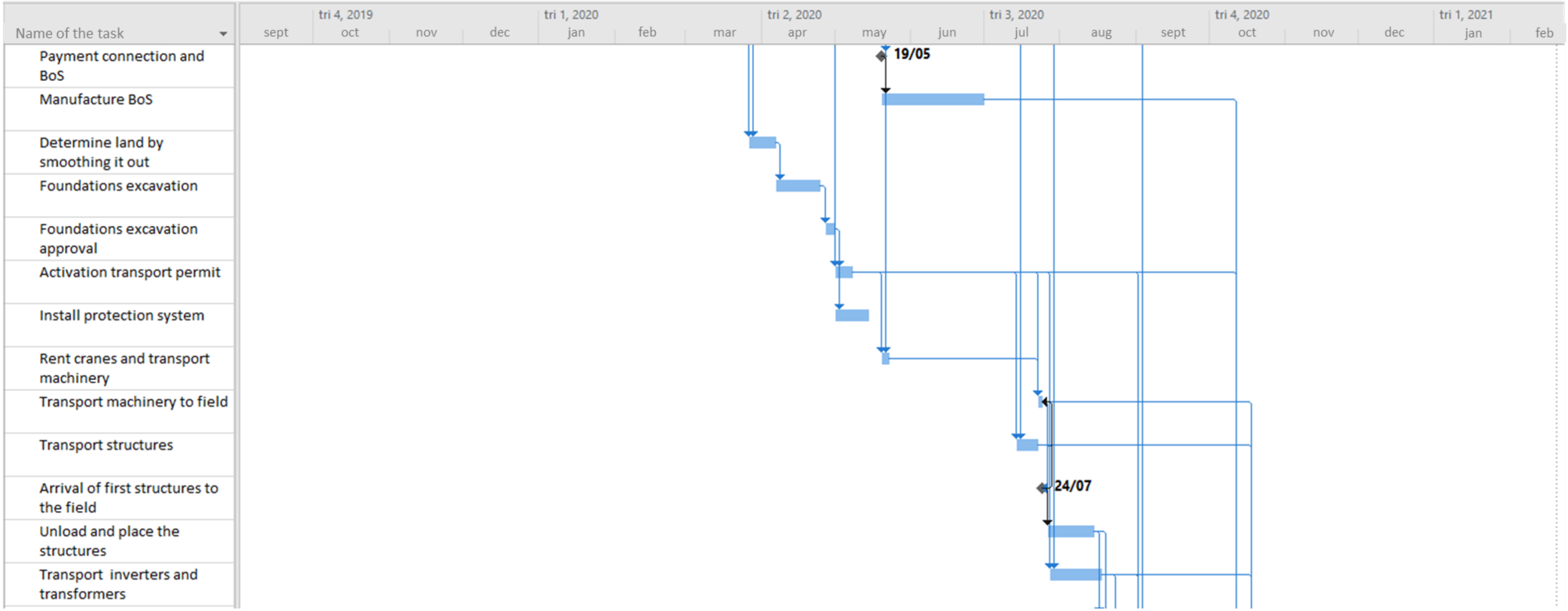
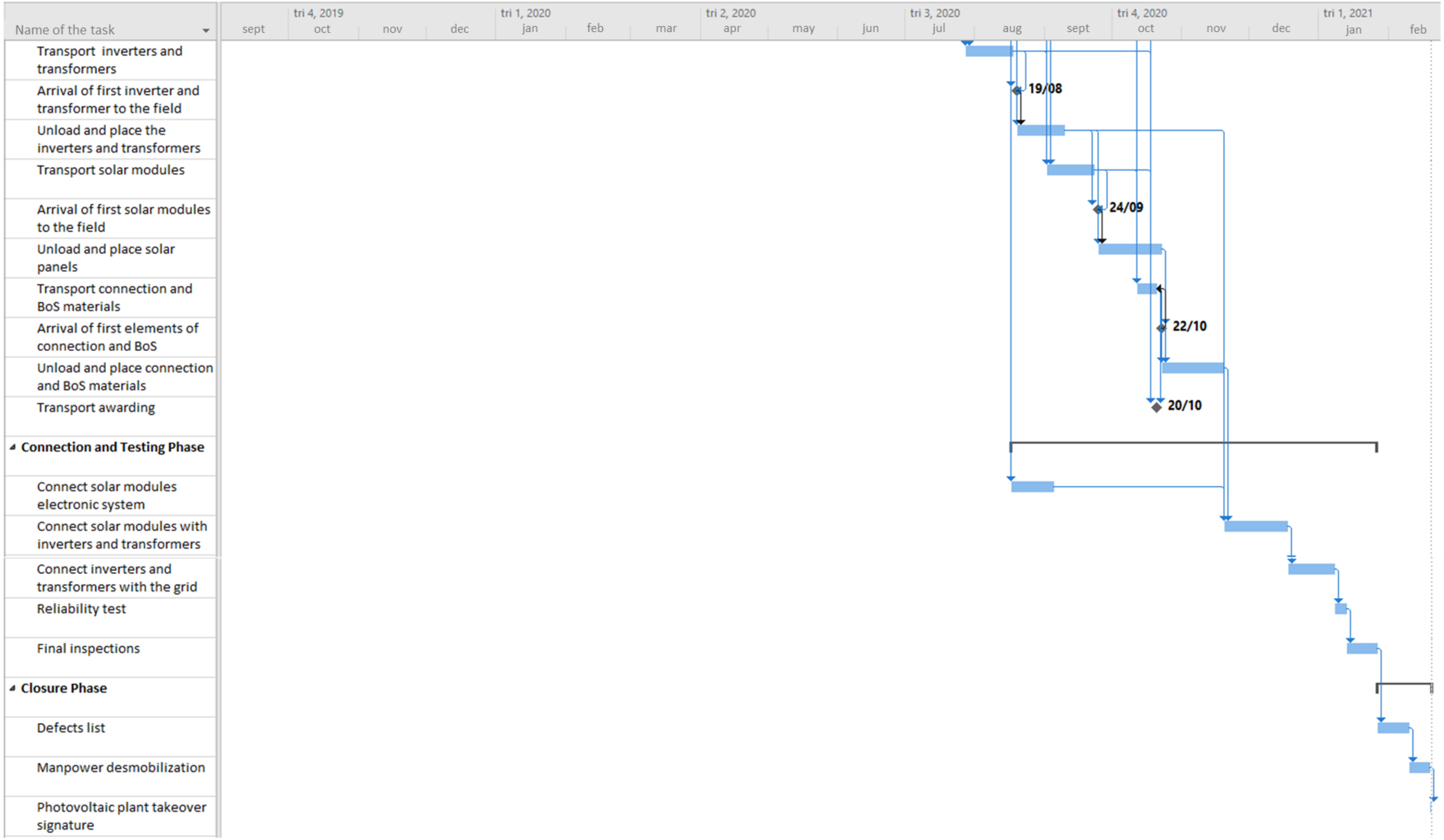


***Table 19**. Activities IV*



ANNEX II. Resources used in each activity

***Table 20**. Resources I*

Name of the task	Duration	Start	End	Predecessors	Name of the resources
Initiation Phase	**15 días**	**lun 02/09/19**	**vie 20/09/19**		
Contract signature	0 días	lun 02/09/19	lun 02/09/19		General Project Manager
Define risks and scenarios	12 días	mar 03/09/19	mié 18/09/19	6	Civil Project Manager;General Project Manager;Mechanical Project Manager
Contract with insurance	2 días	jue 19/09/19	vie 20/09/19	3	General Project Manager
Planning Phase	**148 días**	**lun 02/09/19**	**mié 25/03/20**		
Specify propietary to expropiate land	1 día	lun 02/09/19	lun 02/09/19	2	Civil Project Manager
Expropriate land	50 días	mar 03/09/19	lun 11/11/19	6	Land expropiation[1];Civil Engineer 1;Civil Engineer 2
Geotechnical survey	60 días	mar 12/11/19	lun 03/02/20	7;4	Civil Engineer 2;Civil Engineer 1;Geotechnical survey[1]
Road path inspection	5 días	mar 04/02/20	lun 10/02/20	8	Civil Engineer 1;Civil Engineer 2
Determine road path	2 días	mar 11/02/20	mié 12/02/20	9	Civil Engineer 2;Civil Engineer 1
Construction of road	8 días	jue 13/02/20	lun 24/02/20	10	Civil Engineer 2;Excavator;Workforce
Road finish check	1 día	mar 25/02/20	mar 25/02/20	11	Civil Project Manager;Site Manager
Establish a construction office	3 días	mié 26/02/20	vie 28/02/20	12	Office in site[1];Site Manager;Workforce
Manpower mobilization	3 días	lun 10/02/20	jue 13/02/20	11CF	General Project Manager;Site Manager
Civil drawing	20 días	mar 04/02/20	lun 02/03/20	9CC	Civil Engineer 3;Civil Engineer 4
Civil drawing review and approval	7 días	mar 03/03/20	mié 11/03/20	15	Civil Project Manager;General Project Manager
Engineering designs	30 días	mar 04/02/20	lun 16/03/20	15CC	Electrical Engineer 1;Electrical Engineer 2;Mechanical Engineer 1;Mechanical Engineer 2
Engineering designs review and approval	7 días	mar 17/03/20	mié 25/03/20	17	General Project Manager;Mechanical Project Manager;Site Manager; Electrical Project Manager
Execution Phase	**170 días**	**jue 26/03/20**	**mié 18/11/20**		
Solar modules data sheet	10 días	jue 26/03/20	mié 08/04/20	18	Electrical Engineer 1;Electrical Engineer 2
Solar modules data sheet approval	3 días	jue 09/04/20	lun 13/04/20	20	Electrical Project Manager
Payment solar modules	0 días	lun 13/04/20	lun 13/04/20	21	Payment Solar Modules[0]
Manufacture solar modules	100 días	mar 14/04/20	lun 31/08/20	22	
Solar modules structure data sheet	2 días	mar 14/04/20	mié 15/04/20	21	Electrical Engineer 1;Mechanical Engineer 1

***Table 21**. Resources II*

Name of the task	Duration	Start	End	Predecessors	Name of the resources
Solar modules structure data sheet approval	2 días	jue 16/04/20	vie 17/04/20	24	Mechanical Project Manager;Electrical Project Manager
Payment solar modules structures	0 días	vie 17/04/20	vie 17/04/20	25	Payment solar module structures[0]
Manufacture solar module structures	60 días	lun 20/04/20	vie 10/07/20	26	
Inverter and transformer data sheet	7 días	lun 20/04/20	mar 28/04/20	25	Electrical Engineer 1;Electrical Engineer 2
Inverter and transformer data sheet approval	3 días	mié 29/04/20	vie 01/05/20	28	Electrical Project Manager
Payment inverter and transformer	0 días	vie 01/05/20	vie 01/05/20	29	Payment Inverters and transformers[0]
Manufacture inverters and transformers	60 días	lun 04/05/20	vie 24/07/20	30	
Connection and BoS dimension estimation	7 días	lun 04/05/20	mar 12/05/20	25;29	Electrical Engineer 1;Electrical Engineer 2
Connection and BoS dimension estimation approval	4 días	mié 13/05/20	lun 18/05/20	32	Mechanical Project Manager;Electrical Project Manager
Payment connection and BoS	0 días	lun 18/05/20	lun 18/05/20	33	Payment Connection and BoS material[0]
Manufacture BoS	30 días	mar 19/05/20	lun 29/06/20	34	
Determine land by smoothing it out	7 días	jue 26/03/20	vie 03/04/20	12;16;18	Site Manager;Workforce
Foundations excavation	14 días	lun 06/04/20	jue 23/04/20	36	Workforce
Foundations excavation approval	4 días	vie 24/04/20	mié 29/04/20	37	Site Manager
Activation transport permit	5 días	jue 30/04/20	mié 06/05/20	12;38	General Project Manager
Install protection system	10 días	jue 30/04/20	mié 13/05/20	38	Workforce;Mechanical Engineer 1
Rent cranes and transport machinery	3 días	mar 19/05/20	jue 21/05/20	33;39	Site Manager
Transport machinery to field	2 días	mié 22/07/20	jue 23/07/20	39;41;44FF	
Transport structures	7 días	lun 13/07/20	mar 21/07/20	39;27	
Arrival of first structures to the field	0 días	jue 23/07/20	jue 23/07/20	43FF+2 días	
Unload and place the structures	15 días	vie 24/07/20	jue 13/08/20	44;42	Workforce;Feather crane;Transport machine

***Table 22**. Resources III*

Name of the task	Duration	Start	End	Predecessors	Name of the resources
Transport inverters and transformers	15 días	lun 27/07/20	vie 14/08/20	31;43;39	
Arrival of first inverter and transformer to the field	0 días	mar 18/08/20	mar 18/08/20	46FF+2 días;45	
Unload and place the inverters and transformers	15 días	mié 19/08/20	mar 08/09/20	47;45	Workforce;Feather crane;Transport machine
Transport solar modules	15 días	mar 01/09/20	lun 21/09/20	46;39;23	
Arrival of first solar modules to the field	0 días	mié 23/09/20	mié 23/09/20	49FF+2 días;48	
Unload and place solar panels	20 días	jue 24/09/20	mié 21/10/20	48;50	Workforce;Feather crane;Transport machine
Transport connection and BoS materials	7 días	vie 09/10/20	lun 19/10/20	39;49;35;53FF-2 días	
Arrival of first elements of connection and BoS	0 días	mié 21/10/20	mié 21/10/20	51	
Unload and place connection and BoS materials	20 días	jue 22/10/20	mié 18/11/20	52;51	Feather crane;Transport machine;Workforce
Transport awarding	0 días	lun 19/10/20	lun 19/10/20	42;43;46;49;52	Excavator;Feather crane
◢ Connection and Testing Phase	**117 días**	**vie 14/08/20**	**lun 25/01/21**		
Connect solar modules electronic system	15 días	vie 14/08/20	jue 03/09/20	45	Electrical Engineer 1;Electrical Engineer 2
Connect solar modules with inverters and transformers	20 días	jue 19/11/20	mié 16/12/20	48;57;54	Electrical Engineer 1;Electrical Engineer 2;Mechanical Engineer 1;Mechanical Engineer 2
Connect inverters and transformers with the grid	15 días	jue 17/12/20	mié 06/01/21	58	Electrical Engineer 1;Electrical Engineer 2;Mechanical Engineer 1;Mechanical Engineer 2
Reliability test	3 días	jue 07/01/21	lun 11/01/21	59	General Project Manager;Site Manager;Workforce
Final inspections	10 días	mar 12/01/21	lun 25/01/21	60	Electrical Engineer 1;General Project Manager;Mechanical Engineer 1;Site Manager
◢ Closure Phase	**18 días**	**mar 26/01/21**	**jue 18/02/21**		
Defects list	10 días	mar 26/01/21	lun 08/02/21	61	Electrical Engineer 1;Electrical Project Manager;Mechanical Engineer 1;Site Manager
Manpower desmobilization	7 días	mar 09/02/21	mié 17/02/21	63	General Project Manager;Site Manager
Photovoltaic plant takeover signature	1 día	jue 18/02/21	jue 18/02/21	64	General Project Manager

ANNEX III. Reference case

Table 23. Income statement I

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
				-0,5%	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%
Energy generated (MWh)	-	-	95.343,45	94.867,96	94.394,68	93.923,61	93.445,29	92.988,07	92.523,61	92.061,35	91.601,30	91.132,41	90.687,81	90.234,38
Revenues for selling energy	-	-	**4.491.604,05**	**4.300.054,24**	**4.124.554,10**	**3.963.950,08**	**3.817.088,71**	**3.682.816,33**	**3.559.979,53**	**3.447.424,73**	**3.343.998,41**	**3.248.547,08**	**3.159.917,08**	**3.076.955,00**
				6,0%	8,0%	9,0%	10,0%	11,0%	12,0%	14,0%	16,0%	18,0%	20,0%	24,0%
SLR value in Euros	-	-	0,0364	0,0386	0,0417	0,0454	0,0500	0,0554	0,0621	0,0708	0,0821	0,0969	0,1163	0,1442
Total SLR	-	-	**3.469,73**	**3.659,57**	**3.932,62**	**4.265,17**	**4.667,79**	**5.155,90**	**5.745,76**	**6.517,44**	**7.522,45**	**8.831,06**	**10.545,57**	**13.011,12**
Government grant			**1.999.702,58**	**1.989.729,92**	**1.979.803,49**	**1.969.923,31**	**1.959.891,36**	**1.950.301,68**	**1.940.560,23**	**1.930.865,02**	**1.921.216,05**	**1.911.381,61**	**1.902.056,85**	**1.892.546,62**
Revenues	-	-	**6.494.776,37**	**6.293.443,73**	**6.108.290,21**	**5.938.138,56**	**5.781.647,86**	**5.638.273,91**	**5.506.285,52**	**5.384.807,19**	**5.272.736,92**	**5.168.759,74**	**5.072.519,50**	**4.982.512,74**
Variable costs O&M	-	-	324.167,71	322.551,07	320.941,91	319.340,26	317.714,00	316.159,43	314.580,27	313.008,60	311.444,42	309.850,18	308.338,56	306.796,88
Fix costs	-	-	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00
OPEX			**387.167,71**	**385.551,07**	**383.941,91**	**382.340,26**	**380.714,00**	**379.159,43**	**377.580,27**	**376.008,60**	**374.444,42**	**372.850,18**	**371.338,56**	**369.796,88**
EBITDA	-	-	**6.107.608,65**	**5.907.892,67**	**5.724.348,30**	**5.555.798,30**	**5.400.933,86**	**5.259.114,47**	**5.128.705,25**	**5.008.798,60**	**4.898.292,50**	**4.795.909,56**	**4.701.180,94**	**4.612.715,86**
Amortization	-	-	2.026.470,28	2.026.470,28	2.026.470,28	2.026.470,28	2.026.470,28	2.026.470,28	2.026.470,28	2.026.470,28	2.026.470,28	2.026.470,28	2.026.470,28	2.026.470,28
EBIT	-	-	**4.081.138,38**	**3.881.422,39**	**3.697.878,02**	**3.529.328,03**	**3.374.463,59**	**3.232.644,20**	**3.102.234,97**	**2.982.328,32**	**2.871.822,22**	**2.769.439,28**	**2.674.710,66**	**2.586.245,59**
Financial Expenses	-	-	-1.134.823,35	-510.670,51	-453.929,34	-397.188,17	-340.447,01	-283.705,84	-226.964,67	-170.223,50	-113.482,34	-56.741,17	0,00	0,00
EBT	-	-	**2.946.315,02**	**3.370.751,88**	**3.243.948,68**	**3.132.139,85**	**3.034.016,58**	**2.948.938,36**	**2.875.270,30**	**2.812.104,82**	**2.758.339,88**	**2.712.698,11**	**2.674.710,66**	**2.586.245,59**
Taxes	-	-	736.578,76	842.687,97	810.987,17	783.034,96	758.504,15	737.234,59	718.817,58	703.026,20	689.584,97	678.174,53	668.677,67	646.561,40
EAT - Net Income	-	-	**2.209.736,27**	**2.528.063,91**	**2.432.961,51**	**2.349.104,89**	**2.275.512,44**	**2.211.703,77**	**2.156.452,73**	**2.109.078,61**	**2.068.754,91**	**2.034.523,59**	**2.006.033,00**	**1.939.684,19**

Table 24. Income statement II

	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%	-0,5%
Energy generated (MWh)	89.783,14	89.334,12	88.887,29	88.442,68	88.000,26	87.560,06	87.122,05	86.676,95	86.252,66	85.821,27	85.392,09	84.965,11	84.540,34	84.117,77
Revenues for selling energy	**2.998.507,28**	**2.923.420,37**	**2.850.540,75**	**2.778.714,89**	**2.706.789,25**	**2.633.610,31**	**2.558.024,54**	**2.478.878,43**	**2.395.018,35**	**2.305.290,88**	**2.208.542,44**	**2.103.619,52**	**1.989.368,56**	**1.864.636,06**
	28,0%	34,0%	40,0%	47,0%	52,0%	54,0%	52,0%	50,0%	45,0%	44,0%	43,0%	38,0%	34,0%	29,0%
SLR value in Euros	0,1846	0,2473	0,3462	0,5090	0,7737	1,1914	1,8110	2,7165	3,9389	5,6720	8,1109	11,1930	14,9987	19,3483
Total SLR	**16.570,96**	**22.094,03**	**30.776,93**	**45.015,78**	**68.081,72**	**104.321,37**	**157.775,27**	**235.453,82**	**339.736,81**	**486.774,19**	**692.606,03**	**951.017,13**	**1.267.991,91**	**1.627.533,58**
Government grant	**1.883.082,62**	**1.873.664,87**	**1.864.293,37**	**1.854.968,11**	**1.845.689,09**	**1.836.456,31**	**1.827.269,78**	**1.817.934,41**	**1.809.035,44**	**1.799.987,64**	**1.790.986,08**	**1.782.030,76**	**1.773.121,69**	**1.764.258,86**
Revenues	**4.898.160,86**	**4.819.179,27**	**4.745.611,05**	**4.678.698,78**	**4.620.560,06**	**4.574.387,99**	**4.543.069,59**	**4.532.266,65**	**4.543.790,60**	**4.592.052,70**	**4.692.134,55**	**4.836.667,41**	**5.030.482,17**	**5.256.428,50**
				1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Variable costs O&M	305.262,69	303.736,00	302.216,80	300.705,10	299.200,90	297.704,19	296.214,98	294.701,65	293.259,05	291.792,33	290.333,11	288.881,38	287.437,15	286.000,41
Fix costs	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00	63.000,00
OPEX	**368.262,69**	**366.736,00**	**365.216,80**	**363.705,10**	**362.200,90**	**360.704,19**	**359.214,98**	**357.701,65**	**356.259,05**	**354.792,33**	**353.333,11**	**351.881,38**	**350.437,15**	**349.000,41**
EBITDA	**4.529.898,16**	**4.452.443,27**	**4.380.394,24**	**4.314.993,67**	**4.258.359,16**	**4.213.683,80**	**4.183.854,60**	**4.174.565,01**	**4.187.531,55**	**4.237.260,37**	**4.338.801,44**	**4.484.786,03**	**4.680.045,02**	**4.907.428,09**
Amortization	2.026.470,28	2.026.470,28	2.026.470,28	2.026.470,28	2.026.470,28	2.026.470,28	2.026.470,28	2.026.470,28	0,00	0,00	0,00	0,00	0,00	0,00
EBIT	**2.503.427,89**	**2.425.973,00**	**2.353.923,97**	**2.288.523,40**	**2.231.888,88**	**2.187.213,52**	**2.157.384,33**	**2.148.094,73**	**4.187.531,55**	**4.237.260,37**	**4.338.801,44**	**4.484.786,03**	**4.680.045,02**	**4.907.428,09**
Financial Expenses	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
EBT	**2.503.427,89**	**2.425.973,00**	**2.353.923,97**	**2.288.523,40**	**2.231.888,88**	**2.187.213,52**	**2.157.384,33**	**2.148.094,73**	**4.187.531,55**	**4.237.260,37**	**4.338.801,44**	**4.484.786,03**	**4.680.045,02**	**4.907.428,09**
Taxes	625.856,97	606.493,25	588.480,99	572.130,85	557.972,22	546.803,38	539.346,08	537.023,68	1.046.882,89	1.059.315,09	1.084.700,36	1.121.196,51	1.170.011,25	1.226.857,02
EAT - Net Income	**1.877.570,92**	**1.819.479,75**	**1.765.442,98**	**1.716.392,55**	**1.673.916,66**	**1.640.410,14**	**1.618.038,25**	**1.611.071,05**	**3.140.648,66**	**3.177.945,28**	**3.254.101,08**	**3.363.589,52**	**3.510.033,76**	**3.680.571,06**

***Table 25**. Profits I*

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
EAT	**-**	**-**	**2.209.736,27**	**2.528.063,91**	**2.432.961,51**	**2.349.104,89**	**2.275.512,44**	**2.211.703,77**	**2.156.452,73**	**2.109.078,61**	**2.068.754,91**	**2.034.523,59**	**2.006.033,00**	**1.939.684,19**
Legal reserve			220.973,63	252.806,39	243.296,15	234.910,49	227.551,24	221.170,38	215.645,27	210.907,86	206.875,49	203.452,36	200.603,30	193.968,42
Net profits	**-**	**-**	**1.988.762,64**	**2.275.257,52**	**2.189.665,36**	**2.114.194,40**	**2.047.961,19**	**1.990.533,39**	**1.940.807,45**	**1.898.170,75**	**1.861.879,42**	**1.831.071,23**	**1.805.429,70**	**1.745.715,77**
CAPEX	-1.311.862,75	-39.217.542,75	-	-	-	-	-	-	-	-	-	-	-	-
Profits	-1.311.862,75	-39.217.542,75	1.988.762,64	2.275.257,52	2.189.665,36	2.114.194,40	2.047.961,19	1.990.533,39	1.940.807,45	1.898.170,75	1.861.879,42	1.831.071,23	1.805.429,70	1.745.715,77

***Table 26**. Profits II*

	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
EAT	**1.877.570,92**	**1.819.479,75**	**1.765.442,98**	**1.716.392,55**	**1.673.916,66**	**1.640.410,14**	**1.618.038,25**	**1.611.071,05**	**3.140.648,66**	**3.177.945,28**	**3.254.101,08**	**3.363.589,52**	**3.510.033,76**	**3.680.571,06**
Legal reserve	187.757,09	181.947,97	176.544,30	171.639,25	167.391,67	164.041,01	161.803,82	161.107,11	314.064,87	317.794,53	325.410,11	336.358,95	351.003,38	368.057,11
Net profits	**1.689.813,83**	**1.637.531,77**	**1.588.898,68**	**1.544.753,29**	**1.506.524,99**	**1.476.369,13**	**1.456.234,42**	**1.449.963,95**	**2.826.583,80**	**2.860.150,75**	**2.928.690,97**	**3.027.230,57**	**3.159.030,39**	**3.312.513,96**
CAPEX	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Profits	1.689.813,83	1.637.531,77	1.588.898,68	1.544.753,29	1.506.524,99	1.476.369,13	1.456.234,42	1.449.963,95	2.826.583,80	2.860.150,75	2.928.690,97	3.027.230,57	3.159.030,39	3.312.513,96

***Table 27**. Debt I*

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Loan payments			2.837.058,39	2.837.058,39	2.837.058,39	2.837.058,39	2.837.058,39	2.837.058,39	2.837.058,39	2.837.058,39	2.837.058,39	2.837.058,39	0,00	0,00
Accumulated payments			2.837.058,39	5.674.116,77	8.511.175,16	11.348.233,54	14.185.291,93	17.022.350,31	19.859.408,70	22.696.467,08	25.533.525,47	28.370.583,85	28.370.583,85	28.370.583,85
Principal at the end	28.370.583,85 €	28.370.583,85	25.533.525,47	22.696.467,08	19.859.408,70	17.022.350,31	14.185.291,93	11.348.233,54	8.511.175,16	5.674.116,77	2.837.058,39	0,00	0,00	0,00
Real loan payment			-2.837.058,39	-2.837.058,39	-2.837.058,39	-2.837.058,39	-2.837.058,39	-2.837.058,39	-2.837.058,39	-2.837.058,39	-2.837.058,39	-2.837.058,39	0,00	0,00
Financial Expenses		-567.411,68	-1.134.823,35	-510.670,51	-453.929,34	-397.188,17	-340.447,01	-283.705,84	-226.964,67	-170.223,50	-113.482,34	-56.741,17	0,00	0,00
Cash Flow Debt	0,00	0,00	-3.971.881,74	-3.347.728,89	-3.290.987,73	-3.234.246,56	-3.177.505,39	-3.120.764,22	-3.064.023,06	-3.007.281,89	-2.950.540,72	-2.893.799,55	0,00	0,00

***Table 28**. Debt II*

	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
Loan payments	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Accumulated payments	28.370.583,85	28.370.583,85	28.370.583,85	28.370.583,85	28.370.583,85	28.370.583,85	28.370.583,85	28.370.583,85	28.370.583,85	28.370.583,85	28.370.583,85	28.370.583,85	28.370.583,85	28.370.583,85
Principal at the end	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Real loan payment	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Financial Expenses	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Cash Flow Debt	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00