Risks and opportunities in the solar photovoltaic energy self-consumption for the housing sector in Tenerife Sur.

Final dissertation for Master in Renewable Energies

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ABSTRACT

The development of a stable market of hundreds and thousands of prosumers of PV solar self-consumption in the residential sector has been an opportunity well taken advantage of in some countries and regions to promote the energetic transition.

The present work describes in the first part the current situation of PV solar self-consumption in Europe, Spain and the Canary Islands, summarizing its main characteristics of regulatory support systems for the surplus energy that is injected into the grid. In the second part, a real case of a house that meets the self-consumption profile in the residential sector is studied. The technical and economic viability of the PV solar installation is analysed according to the real calculation of consumption and hourly production. The recent proposal of economic compensation of RD 15/2018, of Self-Consumption of last January 2019 is applied and is pending approval.

In the most unfavourable case is calculated the option to continue for 25 years with the current supply of electric company. The next scenario that does not offer advantages of economic profitability is the case of PV solar installation without batteries, with injection to the network. Unfortunately, the economic compensation is not enough, and the net billing proposed by the RD, in this housing profile is not economically viable. The purchase of energy at a price higher than the energy that is injected, without subsidies to the injection or energy compensation make this scenario unfeasible. The last mode with battery storage is more reasonable, with viable profitability results, but unattractive to investors.

Due to the above, the proposed measures do not encourage or promote the appearance of hundreds of prosumers in the profile of single-family homes in Tenerife.

CONTENTS

INTRODUCTION

Self-consumption in solar PV in the housing sector can have a leading role in the energy transition path. Some European countries have a very mature market in this sector, with decades of experience, while others affected by national policies and local economic and cultural factors that have not allowed democratizing photovoltaic, PV, solar self-consumption to put it at the service of citizens. Therefore, they slow down and restrict the energy transition. (IEA (International Energy Agency) , 2016)

The main purpose of this analysis is to describe some of the most important factors in order to understand the current state of affairs in Europe regarding solar PV self-consumption in the housing sector. This way, opportunities and risks will be identified in Spain in order to describe and profile the right and viable targets for solar PV housing self-consumptions in Tenerife Sur.

The hypothesis of this paper is to assess relevant causes like limitations and blockages to regulatory policies that have not allowed the blooming of prosumers of solar PV self-consumption in Tenerife. In addition, to confirm that, to this day, the best conditions and right polices to promote PV self-consumption in Tenerife had not been yet met.

For the purpose of this study, a hypothesis will be tested out. It will aim to see if in a typical detached house built in the 1980s in Tenerife, the number of occupiers, rooms, size of the house, and income, which makes for higher energy consumption, will influence the viability for investment in renewable energy, and therefore help switch from consumers to active Prosumers.

JUSTIFICATION

"[S]ince everybody can actively take part, even on an individual basis, a solar strategy is 'open' in terms of public involvement… It will become possible to undermine the traditional energy system with highly efficient small-technology systems and to launch a rebellion with thousands of individual steps that will evolve into a revolution of millions of individual steps"

Summary of the text Hermann Scheer. A solar Manifiesto (2005). (IEA (International Energy Agency) , 2016)

PV energy generation for residential self-consumption has been, in some countries, the driver for the change in the energy paradigm. Residential elf-consumption has grown rapidly, in great part thanks to the affordability due to lower costs and on-location decentralized distributed availability of installations. This has offered a democratization of PV systems.

LOWER COSTS. Economic policies that have supported local businesses and service companies to install de-centralized PV have resulted in increased volume of PV installations on rooftops. Europe is leading the way in reducing production costs, with reductions from 40 to 75% both in hardware and installation costs. (IEA (International Energy Agency) , 2016)

China is the biggest producer of PV modules, with 7 of the biggest PV panel makers thanks to its economy of scale. (Lian, 2014)

Despite these advancements in affordability, it is in the PV residential sector where higher costs can be observed. Due to economies of scale there can be perceived a great discrepancy between the different sectors. Even as prices of hardware continue to go down, the variable costs of installation, permits, operation and maintenance depend on each geographical region and/or country. (IEA (International Energy Agency) , 2016)

RAPID INCREASE due to growth in total capacity installed annually. Total global installed capacity of solar power has increased greatly in the last few years: From 770MW in 2014, to 98

GW in 2017. Global PV market places Europe in the 4th position, with total installed PV capacity in 2017 of 9.2GW, after Japan (7 7GW in 2017), United States (10.6 GW installed in 2017) and China in first place with 53GW installed in 2017. (solarpowereurope.org , 2018)

Europa has a total accumulated capacity of 114GW, an increase of 28% from 2017 as shown by the following figure. (IEA PVPS 2018 , 2018)

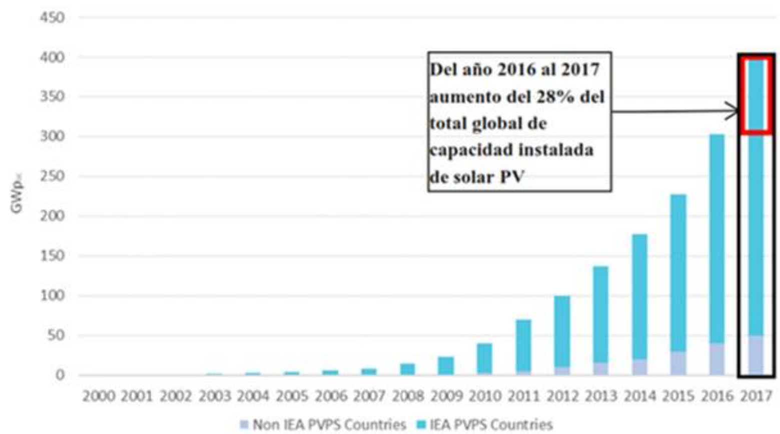


Figure 1 Installed capacity GW-DC (IEA PVPS 2018, 2018)

DECENTRALIZATION. Electricity coming from a PV system is de-centralized when it is produced and consumed in-situ, or self-consumed. Smaller PV systems connected to the power grid represent the 4D of energy: Decarbonized, digitalized, distributed and democratized which empowers smaller players on top of providing 3 times more job opportunities those large-scale projects. Other factors that are related with the growth of decentralized PV systems, and tied with the energetic transition are the bloom of Smart cities, growth in electric vehicles (EVs), improvement in battery storage and buildings, which are increasingly efficient and sustainable. (solarpowereurope.org , 2018)

18 % of total PV systems installed globally in 2017 (98GW) are decentralized small-scale systems for residential or small businesses, the other 82% being centralized large-scale

installations. This has been calculated from data taken from this graph of solar market segmentation from the IEA. (IEA PVPS 2018 , 2018)

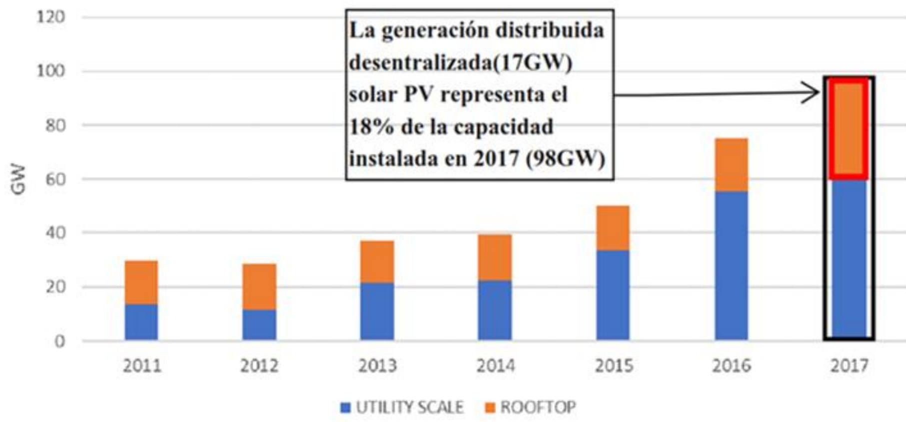


Figure 2 Segmentation of PV installation 2011-2017. (IEA PVPS 2018, 2018

CONTENT OF THIS WORK

This paper will advance in two parts:

Part 1.

Brief comparative description of the current situation of small-scale PV for residential self-consumption in Europe, Spain and Canary Islands.

Part 2.

Case study of an isolated single-family house, starting preliminary study with an analysis of electricity consumption in the residential sector in Canary Islands

A study of the viability of a PV system in the rooftop with the current policy of the Royal decree 15/2018, with and without storage. In addition, its most recent update on self-consumption proposal for economic compensation not yet approved and published on the website of the Ministry of Energy Transition (January 2019).

OBJECTIVES

Part 1

Describe with a general vision the current situation of self-consumption and analyse the causes that have made viable residential electricity self-consumption viable is some countries of Europe, Spain and Canary island.

Part 2

The main interest of this study is to assess the viability for PV self-consumption for a real case of a single-family house in Tenerife with today's economic climate and under current policies and market regulations, it will look at different scenarios using electricity from the grid or storing it in batteries.

The consequences of the current regulations for self-consumption in the Canary Islands will be looked at and compared with the current situation of energy supply with Iberdrola electricity Reference Company. Checking the viability for investors in each one. It will identify risks and opportunities of the different scenarios of future regulations.

CURRENT SITUATION OF SOLAR PV SELF-CONSUMPTION IN EUROPE, SPAIN AND CANARY ISLANDS

Segmentation in the PV market. .Small rooftop vs PV ground mounted systems.

However it is well known that small-scale distribute generation system require more time to penetrate markets, and need more education for the consumers. It also requires the slow start of financial mechanisms and the regulations of technical standards. Solar panels have been made into construction materials that require strict compliance to building regulations. Passive consumers evolve toward prosumers due to increased energy tariffs.

The low cost of solar energy from large-scale installations compared to the cost of rooftop installations in residential and commercial sectors has made a great increase of buying solar power purchase agreements (PPA's) possible. (solarpowereurope.org , 2018)

As shown in the graph, in 2016 Spain, Rumania, and UK have had mostly large-scale installations. This is mainly due to the economic support offered by the policies and regulations in place in the energy sector of each country.

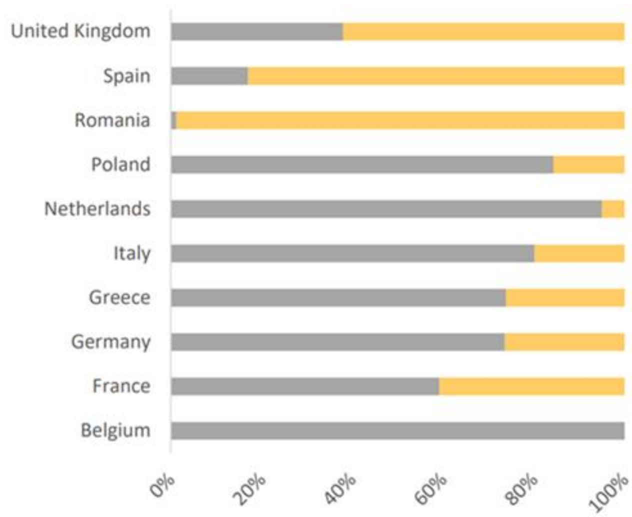


Figure 3 market share per PV market segment in 2016. (solarpowereurope.org, 2018)

In **Rumania** 99% of installations are ground-mounted due to the lack of support to the residential sector and the low and regulated energy prices in the sector. A change is expected in 2017 , loans toward households to help with initial investments on PV self-consumptions installations. Furthermore, there are no rewards for exporting unused electricity back to the grid.

In **Spain** the FIT (Feed-in tariffs) were responsible for a 90% of ground-mounted installations between 2007/2008, however a change of policy and a reduction in the feed-in tariff reduce new installations by 85% in 2014.

In the **UK** from 2014, ground-mounted installations have surpassed rooftop installations toward large-scale projects, allowing owners to receive money for electricity generation. In 2017 there was half the capacity installed (0.954GW) than in 2016 (1.97GW) and this was mainly due to cuts in incentives.

Against this trend, in **Belgium and Netherlands** there were hardly ground-mounted installations before 2016 as rooftop installations were more profitable.

Smaller (<250kw) rooftop installation in **Belgium** are in the residential sector due to financial help in the form of tax cuts for the initial investment, and Green Certificates. In addition, there are very few systems of economic support for large-scale installations (less than 1% of total capacity) exporting electricity back to the grid.

In the **Netherlands** large scale installations were only 1% of total installed capacity but thanks to subsidizes this has grown to 5% in 2016. Therefore, the remaining 95% belongs to small-scale rooftop installations in the residential sector. Between 2017 and 2017, the PV market increased 54% reaching 770MW installed in 2017. (solarpowereurope.org , 2018)

Small rooftop installations in the residential sector in Europe

In 2017 36% of PV rooftop systems in Europe were installed in public service buildings, 26% was installed in residential buildings, 20% in industrial buildings, and 18% in commercial buildings. (solarpowereurope.org , 2018)

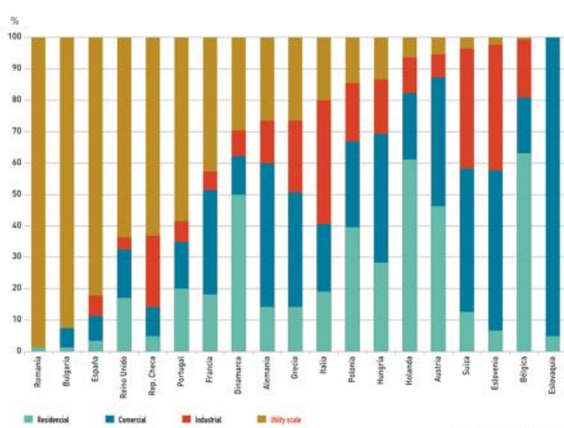


Figure 4 PV power accumulated in European countries by segments. (solarpowereurope.org , 2018)

The European countries with most residential rooftop PV installations in percentage from total PV installations are Belgium 63%, Netherlands 61%, Denmark 50%, Austria 46% and Poland 40%. Although this does not correlate with the list of 10 countries with most PV capacity: Germany, UK, Italy and France they have only 14%-19% of residential PV from total solar PV installation. (solarpowereurope.org , 2018)

Germany: As extracted from the previous graph, Germany has the highest installed capacity in the residential sector: 5.88GW, 14% of its total PV capacity. In 2009, it introduced the self-consumption bonus, allowing the prosumer to receive a complementary payment to the FIT for self-consumed energy. This bond was scrapped in 2012 with some exceptions because self-consumption has lowered in price making it an attractive investment due to his lack of charges for electricity connection and use of the grid for small installations and self-consumption.

Italy: installed capacity in the residential sector: 3.74GW, 19% of total PV installation is small-scale residential PV. FIT has allowed simplified purchase and resale to small-scale producers that export the surplus electricity back to the grid. It is running since 2008 with guaranteed price. It also operates with Net Metering compensation system, (scambio sul posto) the self-generator pays for the energy consumed and receives a credit for the injected energy, of equal value to the electricity purchased.

UK: installed capacity in the residential sector 2.28GW, 18%. Of total PV installation is residential solar PV. FIT, Feed in tariff remuneration introduced in 2010, payment of 20 to 25 years, the rate paid depended on whether the home is individual or collective. In 2011, half have reduced the rate. New facilities have a new rate system since 2016.

France: Holds the 4th place in accumulated installed capacity in households: 1.52GW, 19% of total accumulated. FIT remuneration is paid in agreement with the PPA (Power Purchase

Agreements) in order to incentivise all new renewable energy installations. Bonds vary from €0.0551 /Kwh up to €0.2393 /Kwh.

Belgium: It has 2.43GW residential installed. The systems of compensation of injection to the surplus network are not attractive for large investors. Facilities of less than 250kW have Green Certificate support, as well as tax incentives and tax reduction. It partially uses Net Metering mechanism. (solarpowereurope.org , 2018)

Netherlands: It has 1.79GW installed in the residential sector. Housing rooftop installations stand for 95% of the market. Large installations, however, are also incentivised by a biannual subsidize and since 2014 the percentage of large installations have gone from 1% to 5%. They use partially a net metering mechanism. FIT payments toward Coops and ONGs, increasing the incentive for small and large installations in order to reach 2020 objectives. (solarpowereurope.org , 2018)

From producers to prosumers

Self-consumption in systems connected to the grid are defined technically when the energy consumed happens at the same time that the energy is generated in location. The size of small installations in housing is up to 10kW. (From 10kW to 250kW is defined as commercial, <250kW industrial). (GfK Belgium consortium, May 2017)

Self-consumption success occurs when the energy produced in the rooftop of the house has the same cost tan the energy bought from the utility Company without governmental subsidies. (IEA (International Energy Agency) , 2016)

The essence of self-consumption in the housing sector is to match high consumption hours with high producing hours, and for the price of excess energy exported back to the grid to be higher than the price of energy purchased from the energy company or at the very least these are in equilibrium. (IEA-PVPS. PHOTOVOLTAICS POWER SYSTEMS PROGRAMME., 2016)

Therefore, the variables in the core of self-consumption are shown:

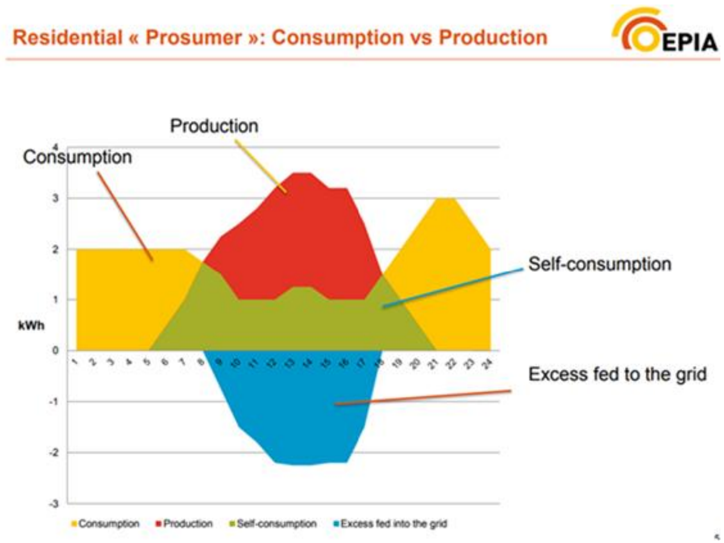


Figure 5 Profile of consumption and production connection to the grid.

Graphic from: Latour, Maire. Senior National Policy Advisor

No European country has a precise definition for "residential Prosumer". However some countries have adopted similar concepts that can focus on production or elements of consumption that define a prosumer, like the size of the installation or the generation capacity. Some countries use 10kW to define residential Prosumers.

European countries generally allow Prosumers to export the excess generated back into the grid, but not all countries will not make this payable back to the prosumer. (. IEA-PVPS., September 2012)

Comparative outline of incentives

Most regulations It is directed to support the use of renewable sources. For self-consumption, the incentive is geared toward exporting back to the grid excess of energy not consumed, with a tariff payment to the prosumer. There exists different versions of these incentives like COMPENSATION OR REMUNERATION, and there are countries that do not reward the injections back to the grid.

COMPENSATION: The selling of excess energy has been subsidized in numerous countries, and the mechanism most used is compensations. Net metering is the measurement of the difference between the energy exported back into the grid and the energy consumed from the grid, so credits can be earned. This is measured with a bi-directional meter during an established period of time (hourly, daily, monthly or yearly)

The most common type of REMUNERATION is the FIT (Feed-in Tariff) system. It is subsidized tariff, with a higher price than the regular one in order to incentivize self-consumption. It is based in buying energy at a retail price and selling the energy back to the grid at a higher regulated price with long-term contracts.

Other compensation method are Green certificates, tax cuts and help on initial investments. It is usually assumed that in Europe 47% of self-generated electricity is self-consumed and the 53% remaining is exported back to the grid. (IEA-RETD, 2014)

BONUSES The law of energy transition in France made the additional bonus FIP (Feed-in Premium), as an additional help to the remuneration to the installations that possess all the specified qualities of the regulations, for up to 20 years, in installations up to 100kW, it is carried out through public tenders for any source of renewable energy . It is necessary to be connected to the grid. The Wallonia region in Belgium has also established a FIP. It is a complementary bond at market price, fixed or variable. (Bancourt, 2018)

Self-consumption register in Spain

Total installed capacity in Spain

Castilla la Mancha, Andalucia and Extremadura have been at the forefront of the PV energy from the beginning, and represent, in total, half the national PV capacity (2.3GW, total PV capacity in Spain, on 31 December 2017 is 4.7GW) And these three communities have similar average irradiation day values compared to the Canary Islands. (5.0 – 5.5 kWh/m2). (Red Eléctrica de España, 2017)

Navarra vs. Canary Islands

The community of Navarra has almost equal capacity installed than the Canary Islands (161MW and 167MW). However, there is a big difference in the number of installations: 9060 PV installations registered in Navarra vs 1531 in Canary Islands. This is because the Navarra regional government has granted very attractive fiscal incentives towards small producers.

Residential sector registry

According to the Administrative Record of Electricity Self-Consumption, the Autonomous Community that has done more registers in section 1, type 1, (power outputs ≤10kW) is Andalucía. It has a total of 50 installations registered with a total capacity of 202kW, which means an average of 4kW per installation. The average in the rest of communities is 3.6kW. According to estimates from the PV yearbook of Anpier 2018, Administrative Record of Electricity Self-Consumption there is 640 entries with 20MW of total installed capacity .Of this total registered (December 2017) it is estimated based on the contracted power that only 4% corresponds to installations in the housing sector. (ANPPIER. National association of PV energy producers, 2018)

Self-consumption registry in the residential sector in the Canary Islands

The Canary Islands is the only Autonomous Community, among the most irradiated, with an installed PV capacity of less than 500GMW in December 2017.

In Las Palmas (capital of Canary Islands) between 2017 2018 only eight installations (type one ≤10kW), with a total of 43kW. Meanwhile in Santa Cruz de Tenerife there were only two installations in 2018. (5.5kW and 9.2kW).

(https://sedeaplicaciones.minetur.gob.es/REA/Vista/RegistroPublico.aspx, 2019)

Despite the statistical data of the Self-consumption Register since 2017, this unique registration is declared unconstitutional, leaving the regulation of the registration of this procedure to the Autonomous Communities, so it is only an indicator with full knowledge that not all existing facilities are inscribed in it.

Electrical consumption in the residential sector

Following an extraction of relevant data from Spahouse study in 2011 Characteristics of the electrical consumption, about the characteristics of housing and their electrical usage in Spain, in the Mediterranean climatic zone, due to it being more similar to Tenerife

- Single-family homes are 30% of total housing stock in Spain. 94 % are in private ownership in the Mediterranean zone.
- Average single-family home size in Spain is 140m2.
- 23 % live in low population density.
- 55.9% of the population has an annual income €6.000 - €23.999
- Single-family homes are correlated with larger houses and the presence of children.
- In the Mediterranean zone, the main source of energy for heating is electric.
- Electrical heating and refrigeration are preferred, like reversible heat pumps and portable electric radiators.
- In Spain only 1% of houses have ACS with solar panels, of this percentage, 87% is in the Mediterranean zone. Also 70% of houses in the Mediterranean zone use electric boiler.
- In the Mediterranean zone, the kitchen uses mostly uses the electric source of energy.
- Lighting, The average number of light bulbs per home increases in Mediterranean homes, as well as in single-family homes. (EUROSTAT. IDAEDepartamento de Planificación y Estudios. , 2011)

EXPERIMENTAL METHODOLOGY

In the following section *Experimental Methodology*, the methods or procedures to carry out the calculations are shown, while in the *Results and Data* section, the results are summarized. At the end of the document, the calculations can be observed in detail in the *Annexes*. The order that has been followed in each of these sections is as follows:

1. Electricity consumption in the house
2. PV solar generation
3. Coincidence between consumption and generation: Self-consumption

Consumption

The experimental method has been followed based on measures of real consumption or demand of the case study house *Casa Sabinita.* A correction factor (or average) has been applied between the estimated data (hourly, daily and monthly) of real consumption of the house by the data of energy company bills Iberdrola, taken from 5 months (they are the only invoices available). Also in this average is included the data resulting from the study *Pilot Project on the Characterization of the final uses of energy,* taking the description of final energy usage of different types of consumers in the Canary Islands (thirteen different single-family detached houses, *chalet* type, in Tenerife Sur). (Dirección General de Industria y Energía delGobierno de Canarias en Colaboración con La Fundación General de la Universidad de Laguna)

Electricity generation

The PV installation has been measured by the standard radiation and temperature of the location, as well as technical requirements for the configuration of the system. According to the demands by the recently established Royal Decree 15/2018, of Self-Consumption and its compensation proposal not yet approved or published in the official state bulletin, *BOE.* from the end of January 2019. (Ministerio para la Transición Ecológica, 2019)

The calculation has taken two modalities available in the RD, of the PV installation and makes a comparison between these modalities and the current state of supply and invoicing with reference company Iberdrola

Different modalities available in the RD:

- Self-consumption installation with battery storage with energy meter.
- Self-consumption installation without storage in batteries and with surplus injection to the local distribution network.

Economic analysis of self-consumption

All calculations have been done by the hour, for a day representing each month, with all appliances working at their real usage, also counting for the month consumption the number of working days and weekends of each month of the year.

Different scenarios have been tested to assert the technical and economical viability for the next 25 years. Profitability has been compared, depending on initial investment, energy costs and export (or not) of surplus energy back to the gird. With compensation and remuneration mechanism: Net billing, according to the Royal Decree proposal in self-consumption economic rates of purchase and sale of electricity.

Residential electrical consumption in the Canary Islands

This is taken from a pilot scheme that profiles energy use in different types of consumers.

Looking at the composition of energy use in the Canary Islands, petroleum products represent 82.3%, electricity 17.5% and solar 0.2% from total use.

A goal of this study is that conclusions made are coherent with an extrapolation to all the population, with the sample of thirteen detached houses in Tenerife.

Features that have been taken into account are number of inhabitants, rooms, size of the house, or number of children or elder (as they spend more time at home) etc. Also take into account that many of the energy use are fixed, so it is not dependent on these features.

Air conditioning and heating in energy use is very low (3%) compared to the rest of Spain (40%). Generally, at the islands houses only have one service of air-conditioning or heating. So annual consumption is low, because is occasional (only during certain months).

In the table below the average between real measurements of homes, using appliances in real time and a representative home using all appliances.

Large appliances	24.6%
Kitchen	19.2%
Hot water	16.2%
TV and computer	12.1%
Interior lighting	10.4%
Acclimatization	7.0%
Small appliances	4.9%
External illumination	2.5%
Others: e.g. pool purification system	3.0%
Total	100.0%

Fridge	22.80%
Drying machine	22.65%
Washing machine	13.50%
Freezer	10.10%
Dishwasher	7.60%
Oven	7%
Iron	6.90%
Vacuum	3.70%
Fryer	3.30%
Hair dryer	2.15%
Grill	0.30%
Total	100%

Table 1 Summary of energy consumption by final uses and detail of large appliances

Large appliances, TV and computers take over 40% of housing electricity use.

In the table below total consumption is shown considering a typical house in Tenerife. (Flat, single-family, semi-detached with terrace). It is made up of the average energy use of 64 houses, which were surveyed in Tenerife (30 Metropolitan, 17 North, and 17 South).

Bi-monthly electrical consumption kWh, island of Tenerife								
	Case studies	January-February	March-April	May-June	July-August	September - October	November-December	Average monthly
Tenerife	64	674.73	528.22	558.29	605.33	592.41	657.13	301.3
							Metropolitan area	351.02
							South	224.22
							North	290.79

Table 2 Summary of bi-monthly consumption

While economical factors that influence electricity consumption are not analysed in detail, it is worth mentioning that income per capita is a decisive factor.

The average consumption per month and per capita in the island of Tenerife is 125.2kW/month/person, with an average of 2.74 people per house.

The relevant data for this study is:

13 detached houses in Tenerife, on average 274m2; 6,1 rooms per house; 3,2 inhabitants per house; 2,7 average number of adults, 0,72 intensive use of the house

	Electrical consumption by type of dwelling			
	Type of dwelling			
Results by Islands	Flat	Semi-detached	**Detached**	Country house
Gran Canaria	285.29 (16)	336.71 (2)	**401.48(4)**	365.19(3)
La Gomera	179.61 (12)	327.42 (2)	**274.12(5)**	199.7(5)
Lanzarote	237.79 (8)	471.58 (3)	**595.51(6)**	313.86(7)
Tenerife	205.61(27)	298.16(12)	**556.92(13)**	243.04(12)
Total	224.98(63)	332.68 (19)	**492.19(28)**	266.95(27)

Table 3 Electrical consumption by types of welling. In parenthesis cases considered.

CASE STUDY: CONSUMER PROFILE

The case study analysed is isolated single-family housing, with six continuous occupants in the year and two young people who occupy only for vacations. The location and distribution of the home are explained in the following graphics.

An isolated single-family home, constructed in 1980, one floor, in the Municipality of Arona

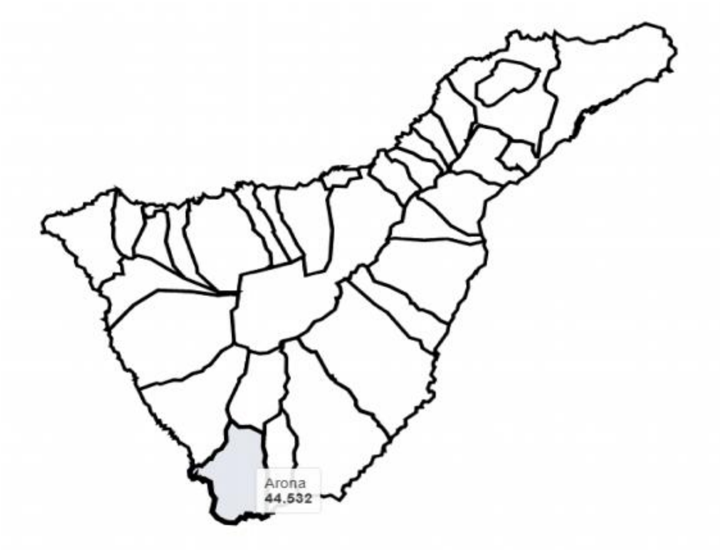


Figure 6 Location of Arona Municipality

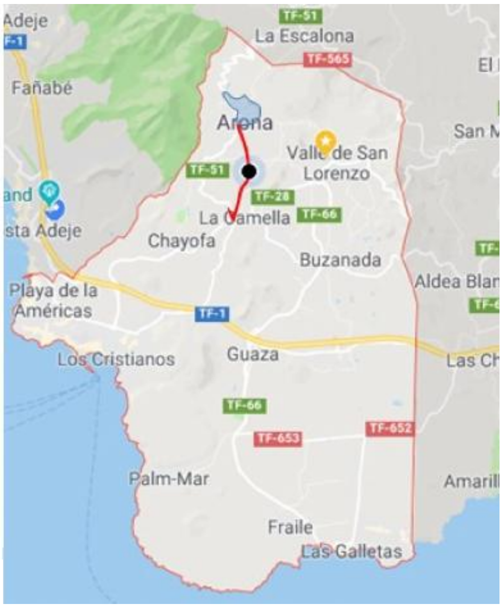


Figure 7 Location of house: La Sabinita 33, Arona

Figure 8 Orthophotoma of housing location Sabinita 33

Location of the plot is on rustic ground, with construction on urban land, in Sabinita Street 33, La Sabinita Alta, Arona.

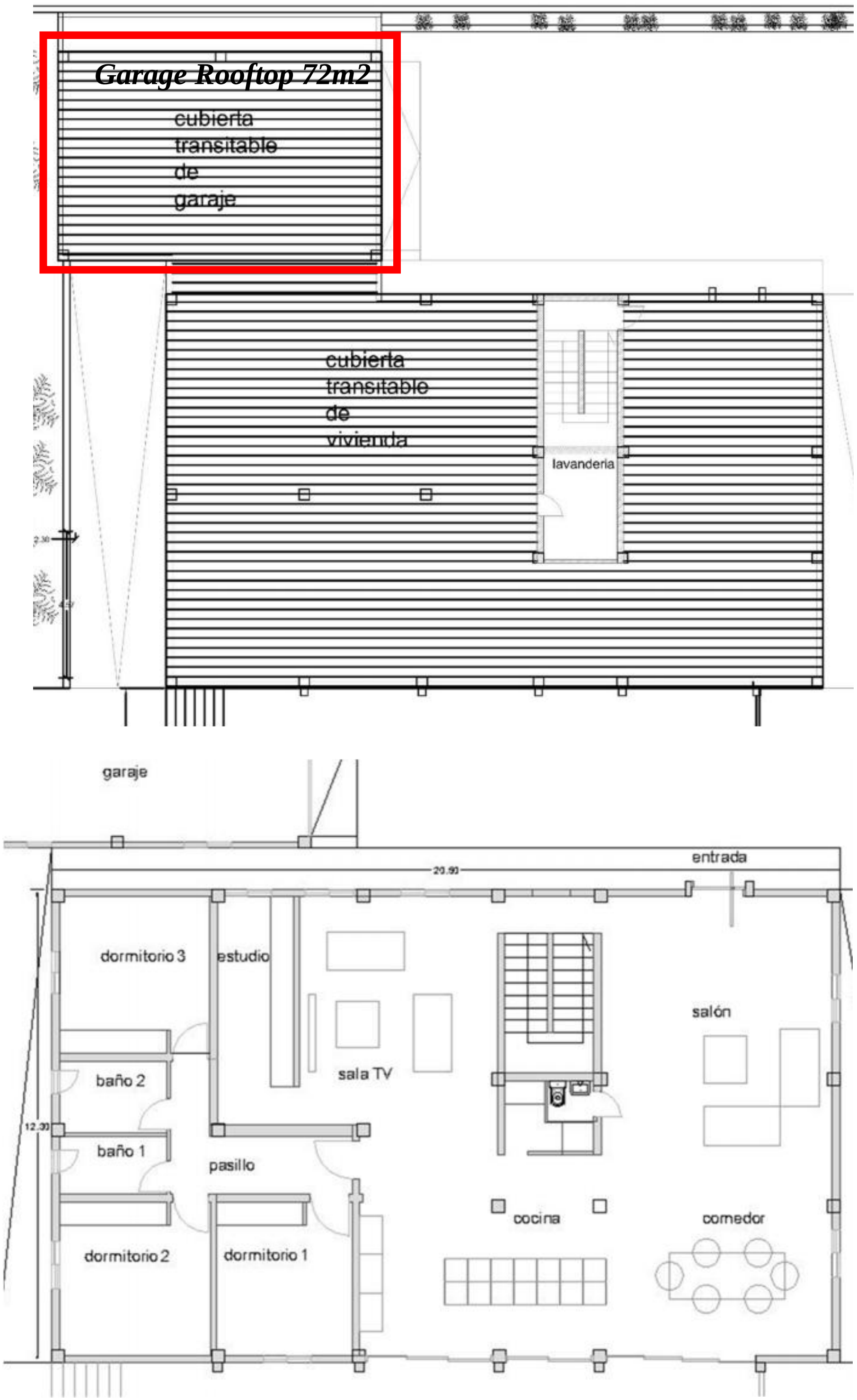


Figure 9 Floor plan of rooftop casa Sabinita

Total Floor area	
House	232.86
Garage	72.74
Total	305.6
Built surface m2	
House	252.15
Garage	78.17
Total	330.32

Built Surface	250m2
Solar surface	2700m2
Building history	Built in 1979
Number of occupiers	4 adults 2 children
Average income	10% of population has an income of €30.000 - €35.900
Ownership	Sole ownership
Type of building	Detached single-family home
Height	320 meters
Municipality	Arona. Population: 79.900
Climate	Temperate / dry climate
Rooftop area available	More than 150m2
Number of vehicles	3
Education level	Master degree
Type of school	International private
Swimming pool	No
Animals	Dogs and cats

Table 4 detail of the characteristics of the self-consumption profile housing

Detailed measurements of the final usage of electricity

All appliances have been checked for their power and for their intensity of use. This intensity has been measured in number of hours per days, and it has been measured in summer (June) winter (December) and spring (March). Consumption in July is much reduced as the family leaves the island, and has done so in the last 7 years. For the remaining months, estimates have been made taking an average of the three initial months of the season, and for summer, it is different, because there are two more occupants.

Acclimatization is only used for cooling 2 months per year, and this is the period where most people live in the house. For the air conditioning, it has a support system with thermal panels, and for the 2 months with less radiation, they only use the electric thermal storage heaters.

				Summer	Winter	Spring/Autun
MAJOR HOME APPLIANCES	**Brand and model**	**Quantity**	**Power (watts)**	**Daily usage (hours)**	**Daily usage (hours)**	**Daily usage (hours)**
Home refrigerator	A++ Samsung side by side 639 lt. RH25H5613	1	82,5	24	24	24
Tumble dryer	A++ Samsung Series 5, 8kg DV80M5010QW/EC	1	720	0,5	0,50	0
Washing machine	A+++. Samsung.Lavadora EcoBubble 8kg WW80J5455DW	1	800	0,5	0,5	0,5
Clothes iron	Bosch TDA5028010	1	2800	0,08	0,08	0,08
Dishwasher	A++ Serie 2 Lavavajillas libre instalaciónPuerta acero antihuellas	1	2400	0,5	0,5	0,2
	Convección	1	2200	0,2	0,2	0,2
2 in 1 Becken oven	Microondas	1	1400	0,5	0,5	0,2
Vacuum cleaner	Dyson ball DC 52 Total animal	1	1300	0,8	0,8	0,8
Hair dryer	Phillips Salon dry	1	2200	0,5	0,5	0,15
Electric griddle	JATA GR-555	1	2500	0,2	0,2	0,2
KITCHEN						
Induction hob	Siemens flexinducción iQ700Placa de	1	2200	1	1	1
	EX675LYC1E					
TV and PCs						
TV	55UF6807 TV LG LED de 55", Resolución 4K, Panel IPS, 900 HZ PMI, SmartTV (webOS 2.0)	1	130	6	3	4
Apple iMac (mediados de 2010)	Pantalla de 21,5 pulgadas, procesador Intel Core i5 a 3,6 GHz, 4 GB de SDRAM DDR3 a 1333 MHz (2 x 2 GB), disco duro Serial ATA de 1 TB, tarjeta gráfica ATI Radeon 4670	1	161	4	3	4
PC (laptop)	HP Chromebook 14 G4	1	2	4	4	5
PC (laptop)	ACER V3-772G-7872	1	37	4	4	5
ACS ELECTRIC BOILER	EQUATION 200lt	1	2200		2,5	2
AC unit	**Haier**	2	1000	2	1	0
MINOR HOME APPLIANCES						
Orange juicer	Taurus 160 Legend - Exprimidor de cítricos - 160 W - acero	1	160	0,16	0,16	0,16
Sandwhich toaster	Taurus Toas anf go	1	700	0,16	0,16	0,16
Blender	Clásica Oster plateada de 3 velocidades	1	600	0,03	0,03	0,03
Burger maker	SilverCrest	1	800	0,16	0,16	0,16
Cupcake maker	Larry House	1	1200	0,41	0,41	0,41
Kitchen robot	Thermomix VorWerk	1	1500	0,25	0,25	0,25
Electric coffee maker	UFESA CG7212	1	600	0,16	0,16	0,16

Table 5 detail of calculation of consumption of all electrical devices of the house

				Summer	Winter	Spring/Autumn
OTHERS	Brand and model	Quantity	Power (watts)	Daily usage (hours)	Daily usage (hours)	Daily usage (hours)
Water softener	Hidrosalud Bio30	1	10	0,5	0,5	1
Reverse osmosis	Versus	1	29	0,5	0,5	0,5
Printer	Imprimiendo		9	0,40	0,10	0,20
WiFi modem	MOVISTAR Home Gateway Unit (HGU	1	7	24	24	24
Gaming consoles	PS4 active	1	165	2	2	
	XBOX One S	1	120	1	1	
Electronic garage doo	Lince 400 Motor line	1	360	0,016	0,016	0,016
Fish tank	Motor de recirculación	1	7	24	24	24
Landline telephone	Panasonic SAGECOM Teléfono DECT	1	1,8	24	24	24
Shaver	Remington SW0400100EU	1	30	0,16	0,1	0,16
Tools	Equipo de soldadura, taladro, calador	1	5000	0,1	0,1	0,1
Mosquito repellent		4	3,6	5	5	5
LIGHTING SYSTEM		Quantity	Power (watts)	Daily usage (hours)	Daily usage (hours)	Daily usage (hours)
INTERIOR	LOCATION					
LED spotlight on ceiling	Living room	3	42	7	8	6
IKEA floor lamp (fluorescent, spiral compact)	Office	3	7	2	2	1
Wall lamp (fluorescent, spiral compact)	Staircase and laundry room on secon	5	7	0,25	0,25	0,25
LED spotlight built-in into dropped ceiling	Bedrooms and bathrooms	7	20	5	5	2
LED tube 1.2m, bathroom mirror	Master bathroom	1	7	1	1	1
Hanging lamp, IKEA miniglob lightbulb (energy saving, fluorescent)	Office and entrance	3	7	3	3	3
IKEA SPARSAM energy saving light bulb (fluoresecent, compact)	4 bedroom nightstands	4	3	1	1	1
Salt lamp, night stand	Master bedroom	1	3	24	24	24
EXTERIOR						
LED spotlight, reflector 20 W	Garage and outdoors	2	100	0,5	0,5	0,5
Light bulb with light sensor	Entrance	1	7	4	4	4
LED spotlight on ceiling	Outdoors yard, garage, and laundry r	8	42	0,5	0,5	0,5
Incandescent light bulbs	Second floor, outdoors	2	60	0,75	0,75	0,75

Table 6 detail of calculation of consumption of all electrical devices of the house

Hourly consumption according to intensity of use

Electricity consumption or demand is considered the same in this case.

To discriminate the energy demand of the family during the day, data of energy consumption in kWh is extrapolated by the classification in the previous table. Appliances, classify details of energy consumption by the time of day –representative of each month of the year and differentiating weekends from weekdays- it will be shown clearly in the next figure. This way it has been able to obtain data as close as possible to real use by the hour, day and month of a sample year. The total results are in the following section of *Results and Data*

Integration of renewable energies. Production profile

The installation is designed to operate with instantaneous self-consumption most of the time, taking advantage of peak generating times and making the curves of generation and production cross. This way the goal of analysing the viability of this prosumer profile can be achieved. Electricity demand has been calculated by the hour, for every day of the year, in order to know which energy generation hourly schedule is enough to satisfy demand. Surplus production that goes back to the grid, or is stored in batteries or the need to take energy from the grid to satisfy demand are also quantified.

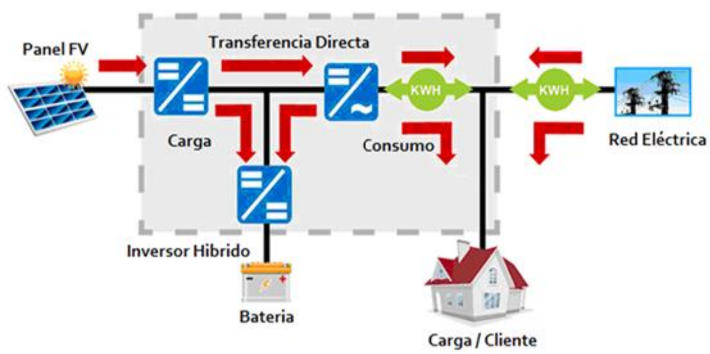


Figure 10 scheme of PV solar installation

- ***Irradiance data and Gdm calculation***

The hourly data (Lat 28 05' N), has been taken from the Meteonorm database. It includes temperature and global horizontal irradiance data for every hour of every day of the year, from which a day is taken as a representative of each month –which has been selected because it is the closest to the average optimal values of Grafcan. (Visor GRAFCAN, Infraestructura de Datos Espaciales de Canarias (IDECanarias), 2019)

The method used to calculate the Global daily average radiation, Gdm [kWh/m2] on a sloping surface has been to multiply global average radiation on a horizontal surface from the most representative day of the month of a year by a corrector factor K, which depends on the inclination of the panels and their orientation. (Inclination 15° and Orientation 0° South). As the following formula shows.

Orientation 0°	
inclined plane 15 °	FACTOR K
january	1,14
february	1,11
march	1,06
april	1,01
may	0,98
june	0,96
july	0,97
august	1,00
september	1,04
october	1,09
november	1,13
december	1,15

$$G_{dm} = G_{dmh} \cdot K$$

	january		february		march		april		may		june	
	horizontal plane. Gdm	inclined plane 15 °. Gdm*K	horizontal plane. Gdm	inclined plane 15 °. Gdm*K	horizontal plane. Gdm	inclined plane 15 °. Gdm*K	horizontal plane. Gdm	inclined plane 15 °. Gdm*K	horizontal plane. Gdm	inclined plane 15 °. Gdm*K	horizontal plane. Gdm	inclined plane 15 °. Gdm*K
Wh/m2	3830,0	**4366,2**	3955,5	**4390,6**	4917,2	**5212,3**	4738,3	**4785,7**	5424,9	**5316,4**	6202,9	**5954,8**

july		august		september		october		november		december	
horizontal plane. Gdm	inclined plane 15 °. Gdm*K	horizontal plane. Gdm	inclined plane 15 °. Gdm*K	horizontal plane. Gdm	inclined plane 15 °. Gdm*K	horizontal plane. Gdm	inclined plane 15 °. Gdm*K	horizontal plane. Gdm	inclined plane 15 °. Gdm*K	horizontal plane. Gdm	inclined plane 15 °. Gdm*K
6889,5	**6682,8**	5733,1	**5733,1**	5281,7	**5493,0**	4337,8	**4728,2**	3555,0	**4017,2**	3195,9	**3675,3**

Table 7 Global daily average radiation with factor K and formula Gdm

Hourly irradiation of effective incidence in the panel has been estimated without losses due to shadow. This is due to the available space in the rooftop of the garage for the installation, which has no shadows by any other objects. The Inclination 15° has been chosen to maximize production in the summer and the benefit from the energy compensation of self-consumption.

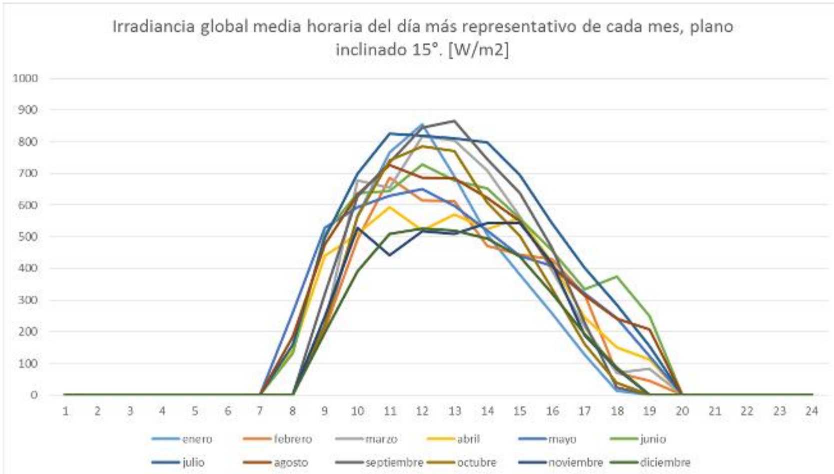


Figure 11 Solar irradiance for a panel with 15 degrees of inclinations and their respective K factor

Performance ratio calculation

$$PR = PR_{TEMP} \cdot PR_{FRE} \cdot PR_{CC} \cdot PR_{DIS} \cdot k_c$$

Calculation of performance ration, *PR*, has been done for every hour of the representative day of each month. The ratio of performance of the PV installation is also a function, as well, of other performance ratios: temperature in function of ambient temperature and of the module (Prep), for Fresnell losses (PRFRE), for loss of serial resistance (PRCC 0.99), for dispersion losses (PRDIS 0.985) and the inverter performance (kc 0.97)

- ***Solar generation calculation***

*Ep [kWh/ /mes] =Gdm*PR*Potencia pico*

The Gdm and PR data (defined above) has been used to calculate the hourly and monthly production values. The values of the solar production calculation are shown in the following *Results* section.

Even though the recent regulation ,still to be passed, and the proposal for self-consumption compensation RD 15/2018 allows for a PV installation to have a power output superior to the one contracted with the energy supplier. For this study, the PV installation has been measured with a power output of 3kWp. Which is the maximum power output that can invested in due to economic limitations. Also higher output would make installing a storage system too expensive for the initial investment.

- ***PV installation: location proposal, configuration and components.***

The garage rooftop is proposed for the placement of the installation. In the next photo area the location of the proposed garage rooftop is shown with a red circle

Figure 12 Floor plan and photomontage with location detail of the solar installation

It has easy access to storage area (garage ground level), to the common grounding point (CGP), and to the main switch (MCCB) as well as a direct and short line to the bidirectional measuring equipment located in the external wall. There are plans for an expansion in the future that could double the power output.

The installation is made with two strings, with 5 modules each one, connected in serial. They are elevated 90cm from the ground, to guarantee that it will not have any shadow from the perimeter wall.

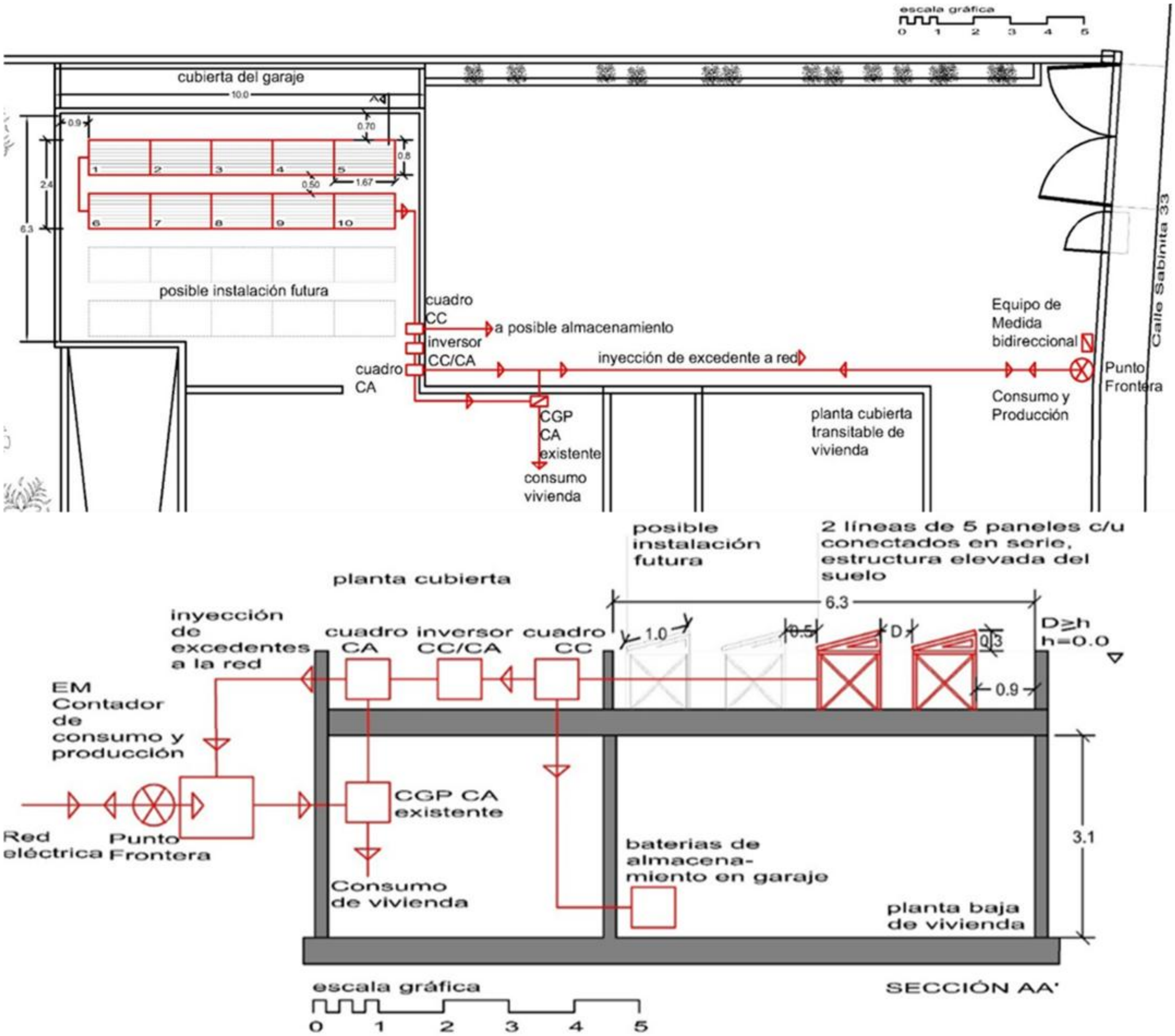
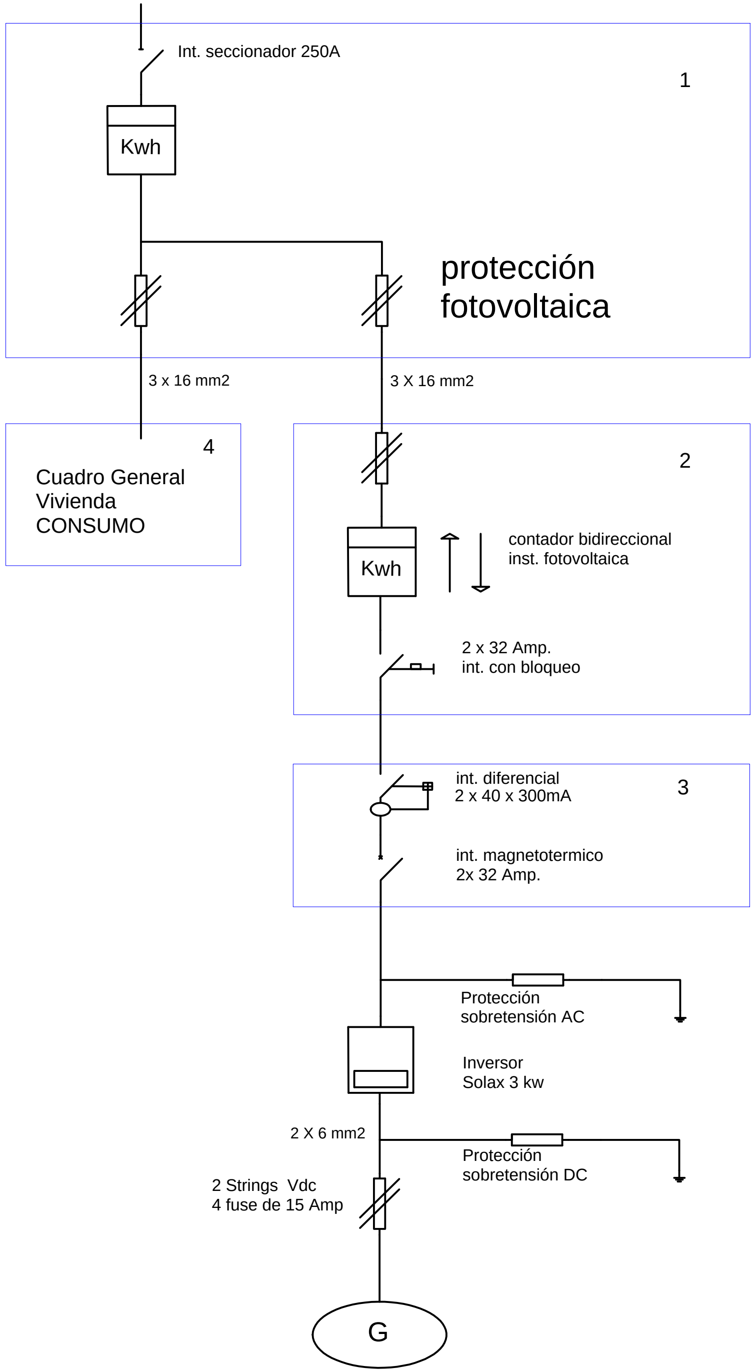


Figure 13 Floor plan and section with location detail of the solar installation

In the following pages a single electrical line schematics of the two modalities are shown, with and without batteries.

ESQUEMA UNIFILAR
Sin baterias. 3kWp

1	Cuarto de contadores de baja tensión
2	cuadro del contador fotovoltaico
3	Protección del generador fotovoltico
4	Cuadro general de la vivienda (consumo)
SIMBOLOS UNE EN 60617	
Kwh	Contador energía activa
	Inversor fotovoltaico
	Interruptor seccionador 250 Amp
	Int. magnetotérmico 2 x 32 amp.
	Int. diferencial 2 x40 x 300ms
	Int. magnetotérmico de 2 x 32 Amp. con bloqueo
	Protección sobretensiones AC o DC
	Puesta a tierra
G	Genenrador Placas fotovoltaicas



Proyecto	planta fotovoltaica 3 kw
Plano	esquema unifilar
Situación	C/ Sabinita alta Nº 33
Fecha:	16-feb.-19
Escala:	s/e
Nº Plano:	1.1

1	Cuarto de contadores de baja tensión
2	cuadro del contador fotovoltaico
3	Protección del generador fotovoltico
4	Cuadro general de la vivienda (consumo)
SIMBOLOS UNE EN 60617	
Kwh	Contador energía activa
	Inversor fotovoltaico
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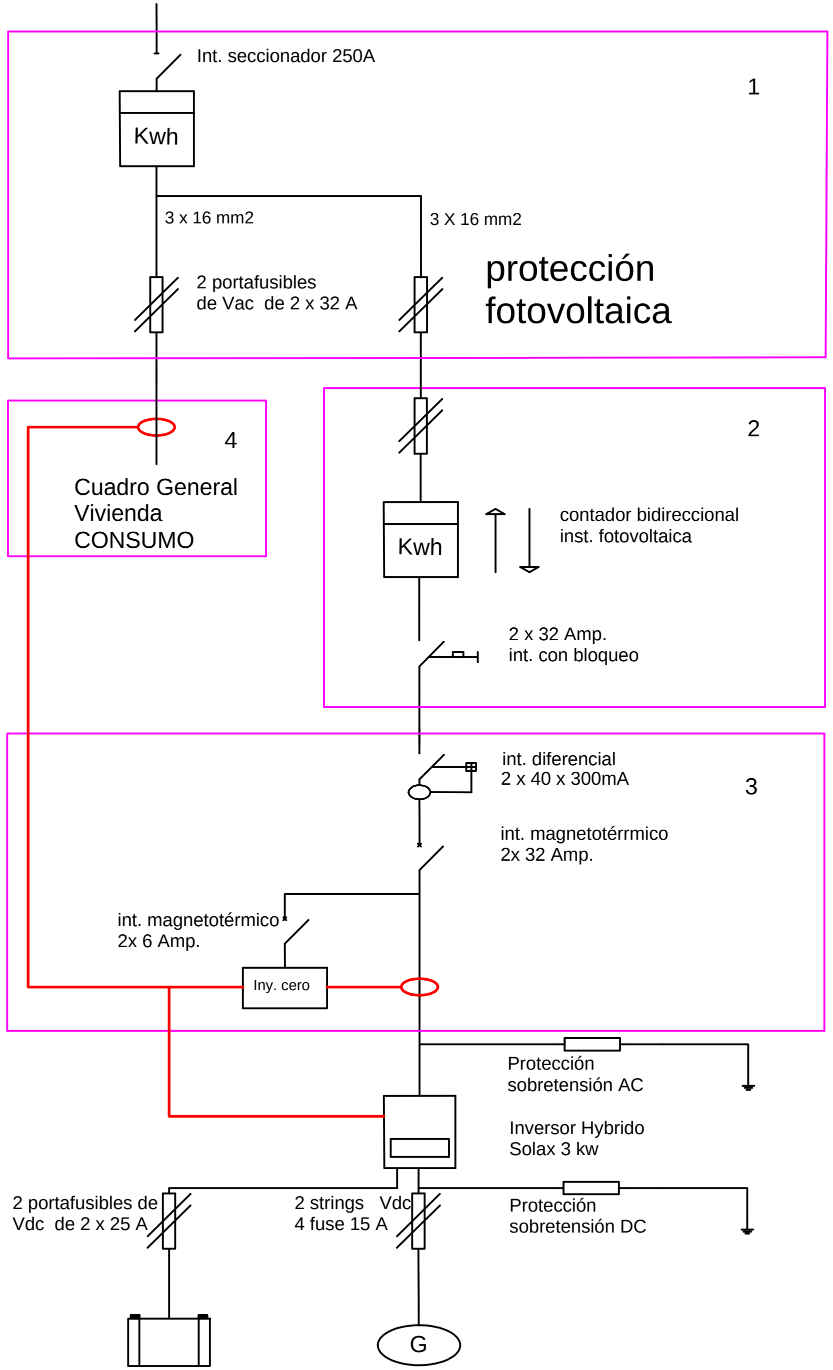
	Int. magnetotérmico 2 x 32 amp.
	Int. diferencial 2 x40 x 300ms
	Int. magnetotérmico de 2 x 32 Amp. con bloqueo
	Protección sobretensiones AC o DC
	Puesta a tierra
G	Generador placas fotovoltaicas
	Baterias de litio
Iny. cero	Inyección cero a red



ESQUEMA UNIFILAR
Con baterias. 3kWp

Proyecto
planta fotovoltaica 3 kw

Plano
esquema unifilar

Situación
C/ Sabinita alta Nº 33

Fecha: 16-feb.-19

Escala: s/e

Nº Plano: 1.1

- ***Storage***

To measure the useful storage capacity, Cu, a value of daily energy is chosen, produced by the installation to storage, for a day representative of August (N number of days) because it is one of the highest electricity generation day of the year.

	solar PV Energy produced [kWh/day] = Ep * Peak power											
	jan	feb	mar	april	may	jun	july	august	sept	oct	nov	dec
Et[kWh]	12,24	11,94	14,01	12,56	14,20	15,35	16,94	14,48	13,97	12,75	10,97	10,12
kWh/month	379,31	334,26	434,39	376,92	440,11	460,42	525,19	449,01	419,24	395,39	329,23	313,58

For economic reasons –in order not to make the installation too expensive- the battery system will only store for one day. The daily energy to be stored results from the following formula:

E=Et / R. Where R is the total yield factor of the installation R=0.80

E= 14.48 kWh / 0.80 = *18.11 kWh*

The depth of maximum charge possible, *Pd,* is 70%. The continuous voltage, *Vdc,* is 48V, as fed by the inverter.

The formulas used are the following:

$$C_u = E \cdot N \qquad C_n = \frac{C_u}{P_d} \qquad C_n(Ah) = \frac{C_n}{V_{DC}}$$

Cu=18.11 kWh / *Cn=25.9 kWh* / *Cn (Ah) =538Ah*

The total storage capacity, Cn, is *Cn (Ah) =538 Ah*

Four commercial stationary solar batteries OpzS of 12v are connected serially, with a depth of charge of 25 A, each one 550Ah.

Cable sizes and current limiters for constant and alternate currents are calculated by the RD norms for self-consumptions, based on the RBTE, which points to installations less than 10kWp.

Have chosen 10 polycrystalline 72 cell 300W module, to add the peak power of the 3kWp installation.

Royal Decree, self-consumption modalities and compensation

The RD 15/2018 established urgent measures for the energy transition. Consumer protection suggested a deep changes to the self-consumption regulations. On the 29nd of January 2019, the government proposed new regulations, which were to be given the last arguments on the 8th of February. (Ministerio para la Transición Ecológica, 2019)

Modalities:

Two viable scenarios are considered. With surplus and without surplus.

Without surplus, with storage batteries. It should have a dynamic power controller (Smart meter).

With surplus: The PV self-consumption installation classified as '*type a*' with the following characteristics and will be allowed to receive economic compensation by injecting surplus energy into the local distribution network:

- Less power output of 100kW.
- Compensation type is Net billing, with simplified compensation.
- The owner of the contract should have one and only one supply contract with the power supply company, and not receive any additional compensation system.
- It is classified as a personal installation, given that it only has one consumer associated to the production installation.
- The owner of the contract and the consumer has to be the same person, and the installations have to be connected to the consumer's internal grid.

A *'type b'* producer, with surpluses over 100kW installed is not included in this compensation scheme.

In all modalities, minimal tenure is one year. During this year it is not possible to switch to another modality.

- ***Compensation for energy balance***
    - Calculation of balance between energy self-generated and self-consumed has a period of monthly billing; therefore, the surplus of energy will not be saved as credit for the following month. Surplus of energy will have to be injected back into the grid daily.
    - Surplus self-generated energy that is injected back to the grid is exempt from generation taxes. This is because it would limit the market penetration of storage systems and this would also make installations too big. (fotovoltaica ya-esta-aqui-el-borrador-de-Real Decreto, 2019)

Simplified mechanism for energy surplus compensation in self-consumption with surplus '*a type*'. Net Billing.

A PV installation with a tariff called 'Supply at a voluntary price of the small consumer' (PVPC in Spanish, established in 2014 by the government, electricity prices are calculated depending on the hour and day depending on the current energy prices in the market). An example has been taken from Iberdrola, as it is one of the few that has this mechanism available to this date.

Net balancing is done in economic terms, which means that you cannot export energy into the grid in order to consume it back as a way of energetic compensation.

The economic value of the surplus energy by the hour will never be greater than the economic value of the energy consumed in kWh, as a way of energy compensation.

The economic value of the surplus energy by the hour will never be greater than the economic value of the energy consumed in the billing period, which will not exceed the duration of a month.

Therefore, the details of the economic compensation or net billing are:

1. **Consumed energy** from the grid in the hours of the day when solar generation does not give sufficient output to satisfy demand, is charged by the hourly energy price, *Tcu*, and

defined in article 7 of the RD 215/2014, 28th of March. This price is the tariff price. The house will have a 2.0A tariff, with no hourly discrimination.

$$TCUh = (1 + PERDh)\ x\ CPh$$

From this formula, the ratio values from loss of access tolls in applying supply in the hour *h*, *PERDh*. It is multiplied by the cost of production, *Cph.*

However due to the impossibility to make a detailed calculation, because we do not have the values for *PERDh*, values from the active energy billing, *FEU*, have been used. Energy consumed (self-generated or not) will have the same pricing mechanism, which follows the hourly and daily energy prices. .*FEU* values are taken from the Spanish Grid website (Red eléctrica española, REE). [*https://www.esios.ree.es/es/pvpc?date=30-03-2018*](https://www.esios.ree.es/es/pvpc?date=30-03-2018).

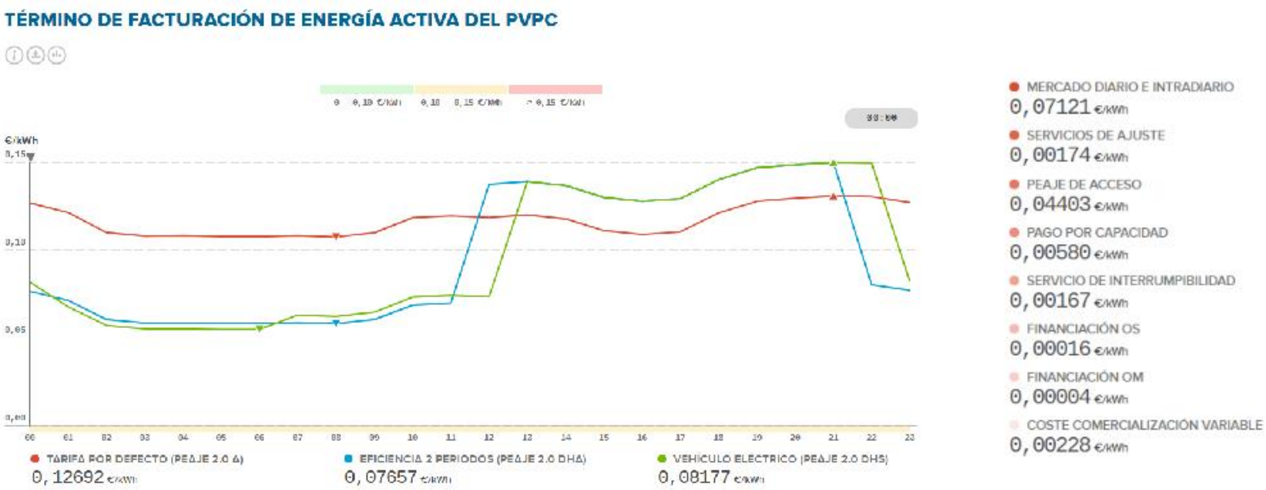


Figure 14 Detail of the calculation methodology performed in each month, from the FEU values from the active energy billing, data taken from the Spanish Electricity Network

There are no monthly averages available, only hourly values of each day of the year, therefore three days (first, 15th and last day of the month) have been taken as a monthly average. Energy consumed is compensated without additional or special electricity taxes, without added IGIC values and without fixed charge per power output. In the following table, it can be observed the calculations made to obtain an effective *FEU* tariff, used for this project.

FEU. Tarifa por defecto 2,0A
ENERO [€/kWh]

Hora	dia 1	dia 15	dia 31	promedio horario
1 h	0,07424	0,12396	0,12556	0,10792
2 h	0,7305	0,11709	0,11997	0,32252
3 h	0,06948	0,1153	0,11731	0,10069667
4 h	0,07025	0,11473	0,11717	0,10071667
5 h	0,06843	0,11566	0,11932	0,10113667
6 h	0,0724	0,12399	0,12338	0,10659
7 h	0,07214	0,12937	0,12479	0,10876667
8 h	0,07091	0,13251	0,12377	0,10906333
9 h	0,0694	0,13267	0,12327	0,10844667
10 h	0,066606	0,13106	0,12289	0,106852
11 h	0,06597	0,12763	0,12224	0,10528
12 h	0,06554	0,12505	0,12163	0,10407333

FEU. Tarifa por defecto 2,0A
ENERO [€/kWh]

Hora	dia 1	dia 15	dia 31	promedio horario
13 h	0,,06579	0,12523	0,12269	0,12396
14 h	0,698	0,1233	0,12271	0,31467
15 h	0,07606	0,12269	0,12282	0,10719
16 h	0,06987	0,12028	0,12225	0,10413333
17 h	0,07421	0,12225	0,12101	0,10582333
18 h	0,08252	0,12668	0,12306	0,11075333
19 h	0,0883	0,13019	0,12506	0,11451667
20 h	0,08553	0,13218	0,1265	0,11473667
21 h	0,08761	0,13015	0,12756	0,11510667
22 h	0,09073	0,12658	0,12727	0,11486
23 h	0,08303	0,1198	0,12698	0,10993667
24 h	0,07613	0,13179	0,12905	0,11232333

Table 8 Detail of the calculation methodology performed in each month, from the FEU values from the active energy billing, data taken from the Spanish Electricity Network

2. **Surplus self-generated solar energy,** which is exported back to the grid at each hour, is priced by the average hourly price, Pmh, (it is the hourly average price by they daily and inter-daily price to calculate the tariff *PVCP),* according to article 10 of the RD 216ç2014 from the 28th of March. Surplus energy exported in this modality is extent from generation or production value taxes.

Pmh values are obtained from the daily and inter-daily market prices published in the OMIE web (Iberian market energy operator – Spanish pole) For the *Pmh* monthly calculations, the daily average of the hourly prices of each day have been taken from the day that is closest to *Pmh* values are taken from .http://www.omie.es/reports/index.php?report_id=211

In the following graph, it can be observed the method to calculate the Pmh value.

Pmh. Euro /MWh	
Enero de 2018	
Día	
1	7,64
2	37,69
3	37,95
4	36,55
5	42,2
6	45,84
7	44,75
8	65,11
9	58,59
10	53,92
11	51,11
12	60,04
13	55,32
14	53,17
15	57,99
16	51,68
17	52,56
18	57,6
19	55,11
20	47,59
21	43,16
22	53,74
23	57,96
24	56,54
25	53,41
26	48,86
27	48,58
28	48,93
29	54,7
30	53,98
31	57,07
promedio	49,9787097

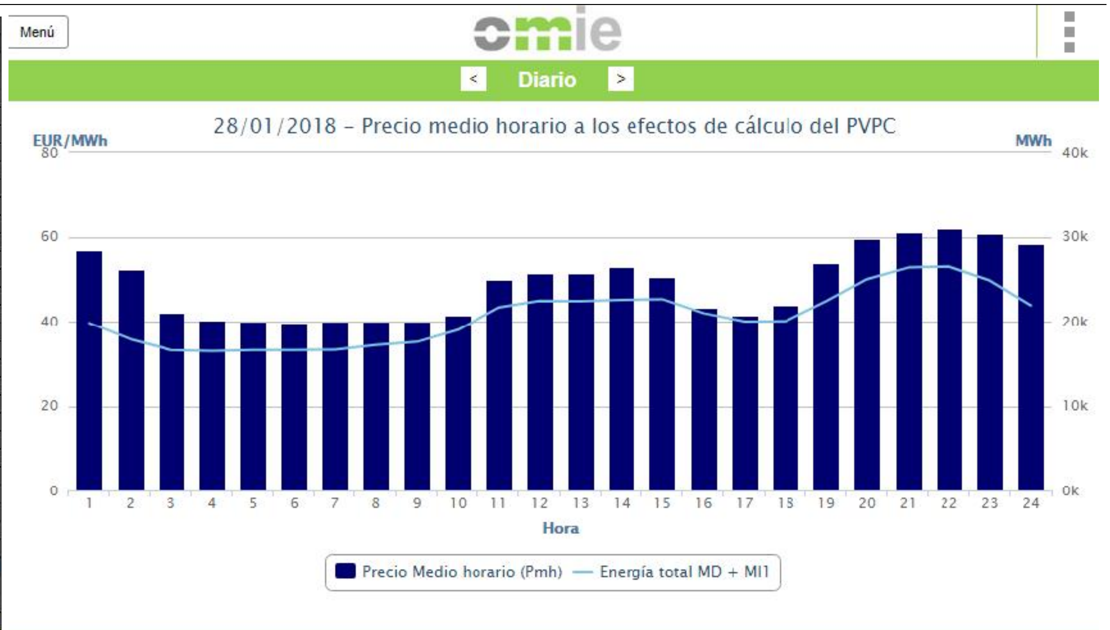


Figure 15 Detail of the methodology of calculation made in each month, of the Pmh, average hourly price, according to the data of OMIE

- ***Development of the simplified compensation RD 15/2018***

Given what is said before, the simplified compensation (Net billing) has been built in the following formula. Economic balance of energy cannot take negative value is the monthly billing, which means that for each month the result must be positive or zero.

(Hourly consumption [kWh]* *FEU* tariff 2.0 [€]) – (surplus export [kWh]* *Pmh* [€])

(Ministerio de Industria, Energía y Turismo, 2019)

In the following example of the month of January, the simplified compensation formula can be seen at work. The total results of all the months of the year are in the following section of *Results and Data.*

Example of simplified compensation for the month of January					
Hour	**Purchase of the network. [kWh/hour]**	**General Rate 2.0A, PVPC, without hourly discrimination [€/kWh]**	**Injection network: Production - Self-consumption. [kWh/hour]**	**Pmh. hourly price of the average day of the month. [€/kWh]**	**Simplified compensation RD Self-consumption. [€/kWh]**
1 h	7,15	0,1079			0,771259241
2 h	7,39	0,3225			2,384600256
3 h	3,84	0,1007			0,387138747
4 h	3,80	0,1007			0,382325704
5 h	3,80	0,1011			0,383920046
6 h	37,86	0,1066			4,035705464
7 h	37,86	0,1088			4,118118313
8 h	39,42	0,1091			4,298796372
9 h	7,15	0,1084			0,775701546
10 h			25,54282516	0,0377	-0,962964508
11 h			62,41593663	0,05625	-3,510896436
12 h			67,77828435	0,06056	-4,1046529
13 h			35,53887974	0,06155	-2,187418048
14 h			40,02498003	0,05638	-2,256608374
15 h			28,13834954	0,05638	-1,586440147
16 h			18,00471229	0,05638	-1,015105679
17 h			6,735705735	0,05638	-0,379759089
18 h	2,68	0,1108			0,296519091
19 h	6,20	0,1145			0,71042681
20 h	12,86	0,1147			1,475638583
21 h	43,65	0,1151			5,024265575
22 h	17,09	0,1149			1,962532699
23 h	13,48	0,1099			1,482200225
24 h	12,04	0,1123			1,352317254
total	**256,27**	**0,12238**	**284,18**	**0,05520**	**13,84**

Table 9 Detail of the calculation methodology performed in each month, with energy purchase and sale rates

Economic analysis

Economic viability has been analysed with an economic and financial analysis of the two compensation modalities, comparing them to the current energy supply of the utility provider Iberdrola

A local installation company has done installation budget. The two budgets, one with battery and the other with direct self-consumption, are shown below.

Budget made by certified local certified company.

MOB SERVICIOS **PRESUPUESTO**

MAURICIO OLIVERA
N.I.F. X-1676353-K
C/ Los Falcones, nº 3 Los Balandros E-0-02 FECHA: 1/02/2019
El Palm-mar (Arona) 38632 Nº 490/19
Teléfono: 607 53 86 48 / 922 74 83 77
1mauricioolivera@gmail.com

CLIENTE: J.MORALES. VIVIENDA SABINITA
Centro Comercial San Eugenio 2ª planta local nº 89
38659 ADEJE
SANTA CRUZ DE TENERIFE
N.I.F. B-38392999

PRESUPUESTO Planta Fotovoltaica

DESCRIPCIÓN	ud	precio €	importe €	total	%
SIN BATERIAS. AUTOCONSUMO DIRECTO	**ud**	**precio €**	**importe €**	**total**	**%**
10 paneles 330w POLY - 72 CELLS - Marca TIER1	10	120	1200	1200	0,22338
1 inversor SOLAX 3 kw con 2 MPPT	1	1160	1160	1160	0,21593
Contador bidireccional	1	345	345	345	0,06422
Cableado y protecciones, 2 armarios, 2 Em, 50m y 5metros c solar				1117	0,20793
Protecciones	1	300	300		
Armarios	2	150	300		
Cable solar tramo1	7,5	10	75		
Cable tramo 2	3	4	12		
Cable tramo 3 en rejilla	10	3	30		
Caja de conexión	1	50	50		
Monitorización con wifi	1	350	350		
Mano de obra	1	700	700	700	0,13031
Estructura de soporte elevada del suelo 1m	10	50	850	850	0,15823
			TOTAL	**5372,0**	
			IGIC 7%	376,0	
			TOTAL	5748,0	
CON BATERIAS KIT AUTOCONSUMO HIBRIDO	**ud**	**precio €**	**importe €**	**total**	**%**
10 paneles 330w POLY - 72 CELLS - Marca TIER1	10	120	1200	1200	0,11432
1 inversor cargador solar hibrido SOLAX 3 kw	1	2000	2000	2000	0,19053
1 bateria LITIO BYD BOX 5kw - alto voltaje	1	4700	4700	4700	1343,24
Dispositivo certificado antivertido Smart Meter 2.0 SMA	1	380	380	380	0,1086
Cableado y protecciones, 2 armarios, 2 Em, 50m y 5metros c solar				667	0,06354
Protecciones	1	200	200		
Armarios	2	150	300		
Cable solar tramo1	7,5	10	75		
Cable tramo 2	3	4	12		
Cable tramo 3 en rejilla	10	3	30		
Caja de conexión	1	50	50		
Mano de obra — Monitorización con wifi	1	700	700	700	0,06669
Estructura de soporte elevada del suelo 1m	10	50	850	850	0,08098
			TOTAL	**10497**	
			IGIC 7%	734,79	

Nota: No están incluidas las obras albañilería
Forma de pago: 50% a la aceptación del presupuesto y 50% a final de obra
Número de cuenta: ES48 0049 4454 77 2810010808 Banco: Santander
Recibí Conforme
Nombre/DNI

Figure 16 Real budget for solar PV installation casa Sabinita

Profitability analysis according to NPV, IRR and PP

Economic viability is determined by the net present value, *NPV*, the internal rate of return, *IRR*, and the payback period, *PP*.

Initial data to calculate with NPV and TIR

$$VAN = I_{nv.} + \sum_{j=1}^{n} \frac{Fj}{(1+i)^j}$$

$$0 = -I_0 + \frac{F_1}{(1+TIR)^1} + \frac{F_2}{(1+TIR)^2} + ... + \frac{F_n}{(1+TIR)^n}$$

$$0 = I_{nv.} + \sum_{j=1}^{n} \frac{Fj}{(1+TIR)^j}$$

NPV=VAN

IRR=TIR

PP=PR

Fj: Net flow in a 25-year period

Inv: Investment at 0 period.

i: Discount rate

n: number of years for the investment : 25 years

Inflation data has been taken from Spanish inflation in 2018. (inflation.eu, 2019)

ECONOMIC FEASIBILITY. Factors	no batteries	with batteries
Inflation %	0,02	
Discount rate %	0,04	
Annual increasel O&M, %	0,03	
Initial cost of the investment€	5.370 €	10.497 €
Fondos propios	5.370 €	10.497 €
O&M cost €	54 €	
Useful life years	25	
Power contratc kWp	3,0	
Annual power loss %	0,1	
Annual average energy consumption [kWh]	4.128	
Average annual production expected [kWh]	4.802	
TOTAL VARIABLE ENERGY CHARGE: Energy amount + lease tax + IGIC. [€/kWh]	0,137484926	
Annual increase in the price of energy %	0,0500	

Table 10 Economic data used to calculate profitability

Energy prices

The following table simulates the Iberdrola energy bill for a year. The reduced bill due to the PV installation has been done including all additional costs that Iberdrola usually charges. The average energy cost is 0.184 €/kWh

		Power contract	**3,45**	Trifa 2.0 A sin discrimnación										
IBERDROLA			0,115187	0,126988			5,11269632%	0,026735			3%	7%		
	days	**Energy to be consumed according to empirical calculation. kWh/month**	**Amount by power. €**	**Amount for energy. €**	**Subtotal = amount per power + impore per energy.€**	**Power electricity tax.€**	**Energy electricity tax.€**	**Rental of equipment. €/mes**	**Payment protection insurance plus. €**	**IGIC reduced by 3% on amount per power + electricity tax per power. €**	**IGIC reduced by 3% on the amount of electricity + energy imposed by energy. €**	**Normal IGIC 7% on equipment rental. €**	**Invoice amount. €**	**Average price of all charges of the bill. euros / kWh**
January	31	351,400	12,319	44,624	56,943	0,630	2,281	0,829	1,950	0,388	1,407	0,058	64,487	0,184
February	28	383,463	11,127	48,695	59,822	0,569	2,490	0,749	1,755	0,351	1,536	0,052	67,323	0,176
March	31	370,696	12,319	47,074	59,393	0,630	2,407	0,829	1,950	0,388	1,484	0,058	67,140	0,181
April	30	324,076	11,922	41,154	53,076	0,610	2,104	0,802	1,892	0,376	1,298	0,056	60,213	0,186
May	31	310,223	12,319	39,395	51,714	0,630	2,014	0,829	1,950	0,388	1,242	0,058	58,825	0,190
June	30	392,174	11,922	49,801	61,723	0,610	2,546	0,802	1,892	0,376	1,570	0,056	69,575	0,177
July	31	110,845	12,319	14,076	26,395	0,630	0,720	0,829	1,950	0,388	0,444	0,058	31,414	0,283
August	31	488,364	12,319	62,016	74,336	0,630	3,171	0,829	1,950	0,388	1,956	0,058	83,317	**0,171**
September	30	272,452	11,922	34,598	46,520	0,610	1,769	0,802	1,892	0,376	1,091	0,056	53,115	0,195
October	31	333,058	12,319	42,294	54,614	0,630	2,162	0,829	1,950	0,388	1,334	0,058	61,965	0,186
November	30	351,388	11,922	44,622	56,544	0,610	2,281	0,802	1,892	0,376	1,407	0,056	63,968	0,182
December	31	440,360	12,319	55,920	68,240	0,630	2,859	0,829	1,950	0,388	1,763	0,058	76,717	0,174
YEAR !		4128,499	145,049	524,270	669,319	7,416	26,804	9,758	22,971	4,574	16,532	0,683	**758,058**	0,190
													0,184	0,190

Table 11 Energy bill Iberdrola detail

Other funding sources, loans or grants

Grants done in 2019 for energy efficiency and renewable energy for residential and commercial buildings, co-finance with FEDER in the Canary Islands programme have closed applications for the residential sector on the past 15th of February. Grant conditions (€4.500 grant, 45% of the minimum budget of €10.000) were not adequate for the surplus modality, because the budget for the 3kWp installation is less than €10.000. However for the PV installations with storage it is adequate, as the complete installation costs €10.497, therefore the 45% grant could finance €4.723, leaving to pay with own funds €5.773, which will be the initial investment to measure the profitability of the installation. (Gobierno de Canarias, 2019)

RESULTS AND DATA

Consumption

Electrical consumption in the case study of the Sabinita home. KWh/day, from each day of the season (summer, winter and spring/autumn) with all consumptions possible, compared with the surveyed homes in the Canary Islands. According to the attached graphics

Only in the kitchen, TV, and computers, do the surveyed Canary Island homes show more consumption that the case study home : Sabinita house.

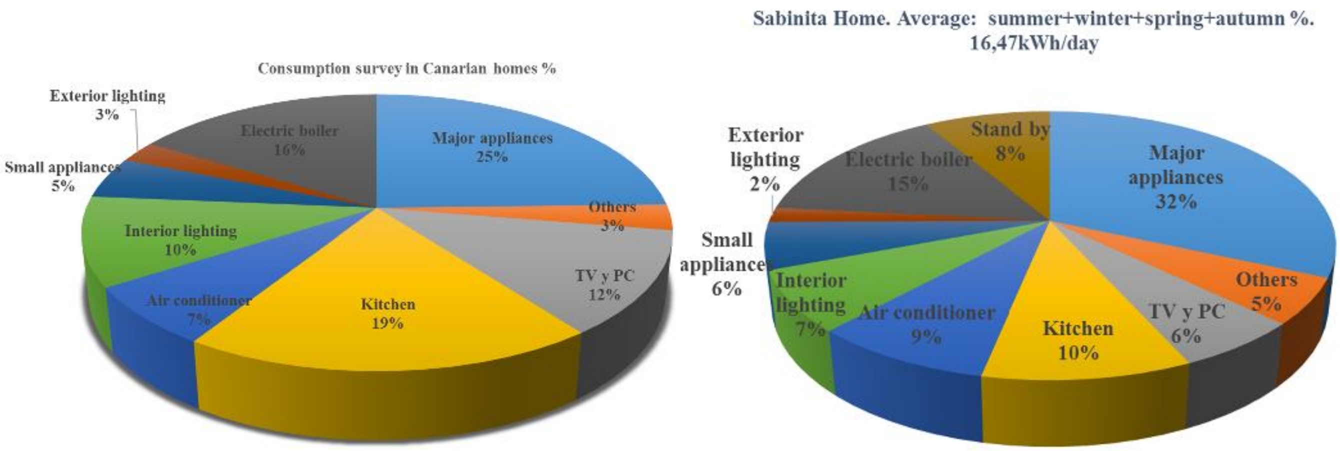
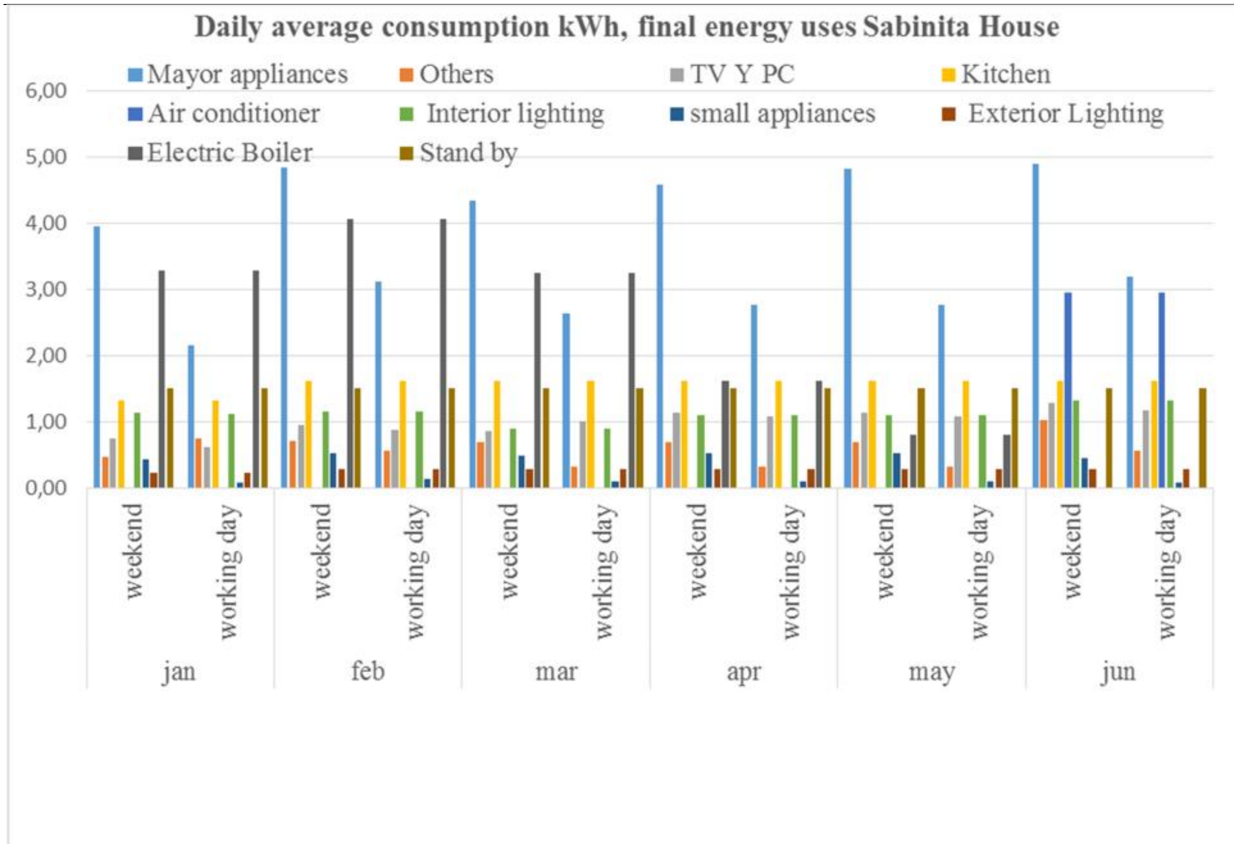


Figure 17 Comparison electrical consumption survey in Canarian homes and Sabinita home

Appliances included in the *Other* classification reflect small appliances which use is dispensable like: aquarium, reverse osmosis machine, water softener, videogame consoles, garage electric door, electric shaver for humans and for animals, anti-insect devices and power tools. This demonstrates an adequate approximation and similarities between the actual measurements of the Canary island houses and the case study



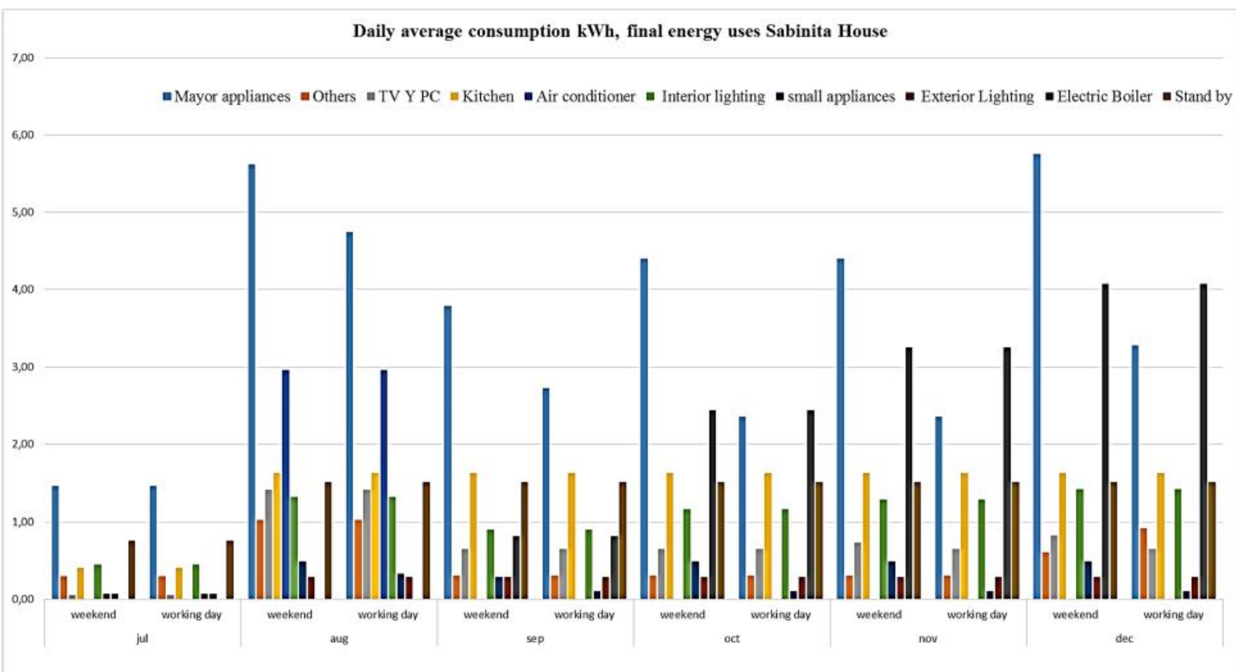


Figure 18 ***Daily average consumption kWh, final energy uses Sabinita House. By months***

It is important to notice that this project does not focus on improving energy efficiency, or limit construction demand. Energy certificates demanded by actual regulation only takes into account acclimatization (heating/air conditioner) and depends on the dimensions of each house. While it has already been shown that in the homes of the Canary Islands, or Tenerife, the highest consumption belongs to major appliances like TV, PC or other appliances.

Correction factor

Due to the difference between the bi-monthly data found in Iberdrola's energy bills and the houses surveyed in the Canary Island, with the study home, it has been decided to multiply these by a correction factor of 0.74 to homogenize consumption toward real usage.

In the following graph shows the hourly consumption of the twelve months of the year.

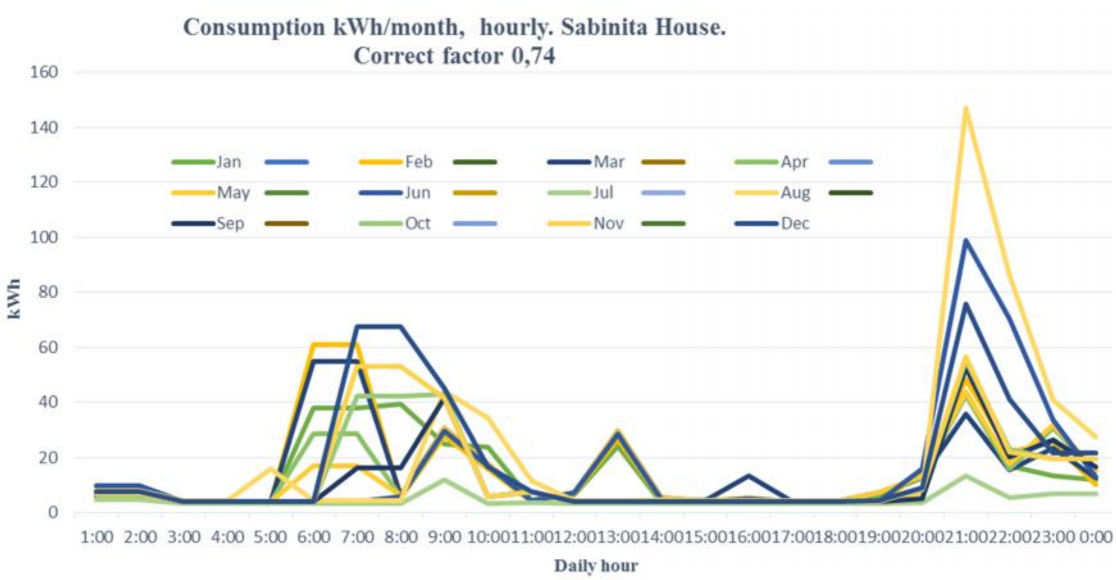


Figure 19 Energy consumption (demand) hourly by month

	Energy consumption (demanded). [kWh/day]. [kWh/month] Average daily and month											
	jan	feb	mar	april	may	jun	july	august	sept	oct	nov	dec
kWh/day	11,34	13,70	11,96	10,80	10,01	13,07	3,58	15,75	9,08	10,74	11,71	14,21
kWh/month	351,40	383,46	370,70	324,08	310,22	392,17	110,85	488,36	272,45	333,06	351,39	440,36

Table 12 Energy consumption by day and month

Solar generation data

	number of days	Gdm [kWh/m2/ día]	Tamb	Tpm	PR temp	PR fre	PR inv	PR	Ep [kWh/kWp /month] =Gdm*PR	Energy produced [kWh/day] = Ep * Peak power	Energy produced [kWh/month]
jan	31	4,37	16,04	16,05	1,04	0,95	0,98	0,94	4,08	12,24	379,31
feb	28	4,39	16,90	16,91	1,03	0,93	0,98	0,91	3,98	11,94	334,26
mar	31	5,21	17,39	17,41	1,03	0,91	0,98	0,90	4,67	14,01	434,39
apr	30	4,79	18,05	18,07	1,03	0,90	0,98	0,88	4,19	12,56	376,92
may	31	5,32	18,32	18,34	1,03	0,91	0,98	0,89	4,73	14,20	440,11
jun	30	5,95	19,11	19,13	1,03	0,89	0,98	0,87	5,12	15,35	460,42
jul	31	6,68	22,43	22,45	1,01	0,88	0,98	0,85	5,65	16,94	525,19
aug	31	5,73	23,19	23,21	1,01	0,88	0,98	0,85	4,83	14,48	449,01
sep	30	5,49	22,43	22,44	1,01	0,89	0,98	0,85	4,66	13,97	419,24
oct	31	4,73	20,65	20,66	1,02	0,93	0,98	0,91	4,25	12,75	395,39
nov	30	4,02	18,58	18,59	1,03	0,94	0,98	0,92	3,66	10,97	329,23
dec	31	3,68	16,52	16,53	1,04	0,94	0,98	0,93	3,37	10,12	313,58
											4857,07

	solar PV Energy produced [kWh/day] = Ep * Peak power										
	jan	feb	mar	april	may	jun	july	august	sept	oct	nov	dec
Et[kWh]	12,24	11,94	14,01	12,56	14,20	15,35	16,94	14,48	13,97	12,75	10,97	10,12
kWh/month	379,31	334,26	434,39	376,92	440,11	460,42	525,19	449,01	419,24	395,39	329,23	313,58

Note that the month of greatest solar generation is the month, in which, particularly in this house, there is less consumption. Due to individual conditions of the users, becoming a reason to change the profile of the user.

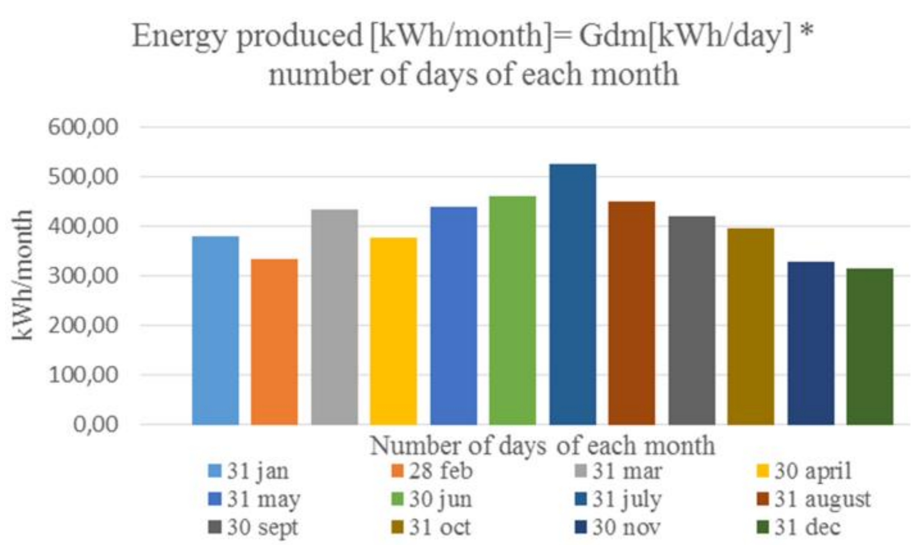


Table 14 Solar PV Production

Generation and consumption curves. Self-consumption ratio

Self-consumption ratio is the amount of energy, *kWh*, that PV electricity generation and demand on location is equal. If this ratio is low, it is worse for the prosumer. If they are not home in peak production hours, then they are wasting a good opportunity to be a *Prosumer*. This ratio depends on the size of the installation and demand profile and they can be modified to increase the ratio by ways of intelligent management.

This study will not mention proposal ways to reduce or limit demand, or to improve the ratio with monitoring or intelligent switching so demand and production can meet. This would be something a different study could cover. (IEA-PVPS. PHOTOVOLTAICS POWER SYSTEMS PROGRAMME., 2016)

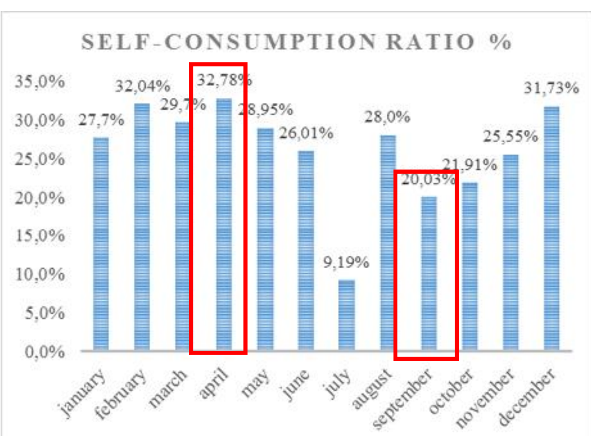
In the following graphs it can be observed how the two months with most and least self-consumption ratio without intervention to improve it: April 32.78% VS September 20 %

In the section of *Annexes* the data of all the months of the year are shown.

Energy ratio percentage, %, has been calculated from consumption (demand) energy kWh/day, which will have met with solar PV production kWh/day.

Self-consumption ratio % =Energy Demand hourly [kWh/day] / PV production hourly [kWh/day]

In the case of the Sabinita house, the average annual self-consumption ratio is 26.13%



	april		september	
Hour	**PV production [kWh/day]**	**Energy Demand [kWh/day]**	**PV production [kWh/day]**	**Energy Demand [kWh/day]**
1:00		0,2220		0,231
2:00		0,2220		0,231
3:00		0,1379		0,138
4:00		0,1379		0,138
5:00		0,1379		0,138
6:00		0,9519		0,138
7:00		0,9519		0,545
8:00	0,382	0,199		0,545
9:00	1,172	0,997	0,822	1,387
10:00	1,347	0,574	1,608	0,196
11:00	1,562	0,149	1,875	0,251
12:00	1,363	0,240	2,147	0,138
13:00	1,492	0,953	2,197	0,138
14:00	1,366	0,175	1,891	0,138
15:00	1,461	0,139	1,614	0,138
16:00	1,092	0,177	1,176	0,138
17:00	0,639	0,138	0,581	0,138
18:00	0,393	0,138	0,063	0,138
19:00	0,295	0,240		0,139
20:00		0,4359		0,176
21:00		1,4264		1,759
22:00		0,5276		0,674
23:00		1,0234		0,876
0:00		0,5095		0,555
	12,56401	4,1185	13,975	2,799
	ratio	**32,78%**	**ratio**	**20,03%**

Table 15 Self-consumption matching: lowest and highest %

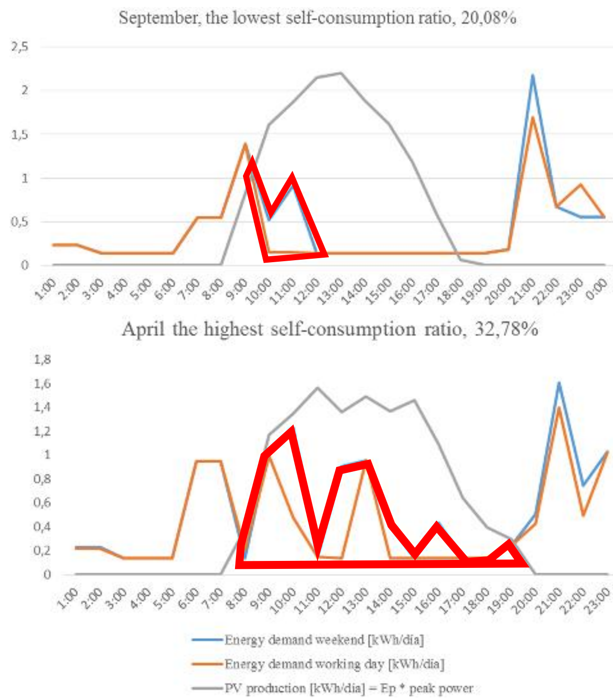


Figure 20 Self-consumption matching: lowest and highest %

In winter, demand grows due to use of electrical heating, while generation capacity decreases. In summer, demand also increases due to refrigeration needs in hours out of solar production, and solar production increases.

Therefore, it is in the spring months that demand and production curves are matching. In these periods are the self-consumption highest ratios. (IEA-RETD, 2014)

Self-consumption ratio variability

In order to analyse the viability of self-consumption the variation between demand and production times needs to be checked in hourly detail. If there is demand but no production, supply needs to be bought from the grid, and if there is production but no demand, then this energy needs to be exported to the grid or saved in batteries.

The following table shows the hourly calculation that has been made for each month, and the following graphs show the monthly and annual totals

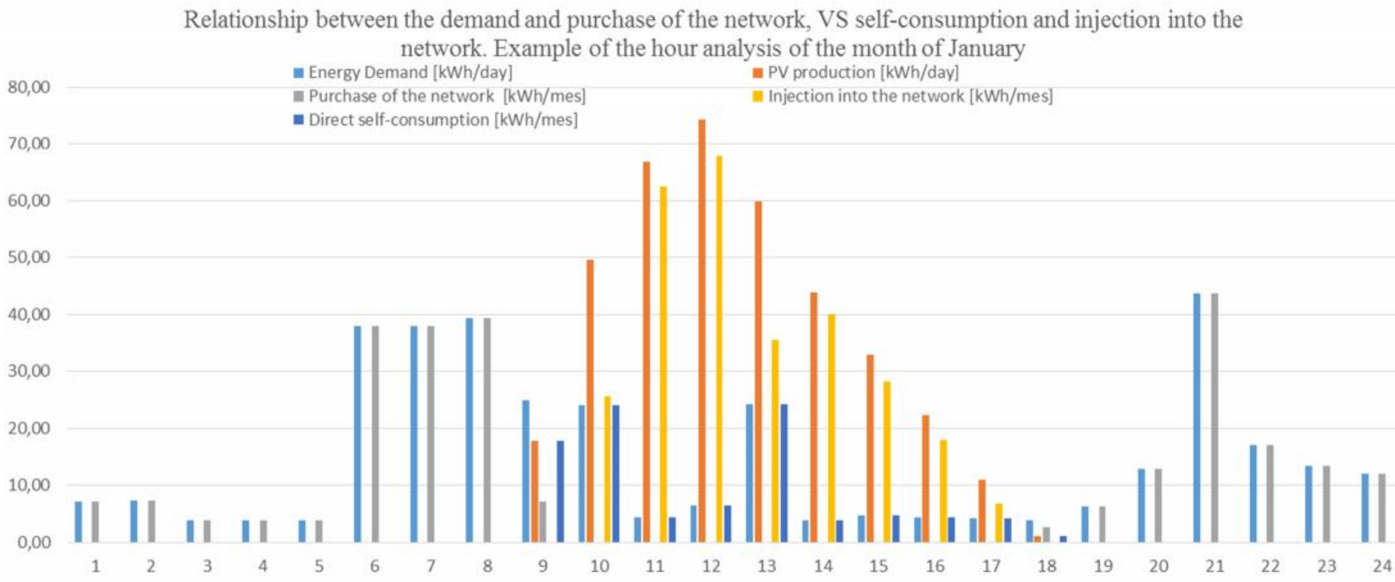


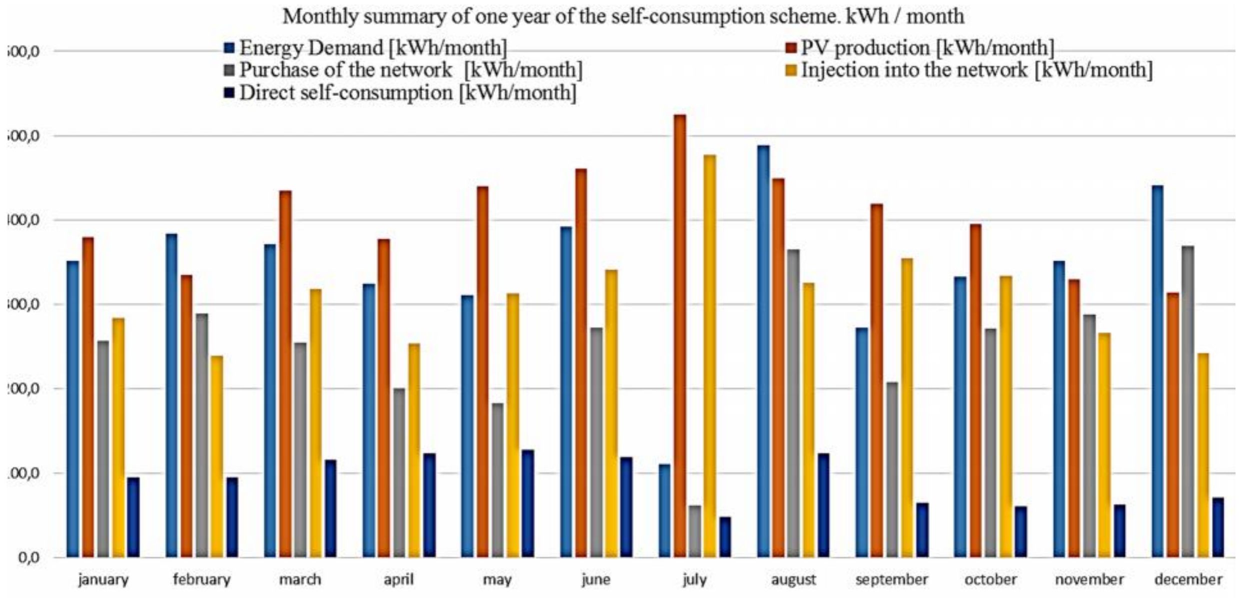
Figure 21 Self-consumption ratio factors

The following table shows the hourly calculation that has been made for each month, and the following graphs show the monthly and annual totals

As shown in the following graph, there is greater production that therefore demands, more injection than it buys from the network; however, it has nothing to do with self-consumption nor its ratio

	Energy Demand [kWh/month]	PV production [kWh/month]	Purchase of the network [kWh/month]	Injection into the network [kWh/month]	Direct self-consumption [kWh/month]	Self-consumption ratio % = Energy Demand kWh/month / PV production kWh/month. Matching hours by day
january	351,4	379,3	256,3	284,2	95,1	28%
february	383,5	334,3	288,6	239,4	94,9	32%
march	370,7	434,4	254,1	317,8	116,6	30%
april	324,1	376,9	200,5	253,4	123,6	33%
may	310,2	440,1	182,8	312,7	127,4	29%
june	392,2	460,4	272,4	340,7	119,8	26%
july	110,8	525,2	62,6	476,9	48,2	9%
august	488,4	449,0	364,5	325,2	123,9	28%
september	272,5	419,2	207,7	354,5	64,8	20%
october	333,1	395,4	271,7	334,0	61,4	22%
november	351,4	329,2	288,4	266,2	63,0	26%
december	440,4	313,6	369,0	242,2	71,4	32%
total	4.128,5	4.857,1	3.018,5	3.747,1	1.110,0	26,13%

Table 16 annual summary Self-consumption ratio



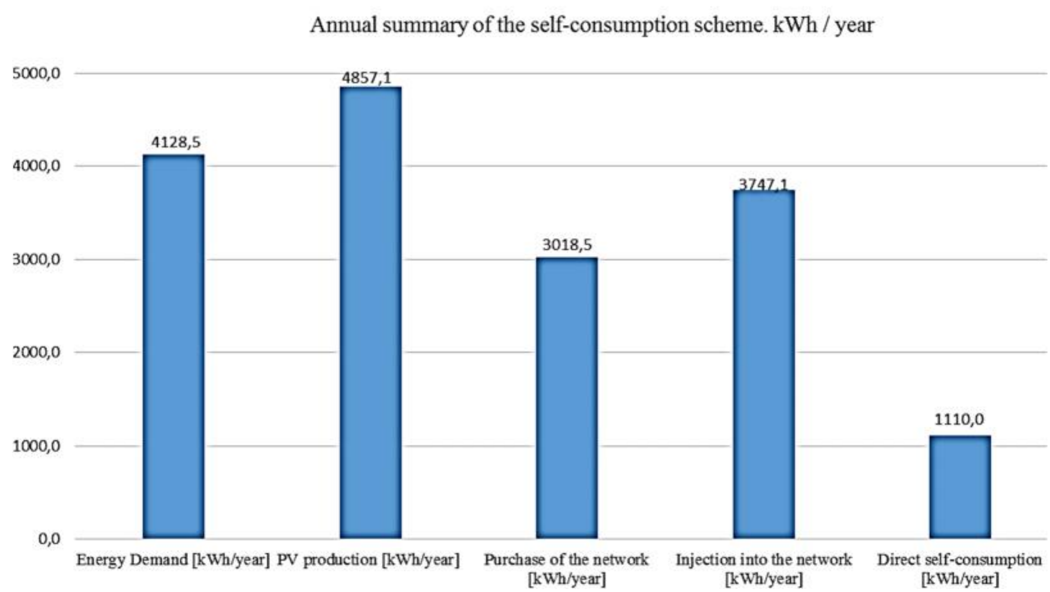


Figure 22. Monthly and annual summary self-consumption

ECONOMIC ANALYSIS

Current situation with the contract with supplying company Iberdrola

Calculations of current electricity use with standard charges with Iberdrola's 2.0A tariff (no hourly discrimination). *PVCP* tariff (Supply at a voluntary price of the small consumer).

The resulting balance over 25 years is €29.437. These calculations are shown in the following table. As well as the breakdown of Iberdrola invoice charges.

In this instance, there is no accounting for the environmental impact of carbon emissions.

IBERDROLA	days	TOTAL VARIABLE ENERGY CHARGE: Energy amount + lease tax + IGIC. €	TOTAL FIXED POWER CHARGE: amount per power + tax electricity + IGIC.€	Equipment rental + Payment protection insurance + IGIC equipment.€	Monthly bills amount.€
January	31	48,312	13,338	2,837	64,487
February	28	52,720	12,047	2,556	67,323
March	31	50,965	13,338	2,837	67,140
April	30	44,556	12,907	2,750	60,213
May	31	42,651	13,338	2,837	58,825
June	30	53,918	12,907	2,750	69,575
July	31	15,240	13,338	2,837	31,414
August	31	67,143	13,338	2,837	83,317
September	30	37,458	12,907	2,750	53,115
October	31	45,790	13,338	2,837	61,965
November	30	48,311	12,907	2,750	63,968
December	31	60,543	13,338	2,837	76,717
YEAR !		**567,606**	**157,039**	**33,412**	**758,058**
average euro/ kWh		**0,137**	**0,038**	**0,008**	**0,184**

Table 17 Breakdown of invoice amounts: fixed charges, variables and equipment. Monthly bills

CURRENT STATUS IBERDROLA. Rate 2.0A PVPC			
Annual increase in the price of energy %			0,05
Price of energy [€ / kWh] according to invoic			0,18362
	Energy consumed = Demand. kWh/año	**Rate value € / kWh**	**Amount of invoices €/ año**
YEAR 0			
YEAR 1	4128,5	0,183616	758,1
YEAR 2	4087,2	0,192797	788,0
YEAR 3	4046,3	0,202436	819,1
YEAR 4	4005,9	0,212558	851,5
YEAR 5	3965,8	0,223186	885,1
YEAR 6	3926,2	0,234346	920,1
YEAR 7	3886,9	0,246063	956,4
YEAR 8	3848,0	0,258366	994,2
YEAR 9	3809,6	0,271284	1033,5
YEAR 10	3771,5	0,284848	1074,3
YEAR 11	3733,7	0,299091	1116,7
YEAR 12	3696,4	0,314045	1160,8
YEAR 13	3659,4	0,329748	1206,7
YEAR 14	3622,8	0,346235	1254,4
YEAR 15	3586,6	0,363547	1303,9
YEAR 16	3550,8	0,381724	1355,4
YEAR 17	3515,2	0,400810	1408,9
YEAR 18	3480,1	0,420851	1464,6
YEAR 19	3445,3	0,441893	1522,5
YEAR 20	3410,8	0,463988	1582,6
YEAR 21	3376,7	0,487187	1645,1
YEAR 22	3343,0	0,511547	1710,1
YEAR 23	3309,5	0,537124	1777,6
YEAR 24	3276,4	0,563980	1847,8
		Treasury balance, payable	**29.437,4 €**

Table 18 Economic analysis status Iberdrola bill for 25 years

Economic analysis of the PV installation proposal

- ***Modality of exporting surplus energy to the grid. NO BATTERIES.***

Simplified compensation counts the energy consumed less the injected one, at the proposed rates pending approval. This calculation must be done by time hourly as the smart meter does.

Economic simplified compensation RD 15/2018. This concept that is related to the cost of electricity produced and consumed. Adding the total of the period without taking into account the energetic coincidence between demand and solar production.

	Purchase of the network. [kWh/hour]	General Rate 2.0A, PVPC, without hourly discrimination [€/kWh]	Injection network: Production - Self-consumption. [kWh/hour]	Pmh. hourly price of the average day of the month. [€/kWh]	Simplified compensation RD Self-consumption. To pay [€]
annual total and average	3018,54	0,18360	3747,11	0,0608	343,94 €

Table 19 Purchase price of energy and the sale price of surpluses

In the following data it can be observed how with the yearly financial compensation, two months give negative compensation values, which are not discounted in the monthly billing and so are lost for the consumer. The rest of months, the consumer has to pay for the energy consumed from the grid.

	Purchase of the network. [kWh/hour]	General Rate 2.0A, PVPC, without hourly discrimination [€/kWh]	Injection network: Production - Self-consumption. [kWh/hour]	Pmh. hourly price of the average day of the month. [€/kWh]	Simplified compensation RD Self-consumption. To pay [€]
january	256,27	0,12238	284,18	0,06 €	13,84 €
february	288,58	0,18700	239,38	0,06 €	30,29 €
march	254,14	0,09485	317,83	0,05 €	11,95 €
april	200,52	0,10087	253,37	0,04 €	11,66 €
may	182,83	0,11043	312,71	0,06 €	5,81 €
june	272,41	0,11916	340,65	0,06 €	18,15 €
july	62,60	0,10812	476,94	0,06 €	-19,81 €
august	364,51	0,12287	325,16	0,07 €	28,99 €
september	207,67	0,12599	354,46	0,07 €	-0,02 €
october	271,70	0,11997	334,04	0,07 €	9,28 €
november	288,36	0,11686	266,20	0,07 €	17,25 €
december	368,96	0,12876	242,18	0,06 €	33,04 €
annual total and average	3018,54	0,12144	3747,11	0,06 €	180,26 €

Table 20 Calculation in detail of economic tariff compensation modality without batteries

While energy compensation shows that, the energy balance of production vs demand is 17% more produced, the consumer still has to pay the utility company.

In this modality the energy balance of demand vs exportation, results in that energy exported back in the grid cannot be consumed in energetic form later, but only in economic compensation, with the important feature that the consumer always has to pay the company.

	NET billing. Iberdrola + PV 3kWp, injection of surplus to the network. WITHOUT BATTERIES.						
	Energy Demand [kWh/year]	**PV production [kWh/year]**	**Purchase of the network [kWh/year]**	**Injection into the network [kWh/year]**	**Energy compensation [kWh / month] = consumption - injection**	**Direct self-consumption [kWh/month]**	**Simplified economic compensation for the injection into the surplus network. To pay [€ / month]. According to the RD. [€]**
january	351,40	379,31	256,27	284,18	-27,91	95,13	13,84 €
february	383,46	334,26	288,58	239,38	49,20	94,88	30,29 €
march	370,70	434,39	254,14	317,83	-63,70	116,56	11,95 €
april	324,08	376,92	200,52	253,37	-52,84	123,55	11,66 €
may	310,22	440,11	182,83	312,71	-129,88	127,39	5,81 €
june	392,17	460,42	272,41	340,65	-68,25	119,77	18,15 €
july	110,85	525,19	62,60	476,94	-414,34	48,24	-19,81 €
august	488,36	449,01	364,51	325,16	39,35	123,85	28,99 €
september	272,45	419,24	207,67	354,46	-146,79	64,78	-0,02 €
october	333,06	395,39	271,70	334,04	-62,34	61,36	9,28 €
november	351,39	329,23	288,36	266,20	22,15	63,03	17,25 €
december	440,36	313,58	368,96	242,18	126,77	71,40	33,04 €
TOTALS	**4128,5**	**4857,1**	**3018,5**	**3747,1**	**910,2**	**1110,0**	**180,26 €**
percentage average			**73%**	**77%**		**27%**	

Table 21 Calculation in detail of economic compensation modality without batteries

Surplus exported back to the grid is 77% of PV production.

Consumption from the grid is 73% of demand.

Direct self-consumption is 27% of demand.

Net billing VS Net metering

If the surplus energy is counted in energy compensation (net metering), between the energy that consumed and the one injected into the network, each month that has been injected more than the consumed one would result in a positive balance of a total 910.2 kWh per year, in favour of the prosumer. If this positive balance would be collected at the price of Pmh (0.0608 €/kWh), it would be paid as economic income. However, as it is done in economic compensation (Net billing), it is lost.

it would be paid as economic income. However, as it is done in economic compensation (Net billing), it is lost.

Modality with surplus production exported to the grid:

-2.180€ Net present value negative (NVT)

-0.47% internal rate of return (IRR)

The economic benefit (saving or profit) is counted from the benefit that is going to be generated by the saving of the reduction in consumption with the solar installation.

The contracted power is reduced since the consumption of the network is reduced. Also, its accounted the minimum bill to pay 136€ + 36 €= 169 € (mandatory fixed charges) with fixed charges such as power charge, equipment rental charge and taxes. The tax electricity payment and IGIC are not counted because it has been eliminated recently, January 2019

	Saving or profit	Mandatory fixed charges, wich must be paid to the company withput energy consumtion.	
	TOTAL VARIABLE ENERGY CHARGE: Energy amount + lease tax + IGIC. €	**TOTAL FIXED POWER CHARGE: amount per power .€**	**Equipment rental + Payment protection insurance + IGIC equipment.€**
08C I 8FK	48,312	3,571	2,837
/ <9F I 8FK	52,720	11,127	2,556
1 8F : ?	50,965	12,319	2,837
, EF@A	44,556	11,922	2,750
1 8K	42,651	12,319	2,837
0 I C<	53,918	11,922	2,750
0 I AK	15,240	12,319	2,837
, I > I GH	67,143	12,319	2,837
5<EH<B 9<F	37,458	11,922	2,750
3 : HD9<F	45,790	12,319	2,837
2DJ<B 9<F	48,311	11,922	2,750
- < : <B 9<F	60,543	12,319	2,837
	567,606	**136,301**	**33,412**
7 . , 4	0,137	0,033	0,008

Table 22 Breakdown of invoice amounts: fixed charges, variables and equipment

Cash flow = Energy that will not be consumed from the grid (saving or profit) – compensation payment – OyM (updated with consumer price index and discount rate) – mandatory fixed charges invoice

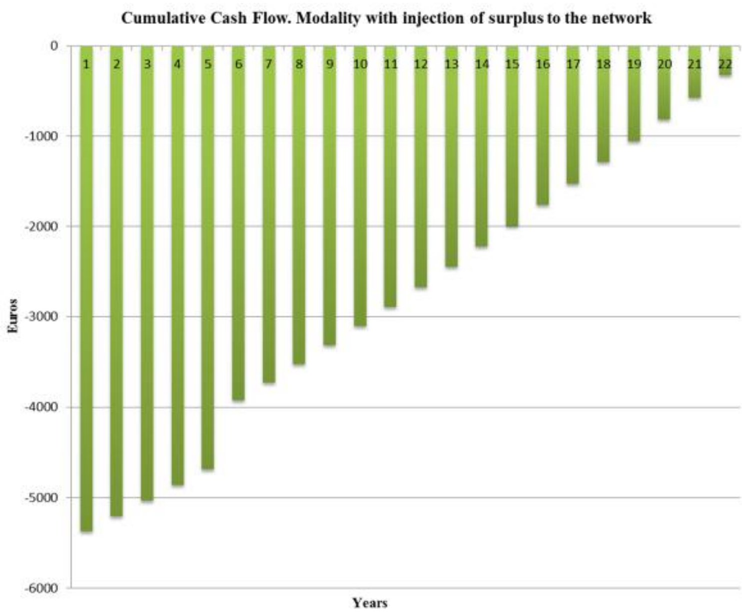


Figure 23 Cash Flow modality without storage

NET billing. Iberdrola + PV 3kWp, injection of surplus to the network. WITHOUT BATTERIES.

Year	Energy demand. Expected consumption to save [kWh]	Rate tariff €/ kWh	Benefit or profit = Energy value euros	Economic compensation. Cost to pay. Euros	Fixed charge cost of the minimum invoice without any consumption. Euros	OyM Cost. Euros	Maintenance cost updated to CPI and Discount. Euros	Cash Flow = Savings - economic compensation - OyM - fixed charge tariff. Euros	Accumulated Cash Flow. Euros
0						5370	5.370	-5370	-5370
1	4.128	0,137	567,61 €	180,26 €	169,71 €	53,70 €	52,67 €	164,97 €	-5.205,03 €
2	4.087	0,144	590,03 €	189,27 €	178,20 €	55,31 €	53,20 €	169,35 €	-5.035,68 €
3	4.046	0,152	613,33 €	198,73 €	187,11 €	56,97 €	53,75 €	173,74 €	-4.861,93 €
4	4.006	0,159	637,56 €	208,67 €	196,46 €	58,68 €	54,29 €	178,13 €	-4.683,80 €
8	3.848	0,193	744,42 €	253,64 €	238,80 €	66,04 €	56,54 €	195,44 €	-3.927,84 €
9	3.810	0,203	773,83 €	266,32 €	250,74 €	68,03 €	57,12 €	199,64 €	-3.728,20 €
10	3.771	0,213	804,39 €	279,64 €	263,28 €	70,07 €	57,70 €	203,77 €	-3.524,43 €
11	3.734	0,224	836,17 €	293,62 €	276,44 €	72,17 €	58,29 €	207,81 €	-3.316,62 €
12	3.696	0,235	869,19 €	308,30 €	290,27 €	74,33 €	58,88 €	211,74 €	-3.104,88 €
13	3.659	0,247	903,53 €	323,72 €	304,78 €	76,56 €	59,48 €	215,55 €	-2.889,33 €
14	3.623	0,259	939,22 €	339,90 €	320,02 €	78,86 €	60,09 €	219,21 €	-2.670,12 €
15	3.587	0,272	976,32 €	356,90 €	336,02 €	81,23 €	60,70 €	222,70 €	-2.447,43 €
16	3.551	0,286	1.014,88 €	374,74 €	352,82 €	83,66 €	61,32 €	226,00 €	-2.221,43 €
17	3.515	0,300	1.054,97 €	393,48 €	370,46 €	86,17 €	61,94 €	229,08 €	-1.992,35 €
18	3.480	0,315	1.096,64 €	413,15 €	388,99 €	88,76 €	62,58 €	231,92 €	-1.760,43 €
19	3.445	0,331	1.139,96 €	433,81 €	408,43 €	91,42 €	63,21 €	234,50 €	-1.525,93 €
20	3.411	0,347	1.184,98 €	455,50 €	428,86 €	94,16 €	63,86 €	236,77 €	-1.289,17 €
21	3.377	0,365	1.231,79 €	478,28 €	450,30 €	96,99 €	64,51 €	238,71 €	-1.050,46 €
22	3.343	0,383	1.280,45 €	502,19 €	472,81 €	99,90 €	65,17 €	240,27 €	-810,19 €
23	3.310	0,402	1.331,02 €	527,30 €	496,46 €	102,89 €	65,83 €	241,44 €	-568,75 €
24	3.276	0,422	1.383,60 €	553,67 €	521,28 €	105,98 €	66,50 €	242,15 €	-326,59 €
	85.206		**22.041,67 €**	**8.021,83 €**	**7.552,57 €**	**1.848,70 €**	**1.423,86 €**	**-2.180**	**VAN**
								-0,47%	**TIR**

Table 23 Indicators of profitability VAN and TIR, modality without batteries

- ***Modality without surplus export to the grid. STORAGE IN BATTERIES.***

In the following calculation of the stored self-produced energy, it can be observed that the amount of consumption from the grid is reduced by the energy stored up to the period of one day. Energy bought from the grid supplier is reduced from a 73% on the modality that exports production, to a 6% of this modality. In the following tables it is shown how PV production is greater than energy demand by 14.4%, therefore in this modality, excess energy that has not been stored (749 kWh) can be added to solar PV production energy if number of batteries increase.

- Battery storage is 77% of PV production
- Consumption from the grid is 1% of demand energy.
- Direct self-consumption is 27% of demand.
- Bought energy from the grid only happens in the second month of the year, a period when there is not enough energy stored. At the end of every month energy that is not consumed can be stored, (749kWh at the end of the year), like the following table shows.

OPTION WITHOUT INJECTION OF SURPLUS: IBERDROLA + PV 3kWp + Batteries 1 day of storage							
Price of energy according to rate. euros /kWh		**0,183615845**					
year	**Energy Demand [kWh/month]**	**PV production [kWh/month]**	**Purchase of the network [kWh/month]**	**Storage [kWh / month]**	**Purchase of the network [kWh / month]. Network consumption - Storage**	**Direct self-consumption [kWh/month]**	**Buy from the network. To pay [€ / year]. At the current electricity rate price. [€]**
enero	351,4	379,3	256,3	284,2	-27,9	95,1	
febrero	383,5	334,3	288,6	239,4	49,2	94,9	9,03 €
marzo	370,7	434,4	254,1	317,8	-63,7	116,6	
abril	324,1	376,9	200,5	253,4	-116,5	123,6	
mayo	310,2	440,1	182,8	312,7	-246,4	127,4	
junio	392,2	460,4	272,4	340,7	-314,7	119,8	
julio	110,8	525,2	62,6	476,9	-729,0	48,2	
agosto	488,4	449,0	364,5	325,2	-689,7	123,9	
septiembre	272,5	419,2	207,7	354,5	-836,5	64,8	
octubre	333,1	395,4	271,7	334,0	-898,8	61,4	
noviembre	351,4	329,2	288,4	266,2	-876,6	63,0	
diciembre	440,4	313,6	369,0	242,2	**-749,9**	71,4	
total	**4128,5**	**4857,1**	**3018,5**	**3747,1**	**49,2**	**1110,0**	**9,03 €**
				77%	**1%**	**0,3**	

Table 24 Calculation in detail of economic compensation modality with batteries

The energy stored in the batteries must be calculated only in time hourly periods as the smart meter does, and it results from the subtraction of the energy solar PV produced (kWh) minus the energy demand (kWh) or consumed in each hour. If there are surpluses these are stored in batteries.

Modality WITHOUT surplus export to the grid:

337 € NVT

4.51 % IRR

17 years PP

Cash flow = Energy saved that will not be consumed from the grid (saving or profit) – OyM (updated with consumer price index and discount rate) – Purchase of energy discounting energy stored - Minimum electricity bill charge without consumption (mandatory fixed charges)

Initial cost of the investment 10.497 €. – 4.723€ (discontinuing the 45% grant) = **5.773€**

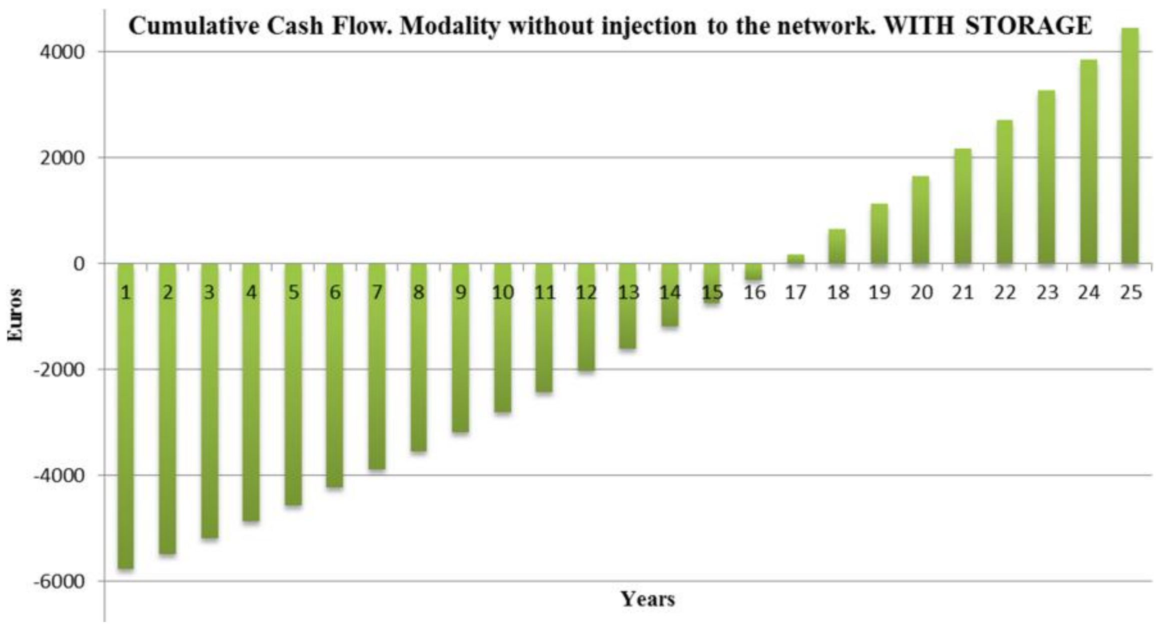


Figure 24 Cash Flow modality with storage

Option Iberdrola + pv 3kwp with storage in batteries without injection of surplus to the network

Year	Energy demand. Expected consumption to save [kWh]	Energy Rate tariff €/ kWh	Benefit or profit = Energy value euros	OyM Cost. Euros	Maintenance cost updated to infaltion and Discount rate. Euros	Purchase energy by discounting storage [kWh/año]	Purchase energy by discounting storage [EUROS/año]	Fixed charge cost of the minimum invoice without any consumption. Euros	Cash Flow = Savings - economic compensation - OyM -fixed charge tariff. Euros	Accumulated Cash Flow. Euros
0				5.773,35 €	5.773,35 €				-5.773,35 €	-5.773,35 €
1	4.128	0,13748	567,61 €	104,97 €	102,95 €	49,20	6,76 €	169,71 €	288,18 €	-5.485,17 €
2	4.087	0,144359	590,03 €	111,27 €	107,03 €	48,71	7,03 €	178,20 €	297,77 €	-5.187,41 €
3	4.046	0,151577	613,33 €	117,94 €	111,27 €	48,22	7,31 €	187,11 €	307,65 €	-4.879,76 €
4	4.006	0,159156	637,56 €	125,02 €	115,68 €	47,74	7,60 €	196,46 €	317,82 €	-4.561,94 €
5	3.966	0,167114	662,74 €	132,52 €	120,26 €	47,26	7,90 €	206,29 €	328,30 €	-4.233,64 €
6	3.926	0,175469	688,92 €	140,47 €	125,02 €	46,79	8,21 €	216,60 €	339,09 €	-3.894,56 €
7	3.887	0,184243	716,13 €	148,90 €	129,98 €	46,32	8,53 €	227,43 €	350,19 €	-3.544,37 €
8	3.848	0,193455	744,42 €	157,84 €	135,13 €	45,86	8,87 €	238,80 €	361,62 €	-3.182,75 €
9	3.810	0,203128	773,83 €	167,31 €	140,48 €	45,40	9,22 €	250,74 €	373,38 €	-2.809,37 €
10	3.771	0,213284	804,39 €	177,34 €	146,04 €	44,94	9,59 €	263,28 €	385,48 €	-2.423,89 €
11	3.734	0,223948	836,17 €	187,99 €	151,83 €	44,50	9,96 €	276,44 €	397,93 €	-2.025,96 €
12	3.696	0,235146	869,19 €	199,26 €	157,85 €	44,05	10,36 €	290,27 €	410,72 €	-1.615,24 €
13	3.659	0,246903	903,53 €	211,22 €	164,10 €	43,61	10,77 €	304,78 €	423,88 €	-1.191,36 €
14	3.623	0,259248	939,22 €	223,89 €	170,60 €	43,17	11,19 €	320,02 €	437,41 €	-753,95 €
15	3.587	0,272211	976,32 €	237,33 €	177,36 €	42,74	11,63 €	336,02 €	451,30 €	-302,65 €
16	3.551	0,285821	1.014,88 €	251,57 €	184,38 €	42,31	12,09 €	352,82 €	465,58 €	162,93 €
17	3.515	0,300112	1.054,97 €	266,66 €	191,69 €	41,89	12,57 €	370,46 €	480,25 €	643,18 €
18	3.480	0,315118	1.096,64 €	282,66 €	199,28 €	41,47	13,07 €	388,99 €	495,30 €	1.138,48 €
19	3.445	0,330874	1.139,96 €	299,62 €	207,18 €	41,06	13,58 €	408,43 €	510,76 €	1.649,24 €
20	3.411	0,347418	1.184,98 €	317,60 €	215,38 €	40,65	14,12 €	428,86 €	526,62 €	2.175,86 €
21	3.377	0,364788	1.231,79 €	336,65 €	223,92 €	40,24	14,68 €	450,30 €	542,90 €	2.718,76 €
22	3.343	0,383028	1.280,45 €	356,85 €	232,79 €	39,84	15,26 €	472,81 €	559,59 €	3.278,35 €
23	3.310	0,402179	1.331,02 €	378,26 €	242,01 €	39,44	15,86 €	496,46 €	576,70 €	3.855,04 €
24	3.276	0,422288	1.383,60 €	400,96 €	251,60 €	39,05	16,49 €	521,28 €	594,24 €	4.449,28 €
	85.206			5.334,11 €	4.003,80 €				337	VAN
									4,51%	TIR

Table 25 Indicators of profitability VAN and TIR, modality with batteries

CONCLUSIONS

• Final comparison enters the two modalities and the current state

The most economically convenient option is the battery modality, due to the subsidy offered by 45% of the installation, and the profitability indicators although with value show the convenience of the investment. The internal rate of return is positive and greater than the current bank interest. The modality of self-consumption with surplus injection, although it has no more convenient returns than to continue with the current state of supply, purchase energy from Electric Company, without any investment.

	ACTUAL STATE	WITH SURPLUSES	WITH BATTERIES
Treasury balance	29.437 €	-327 €	4.449 €
NVT		-2.180 €	337 €
IRR		-0,47%	4,51%
PP			17

Table 26. Scenario comparison

- In the financial compensation type Net Billing, in the no-battery mode, there is a large difference between the purchase price of energy and the sale price of surpluses. The value of the sale is approximately 50% of the purchase price. So are losing money in the injection of energy to the network.

	Purchase of the network. [kWh/hour]	General Rate 2.0A, PVPC, without hourly discrimination [€/kWh]	Injection network: Production - Self-consumption. [kWh/year]	Pmh. hourly price of the average day of the month. [€/kWh]
annual total and average	3018,54	0,12144	3747,11	0,06 €

Table 27. Purchase price of energy and the sale price of surpluses

- The objective is to match the cost of self-produced electricity with electricity consumed from the network and injected into the grid. If these values are similar, the return on the initial investment is not affected.

Cost of self-produced energy, without batteries . euro / kWh	Energy purchase rate,Fixed charge, variable and equipment.euro / kWh	Rate of sale of surplus in injection to the network.euro / kWh
1,18	0,18360	0,0640

Table 28. Cost energy comparison: purchase and rate tariff

- The ideal situation would be that the energy injected in any period exceeds the energy consumed, for which the objective of regulation, subsidy and compensation should focus on improving and rewarding the coincidence or ratio between hours of consumption and production.

- • In this battery-powered case study installation, it is more cost-effective to store the surplus energy in batteries to reduce the purchase of the network. Thus only for a month should energy be purchased to meet the demand. The remaining months work as an isolated installation of the network, without injection or consumption of the network. The power charge to be paid is the minimum billing amount, fixed charge, which is paid to the company without energy consumption (€ 15 / month minimum).
- • In the calculation of the economic compensation for energy consumed, it is paid at the FEU active billing price, according to the RD, whose value is lower than the tariff with taxes, average (FEU 0.1214 € / kWh). On the other hand, if the purchase of energy consumed is paid with the charges included in the tariff, such as the fixed cost plus the variable, plus the rental of equipment, (0.1836 € / kWh) the compensation would be even more disadvantageous.
- In the two modalities the self-consumption ratio is not promoted with any special measure. Thus, net billing compensation does not affect the increase or reduction of self-consumption or the appearance of *Prosumers.*
- • The mode of no surplus is more advantageous than with injection to the network. Only by the existence of the subsidy. However, this depends on the acquisitive capacity of the promoters, since the financial aid is delivered to the Prosumer after paying the installation. So if you it not have the economic liquidity to record the total cost of the installation, this subsidy is not granted.
- Further reducing the appearance of self-consumption prosumers and limiting their profile to a social group with a high level of purchasing power.
- The risk of increasing the need for energy consumption of the network can always be reduced by improving the self-consumption ratio through load management programs to

match the higher consumptions. The electric water heater (two months a year) in hours of higher generation and keep the thermal energy accumulated until the hours of use. Likewise, the use of refrigeration appliances can be reduced by improving comfort, limiting the demand of the house with passive bioclimatic measures such as generating natural cross ventilation, installing solar protections, night free cooling systems, in the south facade, wall application, trombe to have a ventilated facade and protected from solar radiation.

- As well as insulation systems in the housing envelope to avoid the high thermal transmittance of the walls of facades and flat roof, towards the interior of the house.
- The interrelationship between the following aspects should be more advisable and beneficial for the prosumer than for the reference companies. The sum of current factors applied to the developed profile does not promote the appearance of new prosumers due to the high risk and economic disadvantage involved in the energetic transition. The factors are the current retail prices of electricity, (fixed and variable rate and equipment) and schemes of support for renewable energy (low purchase price of injected energy) as well as the possibility of purchasing technological innovation development for improve storage

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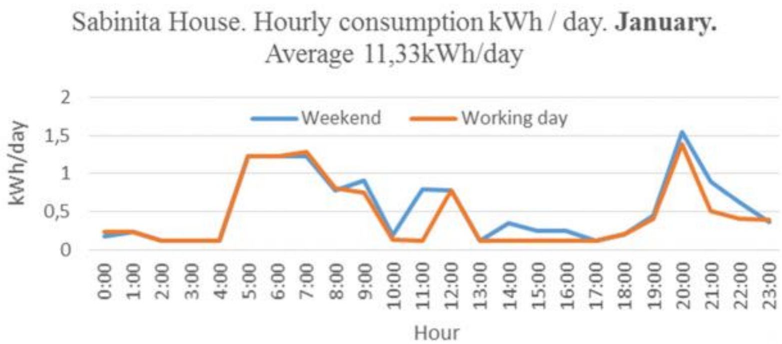
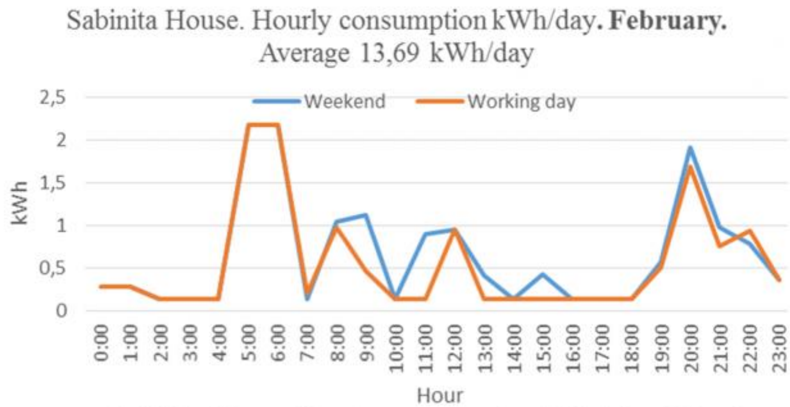
LIST OF ILLUSTRATIONS

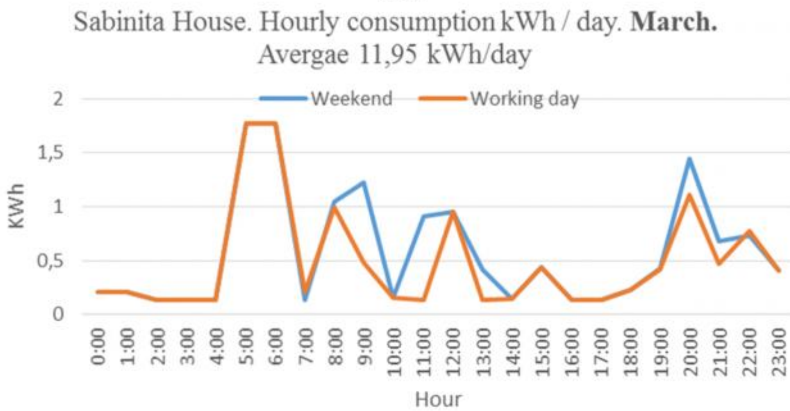
ANNEXES.

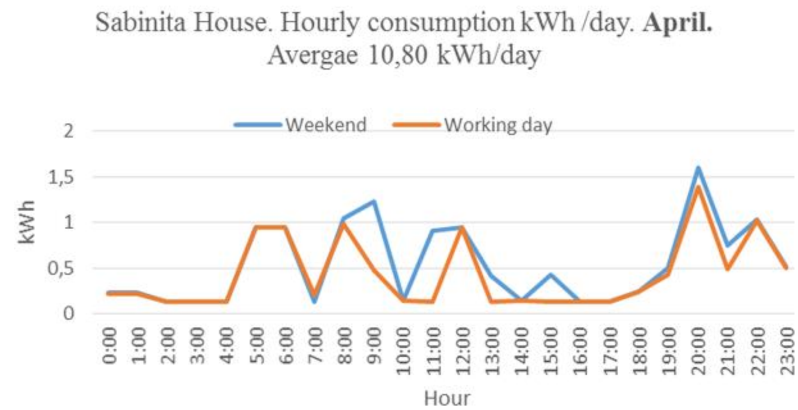
CONSUMPTION

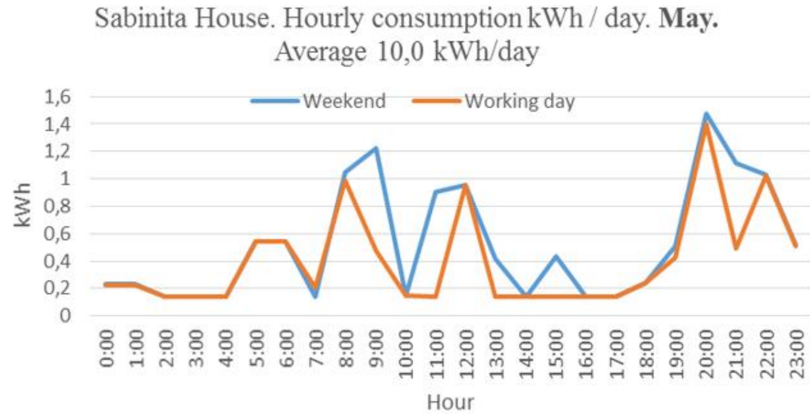
Sabinita house. Consumption kWh/day, with detail working day and weekend by month.

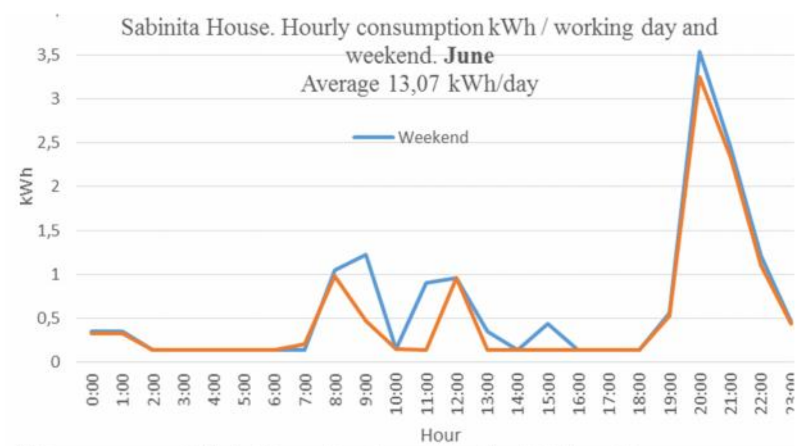


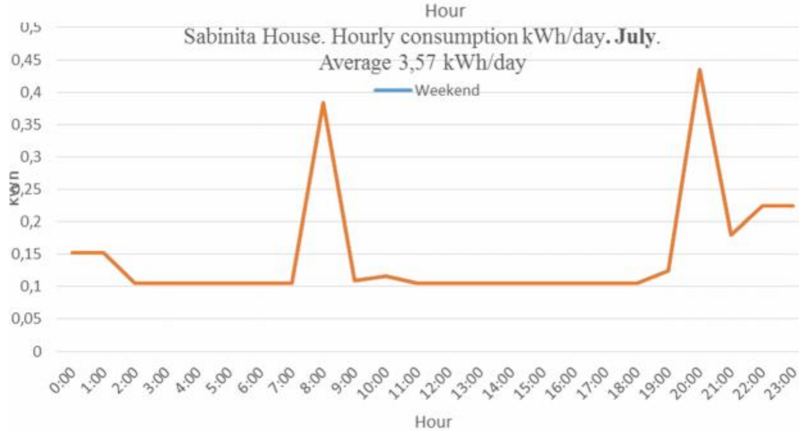


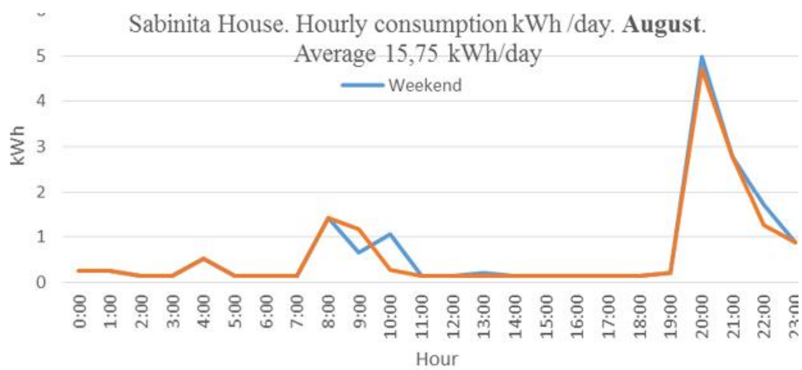



Sabinita House. Hourly consumption kWh /day. **April.**
Avergae 10,80 kWh/day
Weekend
Working day
kWh
Hour

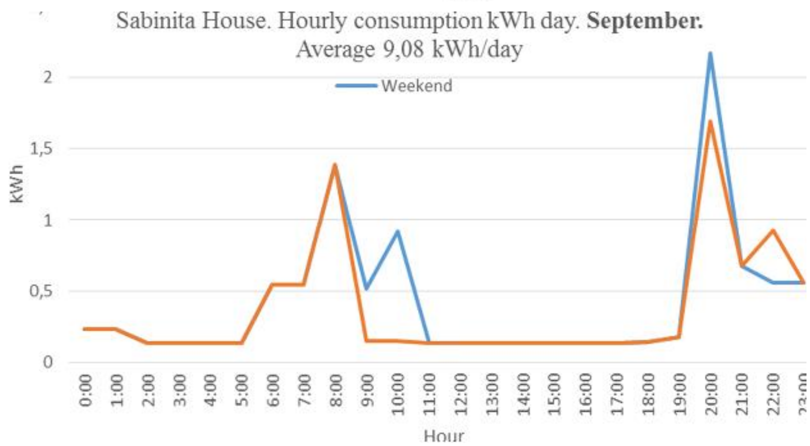

Sabinita House. Hourly consumption kWh / day. **May.**
Average 10,0 kWh/day
Weekend
Working day
kWh
Hour


Sabinita House. Hourly consumption kWh / working day and weekend. **June**
Average 13,07 kWh/day
Weekend
kWh
Hour

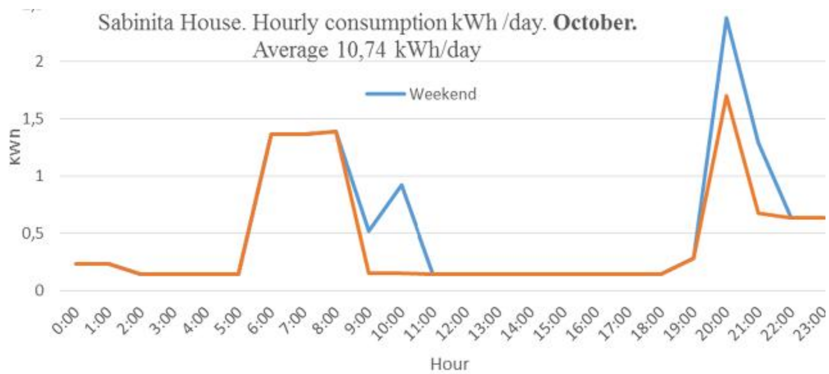

Sabinita House. Hourly consumption kWh/day**. July**.
Average 3,57 kWh/day
Weekend
Hour

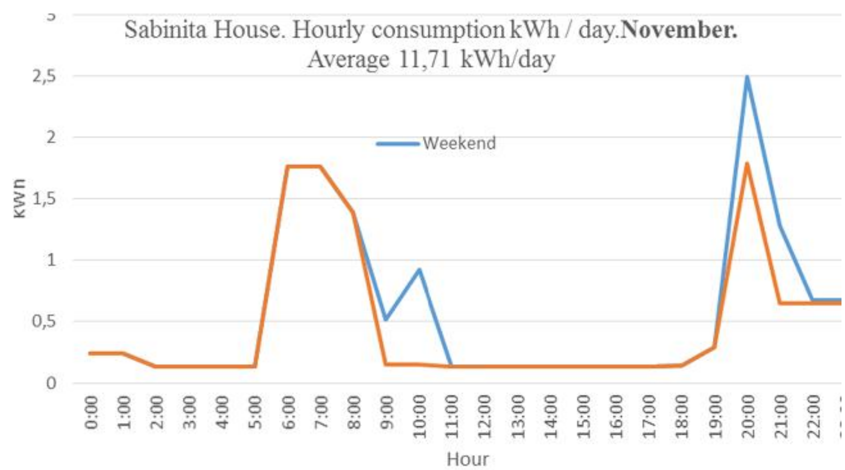


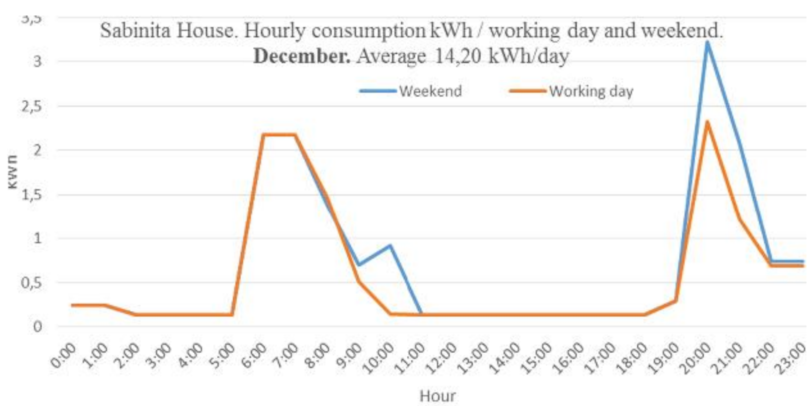
Sabinita House. Hourly consumption kWh /day. **August**.
Average 15,75 kWh/day
Weekend
kWh
5
4
3
2
1
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
Hour



Sabinita House. Hourly consumption kWh day. **September.**
Average 9,08 kWh/day
Weekend
kWh
2
1,5
1
0,5
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
Hour


Sabinita House. Hourly consumption kWh /day. October.
Average 10,74 kWh/day
Weekend
kWh
Hour


Sabinita House. Hourly consumption kWh / day.November.
Average 11,71 kWh/day
Weekend
kWh
Hour


Sabinita House. Hourly consumption kWh / working day and weekend.
December. Average 14,20 kWh/day
Weekend
Working day
kWh
Hour

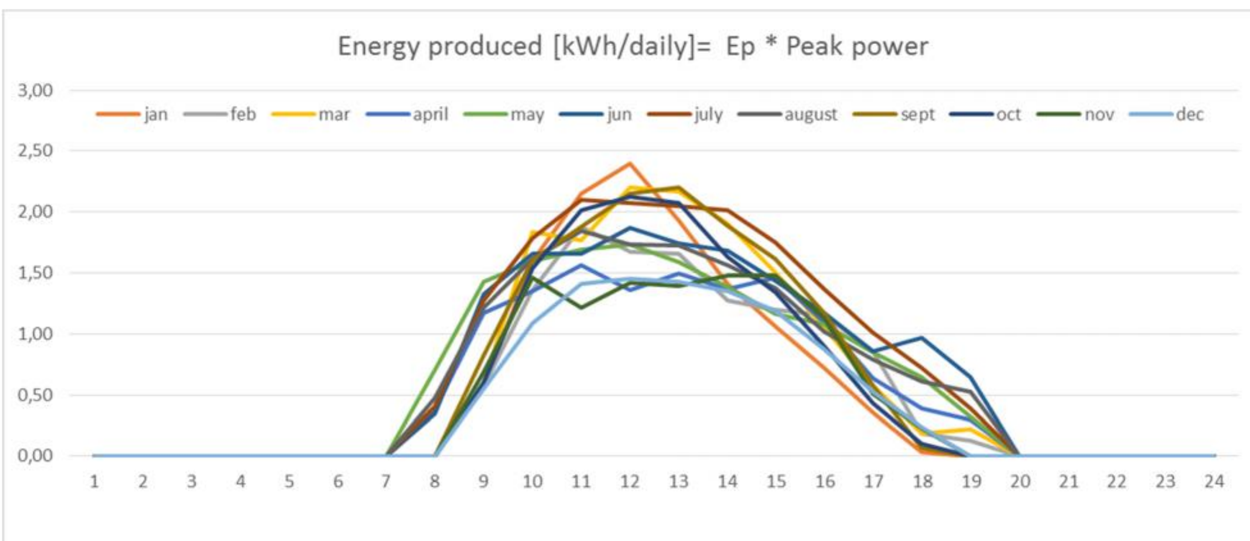
Consumption (average weekend and working days, kWh/day) by energy final uses, Sabinita house

correctiong factor			0,74										
Daily average consumption kWh, final energy uses Sabinita House													
		Mayor appliances	Others	TV Y PC	Kitchen	Air conditioner	Interior lighting	small appliances	Exterior Lighting	Electric Boiler	Stand by	**average**	**average day**
jan	weekend	3,95	0,48	0,76	1,32	0,00	1,15	0,43	0,23	3,30	1,51	**13,13**	11,34
	working day	2,15	0,75	0,62	1,32	0,00	1,12	0,08	0,23	3,30	1,51	**11,08**	
feb	weekend	4,84	0,71	0,96	1,63	0,00	1,16	0,53	0,29	4,07	1,51	**15,69**	13,70
	working day	3,12	0,56	0,88	1,63	0,00	1,16	0,14	0,29	4,07	1,51	**13,36**	
mar	weekend	4,34	0,69	0,87	1,63	0,00	0,90	0,49	0,29	3,26	1,51	**13,97**	11,96
	working day	2,65	0,32	1,01	1,63	0,00	0,90	0,10	0,29	3,26	1,51	**11,66**	
apr	weekend	4,59	0,69	1,13	1,63	0,00	1,11	0,53	0,29	1,63	1,51	**13,11**	10,80
	working day	2,78	0,32	1,09	1,63	0,00	1,11	0,10	0,29	1,63	1,51	**10,45**	
may	weekend	4,82	0,69	1,13	1,63	0,00	1,11	0,53	0,29	0,81	1,51	**12,53**	10,01
	working day	2,78	0,32	1,09	1,63	0,00	1,11	0,10	0,29	0,81	1,51	**9,63**	
jun	weekend	4,90	1,02	1,28	1,63	2,96	1,32	0,45	0,29	0,00	1,51	**15,36**	13,07
	working day	3,20	0,56	1,17	1,63	2,96	1,32	0,09	0,29	0,00	1,51	**12,72**	
jul	weekend	1,47	0,30	0,06	0,41	0,00	0,45	0,07	0,07	0,00	0,75	**3,58**	3,58
	working day	1,47	0,30	0,06	0,41	0,00	0,45	0,07	0,07	0,00	0,75	**3,58**	
aug	weekend	5,62	1,02	1,41	1,63	2,96	1,32	0,49	0,29	0,00	1,51	**16,24**	15,75
	working day	4,74	1,02	1,41	1,63	2,96	1,32	0,33	0,29	0,00	1,51	**15,20**	
sep	weekend	3,79	0,30	0,65	1,63	0,00	0,90	0,29	0,29	0,81	1,51	**10,16**	9,08
	working day	2,72	0,30	0,65	1,63	0,00	0,90	0,10	0,29	0,81	1,51	**8,92**	
oct	weekend	4,40	0,30	0,65	1,63	0,00	1,16	0,49	0,29	2,44	1,51	**12,86**	10,74
	working day	2,35	0,30	0,65	1,63	0,00	1,16	0,10	0,29	2,44	1,51	**10,43**	
nov	weekend	4,40	0,31	0,74	1,63	0,00	1,29	0,49	0,29	3,26	1,51	**13,90**	11,71
	working day	2,35	0,31	0,65	1,63	0,00	1,29	0,10	0,29	3,26	1,51	**11,38**	
dec	weekend	5,75	0,61	0,82	1,63	0,00	1,42	0,49	0,29	4,07	1,51	**16,59**	14,21
	working day	3,28	0,92	0,65	1,63	0,00	1,42	0,10	0,29	4,07	1,51	**13,85**	

SOLAR GENERATION DATA

Solar PV Energy produced each hour in a representative day every month

	Energy produced [kWh/daily]= Ep * Peak power											
hour	jan	feb	mar	april	may	jun	july	august	sept	oct	nov	dec
1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8	0,00	0,00	0,00	0,38	0,71	0,34	0,41	0,48	0,00	0,00	0,00	0,00
9	0,57	0,57	0,60	1,17	1,43	1,33	1,27	1,22	0,82	0,61	0,68	0,55
10	1,60	1,36	1,83	1,35	1,60	1,65	1,78	1,61	1,61	1,54	1,46	1,09
11	2,15	1,88	1,77	1,56	1,69	1,66	2,10	1,84	1,88	2,01	1,21	1,41
12	2,40	1,67	2,20	1,36	1,74	1,87	2,07	1,73	2,15	2,12	1,42	1,45
13	1,93	1,66	2,16	1,49	1,59	1,74	2,05	1,72	2,20	2,07	1,39	1,43
14	1,41	1,27	1,90	1,37	1,38	1,68	2,01	1,56	1,89	1,63	1,47	1,35
15	1,06	1,20	1,50	1,46	1,17	1,43	1,75	1,37	1,61	1,35	1,48	1,19
16	0,72	1,16	1,05	1,09	1,08	1,17	1,37	1,02	1,18	0,90	1,13	0,87
17	0,36	0,86	0,58	0,64	0,85	0,86	1,01	0,79	0,58	0,43	0,51	0,53
18	0,04	0,19	0,19	0,39	0,65	0,97	0,72	0,61	0,06	0,10	0,23	0,24
19	0,00	0,12	0,22	0,30	0,33	0,65	0,39	0,52	0,00	0,00	0,00	0,00
20	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
21	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
22	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
23	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
24	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
average daily kWh/day	12,24	11,94	14,01	12,56	14,20	15,35	16,94	14,48	13,97	12,75	10,97	10,12



Solar PV Energy produced each hour of every days of the months.

	Energy produced [kWh/month]= Gdm[kWh/day] * number of days of each month										
days	31	28	31	30	31	30	31	31	30	31	30	31
hour	jan	feb	mar	april	may	jun	july	august	sept	oct	nov	dec
1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8	0,00	0,00	0,00	11,45	21,87	10,30	12,69	14,73	0,00	0,00	0,00	0,00
9	17,81	16,10	18,73	35,15	44,27	39,76	39,44	37,77	24,66	18,81	20,54	17,09
10	49,59	37,96	56,86	40,42	49,55	49,59	55,33	49,97	48,24	47,64	43,74	33,75
11	66,76	52,61	54,80	46,86	52,35	49,66	64,99	57,15	56,25	62,36	36,37	43,70
12	74,29	46,78	68,15	40,88	53,84	56,11	64,32	53,75	64,42	65,79	42,57	44,99
13	59,79	46,47	67,09	44,77	49,25	52,20	63,40	53,35	65,92	64,23	41,68	44,28
14	43,82	35,62	58,96	40,97	42,83	50,35	62,34	48,49	56,72	50,51	44,23	41,89
15	32,85	33,60	46,65	43,83	36,18	43,00	54,28	42,62	48,43	41,70	44,26	36,99
16	22,28	32,35	32,60	32,75	33,47	35,21	42,37	31,56	35,27	27,81	33,81	27,10
17	11,01	23,98	17,86	19,18	26,35	25,81	31,42	24,60	17,43	13,34	15,25	16,39
18	1,12	5,30	5,77	11,79	20,07	28,99	22,39	18,82	1,90	3,20	6,78	7,41
19	0,00	3,50	6,91	8,86	10,09	19,43	12,22	16,21	0,00	0,00	0,00	0,00
20	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
21	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
22	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
23	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
24	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
average daily kWh/day	379,31	334,26	434,39	376,92	440,11	460,42	525,19	449,01	419,24	395,39	329,23	313,58

GENERATION AND CONSUMPTION CURVES. SELF-CONSUMPTION RATIO

In the following graphs, it can be observed how much energy every month, hourly, matching the solar PV production and the energy self-consumption ratio without intervention to improve it.

PV production [kWh/day]	Energy Demand [kWh/day]

		january		february		march	april			may		june
Hour	**PV production [kWh/day]**	**Energy Demand [kWh/day]**	**PV production [kWh/day]**	**Energy Demand [kWh/day]**	**PV production [kWh/day]**	**Energy Demand [kWh/day]**	**PV production [kWh/day]**	**Energy Demand [kWh/day]**	**PV production [kWh/day]**	**Energy Demand [kWh/day]**	**PV production [kWh/day]**	**Energy Demand [kWh/day]**
1:00		0,231		0,290		0,205		0,2220		0,2219		0,3325
2:00		0,239		0,290		0,205		0,2220		0,2219		0,3325
3:00		0,124		0,138		0,138		0,1379		0,1379		0,1379
4:00		0,122		0,138		0,138		0,1379		0,1379		0,1379
5:00		0,122		0,138		0,138		0,1379		0,1379		0,1379
6:00		1,221		2,173		1,766		0,9519		0,5449		0,1379
7:00		1,221		2,173		1,766		0,9519		0,5449		0,1379
8:00		1,271		0,199		0,200	0,382	0,199	0,705	0,200	0,343	0,199
9:00	0,574	0,805	0,575	0,998	0,604	0,997	1,172	0,997	1,428	0,997	1,325	0,985
10:00	1,600	0,776	1,356	0,567	1,834	0,572	1,347	0,574	1,598	0,570	1,653	0,569
11:00	2,153	0,140	1,879	0,149	1,768	0,149	1,562	0,149	1,689	0,149	1,655	0,149
12:00	2,396	0,210	1,671	0,248	2,199	0,237	1,363	0,240	1,737	0,237	1,870	0,240
13:00	1,929	0,782	1,660	0,953	2,164	0,953	1,492	0,953	1,589	0,953	1,740	0,953
14:00	1,414	0,123	1,272	0,177	1,902	0,174	1,366	0,175	1,382	0,174	1,678	0,166
15:00	1,060	0,152	1,200	0,139	1,505	0,139	1,461	0,139	1,167	0,139	1,433	0,139
16:00	0,719	0,138	1,155	0,180	1,052	0,434	1,092	0,177	1,080	0,176	1,174	0,177
17:00	0,355	0,138	0,856	0,138	0,576	0,138	0,639	0,138	0,850	0,138	0,860	0,138
18:00	0,036	0,123	0,189	0,138	0,186	0,138	0,393	0,138	0,647	0,138	0,966	0,138
19:00		0,200	0,125	0,139	0,223	0,232	0,295	0,240	0,325	0,240	0,648	0,139
20:00		0,415		0,525		0,418		0,4359		0,4356		0,5289
21:00		1,408		1,722		1,152		1,4264		1,4084		3,2946
22:00		0,551		0,796		0,501		0,5276		0,5738		2,3411
23:00		0,435		0,922		0,765		1,0234		1,0234		1,1189
0:00		0,000		0,368		0,407		0,5095		0,5094		0,4425
	12,236	3,386	11,938	3,825	14,013	4,161	12,56401	4,1185	14,1970211	4,1095	15,34734992	3,9922
	ratio	**27,7%**	**ratio**	**32,04%**	**ratio**	**29,7%**	**ratio**	**32,78%**	**ratio**	**28,95%**	**ratio**	**26,01%**

	july		august	september			october		november		december
PV production [kWh/day]	**Energy Demand [kWh/day]**	**PV production [kWh/day]**	**Energy Demand [kWh/day]**	**PV production [kWh/day]**	**Energy Demand [kWh/day]**	**PV production [kWh/day]**	**Energy Demand [kWh/day]**	**PV production [kWh/day]**	**Energy Demand [kWh/day]**	**PV production [kWh/day]**	**Energy Demand [kWh/day]**
	0,152		0,256		0,231		0,231		0,238		0,244
	0,152		0,256		0,231		0,231		0,238		0,244
	0,105		0,142		0,138		0,138		0,138		0,138
	0,105		0,142		0,138		0,138		0,138		0,138
	0,105		0,522		0,138		0,138		0,138		0,138
	0,105		0,142		0,138		0,138		0,138		0,138
	0,105		0,142		0,545		1,359		1,766		2,173
0,409	0,105	0,475	0,142		0,545		1,359		1,766		2,173
1,272	0,383	1,218	1,424	0,822	1,387	0,607	1,387	0,685	1,387	0,551	1,458
1,785	0,109	1,612	1,112	1,608	0,196	1,537	0,194	1,458	0,198	1,089	0,536
2,096	0,116	1,843	0,380	1,875	0,251	2,012	0,248	1,212	0,254	1,410	0,251
2,075	0,105	1,734	0,142	2,147	0,138	2,122	0,138	1,419	0,138	1,451	0,138
2,045	0,105	1,721	0,142	2,197	0,138	2,072	0,138	1,389	0,138	1,428	0,138
2,011	0,105	1,564	0,151	1,891	0,138	1,629	0,138	1,474	0,138	1,351	0,138
1,751	0,105	1,375	0,142	1,614	0,138	1,345	0,138	1,475	0,138	1,193	0,138
1,367	0,105	1,018	0,142	1,176	0,138	0,897	0,138	1,127	0,138	0,874	0,138
1,014	0,105	0,793	0,142	0,581	0,138	0,430	0,138	0,508	0,138	0,529	0,138
0,722	0,105	0,607	0,142	0,063	0,138	0,103	0,138	0,226	0,138	0,239	0,138
0,394	0,105		0,143		0,139		0,139		0,139		0,139
	0,125		0,224		0,176		0,277		0,288		0,299
	0,435		4,748		1,759		1,783		1,885		2,447
	0,180		2,776		0,674		0,753		0,736		1,325
	0,224		1,322		0,876		0,633		0,652		0,700
	0,224		0,883		0,555		0,633		0,652		0,700
16,942	1,556	14,484	4,059	13,975	2,799	12,755	2,794	10,974	2,803	10,116	3,210
ratio	**9,19%**	**ratio**	**28,0%**	**ratio**	**20,03%**	**ratio**	**21,91%**	**ratio**	**25,55%**	**ratio**	**31,73%**
									ratio annual average		26,13%

Self-consumption ratio variability. Summary monthly

	Energy Demand [kWh/month]	PV production [kWh/month]	Purchase of the network [kWh/month]	Injection into the network [kWh/month]	Direct self-consumption [kWh/month]	Self-consumption ratio % = Energy Demand kWh/month / PV production kWh/month. Matching hours by day
january	351,4	379,3	256,3	284,2	95,1	28%
february	383,5	334,3	288,6	239,4	94,9	32%
march	370,7	434,4	254,1	317,8	116,6	30%
april	324,1	376,9	200,5	253,4	123,6	33%
may	310,2	440,1	182,8	312,7	127,4	29%
june	392,2	460,4	272,4	340,7	119,8	26%
july	110,8	525,2	62,6	476,9	48,2	9%
august	488,4	449,0	364,5	325,2	123,9	28%
september	272,5	419,2	207,7	354,5	64,8	20%
october	333,1	395,4	271,7	334,0	61,4	22%
november	351,4	329,2	288,4	266,2	63,0	26%
december	440,4	313,6	369,0	242,2	71,4	32%
total	4.128,5	4.857,1	3.018,5	3.747,1	1.110,0	26,13%

Development of the economic simplified compensation RD 15/2018. Annual summary

NET billing. Iberdrola + PV 3kWp, injection of surplus to the network. WITHOUT BATTERIES.

	Purchase of the network. [kWh/hour]	General Rate 2.0A, PVPC, without hourly discrimination [€/kWh]	Injection network: Production - Self-consumption. [kWh/year]	Pmh. hourly price of the average day of the month. [€/kWh]	Simplified compensation RD Self-consumption. To pay [€]
january	256,27	0,12238	284,18	0,06 €	13,84 €
february	288,58	0,18700	239,38	0,06 €	30,29 €
march	254,14	0,09485	317,83	0,05 €	11,95 €
april	200,52	0,10087	253,37	0,04 €	11,66 €
may	182,83	0,11043	312,71	0,06 €	5,81 €
june	272,41	0,11916	340,65	0,06 €	18,15 €
july	62,60	0,10812	476,94	0,06 €	-19,81 €
august	364,51	0,12287	325,16	0,07 €	28,99 €
september	207,67	0,12599	354,46	0,07 €	-0,02 €
october	271,70	0,11997	334,04	0,07 €	9,28 €
november	288,36	0,11686	266,20	0,07 €	17,25 €
december	368,96	0,12876	242,18	0,06 €	33,04 €
annual total and average	**3018,54**	**0,12144**	**3747,11**	**0,06 €**	**180,26 €**

Development of the economic simplified compensation RD 15/2018. Monthly detail, only shown 2 months: negative compensation months

Compensation for the month of July					
Hour	**Purchase of the network. [kWh/hour]**	**General Rate 2.0A, PVPC, without hourly discrimination [€/kWh]**	**Injection network: Production - Self-consumption. [kWh/hour]**	**Pmh. hourly price of the average day of the month. [€/kWh]**	**Simplified compensation RD Self-consumption. [€/kWh]**
1 h	4,71	0,1256			0,591382212
2 h	4,71	0,1199			0,56458469
3 h	3,26	0,1185			0,386728966
4 h	3,26	0,1182			0,385945519
5 h	3,26	0,1181			0,385553796
6 h	3,26	0,1240			0,404846175
7 h	3,26	0,1268			0,414051676
8 h	0,00	0,1255	9,426648671		0
9 h	0,00	0,0000	27,54694588		0
10 h			51,95210018	0,06317	-3,281814168
11 h			61,39112798	0,06391	-3,923506989
12 h			61,05445504	0,0645	-3,93801235
13 h			60,13590022	0,06486	-3,900414488
14 h			59,07129161	0,06495	-3,83668039
15 h			51,01858634	0,06475	-3,303453466
16 h			39,10795557	0,0641	-2,506819952
17 h			28,15880286	0,06391	-1,799629091
18 h			19,12238622	0,06367	-1,217522331
19 h	0,00	0,0000	8,957778197		0
20 h	3,88	0,1258			0,487885681
21 h	13,49	0,1292			1,742216323
22 h	5,59	0,1299			0,725923717
23 h	6,95	0,1307			0,908900166
24 h	6,95	0,1297			0,90167012
total	**62,60**	**0,10812**	**476,94**	**0,06427**	**-19,81**

Compensation for the month of September					
Hour	**Purchase of the network. [kWh/hour]**	**General Rate 2.0A, PVPC, without hourly discrimination [€/kWh]**	**Injection network: Production - Self-consumption. [kWh/hour]**	**Pmh. hourly price of the average day of the month. [€/kWh]**	**Simplified compensation RD Self-consumption. [€/kWh]**
1 h	6,93	0,1292			0,895404699
2 h	6,93	0,1251			0,867603128
3 h	4,14	0,1253			0,518223258
4 h	4,14	0,1250			0,517023859
5 h	4,14	0,1252			0,517685596
6 h	4,14	0,1357			0,561318919
7 h	16,35	0,1421			2,322092872
8 h	16,35	0,1400	0		2,289074234
9 h	16,95	0,0000	0		0
10 h			42,37042021	0,0749	-3,173544474
11 h			48,71779585	0,0741	-3,609988672
12 h			60,2842245	0,0725	-4,370606276
13 h			61,78613835	0,07329	-4,52830608
14 h			52,57940928	0,07362	-3,870896111
15 h			44,2900351	0,0736	-3,259746584
16 h			31,13751836	0,07362	-2,292344101
17 h			13,29205039	0,07367	-0,979225352
18 h	2,23		0	0	0
19 h	4,17	0,1426	0		0,594373951
20 h	5,29	0,1468			0,777282315
21 h	52,76	0,1424			7,514153873
22 h	20,23	0,1400			2,832927326
23 h	26,28	0,1406			3,693972863
24 h	16,66	0,1298			2,161867901
total	**207,67**	**0,12599**	**354,46**	**0,07366**	**-0,02**