ANALYSYS OF SPANISH SELF-CONSUMPTION NORMATIVE: PROFITABILITY BASED ON CONSUMPTION PROFILES

Escobar-Forján, P.[a] , Jiménez-Macías, E.[b], Martínez-Cámara, E.[c] , García-Alcaraz, JL.[d], Sáenz-Díez, J.C.[e]

[a,c] Department of Mechanical Engineering. University of La Rioja. Logroño. Spain.
[b,e] Department of Electrical Engineering. University of La Rioja. Logroño. Spain.
[d] Autonomous University of Ciudad Juarez. Chiuhauha. Mexico.

[a] pescobarforjan@gmail.com, [b] emilio.jimenez@unirioja.es, [c] e.camara@eolicas.com,
[d] jorge.garcia@uacj.mx, [e] juan-carlos.saenz-diez@unirioja.es

ABSTRACT
This paper analyses the new Spanish normative on self-consumption (Royal Decree 900/2015) and its effects and profitability depending on the consumption profiles. A model based on the discounted cash flows over the life cycle of the plant model is used to analyze the feasibility of a photovoltaic system of self-consumption. The impact of the Royal Decree in the return on investment of a solar photovoltaic system of self-consumption is discussed for three different types of consumers, analysing the effect of the charges associated with the costs and services of the electrical system. In each case solutions are proposed to improve the viability and they are simulated with alternative regulatory schemes such as net metering. Finally, the effect of the difference in electricity production between two Spanish cities like Seville and Oviedo with very different climatic conditions is analyzed.

Keywords: self-consumption, Spanish power normative, viability, profitability analysis

1. BACKGROUND

This paper analyses the new Spanish normative on self-consumption (Royal Decree 900/2015) and its effects and profitability depending on the consumption profiles. First of all, most relevant issues are analysed in relation to different regulatory schemes existing in self-consumption to understand the most important aspects of Royal Decree. A model based on the discounted cash flows over the life cycle of the plant model will be used to analyze the feasibility of a photovoltaic system of self-consumption.
The impact of the Royal Decree in the return on investment of a solar photovoltaic installation of self-consumption is discussed for three different types of consumers, analysing the effect of the charges associated with the costs and services of the electrical system. In each case solutions are proposed to improve the viability and they are simulated with alternative regulatory schemes such as net metering. Finally, the effect of the difference in electricity production between two Spanish cities like Seville and Oviedo with very different climatic conditions is analyzed.

1.1. Self-consumption Support Methods

Historically, lawmakers have given special importance to develop rules on photovoltaic systems in the residential sector. As a result, various schemes have been introduced that are based on methods of support, may be indirect or direct [1].
Indirect methods include funding for research and development of technology, and regulations as affirmative obligation to make a photovoltaic system in new buildings. Other systems supporting the indirect self-consumption are so-called "net-metering" or "net-billing". This system compensates in their bill the energy spilled to network by electricity producers.
Direct methods provide financial support and can be based on quantity or quality.
An example of quantitative support is green certificate (GC), received by the owner of a photovoltaic system for the generation of a certain amount of energy. This system was used in the past decade in a few European countries such as Belgium, United Kingdom, Poland or Romania.
The main direct support schemes are based on the price. The most common policy is "feed-in tariff", which pays producers a specific price for each unit of energy produced and fed into the grid.
Other direct support schemes can be subsidies, tax rebates, and green loans.

1.2. Self-consumption scheme

There is a great diversity of models of electric consumption in the world with schemes and various parameters. In a simplified manner, it can be considered that there are five representative models [2]:
-Self-consumption with limitations. The savings in electricity bills are reduced by some additional fees or taxes. In addition, the excess electricity is fed into the grid but no compensation is obtained and it is lost by the self-consumer. This type of consumption is implemented in Spain.
- Self-consumption with electricity excess premium ("feed-in tariff"). The consumption saves on electricity bills and energy excess is sold under a defined rate that can be fixed or indexed to the retail price of electricity.

This mode is implemented in Germany and other countries.
- Net-billing. There are two streams of energy that could have two different prices. Costs related to the two flows are offset to calculate the reduction in the self-consumer bill. This mode is implemented in Italy.
- Net-metering. The electricity excess is compensated by the energy consumed during a particular time period; usually one year. In this case the price of the exported electricity has the same value as the price of electricity purchased from the grid. This implies a passive subsidy, since this price includes not only the cost of electricity, but also the associated system costs and other fees. This mode is implemented in Belgium.
- Self-consumption with bonus. Self-consumption is stimulated with a price above the market for energy self-consumed or through a certain value for the energy excess fed into the grid, higher than market price.
Website [3] at the initiative of the European Commission contains a database of all legal support mechanisms for renewable energy of 28 member countries and 4 countries of the European Free Trade Association (EFTA countries).

1.3. Self-consuption parameters

The most important parameters of the normative on self-consumption are presented bellow:
- Income from self-consumed electricity. It may be for savings in the bill, or premium, or green certificates.
- Charges to finance the costs of distribution and transportation. This parameter indicates whether the self.consumer have to pay the costs of the network.
- Value of electricity excess. It may be the same price of electricity but reduced by charges or fees. This is what is called "net-metering". This is often described as some energy credits that can be used for a predefined period to reduce the bill. It may be a premium payment or green certificates regulated by legislation. In other instances it may consist in the payment of the price of wholesale market or even it could not be entitled to any payment and therefore it supposes an energy lose.
- Maximum period of time for compensation. It is the time period during which it compensates the energy injected into the network. It can be real-time, 15 minutes, an hour, a day, a month, or indefinitely.
- Geographical compensation. It indicates whether the consumption and generation can be compensated in different locations.
- Duration of regulation. It indicates the period of validity of the regulation of self-consumption.
- Third party rights. It indicates whether a third party is allowed to own generation facilities under leasing schemes, PPAs, etc.
- Limitations on the system size. Regulations often impose limit generation capabilities.

1.4. State of the art

After three years of discussion of all sectors involved, on October 9 2015, the Royal Decree 900/2015 was approved.

Lopez et al. [4] evaluated the profitability of investors in different segments with particular emphasis on charges for costs and system services ("backup charge") and the effect of financing costs. Three alternative regulations dealing with selling energy excess were analyzed: pure self-consumption, net metering, and net billing. The study results show that the regulation will restrict the dissemination of photovoltaic systems of self-consumption, and therefore net billing scheme is proposed, which promotes the dissemination of photovoltaic systems at minimal cost for the system. This scheme is recommended by the European Commission.
De Boeck et al. [1] conducted an evaluation of the regulation of photovoltaic systems in the residential sector of the main European markets (Flanders in Belgium, Germany, Italy, Spain, and France). The feasibility of using an investment based on discounted cash flows from the plant during its life cycle was studied. The results indicated that the system of Italy has been the most profitable of all countries surveyed since 2010. It also indicates that most regulations make investing in a photovoltaic installation in a home to be profitable except in the case of Spain.
Prior to the publication of Royal Decree under study, Talavera et al. [5] conducted a study of profitability of a photovoltaic system installed at the University of Jaen. Levelized Cost of Electricity (LCOE), a payback period of 17.5 years and an internal rate of return of 8.48% in the worst case were calculated. In addition to this, the analysis included a sensitivity analysis of the factors that influence the profitability of the systems, as the initial investment, photovoltaic production, additional fees, and changes in the price of the electricity market.
Rabaza et al. [6] conducted a feasibility study of a network connected to different oil mills photovoltaic systems in Andalusia (southern Spain). The results of this study contemplated a reduction in spending power between 2% and 37%.
Marin-Comitre [7] conducted a feasibility study of several photovoltaic systems in the region of Extremadura (Spain), which is a region with high levels of solar radiation. The results indicate that the consumption without selling surplus energy is not profitable in the domestic sector. Moreover, if the Spanish government aproves the charge for costs and services of the electrical system, profitability would be seriously damaged.
Garcia-Trivino [8] analyzed the feasibility of net metering scheme in small power systems in homes, considering that could help them be feasible. This study was conducted after the publication of two draft Royal Decrees of self-consumption by the Spanish Government.
Colmenar-Santos et al. [9] assessed the potential profitability of self-sufficiency of a house and concluded that self-sufficiency can be achieved at prices of energy discharged to grid below the Feef-in Tariffs (FITs), available at that time but eliminated in 2012 through renewable moratorium with Law 1/2012.

Dufo-Lopez and Bernal-Augustin [10] analyzed the first two drafts and two reports by the National Energy Commission (CNE), concluding that the PV system could be profitable under the first proposed regulation and not in the draft 2015 where a charge on the self-consumed electricity was included (backup charge). This work evaluated the profitability comparing the LCOE of a photovoltaic system under the regulations proposed in the reports with the net value of the purchase of electricity for a home located in Saragossa (Spain), where irradiation is close to the average from Spain.

This work assesses the Royal Decree 900/2015 of self-consumption by analyzing the feasibility of a solar photovoltaic system for three consumer profiles and two different climatic conditions in Spain. The profitability of these systems is valued by payback time, Net Present Value (NPV), and Internal Rate of Revenue (IRR). Besides, the incidence of the net metering scheme on the aforementioned economic parameters is valued.

2. ROYAL DECREE 900/2015

Royal Decree 900/2015 creates two types of self-consumers". Self-consumption type 1 must meet that the contracted power consumer does not exceed 100 kW, that the sum of generation installed power is equal to or less than the power contracted by the consumer, and the holder of the supply is the same as the one of the generation facilities. Therefore, the subject is legally considered as a mere consumer, and electricity injected to the grid is unpaid. Moreover, in self-consumption type 2 it must be satisfied that the sum of installed power generation is equal to or less than the power contracted by the consumer, and all generation facilities must have the same owner. In this case there are two legal subjects: consumer and producer. Therefore, the producer must become an entrepreneur and PV self-consumption is considered as an economic activity, which will be taxed. This does not recognize the net metering scheme nor the figure of the "prosumer". It is unlikely that a residential system becomes type 2 and sells electricity excess to the grid due to administrative barriers and the need to become an entrepreneur. Most often, thus, is that it becomes self-consumer Type 1 exporting surplus energy without receiving compensation. In many cases, in the commercial and industrial segment, they will become self-consumers type 2 thus being able to sell energy as any other producer- This sale is a wholesale market price and paying the grid-access charge (0.5€/MWh) and the generation tax (7%). In case that the contract is in medium or high voltage, requirements by distribution companies for connection are much higher.

Facilities of self-consumption type 1 with less than or equal to 10 kW contracted power and installing a device to prevent the instantaneous energy discharge, shall be exempt from costs of access study and conexion by the distribution company.

Self-consumption type 2 facilities that are hiring in medium or high voltage and install a device to prevent the instantaneous energy discharge shall also simplify the connection requirements (this is not contained in Royal Decree but in the distribution rules).

The Royal Decree establishes fees for costs and system services (backup charge) divided into two parts: on the one hand by the difference between application power positions and power to charge for the purposes of access fees (€/kW) and on the other hand the self-consumed electricity (€/kWh). In a simplified way we can say that the fixed charge shall apply only if the photovoltaic system has a storage element.

These costs and service charges of the electricity system depend on the type of rate and tariff period in which energy is self-consumed.

The facilities of self-consumption type 1 below 10 kW are exempt from the variable charges for self-consumed electricity.

Geographical compensation and self-consumption for several clients are not allowed. Compensation is in real time and the duration of the regulatory scheme is unlimited.

3. METHODOLOGY

The purpose of this work is to determine the profitability of an investment for a solar photovoltaic system of self-consumption at the time that this decision is taken. Retroactive adjustments are not taken into account since they are not known.

The main factors that determine the profitability of photovoltaic installations are weather conditions, consumption profiles, the rate of consumption and self-sufficiency, installation costs, and electricity prices.

3.1. Weather conditions

The annual average global solar radiation on a horizontal surface can range from about 1,220 kWh/m2 in Asturias up to 1,800 kWh/m2 in Andalusia [11], that is, there exists a difference of about 47%. Simplifying, for calculating the energy produced, it is to be considered that the photovoltaic system is mounted and oriented in the optimal way. Let us consider on the one hand the city of Oviedo (capital city of Asturias) with 1,210 kWh of electricity production (35° tilt and 0° azimuth) and Seville (capital city of Andalusia) with 1,600 kWh (33º tilt and 0° azimuth) according to database Climate-SAF PVGIS [12].

3.2. Consumption profiles

Three ordinary consumer profiles are considered:

- Housing of 2 people with job. As shown in Figure 1, Monday through Friday during business hours. 9: 00h - 19:00 there is only residual consumption due to the refrigerator and stand-by of appliances and electronic equipment. Saturday and Sunday electricity consumption exist throughout the whole day.
- Industrial Company nº 1. As shown in Figure 2, there is consumption Monday to Friday during business hours from 6:00-18:00 h. The rest of the time, including Saturday and Sunday, there is only a residual consumption of about 3.5 kW.

- Industrial Company nº 2. As shown in Fig 3, there is increased consumption from Monday to Friday during working hours (6:00-18:00 h) but the rest of the time, including Saturdays and Sundays, there is considerable consumption because of the cold rooms.

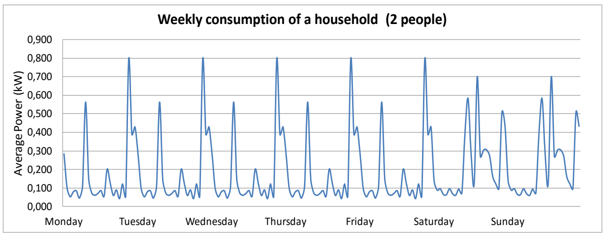

Fig. 1. Weekly consumption of a housing of two people

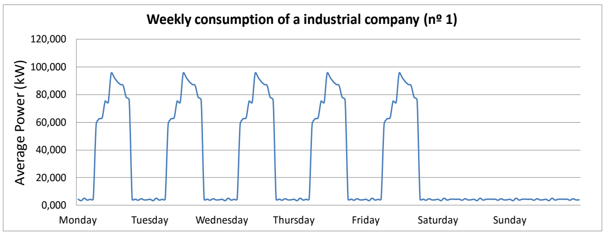

Fig. 2. Weekly consumption of industrial company nº 1

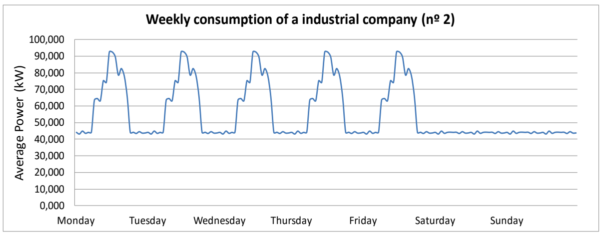

Fig. 3. Weekly consumption of industrial company nº 2

3.3. Self-consumption and self-sufficiency rates

These two rates are very important in the study of the feasibility and dependent consumption profile and the time curve of photovoltaic generation.

The self-consumption rate is the percentage of produced energy which is self-consumed. The self-sufficiency rate is the percentage of self-consumed energy in the total energy consumed.

The overall objective should be that these two rates are as high as possible.

3.4. Costs of photovoltaic solar system

System costs depend on its size and the execution way. For this study, conservative costs have been considered, estinating that the photovoltaic modules are installed in structure with optimal tilt and azimuth, and distance between photovoltaic modules, inverters, electrical panels and module counters are not excessive. A table of costs of facilities ranging from 1 kWp to 100 kWp has benn generated, which is summarized in Table 1. That table shows that in small powers, the costs of inverter, electrical panels and counter modules have much impact. As power increases the cost of photovoltaic modules increases, and therefore total cost decreases.

Table 1. Cost estimations of PV systems of different sizes (VAT not included)

Installation size (kWp)	Cost (€/kWp)
1	3,67
3	2,55
5	1,97
10	1,65
50	1,35
100	1,31

3.5. Electricity prices and charges

In this suty, housings have a tariff type 2.0A with 5kW contracted power, and companies nº 1 and nº 2 have a tariff 3.0 A with 100 kW contracted power. Electricity prices considered for the study are as shown in Table 2.

Table 2. Prices of electricity (VAT not included)

	Tariff period P1 (€/kWh)	Tariff period P2 (€/kWh)	Tariff period P3 (€/kWh)
Housing	0,1210	-	-
Company nº 1 and nº 2	0,1204	0,0996	0,0709

For the housing feasibility study it is taken into account the 21%VAT because it is owned by a person. In the case of the two companies it is not taken into account because this tax is compensated.

As seen in that table, the Royal Decree 900/2015 establishes fees for costs and system services (backup charge) that can be fixed or variable. As the facilities do not have storage elements, it is considered that there are no fixed charges. The housing of this study is exempt from variable charge because its contracted power is less than or equal to 10 kW. Therefore variable charges considered according to Royal Decree are the ones shown in table 3.

Table 3. Variable charges according to Royal Decree 900/2015

	Tariff period P1 (€/kWh)	Tariff period P2 (€/kWh)	Tariff period P3 (€/kWh)
Housing	0,000000	-	-
Company nº 1 and nº 2	0,029399	0,019334	0,011155

3.6. Economic model

The total costs of a photovoltaic system consist of three elements:

-Initial Investment: Composed of the sum of net investment cost and applicable VAT (only applicable in the case of housing, as previously seen). These two costs depend on the capacity of the facility.

$$C_{inv} = C_{net} \times (1 + VAT)$$

-Cost of inverter replacement. It is considered that the replacement of the inverter is held at half the lifetime of the system and therefore the value is deducted in year 12 [13],

$$C_{replace} = \frac{CAP \times replaceC}{(1+d)^{12}}$$

being *CAP* the system size in kWp, *replaceC* the cost of replacing the inverter kWp and *d* the discount rate.

The discount rate applicable to an investment is dependent on the rate of long-term inflation and investment risk in the country. In our case, in Spain, 5% will be considered [14].

- Present value of the total annual cost of maintenance and insurance,

$$C_{main\&insu} = m \times C_{net} \times \frac{1-(1+d)^{-25}}{d}$$

where m is considered equal to 1% and consists of the sum of annual maintenance cost of 0.5% and an annual insurance cost of 0.5%.

The first type of income of a photovoltaic system is through a direct payment via premium (feed-in tariff),

$$Rev_{FIT} = \sum_{i=1}^{I} \frac{FIT \times [(1-s) \times ((Y \times CAP)(1-(i-1)l))]}{(1+d)^i}$$

where FIT is the money received for each kWh fed into the grid, s is the ratio of consumption, Y is the production of photovoltaic electricity kWp, i is the number of year, I the number of years of the scheme after investment, and l is the degradation of the photovoltaic module. In this study, this term is not taken into account.

The second type of income is a direct payment through a green certificate,

$$Rev_{GC} = \sum_{i=1}^{I} \frac{GC \times \frac{((Y \times CAP)(1-(i-1)l))}{1000}}{(1+d)^i}$$

being GC the price at which users of the PV plant can sell their certificates per 1,000 kWh production. This term is negligible in the self-consumption facilities discussed in this article, and therefore it is not taken into account.

The third entry is a direct payment by tax deduction,

$$Rev_{TD} = \sum_{j=1}^{J} \frac{\frac{t \times C_{net}}{J}}{(1+d)^j}$$

being J the period during which tax deductions are active, and t is the percentage of the investment that can be deducted. In this type of facilities in Spain, it does not exist a national tax deduction, and therefore it is not taken into account.

The fourth entry is a savings bill for consumption, because there is less demand on the power grid,

$$Rev_{Selfc} = \sum_{n=1}^{25} \frac{[(Y \times CAP)(1-(n-1)l)] \times s \times [P_1(1+g)^{n-1} + Z]}{(1+d)^{n-1}}$$

where n is the year of operation, $P1$ the price of electricity, g the annual increase in electricity price, and s is the consumption rate. Z represents potential incentives to self-consumption.

Finally, the net-metering scheme is modeled. If the energy fed into the grid is less than the electricity purchased from the network,

$$Rev_{NetMetering} = \sum_{n=1}^{25} \frac{Efed_n \times r_n}{(1+d)^n}$$

$$Efed_n = (1-s) \times ((Y \times CAP)(1-(n-1)l))$$

where $Efedn$ is energy injected into the grid and rn is the rate of reimbursement for it. This formula will be introduced in an alternative model to the existing Royal Decree 900/2015.

If fed into the grid power is greater than the amount of power purchased from the grid, all the energy is bought with rn rate, and in some countries such as Italy it may receive a rate hn by injection excess compared to the acquired power.

$$Rev_{Netmetering} = \sum_{n=1}^{25} \frac{(Edrawn_n \times r_n) + [(Efed_n - Edrawn_n) \times h_n]}{(1+d)^n}$$

$$Edrawn_n = U - ((Y \times CAP)(1-(n-1)l))s$$

where $Edrawnn$ is the energy acquired from grid and U is the annual energy consumption. This formula is not taken into account.

The first parameter of performance is the payback period, which indicates the number of years required to recover the investment. From the economic point of view it is an imprecise parameter since it does not account for the value of money and does not account for income once the initial investment is recovered. Anyway it is the most understandable and simple concept for homeowners.

The second parameter is the net present value and gives a more accurate view. It calculates the total return on investment through its life cycle taking all incoming and outgoing cashflows. Future cashflows are discounted in order to represent the present value of money.

The third parameter is the internal rate of return. It is a percentage value for which the net present value of all cash flows resulting from investment is zero. If the internal rate of return is higher than the discount rate, investment worthwhile.

4. RESULTS AND DISCUSSION

Figure 4 shows the adaptation of the housing consumption curve with the horly curve of average daily production of electrical energy from a solar photovoltaic installation of 1 kWp in Seville and Oviedo. The curve of electricity production is displayed for July (maximum) and December (minimum).

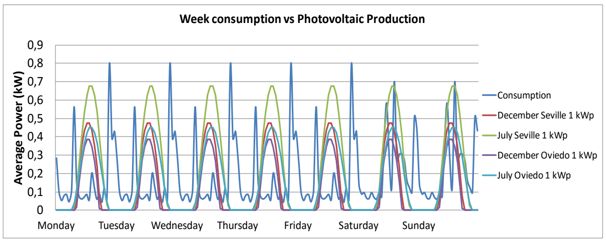

Fig. 4. Weekly consumption of housing vs photovoltaic production with 1 kWp installation, in two months and two different locations

As can be seen, the hours of maximal production of electrical energy coincide with the hours of lest consumption. This suggests that it can be interesting to introduce a system of energy storage and/or demand management system, but this is not the subject of this study. Table 4 shows the results of a simulation with various ranges of photovoltaic power in Seville.

Tolls are not considered because the contracted power is less than 10 kW. It is clear that with Royal Decree 900/2015 makes not viable photovoltaic systems in housings with this profile of consumption. With a self-consumption system of 1 kWp, only 36.31% of the power generated will be self-consumed, and the rest (63.69%) will be injected to the network without any remuneration. As a result, values have negative NPV and payback period exceeding 25 years. If the power of the PV system is increased, the rate of self-consumption and self-sufficiency hardly increases, and therefore the economic results worsen.

Power (kWp)	IRR (%)	NPV (€)	Payback (years)	Self-Consumption	Self-sufficiency
1	-	-3.630	> 25	36,31%	35,49%
2	-	-5.526	> 25	20,01%	39,12%
3	-	-7.595	> 25	13,58%	39,81%
4	-	-9.779	> 25	10,32%	40,33%
5	-	-12.214	> 25	8,32%	40,67%

Table 4. Simulation of photovoltaic installation of a housing in Seville according to Royal Decree 900/2015

A simulation has been developed with a net metering model with a payment of reimbursement for electricity fed into the grid (rn) whenever the poured energy into the grid is less than the acquired network Table 5).

Power (kWp)	IRR (%)	NPV (€)	Payback (years)	Self-Consumption	Self-sufficiency
1	5,74%	27	16	36,31%	35,49%
2	1,26%	-2.924	22	20,01%	39,12%
3	-0,57%	-5.023	>25	13,58%	39,81%
4	-1,98%	-7.229	>25	10,32%	40,33%
5	0	-9.679	>25	8,32%	40,67%

Table 5. Simulation of PV housing in Sevilla with net-metering

Results improve, but not enough to make the investment viable. The best system is theone of 1 kWp. As the power is increased, more energy is generated annually than is consumed and therefore energy excess is injected to network without any compensation.
It could be thought therefore that to achieve viability with this type of consumption profile it is necessary a primed tariff (FIT) with a value above the market, or, similarly as in the Ilatian case, an *hn* rate for the energy excess to the grid compared to the acquired. Table 6 shows the results with Royal Decree 900/2015 in Oviedo.

Table 6. Simulation of photovoltaic installation in housing in Seville according to Royal Decree 900/2015

Power (kWp)	IRR (%)	NPV (€)	Payback (years)	Self-Consumption	Self-sufficiency
1	-	-3.772	> 25	42,91%	31,99%
2	-	-5.566	> 25	25,58%	38,13%
3	-	-7.626	> 25	17,46%	39,04%
4	-	-9.806	> 25	13,30%	39,66%
5	-	-12.234	> 25	10,78%	40,17%

Results are worse compared to Seville. The rate of self-consumption increases because there are fewer photovoltaic production but the self-sufficiency rate decreases. Table 7 presents the results with net metering in Oviedo.

Table 7. Simulation of photovoltaic installation housing in Seville with net-metering

Power (kWp)	IRR (%)	NPV (€)	Payback (years)	Self-Consumption	Self-sufficiency
1	3,39%	-1.272	19	42,91%	31,99%
2	1,26%	-2.922	22	25,58%	38,13%
3	-0,56%	-5.021	26	17,46%	39,04%
4	-1,97%	-7.228	26	13,30%	39,66%
5	0	-9.678	26	10,78%	40,17%

The results worsen in economic terms over Sevilla. Figure 5 shows the rate of self-consumption and self-sufficiency in terms of the power of the photovoltaic solar installation in the company nº 1 in Seville.

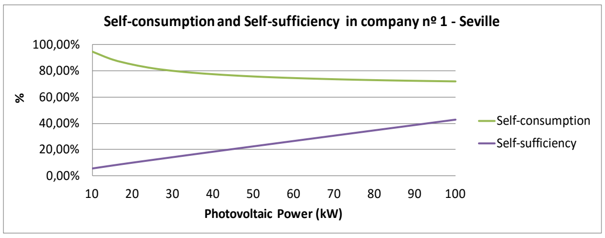

Fig. 5. Self-consuption and self-sufficiency in industrial company nº 1 in Seville

As the system size of the PV increases, the rate of self-consumption decreases in an important way among other factors because Saturday and Sunday there are only residual consumption.
Figure 6, Figure 7 and Figure 8 show the simulation of economic parameters with charges related to the costs and services of the system (according to Royal Decree 900/2015) and without charge.

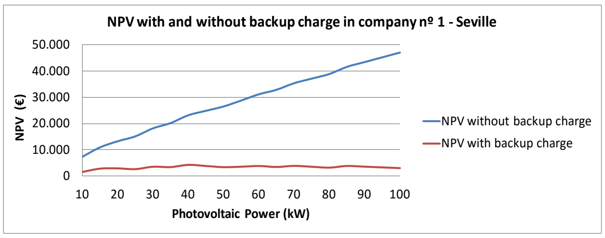

Fig. 6. NPV NPV of photovoltaic installation of self-consumption in industrial company nº 1 in Seville according to Royal Decree 900/2015 (with charges) and without charge

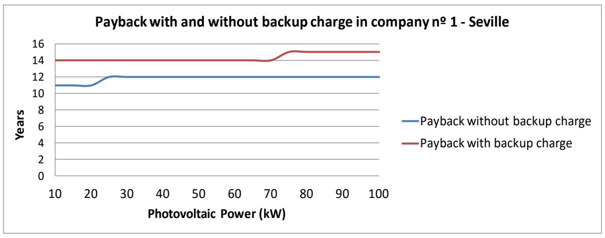

Fig. 7. Payback time consumption of photovoltaic installation in industrial company nº 1 in Seville according to Royal Decree 900/2015 (with charges) and without charge

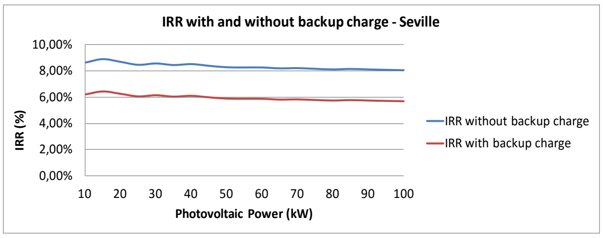

Fig. 8. IRR of photovoltaic installation of self-consumption in industrial company nº 1 in Seville according to Royal Decree 900/2015 (with charges) and without charge

With the application of charges the NPV is practically constant in all powers with a slight negative slope. This is because although the cost per kWp decreases as increases in power, it is offset by the decrease in the rate of consumption. The payback period is 14 years until 70 kW, and from there up it is 15 years. The IRR starts at 6.23% and remains more or less constant with a slight negative slope to reach 5.72% at 100 kW. Therefore solar photovoltaic self-consumption, according to Royal Decree 900/2015, for companies that only have a residual consumption during the weekend, have a very fair return.
Demand management could be interesting to increase the rate of self-consumption, but is not the subject of this study.
If no charges are considered, the NPV shoots-up as the power of the PV system increases, while the payback period and IRR follow parallel paths. The payback period improves between 2 and 4 years, resulting between 10 and 12 years depending on the power and IRR improves around 2 percentage points. This suggests that therefore simply removing charges can make these investments viable.
However, results varie in next Figures with the same case simulated with charges but with net metering to compensate for the energy produced on Saturday and Sunday.

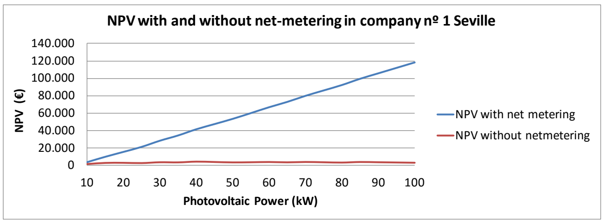

Fig. 9. NPV of photovoltaic installation of self-consumption in industrial company nº 1 in Seville according to Royal Decree 900/2015 (with charges) and net metering

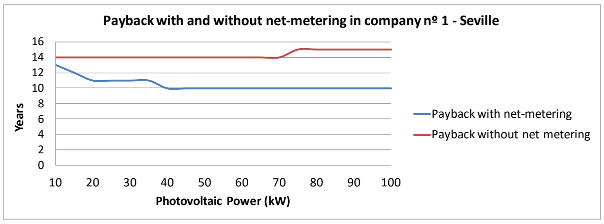

Fig. 10. Payback of photovoltaic installation of self-consumption in industrial company nº 1 in Seville according to Royal Decree 900/2015 (with charges) and net metering

It can be seen how the NPV with net-metering shoots-up compared to that achieved with Royal Decree 900/2015. The payback period decreases 1 year with a power of 10 kWp, but as power increases, and therefore the rate of self-consumption decreases, this difference grows, until achieving five years of difference in 100 kWp. That would mean 10 years of payback.

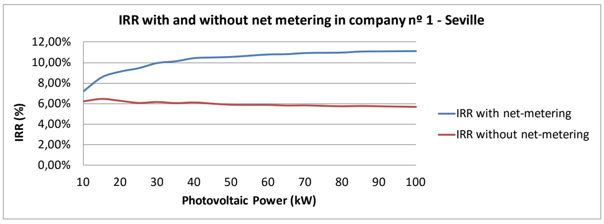

Fig. 11. IRR of PV installation of self-consumption in industrial company nº 1 in Seville according to Royal Decree 900/2015 (with charges) and net metering

Regarding the IRR, in 10 kWp there is only a difference of 1% but as the power increases, the difference increases up to a difference of about 4.5%. The IRR reaches 11.11% in 100 kWp, which results very interesting.
Now the photovoltaic solar system of company nº 2 in Seville will be analyzed.

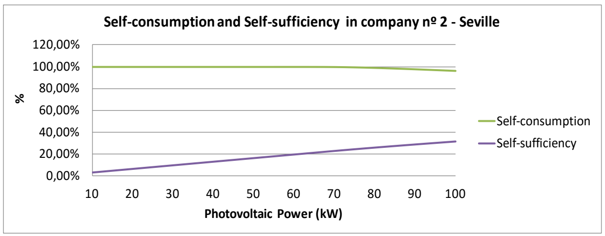

Fig. 12. Self-consumption and self-sufficiency of PV installation of self-consuption in industrial company nº 2 in Seville

In this case (Figure 12) the consumption is almost 100% since there is a significant consumption 24 hours 365 days a year due to cold storage. It just seems to go down something when reaching 80 kWp. The self-sufficiency rate rises in proportion to the increase in power. Figure 13, Figure 14 and Figure 15 show respectively NPV, IRR and payback period of the company nº 2 in Seville with and without charge.

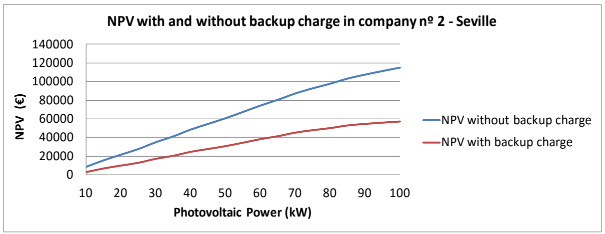

Fig. 13. NPV of self-consumption PV installation in industrial company nº 2 in Seville according to Royal Decree 900/2015 (with charges) and without charge

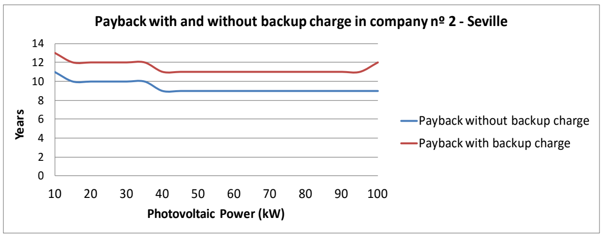

Fig. 14. Payback of of self-consumption photovoltaic installation in industrial company nº 2 in Seville according to Royal Decree 900/2015 (with charges) and without charge

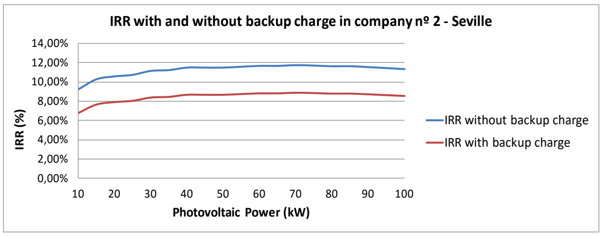

Fig. 15. IRR of self-consumption photovoltaic installation in industrial company nº 2 in Seville according to Royal Decree 900/2015 (with charges) and without charge

Now the NPV is incrementing in both cases, because if the power is increased the rate of consumption is almost equal to 100%. Best NPV is achieved in the case of not having charges.

The payback period is represented by two parallel lines with a distance of 2 years. With charges the payback period is about 11 years, and without charge it is about 9 years.

The IRR with and without charge are two parallel lines with a difference of 3%. A maximum of 11.70% and 8.90% can be reached, with an output of 70 kWp.

In this case the net metering regulatory scheme does not provide a significant improvement because all the energy is consumed.

Finally the effect of less solar radiation will be analysed observing Oviedo results.

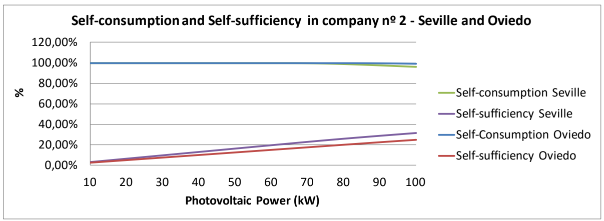

Fig. 16. Self-consumption and self-sufficiency of photovoltaic installation of self-consumption in industrial company nº 2 in Seville and Oviedo.

The rate of self-consumption is similar, except from 80 kWp where self-consumption is higher in Oviedo, because electricity production is lower. Regarding self-sufficiency, it is clear that the increase in the rate of self-sufficiency in Seville is greater, because electricity production is higher. Figure 17, Figure 18, and Figure 19 present NPV, Payback, and IRR respectively.

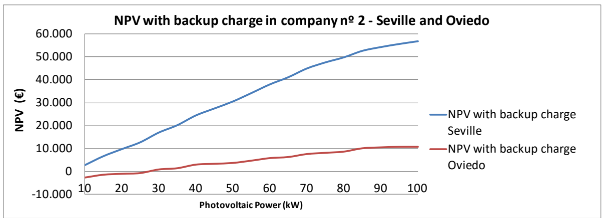

Fig. 17. NPV of self-consumption photovoltaic installation in industrial enterprise nº 2 according to Royal Decree 900/2015 (with charges) in Seville and Oviedo.

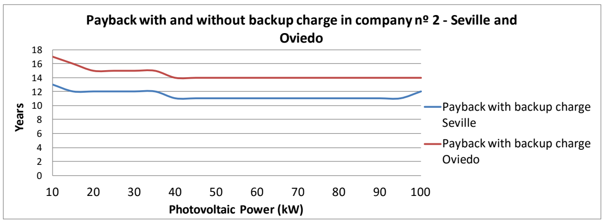

Fig. 18. Payback of photovoltaic installation of self-consumption in industrial enterprise nº 2 according to Royal Decree 900/2015 (with charges) in Seville and Oviedo.

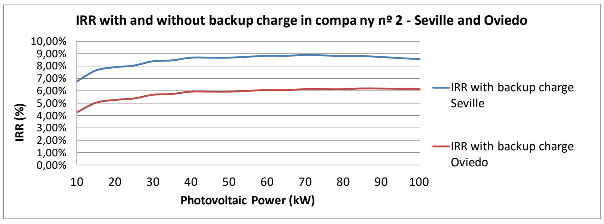

Fig. 19. IRR of self-consumption photovoltaic installation in industrial company nº 2 according to Royal Decree 900/2015 (with charges) in Seville and Oviedo.

NPV is much greater in Seville and the payback may present average differences of 3 years. Oviedo presents a minimum payback of 14 years.

The IRR are two parallel lines with a gap between them of about 2.5%. Therefore, IRR in Oviedo is about 6%, which is a very fair rate.

Therefore the weather affects strongly the investment profitablility, and for instance a profitable system in Seville can be unprofitable in Oviedo.

5. CONCLUSSIONS

This article has analyzed the impact of Royal Decree 900/2015 on the profitability of a photovoltaic solar system of self-consumption for three consumer different profiles and two climatic conditions.

In the case of housing in Seville with 2 people working, is not profitable in any case because the rate of consumption is very low.

The period of the day on which the photovoltaic production is higher is precisely when less energy is consumed. It is estimated that the payback period can be more than 25 years. Even with a net metering scheme limited to the case of energy transferred being than or equal to the acquired network, it does not give a very interesting payback (16 years).

It is estimated that for an interesting investment it is necessary a scheme of self-consumption with FIT rate with a value above the market price or *hn* rate by excess to the grid compared to acquired power.

In addition installation of storage elements or load management systems could be assessed, especially in homes with more consumption.

In Oviedo, with electricity production 24% lower than in Seville, results a considerably worse.

In the case of industrial company nº 1 in Seville, which does not work Saturdays or Sundays or has significative

consumption 24 hours, the results of profitability with Royal Decree are very fair (about 14 years of payback and 6% IRR). Especially relevant are charges associated to costs and services of the system, which impact in a negative way. Without charges a payback of approximately 12 years and 8% IRR could be obtained. Therefore, the charges decrease by 2 years payback and 2 percentage points IRR. As a result, a net-metering scheme could have a very positive influence on this facility compared to the current Royal Decree, providing an average of four years less of payback and 4 percentage points more of IRR.
Finally, results shown that the industrial company nº 2 in Sevilla, with has 24 hours a day, 365 days a year consumption of importance, presents the best economic results obtained. It can reach about 9% IRR and 11 years payback, which are interesting results. Anyway, if there were no charges, 3 years less payback and 3% more of IRR would be obtained. Oviedo worsens results in a very important manner with a payback of 14 years and an IRR of 6%.

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