# An expert judgement approach to determine measures to remove institutional barriers and economic non-market failures that restrict photovoltaic self-consumption deployment in Spain

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## Abstract

Despite the Spanish privileged geographical location and business leadership in the renewable energy field, currently is can be observed that the solar photovoltaic generation, electric self-consumption systems and net-metering policies deployment is much lower than it can be observed in other countries, even with lower energy sources for self-consumption. Energy policy experts assess as main reason the absence of a stable regulatory framework and the existence of clear disincentives. These disincentives are based on several economic non-market failures and institutional barriers. One key factor has proven to be the regulatory uncertainty created mainly by the recent national most relevant ministerial orders regarding energy generation and consumption, which suggests that, *de facto*, the regulatory framework is currently still under development. This paper includes first a brief but deep description of the prosumers penetration existing scenario in Spain, and then it focuses on feasible strategies to accelerate higher solar photovoltaic and self-consumption growth rates in Spain. Then, new policy measures to eliminate, or at least, mitigate, current barriers to their deployment are proposed and discussed. It is concluded that it results mandatory the urgent modernization of the energy regulatory framework promoting an active role for distributed PV generation which could have a significant positive impact in the voltage control and frequency regulation in distribution networks, among other advantages.

***Keywords*****:** Solar photovoltaic generation; Self-consumption; Prosumers, Energy policies, Institutional barriers; Voltage control; Frequency regulation.

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## Nomenclature

| | |
|---|---|
| BIPV | Building Integrated Photovoltaics. |
| DRES | Distributed Renewable Energy Source. |
| DSO | Distribution System Operator. |
| CNMC | Comisión Nacional de los Mercados y de la Competencia (National Competition Commission). |
| EEG | Erneuerbare-Energien-Gesetz (German Renewable Energy Sources Act). |
| EU | European Union. |
| FiP | Feed-in Premium. |
| FiT | Feed-in Tariff. |
| GHG | Greenhouse gasses. |
| GW | Gigawatt. |
| IRR | Internal rate of return. |
| kW | Kilowatt. |
| kWh | Kilowatt hour. |
| kWp | Kilowatt peak power. |
| LCOE | Levelized Cost of Energy. |
| M€ | Millions of euros. |
| MW | Megawatt. |
| PV | Photovoltaic. |
| $R^2$ | Coefficient of determination. |
| RES | Renewable Energy Source. |
| toe | Ton of oil equivalent. |
| TSO | Transport System Operator. |
| TWh | Terawatt hour. |
| VAT | Value-added tax. |

## I. INTRODUCTION

The countries that participated in the United Nations Framework Convention on Climate Change, in the Agreement of Paris, hold on 12 December 2015, officially recognized the great impact of the climate change effect on Earth and agreed to take urgent action by setting the limitation of global warming to *"well below 2 °C"* compared to pre-industrial levels (NRDC, 2015). The Intergovernmental Panel on Climate Change in its Fifth Assessment Report, published in 2014, identifies the generation of electricity as one of the main causes of the increase in global emissions of greenhouse gases (GHG) (IPCC, 2014). Likewise, Article 45 of the Spanish Constitution in force recognizes *"the right to enjoy an adequate environment for the development of the person himself and the duty to preserve it"*; and imposes *"a mandate on public authorities to ensure the rational use of natural resources to protect and improve the quality of life and defend and restore the environment"* (Cortes Generales Españolas, 1978).

Self-consumption of renewable electricity seems to be one of the most appropriate instruments to reduce the environmental impact of electricity generation (Ascione, 2017; Germani et al., 2015; Norton et al., 2011). Moreover, it is anticipated that, in the medium term (2030), it would not imply a higher levelized cost of electricity (LCOE) than the base electricity mix (fossil and nuclear energy) (CEA, 2016; General Electric International, 2014; Kost et al., 2012; Lu et al., 2011;Wu et al., 2015). The recent outstanding technological developments (Ernst & Young, 2016), linked to the extraordinary high radiation levels in Spain, should promote a high coverage of solar generation (photovoltaic or concentrated). Furthermore, recent studies (Di Francia, 2014; Jäger-Waldau, 2017) show immediate profits for this sort of installations by savings in the energy term of the electricity bill, without the need of any financial aid. Fig. 1 shows how Spain achieves one of the largest differences between the PV LCOE and the price of the energy term for household owners in the retail market.

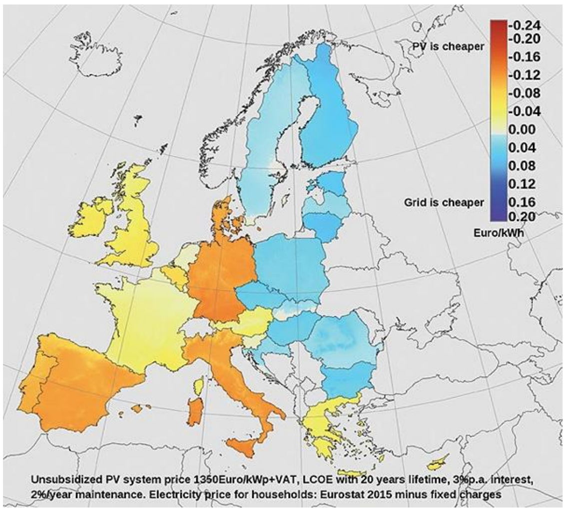



Fig. 1: Price difference between PV levelized electricity cost and household retail prices. Source: (Jäger-Waldau, 2017).

On the other hand, Directive 2009/28/EC, in force, establishes an overall and coordinated policy for the production and promotion of energy from RES in the EU (European Commission, 2009). The EU Directive highlights that RES generation offers a greater security for local energy supply, lower losses in energy transportation as generation sources are usually closer to the consumer, and promotes the development and cohesion of the local community by providing sources of income and creating local employment (IEA, 2016).

Furthermore, energy self-consumption strengthens the energy independence of Spain and favors the reduction of imported fossil fuels, allowing equalization of the trade balance (APPA, 2015; Dabaieh et al., 2016; Mateo et al., 2017). In 2015, Spain imported 1,422 toe less than the previous year thanks to the renewable energy sources (RES) generation, which represented € 357.1 million savings (UNEF, 2017). Electricity generated from grid-connected PV systems contributed 8.3 TWh, representing 3.2% of the Spanish annual electricity consumption, in 2015 (Lacal-Arantegui, et al., 2017), although it is estimated for Spain a potential of electric energy generation from solar technologies of 4,266 GWp, where 494.5 GWp would be building integrated photovoltaic systems (BIPVs) and 708.4 GWp of ground installed photovoltaic facilities (GREENPEACE, 2018). Thus, it means that the PV sector in Spain is still developed lower than 0.5% of its maximum potential. According to Figs. 2a and 2b, it can be seen that, until 2008, there was a development phase in Spain for PV technology, with a fast growth which showed its maximum for 2008. However, abrupt and unexpected regulatory framework changes in 2009 slowed down completely the solar sector in Spain, with a marked downward trend in the period from 2010 and 2014 and a slight recovery since then, although significantly lower than in the first phase (see Fig. 2b). These figures are considerably lower than elsewhere in Europe; such as Italy, Greece or even Germany, where the share of PV energy is in the range from 7 to 8% (see Fig. 2c) (IEA, 2015).

Despite the described advantages of RES generation and the high availability in Spain, although it was expected that Spain would drive the global solar photovoltaic market in 2008, the Renewable Energy Policy Network for the 21st Century points out that Spain has *"virtually disappeared"* from the solar PV picture. The retroactive policy changes and a new tax on self-consumption (REN21, 2017) made Spain fall from being the largest market in 2008, to a modest fifth place in 2015 in Europe, with regard to the total installed capacity (Lacal-Arantegui, et al., 2017). As Figs. 2a and 2b show, changes to the regulatory framework (since 2008) have had a detrimental effect both on annual PV capacity, and additions to solar PV capacity for the year 2016, were it is, by far, the lowest of the top-10 countries (Fig. 3). Furthermore, even though there is both a global and European growth trend (see Fig. 3), Spain is not even foreseen to be among the 20 top ranked markets by cumulative historical and forecasted solar PV demand (2001-2022) (Attia et al., 2017), which is a consequence of the energy policy taken by Spanish Governments since 2008. One of the impacts of these policies has been the effect on employment and the local economy: in 2008 the solar photovoltaic industry provided 31,300 jobs in Spain, but a year later, in 2009, there were only 13,900 jobs (Cinco Días, 2009) and in 2015, there were only 7,165 jobs (UNEF, 2017).

As it can be seen from the recent research carried out by López-Prol (López-Prol et al., 2017) on the current regulatory framework for the solar photovoltaic sector in Spain, the average self-consumption in both residential and industrial sectors face negative (residential sector) or negligible (industrial sector) returns. The study shows that, for the current regulatory situation in Spain, and assuming the most "typical" conditions, only commercial solar photovoltaic facilities can have positive returns. However, as this internal rate of return is barely 2% (Lopez-Prol, et al., 2017) it makes any investment quite risky, or at least questionable. A summary of the internal rates of return evaluated by (Lopez-Prol, et al., 2017) are shown in Table I.

As it can be seen in Table I, the current regulation on solar photovoltaic energy is ineffective since, in some sectors, such as the industrial segment, it is more economically beneficial to disconnect the photovoltaic system from the electricity power grid (even, if it implies wasting part of the total generated electricity) to avoid the costs associated with the power grid backup services. This circumstance, apart from being inefficient from the technical point of view, discourages any adjustment on the demand side and is in total contradiction to what the European Commission advocated in its working document "Best practices on Renewable Energy Self-consumption" (European Commission, 2015).

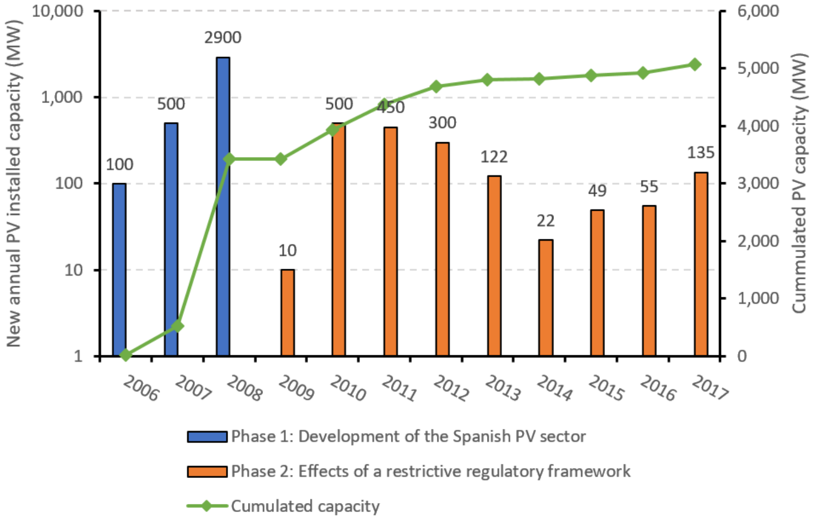
TABLE I. INTERNAL RATE OF RETURN FOR EACH MARKET UNDER AVERAGE CONDITIONS FOR CURRENT SETTINGS OF THE SPANISH REGULATORY FRAMEWORK. Source: (López-Prol et al., 2017).

| **INTERNAL RATE OF RETURN (%)** | | **TYPE 1[1]** | | **TYPE 2[2]** | | | |
|---|---|---|---|---|---|---|---|
| **Equivalent hour conditions (kWh/kWp)** | **Segments** | Residential | | Commercial | | Industrial | |
| | **Configurations** | Backup | No Backup[3] | Backup | No Backup | Backup | No Backup |
| Average (1328) | Own capital | -6.12 | -2.53 | 2.11 | 3.59 | 0.94 | 3.30 |
| | Externally financed | -10.06 | -5.77 | 0.67 | 2.61 | -0.21 | 2.95 |

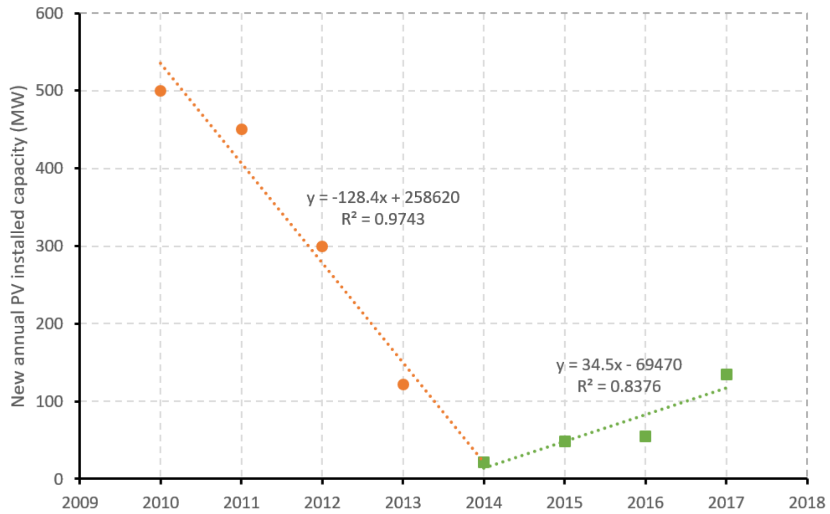
[1] Modality of self-consumption type 1 (according to Royal Decree 900/2015): In the case of a consumer who has a generation facility for his/her own consumption connected inside the network of his point of supply and which is not registered in the corresponding registration as a production facility (although it has to be registered in the Register of Self-Consumption Facilities). In this case, there will be a single subject, which is the consumer. These are small consumers whose facilities are less than 100 kilowatts of installed peak power and which will be allowed to "sell" into the electricity grid the surplus energy they generate without receiving economic compensation for it (although they can be required to apply generation limitations).

[2] Modality type 2 (according to Royal Decree 900/2015): In the case of a consumer associated with a production facility duly registered in the Administrative Register of Electric Power Production Facilities (as well as in the Register of Self-Consumption Facilities) connected within its network. In this case, there will be two subjects: the consumer and the producer. The Government has established the economic conditions so that the production facilities receiving this modality of self-consumption sell the energy not self-consumed to the system.

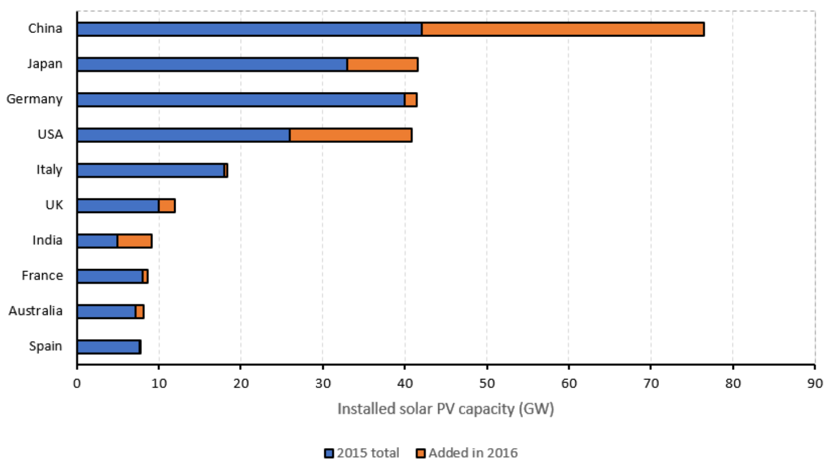
[3] For the "No Backup" configuration, backup charges established by the RD 900/2015) are not considered.




(a)




(b)




(c)

Fig. 2. (a) Annual PV installed capacity in Spain. Source: Adapted from (PVFINANCING, 2016; Deloitte, 2017; UNEF, 2018); (b) New installed solar PV capacity trends analysis in Spain. Adapted from (PVFINANCING, 2016; Deloitte, 2017; UNEF, 2018); (c) Solar PV capacity and additions, Top 10 Countries, 2016. Source: Adapted from (REN21, 2017).

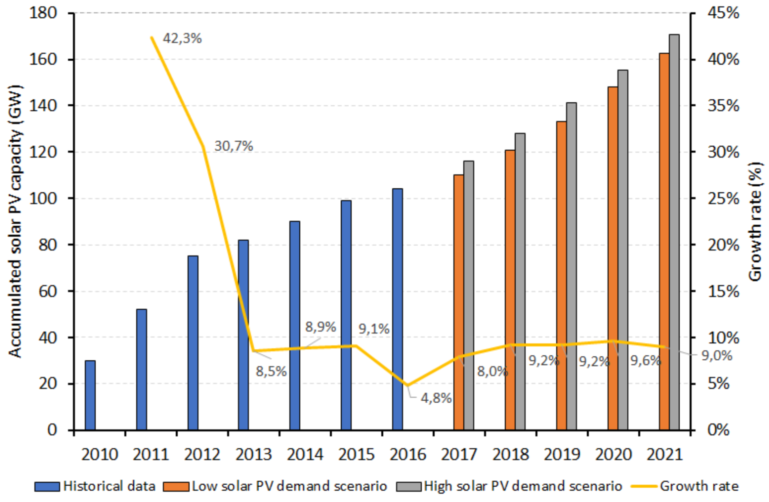



Fig. 3. Projected scenarios of the European accumulated solar photovoltaic market in 2021.
Source: (UNEF, 2017).

As it can be seen in Table II, installed PV capacity took off in Spain at the beginnings of the 21st Century, outstanding year 2008, when installed capacity growth approximately 500% due to the favorable conditions set by Royal Decree 551/2007. Since then, new installed capacity had negative growth rates (see Fig. 2.b) until 2014 when a slight positive trend is seen again, although much lower than in the past "golden age" for PV installations in Spain.

The average capacity of each generation facility raised from 7.04 kW in 2004 to 76.13 kW in 2016. However, the average size of new PV power plants in the latest five years is observed to be 113.76 kW per installation.

On the other hand, comparing the new installed capacity with the number of installations it can be observed that the equivalent hours, or energy produced per installed capacity unit (MWh/MW) has significantly increased from 739.13 h on average in 2004 to more than 1,200 h on average in 2016. Nevertheless, in the period from 2011 to 2015, the average number of equivalent hours were higher than 1,700 h. This means that, considering similar radiation conditions in the latest decade, installations are getting much more efficient and capacity factors in the range from 19% to 22% are feasible and closer to other RES, such as wind energy power plants (with typically capacity factor ratios in Spain in the range from 25% to 40%).

TABLE II. KEY DATA REGARDING SPANISH SOLAR PV SECTOR. Source: Adapted from (CNE, 2011; CNE 2017).

| | INSTALLED CAPACITY (MW) | ELECTRICITY GENERATION (GWh) | NUMBER OF INSTALLATIONS | TOTAL SUPPORT (M€) | AVERAGE SUPPORT (€/MWh) |
|---|---|---|---|---|---|
| 2016 | 4,675 | 5,794 | 61,404 | 2,764 | 318 |
| 2015 | 4,663 | 8,211 | 61,338 | 2,863 | 349 |
| 2014 | 4,646 | 8,170 | 61,096 | 2,805 | 343 |
| 2013 | 4,637 | 8,261 | 60,984 | 3,265 | 395 |
| 2012 | 4,510 | 7,994 | 59,883 | 2,855 | 357 |
| 2011 | 4,247 | 7,248 | 57,710 | 2,665 | 359 |
| 2010 | 3,839 | 6,400 | 54,920 | 2,897 | 452 |
| 2009 | 3,630 | 6,073 | 52,100 | 2,868 | 462 |
| 2008 | 3,463 | 2,503 | 51,310 | 1,155 | 453 |
| 2007 | 690 | 473 | 20,284 | 215 | 433 |
| 2006 | 146 | 99 | 9,874 | 45 | 427 |
| 2005 | 47 | 38 | 5,391 | 16 | 399 |
| 2004 | 23 | 17 | 3,266 | 6 | 367 |

Although the research presented in this paper focus specifically in the photovoltaic sector (since it is the most widespread self-consumption sector in Spain), discussion and results can be extended to all distributed RES, such as wind power. From both an extensive survey of grey and scientific literature and a significant number of interviews with experts, it is clear – even though there are many other approaches– that this paper can contribute to the pool of existing knowledge by giving an updated (2018) perspective of the Spanish economic non-market failures and institutional solar PV barriers.

This paper combines the budgetary requirements of the Spanish Government in the short term with the necessary development of a RES technology, such as solar photovoltaic, which should place an important part of the energy mix of a country characterized by both high levels of solar radiation and energy dependence. To the authors' concerns, it results mandatory an expert judgement approach which proposes in a coherent way, measures to remove existing institutional barriers and economic non-market failures that restrict photovoltaic self-consumption for the Spanish case (updated to the years 2017/2018). This research including an expert judgement approach to the updated scenario (2017/2018) differs from previous studies available in the literature, such as (CNE, 2011; CNE, 2013; CNE 2017; Ramírez et al., 2017; UNEF, 2017) and the results are expected to create outputs with high impact as the measures proposed are likely to produce an impact that itself represents novelty. As a consequence, and by definition, novelty is ensured (Fleming, 2001; Fleming, 2007). Furthermore, the field variety (interdisciplinarity), task variety (division of labor), and the affiliation variety of the authors of this paper (five authors from four different institutions) enable higher access to broader information and generate information advantages that produce more novel outputs (Taylor, 2006; van Knippenberg, 2004). This combination of topics[4] (an expert judgement approach applied to determining measures to remove institutional barriers and economic non-market failures to short term future PV self-consumption in Spain) further contributes to the novelty of the paper (Mishra, 2016). By conducting the aforementioned "combinatorial originality", and by performing a thorough literature review and interviews, we ensure the originality of the idea and the information presented here (Lee, 2015).

The remainder of this paper is structured as follows. Section II describes the methods to allow the work to be reproduced. Section III summarizes theoretical arguments, which serve as a basis for the proposition of the measures needed to promote self-consumption in Spain, focusing in particular on the negative impact of both Royal Decree 900/2015 and Law 24/2013 on its development. Section IV shows both identified economic non-market failures and institutional obstacles, which currently discourage the use of solar photovoltaic technology and self-consumption in Spain; this section also shows measures aimed at eliminating those barriers (in Appendix B, it is briefly analyzed which ones have been recently adopted by or are aligned with the latest modification of the regulatory framework in October 2018 through the Royal Decree-Law 15/2018). Finally, in Section V, the importance of the results of the paper as well as its political implications are presented.

## II. Material and Methods

As remarked by Weber in (Weber, 1997), *"energy obstacles are indiscernible, and even though real, there is no possibility of breaking them down in an empirical way"*. The different classifications available in the scientific publications are a consequence of assumptions without formal organization or structure (Dunstan et al., 2008; Sorrell et al., 2011). The classification used here derives from (Chai et al., 2012), who categorized energy hurdles in: behavior, market failures, environmental restraints, institutional, and economic non-market failure hurdles. This paper focuses in which experts have arranged to be more

[4] "…an article published on a combination of topics can be considered novel even if it is not novel in any of its individual topics…" (Mishra, 2016).

general and with greater impact: institutional, and economic non-market failure hurdles, while behavioral and environmental restraints will be analyzed in further more specific works.

Concerning the determination of obstacles to the employment of solar photovoltaic technology and self-consumption in Spain, and taking their specificities into account, a broad review of recent scientific publications related to the topic was undertaken. This information was used to connect with recognized authorities on this topic (see the Acknowledgments section where experts and their affiliation have been included) through an expert judgement approach. Contacts with experts took place between February 2017 and June 2017.

The following seven questions were put to more than 30 experts (both industry and academia experts) in the Spanish self-consumption sector (as an example, a conversation transcript with one of the experts is included as supplementary material):

1. In your opinion, is there any obstacle to the development of self-consumption and, therefore, of the PV sector in Spain?
2. What measures could be taken to achieve widespread use in the photovoltaic sector in Spain as well as a rapid reduction in costs?
3. Do you consider it appropriate to recognize the right to self-consumption without any tax being imposed?
4. Do you think that the Administrative Register of Electric Energy Consumption is a hindrance to the development of the PV sector in Spain?
5. Do you see a justification for several consumers sharing the same installation?
6. Do you understand that, according to the corresponding technical regulations, self-consumption facilities that do not transfer electricity into the electricity grid should be legalized?
7. Do you think it is necessary to adapt the penalty system for self-consumption?

As a result of the interview survey, material for identifying energy hurdles, their eradication/moderation and determination of whether ongoing energy policies in Spain are satisfactory or not, was collected. Roughly 60 scientific papers/reports were consulted in the research part of this work. Even though this provides valuable information on recent energy hurdles in this field, it should be understood that it would be impossible to review all existing works related to the topic addressed here. The barriers identified by Chai (Chai et al., 2012), Sorrell (Sorrell et al., 2000), and Brown (Brown, 2001), as well as the seven questions shown in this section, were given to 70 experts on solar photovoltaic technology and self-consumption from Spain, of whom 33 (see the Acknowledgements section) suggested different policy measures and validated the scientific literature.

Barriers analysis in the PV and self-consumption deployment in Spain, where there exists a considerable potential, yet the technically feasible and economically viable measures which could be taken are by no means fully exhausted, is similar to the evaluation of energy conservation and energy savings policies. In this late case, it is called “efficiency gap” or “energy paradox” so, in our case it can be described as “self-consumption gap” or “PV paradox” and, in a similar way, it also could be described in terms of institutional, market-related, organizational and behavioral barriers (Webber, 1997). A deepest exploration and a taxonomy proposal of these barriers can be found in (Blumstein et al., 1980).

According to (Chai et al., 2012), it results mandatory to proper identify barriers and propose measures that take them into account in a holistic manner as they usually are characterized by an interconnected nature. The overall effectiveness of energy policies is then limited by the weakest link between identified barriers. This study also identifies the roles and responsibilities of major stakeholders, where highlights the role of Governments and energy service companies. Thus, institutional barriers, which are created by Governments, have a great impact in the policies deployment. On the other hand, (Brown, 2001) provides compelling evidence that large-scale market failures prevent consumers from obtaining energy services at certain conditions. The author in this case, suggests that public interventions can overcome many of the market obstacles. Then, the author proposes a policy portfolio defining different scenarios for a clean energy future in the United States, identifying barriers and ways of addressing them which can be clearly extrapolated to the current European case, specially, the Spanish situation.

In (Sorrell et al., 2000), a deep analysis of existing barriers to energy efficiency are presented, based in the United Kingdom experience. The authors propose to classify found barriers into three categories: market failures, organizational failures and rational behavior. In related studies from the same authors, barriers of each category are identified for several industrial sectors and an interview protocol for energy manager is presented. That protocol has been adapted in this case for the preparation of the interviews. It must be highlighted that, according to (Sorrell et al., 2000), market failures occur when the basic requirements for efficient allocation of resources through well-functioning markets are violated. This conducts to (i) incomplete markets; (ii) imperfect competition; (iii) imperfect information or; (iv) asymmetric information. From these four market failures, although the two first categories can be important they are less relevant than the other two in energy service markets. On the other hand, organizational failures are those that affect (a) principal-agent relationships within organizations, or; (b) split incentives and appropriability within organizations. Finally, the rational behavior barriers include all those factors that cannot be classified as either market failures or organizational failures (i.e., sunk costs, parallel economic alternatives, technology learning curves, risks, etc.)

Many research works, such as (Langlois-Bertrand et al., 2015), (Thollander et al., 2010), (Thollander et al., 2013) or (Schleich, 2009) claim the importance of political-institutional barriers in energy efficient development and consider them as main obstacles in a wide range of scenarios. Moreover, it should be noticed that their effect can be amplified due to they often interact between themselves and, even when some barriers are removed, efficient energy policies may remain blocked. Thus, it results of critical importance, to identify these “key” or “reliable” barriers in order to make policy efforts successful (Harmelink et al., 2008). Similar barriers can be found in other energy technologies, such as in cogeneration and district heating networks (Colmenar-Santos et al., 2015). Nevertheless, well designed policies considering potential barriers and with a holistic point of view can harness extraordinary results, like it has been demonstrated related with energy savings in California, Japan and some European countries (Geller et al., 2006).

To clarify how the returned questionnaires were analyzed, the approach for extracting the interview data is described below and summarized in a flow chart in Fig. 4:

a) First, 41 experts were consulted to identify the main barriers and economic non-market failures that restrict solar photovoltaic self-consumption in Spain. To do so, a “first round” of questionnaires was conducted (see, as an example, Supplementary material S.1).
b) From data collected from various data sources, including the (in-depth) interviews of the 41 experts from the Spanish solar PV sector, that were mentioned previously and that participated in the conceptual framework development; scientific literature about barriers (Brown, 2001; Chai et al.,

2012; Sorrell et al., 2000); and from normative and legal documents and other public data sources; 16 barrier indicators were identified (see Table A.I).

c) To give the needed reliability to the questionnaires, it was then necessary to carry out an evaluation of the relative relevance (weight) of each of the barrier indicators through a second consultation with the same experts. Eight out of the 41 experts consulted in the “first round” declined to proceed to the “second round”, with the result that there were 33 experts that finally participated in the identification of the barriers. As result, the conceptual framework of the prospective barriers was developed in this step.

d) The third conducted step consisted on the quantification of the indicators. To be considered as a “reliable” barrier, it was supposed that the barrier indicators would need to score a “median PV barrier value”[5] of at least 5.0 on a scale of zero (“not relevant at all”) to ten (“extremely relevant”). The evaluation of the relative weight of each of the 16 tentative barriers (see Table A.I) is a particularly critical issue, because the weighting of them can strongly influence the overall score and, hence, the message provided by the indicator. Then, if a “median PV barrier value” of at least 5.0 on a scale of zero to ten was not reached, the barrier identified by the expert was discarded. Therefore, the weighting of the indicators presented is based on empirical results of a comprehensive process of stakeholder consultation (i.e. from an expert judgement approach process).

e) From the identified 16 barrier indicators, 11 of them scored at least 5.0 points (those that are coloured red in Table A.I). These 11 barrier indicators were merged into 6 barriers (see Table III).

f) Once the reliable barriers were identified, they were transferred to the consulted experts who first suggested some modifications (third round) and finally agreed with the “explanation” of the six “final” identified barriers (see Table III).

g) Finally, measures to remove/mitigate found barriers are presented in the Results and Discussion section (see Table IV). These tables aim to clearly connect Sections III (Analysis of the regulatory framework) and IV (Results and discussion) by linking the issues with the suggestions.

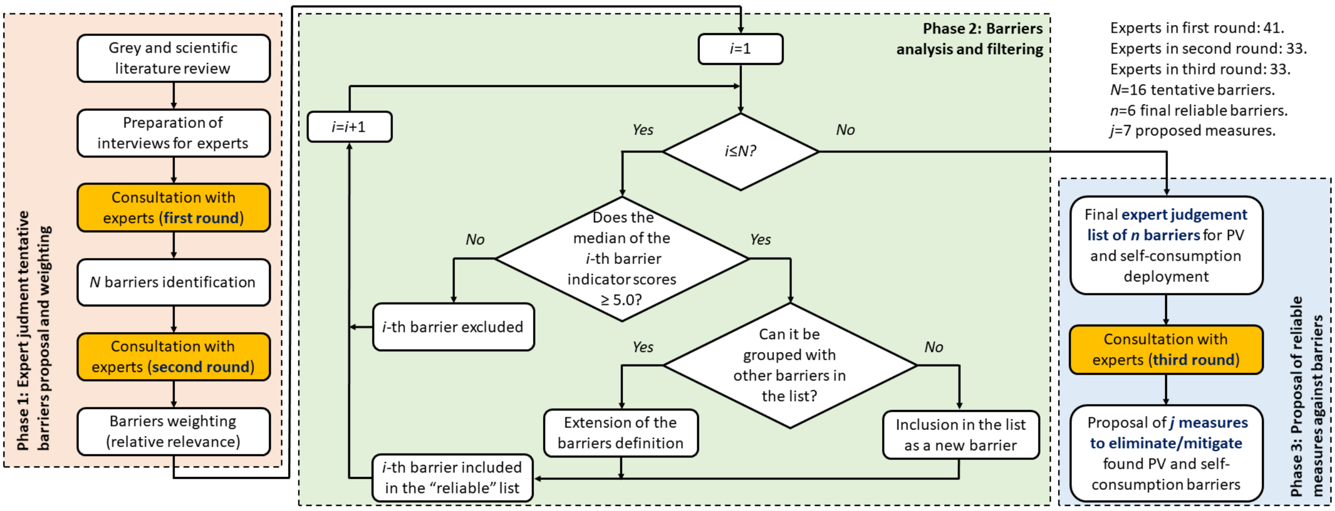



Fig. 4. Flow chart of the “Expert judgement” adopted approach. Source: Own elaboration.

5 In this case, the median value was chosen as a more reliable statistic indicator than the average due to the small size of the samples.

## III. Analysis of the Regulatory Framework

Although it has been presented as a standard for the promotion of DERs, the fact is that the regulation of the regime of self-consumption contained in Royal Decree 900/2015 (Spanish Ministry of Industry, Energy and Tourism, 2015) presents numerous obstacles and uncertainties that predict weak implementation of such a system in the future. There are some positive proposals on energy self-consumption of solar PV in Spain in Royal Decree 900/2015, such as the fact that there is no need for prior authorization for installations below 100 kW, and that it is also not necessary to pay for an access and connection study for Type-1 installations that would have a rated power up to 10 kW.

Below, some of the more conflicting aspects of Royal Decree 900/2015 are described:

**III.a Only Type-2 prosumers (net-metering) are entitled to receive a fee for energy being discharged into the power grid.** Type-1 consumers (self-consumers) are not entitled to receive any remuneration for surplus energy nor credits[6], and limits can be set by the Ministry of Industry, Energy, and Tourism (currently known as the Ministry of Ecological Transition) on the generation of this type of energy. This regulation converts Type-1 consumers into a unique scheme among the PV financial compensation policies of developed economies[7].

**III.b The implementation of energy-efficient mechanisms does not guarantee consumers enough reciprocal advantages[8] with regard to Royal Decree 900/2015.** This is the consequence of that a discharge to the electricity grid is only authorized in exceptional circumstances; the energy produced may not be higher than the energy consumed in hourly periods, and the consumer must pay for the backup of the energy produced.

Thus, according to the second additional provision of Royal Decree 900/2015, the consumers of high-voltage electricity, who carry out an activity whose secondary product is the generation of electric energy and, who due to the implementation of a system of savings and energy efficiency, have at certain times electrical energy that cannot be consumed where it is generated, may be authorized by the Ministry of Industry, Energy and Tourism (currently known as the Ministry of Ecological Transition) to sell such energy to the electric grid in exceptional circumstances, provided they meet the requirements established in the Royal Decree, among which is the presentation of a draft of the savings and efficiency measures they will adopt, in which they indicate their electricity consumption.

It is striking that for these purposes, energy-saving systems that include the installation of a generator, a battery, or energy storage systems are not considered.

Where electricity selling is authorized, billing the supply and tolls for access to the electricity networks shall be made based on the hourly demand (net hourly electric energy received from the transmission or distribution network) and on all power demanded, in accordance with what is established in Article 9 of Royal Decree 1164/2001 (Jefatura del Estado, 2013). The meter located at the border point of the installation is used for this purpose. The hourly demand can never be negative. The billing of charges or

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[6] Unlike in Spain, in other locations like California, the so-called "net metering" is used, through which prosumer (consumer-generator) credits are granted for the excess electricity generated (the consumer pays only the net amount, in addition to part of the distribution costs and other services) (CALIFORNIA PUBLIC UTILITIES COMMISSION, 2017). In the State of California, renewable facilities of up to 1 MW are eligible for this modality, with the self-consumption limit being up to 5.0% of the aggregate peak demand of each utility (CALIFORNIA PUBLIC UTILITIES COMMISSION, 2017).

[7] In a study carried out by the International Energy Agency for 18 OECD countries (plus China and Brazil), Spain was found to be the only one in which "the excess PV electricity is not paid at all" (Masson et al., 2016).

[8] As mentioned above, decentralized energy production has, among other things, many advantages such as greater security of local energy supply and lower energy losses.

other prices resulting from applications in accordance with current regulations will be carried out on the demand for energy and on all the demanded power recorded in the meter located at the border point of the installation. In view of this regulation, it can be concluded that the regulation hardly encourages the implementation of energy-efficient mechanisms.

**III.c Consumer associations are prohibited.** The owner of the energy point of supply will be the same as that of all consumer equipment and generation facilities connected to its network. In no case may a generator be connected to the internal network of several consumers. This prohibition is a clear disadvantage for the communities of particular consumers.

**III.d As regards the application of access tolls, system costs, and backup costs for self-produced energy, Article 18 of Royal Decree 900/2015** (Spanish Ministry of Industry, Energy and Tourism, 2015) **regulates the most controversial aspects of the self-consumption regime.** These are the so-called "system support costs", also called "sun tax"[9], the amount corresponding to the charge for the other services of the system, which is defined as the payment for the backup function carried out by the entire electricity system to implement self-consumption. This charge applies to the power contracted from the utility and the hourly consumption of electricity, i.e., the net hourly consumption of electricity from generation facilities connected inside a consumer or producer network with which network connection facilities are shared or connected through a direct line.

**III.e** The most counterproductive aspect of Law 24/2013, with respect to the development of self-consumption in Spain, is the fact that by its application, **self-consumption facilities are obliged to contribute to the financing of the costs and services of the electricity system in the same amount as other consumers** (Jefatura del Estado, 2013)**[10].** To this respect it should be pointed out that:

a) The National Energy Commission (today the National Competition Commission, CNMC) ruled against tolls for self-consumption and suggested using other possible alternatives[11], but the Ministry of Industry has chosen to avoid the "leakage" of demand that would provoke consumers to save tolls.

b) In the opinion of the CNMC, the establishment of a "toll of support" only for self-consuming consumers meant "discriminatory treatment" [see page 18 from (Consejo de Estado, 2015)] with respect to other consumers, who, being able to reduce their consumption if energy efficiency measures were adopted (such as the insulation of their homes or the use of energy-saving lamps), they [sic] would not pay this toll for the energy they could save. As the CNMC points out, the arguments on which this measure sought to justify (both the economic sustainability of the system in the short term and the support provided by the electricity system) were insufficiently robust enough to impute these concepts to self-consumed energy. This is due to the fact that Royal Decree 900/2015 had an impact on the amount of the "back-up toll" for the costs of the whole system but without detracting from the advantages of distributed generation (i.e. without putting in a prospective value), which "does not constitute a good regulation" (Consejo de Estado, 2015). Therefore, the CNMC proposed the elimination of the "toll of support", sacrificing economic

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[9] Due to the current lack of an absolute majority in the Spanish Parliament and to get the approval of the 2017 Spanish Budget, on May 30, 2017 the party in government in that moment (People's Party) and Nueva Canarias reached an Agreement which (except for the Canary Islands) exempts the transitional charge for self-consumed energy for self-consumption facilities that are put into operation before December 31, 2022. This "patch" is exclusive of the Canary Islands and is motivated by the approval of the 2017 Spanish Budget, which demonstrates the lack of rigor that covers this provisional Royal Decree, as well as the need to establish a definitive normative.

[10] This is in conflict with the first Transitional Provision of Royal Decree 900/2015, through which it is possible to observe different fixed charges (depending on the power) and variables (as a function of hourly self-consumption).

[11] This could be the establishment of a universal and fixed charge per client that is regarded as part of the sunk costs [see point 4.12 from (CNE, 2013)].

efficiency in the short term in the interest of medium and long-term economic sustainability [see pages 5 and 17 from (CNE, 2013)].

c) As pointed out by the CNMC, the current regime is "unnecessary or disproportionately restrictive" (Comisión Nacional de los Mercados y de la Competencia, 2013) for the production of electric energy in a self-consumption regime (which, in reality, is still a competitive pressure for the rest of the conventional supplies).

d) For the Ministry of Industry, the economic burden of tariff deficit annuities and aid for renewable energy must be borne by all consumers connected to the grid and by their electricity consumption. If the fall in demand for electricity due to the economic crisis and the depopulation rate were combined with the fall in demand due to self-consumption and net-metering, the sector's income and cost balance would be unattainable without requiring more effort from consumers, which would further encourage self-consumption. In spite of this, the Ministry of Industry is against a generalization of the use of self-consumption and net-metering, which has a clear negative effect on its development in Spain.

The main economic non-market failures and institutional barriers and uncertainties that hamper the further development of solar photovoltaic technology, self-consumption and net-metering in Spain are presented as a summation of the hurdles presented here (see Table III). To place national analysis in an international context, a succinct comparative study of the existing regulations in Germany, the United States, Israel, China, and Australia is shown in the Appendix (see Table A.II). The purpose of this table is not only to serve as a comparative analysis of existing mechanisms that support self-consumption of electricity in key countries around the world, but rather to highlight the challenges and opportunities associated with their development. As a result, this paper shows the relevance of its focus by comparing Spanish policies with those existing in other countries that, having previously reported similar problems to the one existing in Spain, have addressed them with other energy policies. As a consequence, this paper is relevant to readers from countries other than Spain.

TABLE III. MOST SIGNIFICANT SPANISH ECONOMIC NON-MARKET FAILURE AND INSTITUTIONAL BARRIERS TO THE SOLAR PHOTOVOLTAIC TECHNOLOGY AND SELF-CONSUMPTION TAKE OFF. Source: Own elaboration.

| BARRIER INDICATOR NO. (Table A.I) | IDENTIFIED BARRIERS | SUCCINT CONTEXT |
|---|---|---|
| 1, 3 | Consumers of self-consumption Type-1 are not entitled to receive any remuneration for surplus energy[12]. | Only consumers using Type-2 self-consumption are entitled to receive a fee for energy being discharged into the power grid. To the author's knowledge, in 2016, Spain was the only OECD country where the surplus RES electricity was not paid for at all (Masson et al., 2016). Since the concept of the individual or shared net-metering is not considered in the current regulatory framework in Spain, there is also no credit compensation system (Colmenar-Santos et al., 2015). |
| 2 | Only prices (per kWh produced) charged for non-peninsular* electric power systems, and under certain circumstances, can be reduced. | For non-peninsular* Spanish electrical systems, it is not possible to achieve reductions in kWh if the market price of electric energy is lower than the peninsular rate*. |
| 6 | The implementation of energy efficiency mechanisms does not guarantee consumers enough reciprocal advantages with regards to Royal Decree 900/2015. | According to the second additional provision of Royal Decree 900/2015, the consumers of high-voltage electricity who carry out an activity whose secondary product is the generation of electric energy and, due to the implementation of a system of savings and energy efficiency, have at certain times electrical energy that cannot be consumed where it is generated; as a general rule, are not authorized to sell such energy to the electric grid. |

[12] Consumers with self-consumption of rated power lower than 10 kWp do not have to pay for the energy produced.

| | | |
|---|---|---|
| 5 | Consumer associations are prohibited. | The owner of the point of supply will be the same as that of all consumer equipment and generation facilities connected to its network. In no case may a generator be connected to the internal network of several consumers. |
| 8, 10, 11 | Application of access tolls, system costs, and backup costs for self-produced energy[13]. | There is a charge, the so-called "sun tax", which is defined as the payment for the backup function carried out by the whole electrical system to enable the application of self-consumption. |
| 16 | According to Law 24/2013, self-consumption facilities are obliged to contribute to the financing of the costs and services of the electricity system in the same amounts as the rest of the consumers. | This is in conflict with the first Transitional Provision of Royal Decree 900/2015, through which it is possible to observe different fixed charges (depending on the power) and variables (as a function of hourly self-consumption). |

*In Spain it should be differentiated the peninsular power system, which comprises the national system placed in the Iberian Peninsula and the Balearic Islands (linked to the peninsular power grid through a submarine HVDC power link) and the non-peninsular part, in which the Canary Islands and the Autonomous Cities of Ceuta and Melilla are included. The peninsular system operates through a regulated electricity pool market, coupled with Portugal when there exists enough power exchange capacity, while the non-peninsular systems are operated by economic dispatches.

## IV. Results and discussion

In pursuit of legal certainty, Royal Decree 900/2015 on self-consumption must be defined and clarified through a constructive dialogue between all the stakeholders and all the barriers that lack proper justification removed.

A legal reform that would eliminate the mainly existing obstacles for the development of self-consumption in the electricity sector and, therefore, the photovoltaic sector in Spain and, at the same time, increase savings to the system due to distributed generation (mainly in insular systems) must be promoted and supported. It is precisely on the elimination or, at least, on the mitigation of those barriers that this paper focuses, presenting the necessary measures for accelerating a high PV growth rate and a rapid cost reduction, which is critical to the success of PV deployment in Spain[14].

This paper proposes an amendment to Article 9 of Law 24/2013 of the electricity sector; the definition of the true cost of power grid backup to self-consumers and net-metering users (substituting the first Transitional Provision of Royal Decree 900/2015); and a repealing of certain provisions of Royal Decree 900/2015 of 9 October, which regulates the administrative, technical, and economic conditions of the modalities of electric power supply with self-consumption and production with self-consumption.

In particular, this paper proposes seven main changes in the regulation of self-consumption, which have been summarized, relating with found economic non-market failures and institutional barriers in Table IV:

**IV.a** First of all, it is proposed that the right of self-consumption and net-metering of electricity must be recognized, thus avoiding specific taxes for self-consumed electricity [15].

In doing so, it considers that both instantaneously self-consumed electricity and energy stored in batteries, and subsequently self-consumed, should not involve the payment of additional costs for the use

[13] This barrier can be lowered for the Spanish non-peninsular electrical systems and certain categories of consumers that have some financial reductions.

[14] As a way of demonstrating the effect of the current regulatory framework in Spain on the development of the photovoltaic sector, in Appendix A (Table IV), information on installed power, electricity production, number of installations, average remuneration per kWh generated, and total support provided is shown. Through Table IV, it can be observed that from 2004, and mainly from 2007, a firm commitment was made to solar photovoltaic energy through Royal Decrees 436/2004 and 661/2007, which established premiums for producers of photovoltaic energy. However, the compensation system established in 2007 was poorly designed since there were no limits on installed capacity, which caused the boom of 2008 installations and all the regulatory chaos that followed. Since 2011, a whole series of rules has been adopted to retroactively cut premiums for renewable energies, which has in fact led to the application of a genuine moratorium on these energy sources (under the pretext of reducing the deficit of the electricity sector) and caused the new RES power capacity installed in the last years to be almost negligible.

[15] As previously mentioned, from a study carried out by the International Energy Agency for 18 OECD countries (plus China and Brazil) (Masson et al., 2016), it was verified that Spain was the "only example" of a specific tax for self-consumers.

of the electrical system, as the electricity grid is not used at any time. It is, therefore, a matter of equating the treatment of self-consumption to any other measure of energy saving or efficiency.

This treatment [successfully implemented in countries such as Germany, Denmark, Japan, Israel, and Mexico (Masson et al., 2016)] has significantly simplified self-consumption modalities to date. As the only relevant issue is the existence (or lack thereof) of surplus, they are still treated like any other modality of electricity production—in the same way as "conventional" electricity consumed by self-consumers is treated under the same conditions as those applying to any other type of consumer.

**IV.b** Second, it is proposed to enable the possibility of several consumers sharing a self-consumption facility. This arrangement is considered essential if self-consumption is to be developed in the domestic urban environment. To this end, the repeal of Article 4.3 of Royal Decree 900/2015 is proposed.

In fact, already in 2016, the Government of Catalonia denounced this situation before the Constitutional Court which, in May 2017, declared "unconstitutional" the prohibition of RD 900/2015 of self-consumption facilities for neighborhood communities (Tribunal Constitucional, 2017). Despite this, almost one year after this ruling (May 2018), there is no regulation to carry them out. At the moment, “shared” self-consumption in Spain is not “real”; and a regulation that regulates the procedure to regulate the connection point is needed. In this case, the ideal would be a reform at the whole-country level that would allow us to adapt to the needs of consumption and the evolution of technologies. However, this is an option that, in the short term, does not make sense (looks to be very unlikely to happen). Therefore, it is necessary that each of the regions ("Autonomous Communities"), which have competence in energy matters, take action and set a procedural precedent for the future adoption of legal documents. In this regard, Catalonia has taken the lead and, recently in Barcelona (September 2017) the first shared self-consumption facility has been carried out in a community of neighbors (La Vanguardia, 2017).

However, and assuming the "worst" of the scenarios, performing this type of facility without a defined regulatory framework (a situation that currently exists in Spain) can have consequences, since it could include taxes that would have to be paid retroactively. Therefore, it is imperative that the governments of the different Autonomous Communities (with powers in energy matters) are those that develop the "unconstitutionality" of the shared self-consumption prohibition in order to avoid further legal problems for the neighboring communities.

**IV.c** Third, the Ministry of Industry (actually, the Ministry for Ecological Transition) must establish a clear methodology that defines how to calculate the charges that would have to be paid by all users in general, and self-consumers in particular, especially as part of these charges is proportional to the electricity consumed whether it is received from the transmission or distribution network or “self-produced” instantly.

As a feasible alternative, a methodology of allocating costs based on the application of charges calculated mainly from fixed terms, which allows recovery of the costs of the system without resorting to variable-term charges applicable to self-consumed energy could be considered.

**IV.d** Fourth, it should be considered that the processing of facilities in self-consumption with zero injection to the distribution network (Type-1 installations) should revert to the previous self-consumption processing procedure (i.e. before Royal Decree 900/2015 entered into force). This Royal Decree requires that all installations up to 100 kW are processed according to Royal Decree 1699/2011. A point of connection to the utility is requested, and an access contract to the electricity grid is signed regardless of whether or not they inject power into the grid (CIRCUTOR, 2015).

Instant self-consumption consists of generating one's own electrical energy and consuming it at the same time, with the apparent effect to the utilities that no electricity is demanded. This particular form of electricity generation is showing a notable increase (Colmenar-Santos et al., 2015) despite the current legal situation in some countries, such as Spain. This simplifies and lowers the management of the photovoltaic system for the authorities in a way that makes it equivalent to a diesel generator. By using dynamic power control, the maximum active power generated by the inverter can be controlled and the PV power generated can be only used for self-consumption without any injection to the distribution grid (SMA, 2014), so it is not a technical issue. By reverting to the situation as it was before the entry into force of Royal Decree 900/2015, a simplified processing option (according to the Complementary Technical Instruction REBT ITC-BT-40) would be possible.

Then, the authors of this paper propose the installation of self-consumption systems, simplifying their processing to the maximum extent (CIRCUTOR, 2015; CIRCUTOR, 2017):

a) as grid network-assisted installations in which a parallel connection for the use of the grid AC signal for synchronism is exceptionally allowed, but ensuring both zero electricity injection and a level of protection of the installations connected under the ITC-BT-40.

b) Or as installations connected to the electricity grid with a guarantee that there is zero electricity injection, and therefore it would not be necessary to have a contract with the utility nor register the activity since there would be no sale of energy.

In order to maintain the same indices of quality and safety of the electricity supply, it is necessary to (CIRCUTOR, 2015; CIRCUTOR, 2017):

a) install protections to prevent network and autonomous generators working in parallel.

b) include a device that prevents injection into the network (or provide a technical study that guarantees there is no possibility to inject electric energy to the external grid).

c) submit a project with details of the protections to the distributor company (which can verify the protections of the connection).

But, in no case would an administrative registration be required, which has demonstrated to be one significant barrier. This would mean that the procedure required for a DERS would not apply, but would rather be a mere modification of the installation of consumption with associated self-consumption according to the low voltage regulation. Therefore, it is proposed to return to the previous situation where self-consumption facilities that do not inject power into the electricity grid are legalized according to the corresponding technical regulations following the notification procedure without requiring a connection point to be obtained or any other administrative procedure as they would not use the electricity grid. This measure is proposed for the sake of administrative simplification.

**IV.e** Fifth, it is proposed that a combination of feed-in tariff or feed-in premiums and net-metering mechanisms should be implemented as a support scheme to enable the consumers to compensate their electric consumptions and receive economic compensation for the surplus electric energy that they inject into the electric network; this would also offer the alternative of "credits" per kWh injected to the grid, or "green certificates" which could be negotiated in parallel markets.

It is true that the combination of the feed-in tariff and the feed-in premium, as a means of retribution, is the basis of the development of the photovoltaic sector in leading countries like Germany (see Table A.II, which shows a comparison of the remunerations for the case of Germany, the United States, Israel, China, Australia, and Spain). However, it is also a fact that these compensation schemes can have a negative impact on the reliability of the electricity network (since they imply a guaranteed connection to the same, regardless of where the generators are located), and they also implicitly represent a distortion of electricity prices in the wholesale market (Lesser et al., 2008; Menanteau et al., 2003).

On the other hand, "pure" net-metering policies, despite being successful in the development of specific technologies with a limited implementation, presents the problem of long-term remuneration, so it represents a barrier (EPIA, 2013).

Based on evaluations, made specifically for Spain, that have been shown to be "a viable option for PV development" (Ramírez et al., 2017), a combination of net-metering and feed-in tariff is adequate to solve each problem separately at the time that the development of solar photovoltaic technology and self-consumption is achieved in Spain. As a consequence, this combined policy mechanism is the one proposed in this paper.

As studied by (Ramírez et al., 2017), PV energy generation is not profitable in most cases (7 top PV producers in Europe) without the support of an electricity compensation scheme. Results are only favorable once the FiT price rate achieves a greater level than the electricity costs. Then, a full net-metering or self-consumption scheme are feasible once upfront costs are low enough to make PV energy economically profitable. The only other possibility is a scenario where electricity prices are high enough to balance those costs. Moreover, the authors remark that plant size is a key factor as scale economies still influence in a high amount the PV market. This fact must be considered when defining domestic self-consumption promoting energy policies. However, the excellent solar irradiation levels in Spain makes it one of the most attractive countries to invest in PV projects.

Considering all previously described considerations, results in (Ramirez et al., 2017) show that the optimal PV self-consumption option in Spain should be a scheme which prioritizes FiT against net-metering. Feasible FiT/net-metering rates should be from 75/25 to 100/0, where estimated minimum FiTs[16] are achieved in the simulations (from 120 €/MWh for 1 MW installed capacity facilities, up to 240 €/MWh for 5 kW rated power fixed PV power plants). On the contrary to other similar irradiation countries, like Italy, the higher the FiT/net-metering rate, the better.

Nevertheless, the accurate FiT/net-metering ration and the FiT minimum must be defined according to the location (irradiation levels) and the size of the power plant.

**IV.f** Sixth, Royal Decree 900/2015 overlooks smart grids and self-consumption, potential ancillary services to stabilize the grid, not remunerating services, and not allowing small players to participate in the balancing market.

A smart grid can always be defined through three types of nodes: generation nodes, consumption nodes, and the point of interconnection. Normally, the control of such micro-grids is carried out by the management of the variables of the point of interconnection with the utilities. Depending on the application, these variables can exchange real and reactive power, or voltage and frequency control,

[16] The authors in (Ramirez et al., 2017) introduce the concept of FiT minimum as the minimum FiT price that makes the investment profitable.

respectively. In all these cases, a fourth type of node must be used to allow full management of smart grids: an energy storage node.

The use of energy storage systems in photovoltaic plants allows for the optimum performance of all applications in the photovoltaic system. In self-consumption-oriented plants, energy storage systems allow for minimal exchanges with the grid, which increases the percentage of use of energy from photovoltaic sources. If the Spanish regulations facilitated it (as already happens, for example, in countries like Singapore or Malaysia), this increase of self-consumption could bring an extra benefit to the operation of the systems. In this case, energy storage systems would allow the use of extra energy that has not been used during the day.

Smart grids would allow participation in the regulation of both frequency and voltage, which is particularly interesting in the case of weak electrical grids, such as those in insular systems like the Canary Islands in Spain. Frequency regulation would be done through storage systems, as the power source is not always available (batteries, in this case, should be sized to obtain the power required by the system operator). The regulation of the voltage, on the other hand, would be carried out through the injection or the consumption of reactive power. Such reactive power could be supplied by a photovoltaic inverter, provided it has an extended reactive power supply capability (Colmenar-Santos et al., 2016).

As a consequence, recognition of the value of the services offered by storage systems is central to creating the business case for storage and will be proposed in this paper, including rewards for grid services and overall capacity of energy storage to stabilize quality and supply for renewables generation. This recognition should be made both for its capability to efficiently regulate the voltage level locally and for the capacity to interrupt and move the electric load at the DSO or TSO command.

Particularly, it can be proposed a similar mechanism that currently works in the Spanish wholesale market for generators which are allowed to offer their capability for voltage regulation on the one hand, and, on the other hand, for intensive energy consumers, to interrupt their electric consumption. While the voltage control ancillary service has been largely operated in the Spanish power grid, the interruption service has been implemented just a few years ago. However, this service has been operating in other countries, like the UK since long time ago.

The voltage service is remunerated (partially is a mandatory service for the connected generators to the power grid) according to the reactive power that each generator is capable to inject or absorb to the power grid, at a certain moment. It is offered to the TSO, who organizes the offers from the most economic to the least (competitive tender). The interruption service, on the other hand, is completely voluntary (although a potential bidder must be technically approved by the TSO) and bidders can offer energy interruption blocks of 5 MW or 90 MW (with very high availability) with three execution options: (i) instantaneous; (ii) quick execution (15 minutes); or (iii) hourly (minimum advice two hours earlier of the execution) (Ministry of Industry, Energy and Tourism, 2010; Ministry of Industry, Energy and Tourism, 2010).

Although distributed energy storage systems integrated in self-consumption facilities which would provide voltage control and interruption services (that significantly help with the frequency regulation in a similar way as the load shedding) may have lower sizes (hundreds of kW instead of tenths of MW) its location in the distribution network results a great advantage as voltage and frequency disturbances should affect locally (Delfino et al., 2018). Then, adapted tender mechanisms for both services, in an appropriate power size scale, seems to be feasible and, thus, it is proposed.

**IV.g** Finally, this paper proposes to adapt the sanctioning regime concerning self-consumption to the true impact of the same in the electricity sector.

The Government has included in its Royal Decree of Self-Consumption (RD 900/2015) fines of up to € 60 million for self-consumers who fail to comply with the Royal Decree. If we compare this amount with the € 30 million maximum set for the abandonment or release of radioactive materials (El Confidencial, 2015), it can be understood how disproportionate this Royal Decree is.

TABLE IV. PROPOSED MEASURES TO ADDRESS THE ECONOMIC NON-MARKET FAILURES AND INSTITUTIONAL BARRIERS THAT HINDER THE DEVELOPMENT OF SOLAR PHOTOVOLTAIC TECHNOLOGY AND SELF-CONSUMPTION IN SPAIN. Source: Own elaboration.

| IDENTIFIED BARRIERS | MEASURES PROPOSED | JUSTIFICATION FOR THE PROPOSED MEASURE |
| --- | --- | --- |
| According to Law 24/2013, self-consumption facilities are obliged to contribute to the financing of the costs and services of the electricity system in the same amounts as the rest of the consumers. | The right to self-consumption of electricity is to be recognized and without the application of any charges for electricity self-consumed. | In doing so, it considers that both instantaneously self-consumed electricity and energy stored in batteries, and subsequently self-consumed, should not involve the payment of additional costs for the use of the electrical system, as the electricity grid is not used at any time. It is, therefore, a matter of equating the treatment of self-consumption to any other measure of energy saving or efficiency. |
| Consumer associations are prohibited. | Possibility of several consumers sharing a self-consumption facility. | This arrangement is considered essential for self-consumption to be developed in the domestic urban environment. |
| Application of access tolls, system costs, and backup costs for self-produced energy. | The Ministry of Industry/for Ecological Transition, must establish a clear methodology that defines how to calculate the charges paid. | This is justified by the fact that part of the charges paid by all users in general, and self-consumers in particular, are proportional to the electricity consumed, whether it is received from the transmission or distribution network or "self-produced" instantly. |
| | Self-consumption facilities that do not inject power into the electric grid should not be required to obtain a connection point or perform any other administrative procedure. | Since these facilities would not be using the electric grid, there would be no point in having this administrative burden. |
| Consumers of self-consumption Type-1 are not entitled to receive any remuneration for surplus energy[17]. | Implementation of a combination of feed-in tariff and net-metering. | This support scheme would enable prosumers to compensate for their electricity consumption and receive economic compensation for the excess electric energy they inject into the electricity grid. This would help prevent the problems associated with the feed-in tariff, net metering, and wholesale market price minus taxes schemes, or the total lack of remuneration (as in the case of Spain, when the installed power is less than 100 kW). |
| The implementation of energy efficiency mechanisms does not guarantee consumers enough reciprocal advantages with regards to Royal Decree 900/2015. Only prices (per kWh produced) charged for non-peninsular electric power systems, and only under certain circumstances, can be reduced. | Rewards for grid services and overall capacity of energy storage to stabilize quality and supply for renewables generation. | Royal Decree 900/2015 overlooks smart grids and self-consumption, potential ancillary services to stabilize the grid, not remunerating these services, and not allowing small generators to participate in the balancing market. |
| The implementation of energy efficiency mechanisms does not guarantee consumers enough reciprocal advantages with regards to the Royal Decree 900/2015. | Adapt sanctioning regime concerning self-consumption to the true impact of the same in the electricity sector. | The Government has included in its Royal Decree of Self-Consumption (RD 900/2015) fines of up to € 60 million for self-consumers who fail to comply with the Royal Decree. If this amount is compared with the € 0 million maximum set for the abandonment or release of radioactive materials, it can be understood how disproportionate this Royal Decree is. |

It should be borne in mind that the measures proposed in this paper do not imply an increase in the credits requested by the Spanish government or a decrease in budgetary revenue. Indeed, after the entry into force of Law 24/2013, the balance between costs and revenues of the electricity system is guaranteed so that a potential imbalance would be corrected automatically without generating a tariff deficit and, therefore, no requirement whatsoever of budgetary burden.

[17] Consumers with self-consumption of rated power lower than 10 kWp do not have to pay for the energy produced, but they cannot inject surplus energy.

In addition, for the calculation of application access tolls since 1 January 2016, the Government has considered a forecast of electricity demand lower than that estimated by the CNMC based on data from the operator of the system (TSO). In view of the small size of the production facilities associated with solar photovoltaic technology and self-consumption, it can be considered that their effect on the income of the electricity system will be negligible in the first years and, in any case, of the same order of magnitude as the errors in the estimation of the electric demand, which will necessarily occur. Furthermore, as in other countries and USA states, if the recommendations proposed in this paper for self-consumption and net-metering produce distortions in the power system, any of these rules can be modified in the future. The beneficial effects of solar photovoltaic technology and self-consumption, both on the electricity system itself (reduction of losses in the network and reduction of prices in the wholesale market derived from the displacement of marginal technologies) and on the rest of the economy (creation of employment, positive fiscal impact derived from investment, etc.), offset the revenue reduction that could be caused on the electrical grid power system.

Bearing the above in mind, it will be proved here how the measures proposed, measures that are expected to promote the development of the solar PV technology in Spain, will improve the economics of solar power. To do that, potential losses and benefits from adopting this technology will be compared.

Currently in Spain, and considering the MINETAD self-consumption registry (MINETAD, 2018), there is an installed power of self-consumption of about 867.5 MW, which are distributed in cogeneration, biomass, bioliquid and biogas installations, waste energy, wind, photovoltaic, hydroelectric, diesel engines and other thermal power plants. According to the total installed power at a national level (peninsular and non-peninsular), – around 105 GW – the self-consumption that encompasses all the technologies present in the Registry, represents 0.82% of the installed capacity in Spain. Considering electricity consumption values of Red Eléctrica de España (the national TSO), it is estimated that, from the approximately 265,000 GWh demanded in 2016, around 3,000 GWh were self-consumption, which means that 1.19% of the demand for self-consumption is currently covered. Of these 3,000 GWh, self-consumption generated from RES is only 576 GWh, which represents a 0.22% coverage of the electric consumption. If only photovoltaic installations were considered, this percentage drops to 0.01%. Table V presents these data about electricity coverage.

TABLE V. DEMAND COVERAGE PERCENTAGE FOR DIFFERENT TYPES OF SELF-CONSUMPTION. Source: Adapted from MINETAD, 2018.

| DEMAND COVERAGE | PERCENTAGE |
|---|---|
| Demand coverage with installed facilities for self-consumption | 1.19% |
| Demand coverage with only RES self-consumption | 0.22% |
| Demand coverage with only solar PV self-consumption | 0.01% |

However, it must be noted that self-consumption in cogeneration facilities is exempt from the payment of the back-up toll according to the fourth transitory provision “Exemptions of the charges associated with the system’s costs and the charge for other system services” in Royal Decree 900/2015. This means that approximately 95% of the cogeneration facilities will not assume payment of these charges until 1 January 2020. As a consequence, the percentage of self-consumption facilities that are subject to the payment of the backup toll is reduced from 1.19% to 0.46%. Considering the current installed power of self-consumption and the assumption of an average electricity wholesale price of € 50/MWh (ENDESA, 2017), the loss of revenues from the Electric Pool would be as shown in Table VI.

TABLE VI. POTENTIAL REVENUE REDUCTION CAUSED TO THE ELECTRIC POWER SYTEM AS A RESULT OF THE ADOPTION OF SELF-CONSUMPTION. Source: Adapted from ENDESA, 2017; MINETAD, 2018.

| **DEMAND COVERAGE** | **DEMAND COVERAGE PERCENTAGE** | **REVENUE REDUCTION** |
|---|---|---|
| Coverage demand with installed facilities for self-consumption | 0.46% | € 59,817,789.55 |
| Coverage demand with only RES self-consumption | 0.22% | € 28,835,983.55 |
| Coverage demand with only solar PV self-consumption | 0.01% | € 1,257,474.51 |

That is to say, the real value of the loss of revenues of the Electric Pool considering the data of the Self-consumption register (MINETAD, 2018) would be almost € 29 million for all renewable self-consumption and € 1.2 million for photovoltaic self-consumption. Therefore, the loss of taxes associated with the decrease in income in the market would reach the values presented in Table VII.

TABLE VII. POTENTIAL DIRECT TAXES LOST AS A RESULT OF THE ADOPTION OF SELF-CONSUMPTION. Source: Adapted from AGENCIA TRIBUTARIA, 2017; ENDESA, 2017; MINETAD, 2018.

| **DEMAND COVERAGE PERCENTAGE** | **GENERATION TAX (7%)** | **ELECTRICITY SPECIAL TAX (5.11%)** | **VAT (21%)** | **LOSS OF DIRECT TAXES** |
|---|---|---|---|---|
| 0.46% | € 10,736,548.01 | € 7,837,680.04 | € 32,209,644.02 | € 19,805,670.12 |
| 0.22% | € 2,018,518.85 | € 1,473,518.76 | € 6,055,556.55 | € 9,547,594.15 |
| 0.01% | € 88,023.22 | € 64,256.95 | € 264,069.65 | € 416,349.81 |

Figures in Table VII allow us to verify that the loss of income from taxes would be € 9.5 million for all renewable technologies, and € 0.4 million if only photovoltaic self-consumption was considered. From the Government perspective, once the reduction in incomes due to self-consumption was calculated, it was necessary to calculate the loss of income from tolls and taxes associated with this income. To analyze the economic repercussions produced in the event that consumers choose to implement a self-consumption electricity installation, we have to consider that self-consumers would continue paying the "power term", with which most of the fixed costs of the electricity system are absorbed and would stop paying the "energy term" for self-consumed energy. From the tolls linked to the term of energy and with the energy consumptions of the tariffs considered, we will obtain an average toll that will allow us to estimate the reduction of income, both for access tolls and for electricity taxes.

According to a recent report (December 2017) of the National Commission of Markets and Competition (CNMC, 2017), which establishes the electric power access tolls for 2018, the system costs are equal to approx. € 18,000 million, of which about € 11,000 million are charges, of which approximately 75% comes from tolls. That is, the tolls would cover some € 8,400 million of charges, of which approximately 30% is paid as a variable charge, about € 2,500 million. In compliance with Order IET/107/2014 and Order IET/2735/2015, we were able to assign a percentage of consumption to each tariff. The average toll allowed us to estimate the reduction of income. To calculate it, we considered the energy consumed and the rate of consumption of the tariffs. Therefore, considering all these considerations and the current installed power of self-consumption, the loss of taxes associated with tolls are presented in Table VIII.

TABLE VIII. POTENTIAL TOLLS AND ITS DIRECT RELATED TAXES LOST CAUSED AS A RESULT OF THE ADOPTION OF SELF-CONSUMPTION. Source: Adapted from CNMC, 2017; AGENCIA TRIBUTARIA, 2017; ENDESA, 2017; MINETAD, 2018.

| **DEMAND COVERAGE PERCENTAGE** | **LOSS OF REVENUES FROM ELECTRICITY "TOLLS" (€)** | **ELECTRICITY SPECIAL TAX (5.11%)** | **VAT (21%)** | **LOSS OF TAXES DUE TO A REDUCTION OF INCOME FROM ELECTRICITY "TOLLS" (€)** |
|---|---|---|---|---|
| 0.46% | € 11,806,769.38 | € 730,024.36 | € 2,479,421.57 | € 3,209,445.93 |
| 0.22% | € 5 691,614.65 | € 351,918.23 | € 1,195,239.08 | € 1,547,157.30 |
| 0.01% | € 248,198.93 | € 15,346.39 | € 52,121.78 | € 67,468.16 |

In summary, considering only renewable self-consumption, the “negative” impact would be € 21.5 million; and considering only the photovoltaic self-consumption, this figure would fall below € 2 million euros (to be exact, € 1.74 million).

Then, if according to the Registry (MINETAD, 2018), 16 MW of photovoltaic self-consumption corresponds to a loss of income in the system of about € 1.74 million, thus in the event that 100 MW was entered into the system in one year, the loss of income would not be more than € 11 million. Assuming $CO_2$ emission rights of € 13.54/ton and knowing the intensity of primary energy in Spain (Ministry of Energy, Tourism and Digital Agenda, 2017), an accumulated power of 100 MW of photovoltaic solar energy would have the impact on the environment and on energy dependence as shown in Table IX.

TABLE IX. IMPORTS OF FOSSIL FUELS AVOIDED AND ECONOMIC SAVINGS FOR A 150 GWh SELF-CONSUMPTION SOLAR PV SCENARIO. Source: Adapted from Ministerio de Energía, Turismo y Agenda Digital, 2017; SENDECO, 2018.

| | |
|---|---|
| GENERATION (GWh) | 150 |
| IMPORTS OF FOSSIL FUELS AVOIDED (toe) | 33,871 |
| ECONOMIC SAVINGS AS A RESULT OF NOT IMPORTING FOSSIL FUELS (€) | 6,394,692 |
| $CO_2$ EMISSIONS AVOIDED (TONS) | 87,803 |
| ECONOMIC SAVINGS BY EMISSIONS (€) | 1,188,843 |

According to the contemplated scenario, 150 GWh of self-consumed energy would avoid importing 33,871 toe per year and the emission into the atmosphere of 1,756,513 tons of $CO_2$, which would entail savings of about € 7.5 million. It should also be noted that there are other potential benefits of self-consumption, such as a reduction of energy dependence; a potential reduction of prices in the wholesale market derived from the displacement of marginal technologies[18]; creation of (local) employment; or a positive fiscal impact derived from investment, etc., even real, have not been considered in the income evaluation due to their inherent subjectivism. As a consequence, those losses of € 3.5 million that result from applying a pure “legal” perspective are expected to be offset if those “subjective” elements are taken into account. As already mentioned, if the recommendations proposed in this paper for self-consumption and net-metering produce distortions in the power system, any of the rules proposed in this work can be modified in the future.

## V. CONCLUSIONS

Due to its regulatory inconclusiveness, which implies that, *de facto*, Royal Decree 900/2015 is currently under development, current legislation is a burden to the development of self-consumption in Spain**.** In this sense, it restricts any renewable facility that intends to develop in this manner. Irrespective of the existence of the Administrative Register of Electric Power Consumption, the spirit of the current legislation affects the development of the sector in Spain. This paper proposes a stable legal framework design, which contemplates the implementation of distributed generation systems as envisioned by the Electricity Sector Law, in line with the provisions of Directive 2009/28/EC, without neglecting net-metering, to allow for the management of electricity self-consumption systems. Adapting the successful energy policies executed by Germany, the EU leader in terms of PV installed, and other developed countries, measures that are relevant to the Spanish situation are proposed to promote the deployment of its PV sector, especially for distributed generation facilities target to the self-consumption. For comparative purposes, it can be seen that policies with the aim to charge the electricity consumers to finance Transportation & Distribution (known as "solar tax"), imposed taxes on batteries, or the non-

[18] The potential reduction of the wholesale prices of electricity is linked to the characteristic technology’s kurtosis factor.

existence of revenues from excess electricity for facilities below 100 kW, differ radically from the policies promoted in other countries. This paper combines the budgetary requirements of the Spanish Government in the short term with the necessary development of a technology such as solar photovoltaic, which should be an important part of the energy mix of a country with both high levels of solar radiation and energy dependence, such as Spain is. If the recommendations set out in this paper were taken into account, the energy policy implications are that both generation and distributed storage as well as self-consumption would be encouraged. The energy would preferably be generated from renewable and manageable sources. Furthermore, the resulting regulation would be much easier for consumers to implement and for the network operators and competent administrations to supervise, which strengthens the importance of the measures proposed throughout this paper and suggests the necessity to update the Royal Decree on Energy Self-Consumption, if it is desired that self-consumption in general, and solar photovoltaic technology, in particular, were to be deployed in Spain as it is in other solar PV world-leading countries.

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## APPENDIX A

TABLE A.I. QUESTIONNAIRE AND "SECOND ROUND" RESULTS FOR THE EVALUATION OF THE RELEVANCE OF INSTITUTIONAL BARRIERS AND ECONOMIC NON-MARKET FAILURES THAT RESTRICT PHOTOVOLTAIC SELF-CONSUMPTION IN SPAIN. Source: Own elaboration.

| NO. | BARRIER INDICATOR | OBS. | MEDIAN PV BARRIER INDICATOR VALUE* | MINIMUM BARRIER INDICATOR VALUE* | MAXIMUM BARRIER INDICATOR VALUE* |
|---|---|---|---|---|---|
| **1** | Existence and reliability of solar PV strategy and support scheme | 33 | 6.9 | 3 | 10 |
| **2** | Relative remuneration level of solar PV | 33 | 5.3 | 4 | 10 |
| **3** | Solar PV revenue risk | 33 | 9.2 | 3 | 10 |
| **4** | Access to finance | 33 | 4.3 | 2 | 10 |
| **5** | Fair and independent regulation of the solar PV sector | 33 | 8.1 | 4 | 10 |
| **6** | Existence of functioning and non-discriminatory short-term markets for solar PV | 33 | 5.8 | 3 | 9 |
| **7** | Availability of reliable long-term contracts (PPA) | 33 | 3.5 | 3 | 10 |
| **8** | Grid access cost | 33 | 5.5 | 0 | 10 |
| **9** | Solar PV grid access lead time | 33 | 4.3 | 3 | 10 |
| **10** | Utility and transparency of grid connection procedures | 33 | 5.2 | 2 | 10 |
| **11** | Treatment of solar PV access and curtailment | 33 | 5.8 | 2 | 9 |
| **12** | Transparency and predictability of grid development | 33 | 4.4 | 2 | 9 |
| **13** | Administrative costs | 33 | 4.8 | 0 | 10 |
| **14** | Duration of administrative procedures | 33 | 3.8 | 2 | 9 |
| **15** | Administrative complexity | 33 | 4.3 | 3 | 9 |
| **16** | Integration of solar PV in spatial and environmental planning | 33 | 5.6 | 4 | 10 |

[*] 10 = Extremely relevant, 5 = Moderately relevant, 0 = Not relevant.

TABLE A.II. COMPARISON BETWEEN SPANISH AND OTHER SELF-CONSUMPTION SCHEMES AROUND THE WORLD. Source: Adapted from (Masson et al., 2016).

| | | | **SPAIN** | | **GERMANY** | **UNITED STATES** | **ISRAEL** | **CHINA** | **AUSTRALIA** |
|---|---|---|---|---|---|---|---|---|---|
| | | | Below 100 kW | Above 100 kW | | | | | |
| PV Self-consumption | 1 | Right to self-consume | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | 2 | Revenues from self-consumed PV | Savings on the electricity bill | Savings on the electricity bill | Savings on the electricity bill | Savings on the electricity bill | Savings on the electricity bill | Savings on the electricity bill + bonus | Savings on the electricity bill |
| | 3 | Charges to finance Transportation & Distribution | Yes (“solar tax”) | Yes (“solar tax”) | None | In specific states | None | None | Tariff structure changes in some states |
| Excess PV electricity | 4 | Revenues from excess electricity | None | Wholesale market price minus taxes | Feed-in Tariff (FiT) or Feed-in Premium (FiP) | Retail Electricity Prices (full net-metering) | Retail Electricity prices (full net-metering) | Market price + bonus | Feed-in Tariff |
| | 5 | Maximum timeframe for compensation | Real-time | Real-time | Real-time | Vary by state | 2 years | Real-time | 30 minutes |
| | 6 | Geographical compensation | None | None | On site only | On-site | Credits can be transferred to other consumers (but without transmission and distribution costs) | On site only | On site only |
| Other system characteristics | 7 | Regulatory scheme duration | Unlimited | Unlimited | 20 years Feed-in Tariff (FiT) | Unlimited | Unlimited | 20 years | Unlimited but FiT are revised annually |
| | 8 | Third party ownership accepted | None | Yes | All | Yes | Yes | None | Yes (e.g. Solar Leasing) |
| | 9 | Grid codes and additional taxes/fees | Above 10 kW (except the Canary and Baleares islands) | Yes (except the Canary and Baleares islands) | Grid codes compliance and partial EEG-surcharge | Vary by state. e.g. in Massachusetts, net energy metering is calculated monthly with a minimum bill. Arizona utilities have implemented fixed charges to account for grid costs | System costs – grid, back-up and balancing costs | None | Yes (Injection control/ramp-rate control/no DC-injection) |
| | 10 | Other enables of self-consumption | None | None | Battery storage incentives | Time of use tariff in some states | None | None | None |
| | 11 | PV system size limitations | 100 kW but below or equal to capacity contracted | Below or equal to capacity contracted | Minimum 10% of self-consumption | Yes, but depends on the state: from 10 kW to 10 MW (or no limit) | 5 MW | 20 MW – 35 kV | None |
| | 12 | Electricity system limitations | Distributor’s License | Distributor’s License | 52 GW of PV installations | In some states | No, but costs are linked to PV penetration | 7 GW for distributed PV installations | None (except additional grid codes) |
| | 13 | Additional features | Taxes on batteries | Taxes on batteries | Renewable Energy Sources Act (EEG) levy must be paid anyway by the prosumer (>10 kW) | Multiple other policies depending on the state or at federal level | None | None | None |

## APPENDIX B

### B.1. LATEST UPDATES IN THE SPANISH ENERGY SECTOR REGULATORY FRAMEWORK

During the review process of this paper, Government in Spain, through the Ministry for Ecological Transition (formerly called Ministry of Industry, Energy and Tourism), approved the Royal Decree-Law 15/2018 of 5 October, on urgent measures for the ecological transition and the protection of the consumers (Spanish Ministry for Ecological Transition, 2018), which significantly modifies the existing regulatory framework. The main justification of this suddenly regulatory framework revision was the unaffordable increment of the wholesale prices of electricity and the intentions of the new cabinet to accelerate the transition to a decarbonized economy.

Apart from the approval of several measures to avoid the energy poverty and to protect the most vulnerable energy consumers (Title I of the Royal Decree-Law 15/2018) and the promotion of the sustainable electric mobility (Title IV), the new regulation focuses on the self-consumption policies (Title II) and the integration of renewable energy sources (Title III).

As main modifications regarding the self-consumption policies, which specially concerns this paper, it should be highlighted:

(a) The self-consumption modalities are reduced to just two: with and without energy injection. In this late case, there would be only the role of consumer, while electricity injection allowed facilities must distinguish between the generator and the consumer.

(b) The elimination of tolls for self-consumed energy.

(c) The administrative definition of "self-consumption" is modified and it is recognized the right of running shared self-consumption facilities, allowing private owners communities the installation of their self-consumption generators, taking advantage of scale economies.

(d) The promotion of the simplification of the administrative process to authorize low size generation facilities (i.e. installations of rated power up to 100 kW, even with electricity injection capacity, are exempted to be registered in the Registry of Energy Producers).

(e) The new regulatory framework admits the possibility of introducing net-metering mechanisms for unbalances lower than 100 kW.

(f) The Royal Decree-Law proposes to develop the concept of "close self-consumption facilities" which may include not only inner generators on consumers' facilities but also those generation systems connected to an electrical consumer through a direct electric wire or the low voltage distribution grid derived from the shared power transformation station.

Regarding the promotion of the RES integration in the power grid, (i) new mechanisms to guarantee the investments from energy auctions are included; (ii) grid access and connection permissions for RES generators given previously to Law 24/2013 are extended and; (iii) new measures to avoid speculation with RES projects are proposed.

Although it results mandatory a complete development of the presented new regulatory framework (the Government commit itself to act within 3 months) it should be noticed that (a) those existing regulatory conditions which have been pointed out in this paper will be cancelled, as proposed, for being clearly unfair conditions for energy prosumers in Spain, and (b) New measures depicted in the new Law are strongly aligned with those proposed in this work. Thus, the "expert judgement approach" presented in this paper shows to be realistic and effective.

As final remark, the authors expect that the new regulatory framework will consider the rest of the proposed measures in this work as they are intended to accelerate the Spanish transition to a more fare, clean and sustainable energy generation scenario.

SUPPLEMENTARY MATERIAL

## S.1 Conversation transcript with one of the experts, Dr. Rosa María Regueiro Ferreira (see Acknowledgements section) for example purposes

**[Interviewer] In your opinion, is there any obstacle to the development of self-consumption and, therefore, of the photovoltaic sector in Spain?**

[Expert answer]: The current legislation is a clear obstacle for the development of self-consumption in Spain, in particular by what is established in Royal Decree 900/2015. In this sense, it restrains any type of renewable facility that purports to develop under this perspective.

**[Interviewer] What measures could be taken to achieve an acceleration of the photovoltaic sector in Spain and a rapid reduction of costs?**

[Expert answer]: Firstly, to design a stable legal framework, which contemplates the implementation of distributed production systems, for example from the Electricity Sector Law and in line with Directive 2009/28/EC. Neither should the net balance be left aside to allow the management of self-consumption electric systems. The elimination of the fixed cost by installation of accumulating batteries would allow to obtain a reduction of costs, although with a new system of charging of costs to the whole energy mix that also considered the environmental cost, the overall cost would be reduced.

**[Interviewer] Do you consider it appropriate to recognize the right to self-consumption without any tax being imposed?**

[Expert answer]: The right to self-consumption is related to a business model based on shared ownership. If there is a penalty system it should be proportional to the size of the facilities, and not allow the current situation, where there is a capital disproportion that penalizes the establishment of new renewable facilities.

**[Interviewer] Do you believe that the Administrative Register of Electric Energy Consumption is a drag on the development of the photovoltaic sector in Spain?**

[Expert answer]: The spirit of the current legislation is affecting the development of the sector in our country, beyond the existence of this registry.

**[Interviewer] Do you see a justification for several consumers sharing the same installation?**

[Expert answer]: Totally, it is a model that has been working in other European countries for more than 30 years and with fantastic results.

**[Interviewer] Do you understand that, according to the corresponding technical regulations, self-consumption facilities that do not inject electricity into the electricity grid should be legalized?**

[Expert answer]: The legalization of a facility should be studied and considered at least to ensure the operational safety of the facility.

**[Interviewer] Do you think it necessary to adapt a penalty regime for self-consumption?**

[Expert answer]: As I indicated earlier, yes. Sanctions should be proportional to the size of the facility.