EVALUATING THE 2014 RETROACTIVE REGULATORY FRAMEWORK APPLIED TO THE GRID CONNECTED PV SYSTEMS IN SPAIN

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Abstract

The RD 413/2014 new economic and regulatory framework for producers of electricity from renewable energy sources in Spain has been here analysed, putting the focus on its impact on the economic results of the existing grid connected PV systems. A complete formulation of the new remuneration scheme is first presented, making evident its high complexity and the great number of regulatory parameters involved. Then, in order to facilitate the discernment of its operating mechanism a simplified model is proposed. This approach has proven to be a useful tool to identify the most influential regulatory parameters and also which could be the plausible future regulatory actions in order to contain the cost to the Spanish

Electricity System. Finally, the NPV and the IRR among other indicators are calculated for a representative case study facility, evidencing a substantial profitability reduction in the transition from the former economic and regulatory framework to the RD 413/2014 new remuneration scheme.

Keywords

Renewable Energy, Retroactivity, Photovoltaic, Market, Regulations, Spain, Feed in tariff (FIT)

1. Introduction

From early 2000s, the renewable energy policy of the European Union (EU) has boosted the electricity from renewable energy sources (RES-E) throughout Europe [1, 2]. As a result, in the recent period 2011-2013 at least three EU countries (Germany, Spain and Italy) were among the top 5 performers in the world with highest rates of renewable capacity per capita (excluding hydropower) [3-6]. Moreover, in the case of photovoltaic (PV) capacity, these good results were even better. Since 2006, the EU has accounted for more than half of the total worldwide PV capacity. Once again, at the top of the PV global rank in 2013 were Germany (35,715MW), Italy (17,928 MW) and Spain (5,340MW).

All the countries occupying the first positions in the PV promotion had adopted the feed-in-tariff (FIT) mechanism [3-7]. Notwithstanding the excellent results achieved, the fact remains that the FIT has been blamed for some malfunctions in the electricity sectors of the implementing countries. One of the most important malfunctions was the so called “call for inversion” effect, responsible for the exponential growth of the PV capacity and the cause of the overrun cost to the electricity systems of these countries.

Despite these malfunctions the FIT mechanism continues to be used and, consequently, is one of the key elements analyzed in the scientific literature of the last years.

For example, attention has recently been focused on the FIT for promoting RES-E in the United Kingdom as a vehicle towards to a low carbon transition, reviewing again the pros and cons of this mechanism, specially its inherent boost effect [8-11]. As well, concerning the effectiveness of the FIT mechanism in avoiding CO₂ emissions, it is possible to find recent studies related to countries such as Germany, Taiwan, Malaysia or Australia [12-15]. The German experience has also been used as a reference for comparing the German FIT against other promotion mechanisms [16], and for countries such as Japan and Kenya, the prospects of the evolution of the grid connected PV systems (GCPVS) have been analyzed taking into account the FIT mechanism in their models [17,18]. Likewise, when analyzing different values and grades of support to energy storage systems facilitating the large-scale the integration of wind energy, the FIT mechanism has been praised as an effective tool [19, 20].

Nevertheless, two new regulatory trends appeared in the countries that applied FIT mechanisms and experienced a power capacity boom far exceeding their policy objectives, especially for GCPVS. The first of these trends was the introduction of limiting regulatory elements for the new facilities to be installed [21]. Spain, which due to the malfunction of the FIT mechanism led the PV market in 2008 [22], was one of the first countries that introduced these modifications in the international context [23]. In this regard, Italy, the second country in the PV global rank in 2013, did not take into account the 2008 Spanish experience to prevent the malfunctions of its FIT scheme and saw how its PV capacity even exceeded the exponential growth that occurred in Spain. This evolution finally forced Italy to introduce limiting arrangements -capacity caps- in their PV legal frameworks [5].

The scientific literature devoted to analyse the overrun cost to the electricity systems caused by the existing GCPVS has concentrated its attention on the world leading countries in PV capacity, namely, Germany, Italy and Spain. As early as 2008, the cost of the GCPVS promotion was studied in the case of Germany [24, 25], and this concern has been followed keenly to date [26-30]. Comparatively, the Italian and the Spanish cases have received less attention in the scientific literature. With regard to Italy, the cost introduced by the FIT scheme to the electricity sector is discussed in [31, 32]. With respect to Spain, the benefits and costs of the

RES-E promotion are discussed in [33] for the period 2002-2011, and in [34] the cost to the Spanish Electricity Sector (SES) of the GCPVS installed in 1998-2008 is analyzed for all their regulatory lifetime.

The second regulatory trend has involved applying retroactive measures to mitigate the economic burden that the promotion of RES-E had introduced in the electricity systems. Despite the importance in terms of legal security and the economic implications that these measures might have had on the economic results of the pre-existing facilities, there have not been many studies in the scientific literature analyzing this subject. Spain was one of the countries that started to undertake these retroactive measures [34], as well as other countries did, such as the Czech Republic, Bulgaria and Greece [5, 35, 36]. The retroactive measures adopted in the Czech Republic and Greece are outlined in [37-40]. The measures undertaken in Spain in the period 2010-2013 are briefly described in [38, 39, 41-47] and are discussed in greater detail in [34, 48] assessing the economic impact on the GCPVS through their regulatory lifetime.

The importance and relevance of the regulatory retroactive activity in Spain in the international context in terms of economic impact can be easily understood when taking into account the high exposure that the international funds have in Spanish renewable energy assets, no less than 13 billion Euros. As a consequence, Spain is seeing how these international investors are proceeding with a flood of legal actions under the Energy Charter Treaty or under the European Law against these retroactive measures [49]. Spain ranks first when considering the number of Renewable Energy Claims faced under the Energy Charter Treaty, and some authors highlight that this might be the beginning of a boom of renewable energy arbitrations [50]. The result of one of these arbitration processes is already known and gave judgment in favour of Spain [51]. However, this judgment concerns the first retroactive measures enacted in 2010 to mitigate the economic burden of the promotion of the RES-E. It does not apply to the new retroactive regulatory activity in Spain that gained further momentum in 2014 with the issuance of a new economic and regulatory framework (RD 413/2014) applying retrospectively to all the renewable energy facilities existing prior to its entry. The 2014 new Spanish retroactive measures might have a crucial economic impact not only on the national

renewable energy facilities but also on an international economic context due to the high exposure of the international funds in Spanish renewable energy assets. Nevertheless, to the authors' knowledge the economic effect of the 2014 new retroactive regulation on the pre-existing GCPVS has not yet been studied.

Following this gap and on the basis of the methodology applied by the authors in [34], this paper contextualizes the new economic and regulatory framework enacted in 2014 in Spain for the pre-existing GCPVS. Due to its importance in numbers and its impact on the cost of the SES [22 and 34], the paper focus its attention especially on those facilities under the RD 661/2007 that were put into service in 2008. In the paper the new economic model is described and formulated, being its most influential parameters identified (section 2). Next, the implications of the new economic framework are analyzed, as well as the plausible regulatory decisions related to the new economic scheme that the Government might undertake in order to limit the economic burden of the promotion of GCPVS for the SES (section 3). Hence, the economic impact of the new framework on the chosen pre-existing GCPVS is evaluated and its effect on their viability is assessed and discussed (section 4). Finally, all the factors deemed relevant for the evolution of the PV sector during the period of analysis are duly systematized and conclusions are raised (section 5).

2. The RD 413/2014 economic and regulatory framework for the GCPVS in Spain

2.1. Setting the context

In July 2013, the Spanish Government enacted the Royal Decree-Law (RDL) 9/2013 [52] addressed to guarantee the financial stability of the SES. In what has to do with the

GCPVS, this RDL broke with the philosophy applied so far which had introduced cost containment measures without dismantling the established economic frameworks¹. Thus, the RDL 9/2013 abolished the economic frameworks set by the RD 661/2007 and the RD 1578/2008, although it stated that they would be still applied provisionally until the appearance of a new regulatory and economic framework to come. The economic structure of this new framework would be based on the changes that the RDL 9/2013 introduced in the article 30 of the Law of the SES [53].

Next, in December 2013 a new Law of the SES was enacted, the Law 24/2013 [54]. In its Third Final Disposition it was stated again that all the GCPVS entitled to receive a FIT prior to the appearance of the RDL 9/2013 would have a new economic framework in accordance with the articles 16 and 30 of the former Law of the SES. This new economic framework would also be consistent with the provisions of the article 14 of the new Law of the SES. There, four remuneration concepts were set for mainland electricity generation facilities, namely, the energy price negotiated in the market, the ancillary services, the capacity payments and the specific remuneration (SR). Specifically, the SR only would apply to the RES-E producers, high efficiency cogeneration and waste and was intended to guarantee a reasonable profitability that might not be attained by the energy price negotiated in the market.

Following, the economic framework of the SR was developed in June 2014 by the RD 413/2014 [55] which enrolled the existing GCPVS in a SR register. The SR would take into account the standard cost of the initial undertaken investment, and the standard revenue and operation costs. All these economic concepts would be determined using a set of regulatory parameters defined by the Government for efficient and well managed facilities. It was the Ministerial Order (MO) IET 1045/2014 of June 2014 [56] that was responsible for defining those parameters for all the GCPVS in Spain.

¹ The adopted cost containment measures were based on RD 1003/2010, RD 1565/2010, RDL 14/2010, Law 2/2011, Law 15/2012 and RDL 2/2013 [34].

Definitely, only two of the four remuneration concepts identified in the RDL 9/2013 apply to the GCPVS, namely, the market energy price and the SR. As regards the capacity payments and the ancillary services, they were declared not suitable for the GCPVS by the RD 413/2014 and the MO ITC/3127/2011 [57], respectively.

2.2. Description of the RD 413/2014 economic and regulatory framework

As previously discussed, the revenue perceived in a year i ($Revenue_i$) by the owners of the existing GCPVS in the RD 413/2014 economic and regulatory framework is the sum of the market revenue ($Market_Revenue_i$) and the SR revenue ($SR_Revenue_i$):

$$Revenue_i = Market_Revenue_i + SR_Revenue_i \quad (1)$$

The $SR_Revenue_i$ is perceived during the regulatory lifetime of the facilities (VU); from then on, only the $Market_Revenue_i$ will apply.

As regards $Market_Revenue_i$, it can be calculated as the total energy generated within a year i (E_i) by the yearly average energy market price per unit of generated energy (Pm_i):

$$Market_Revenue_i = E_i \cdot Pm_i \quad (2)$$

In turn, E_i can be expressed as the product of the GCPVS nominal power (P_n) by the number of equivalent operating hours within the year i (Nh_inst_i):

$$E_i = P_n \cdot Nh_inst_i \quad (3)$$

Where Nh_inst_i represent the number of hours of operation at rated power needed to obtain the actual E_i output of the system, and is modelled as a decreasing function of the yearly

170 degradation rate (K_R) of the GCPVS, the year when the facility obtains the operating permit (a),
 171 and the initial number of equivalent operating hours within the year $a+1$ (Nh_inst_{a+1})²:

$$172 \quad Nh_inst_i = Nh_inst_{a+1} \cdot [1 - K_R \cdot (i - (a + 1))], \quad i \geq a + 1 \quad (4)$$

173 On the other hand, the $SR_Revenue_i$ in a year i is determined as:

$$174 \quad SR_Revenue_i = (Op_R_i + Inv_R_i) \cdot d_i \quad (5)$$

175 Where Op_R_i and Inv_R_i are the remuneration in the year i for the operation of the
 176 GCPVS and for the undertaken investment, respectively, while d_i is a coefficient correcting the
 177 annual revenue according to the performance of the facility in terms of equivalent operating
 178 hours.

179 Specifically, d_i is defined as follows:

$$180 \quad d_i = \begin{cases} 1 & Nh_inst_i > Nh_min_i \\ \frac{Nh_inst_i - Uf_i}{Nh_min_i - Uf_i} & Uf_i \leq Nh_inst_i \leq Nh_min_i \\ 0 & Uf_i > Nh_inst_i \end{cases} \quad (6)$$

181 Where Nh_min_i is the minimum value of Nh_inst_i that does not entail a reduction of
 182 $SR_Revenue_i$ and Uf_i is the threshold of Nh_inst_i for perceiving $SR_Revenue_i$, within the year i .

183 The Op_R_i is obtained multiplying E_i by the remuneration for the operation per unit of
 184 generated energy (Ro_i):

² The MO IET 1045/2014 set at 0.5% the loss of efficiency or degradation rate K_R that would reduce the initial number of equivalent operating hours on an annual basis. It is also considered that the facility has not any revenue, cost or energy production in the year a .

$$Op_{R_i} = E_i \cdot Ro_i \quad (7)$$

Where E_i is subjected to:

$$E_i \leq E_{max_i} \quad (8)$$

$$E_{max_i} = P_n \cdot Nh_{max_{(Ro)_i}} \quad (9)$$

where E_{max_i} and $Nh_{max_{(Ro)_i}}$ are the maximum values of E_i and Nh_{inst_i} , respectively, eligible to perceive the Ro_i within the year i .

The value of Ro_i is set so as to compensate for the standard operating cost per unit of generated energy estimated for an efficient and well managed facility (C_{Eexpf_i}) that cannot be recovered with the estimated future market price per unit of generated energy (Pmf_i):

$$Ro_i = C_{Eexpf_i} - Pmf_i \quad (10)$$

Six-year regulatory periods were defined, divided into three-year half-periods (j)³. The value of Pmf_i for each i belonging to j is determined as the arithmetic average of the yearly futures contracts prices negotiated in the Spanish regulated electricity futures market for the six months prior to the beginning of j .

³ Exceptionally, the first regulatory half-period ($j=1$) starts on 12 July 2013 and ends on 31 December 2016. The following half-periods last exactly 3 years.

As regards Inv_R_i in (5), it is calculated as the product of P_n and the remuneration for the investment per unit of installed power ($Rinv_{j,a}$), which has the same value for every year i within a regulatory half-period j of a GCPVS obtaining the operating permit in the year a :

$$Inv_R_i = P_n \cdot Rinv_{j,a} \quad (11)$$

$Rinv_{j,a}$ is intended to compensate for the undertaken investments cost not recovered with the market revenue. Nevertheless, as established by the MO IET 1045/2014, $Rinv_{j,a}$ will be set to zero for the facilities reaching the reasonable profitability before the end of their regulatory life. $Rinv_{j,a}$ is calculated as follows:

$$Rinv_{j,a} = C_{j,a} \cdot VNA_{j,a} \cdot \frac{t_j \cdot (1 + t_j)^{VR_j}}{(1 + t_j)^{VR_j} - 1} \quad (12)$$

Where, for the regulatory half-period j of a facility obtaining the operating permit in the year a , $C_{j,a}$ is a per unit adjustment coefficient representing the investment cost that cannot be recovered with the market revenue, $VNA_{j,a}$ is the net value of the asset per unit of installed power, t_j is the per unit discount rate corresponding to the reasonable profitability and VR_j is the remaining number of years at the beginning of j to the end of the facility VU .

As regards $C_{j,a}$, it is determined from the expression:

$$C_{j,a} = \frac{VNA_{j,a} - \sum_{i=p}^{a+VU} \frac{(Ingf_i - Cexpf_i)}{(1 + t_j)^{i-p+1}}}{VNA_{j,a}} \quad (13)$$

Where p is the first complete year⁴ of j and $Ingf_i$ and $Cexpf_i$ are the future estimated operating income and cost, respectively, per unit of installed power within the year i .

In turn, $Ingf_i$ and $Cexpf_i$ are calculated as:

$$Ingf_i = (Pmf_i + Ro_i) \cdot Nh_{i,j} \quad (14)$$

$$Cexpf_i = C_Eexpf_i \cdot Nh_{i,j} \quad (15)$$

Where $Nh_{i,j}$ is the number of standard equivalent operating hours within the year i .

Regarding $VNA_{j,a}$, it is calculated with different expressions for $j=1$ and for $j>1$:

$$VNA_{j,a} = \begin{cases} VI_a \cdot (1 + t_j)^{p-a-1} - \sum_{i=a+1}^{p-1} (Ing_i - Cexp_i) \cdot (1 + t_j)^{p-i-1}, & j = 1 \\ VNA_{j-1,a} \cdot (1 + t_{j-1})^{sm} - \sum_{i=p-sm}^{p-1} (Ingf_{i,j-1} - Cexpf_{i,j-1} - Vajdm_{i,j-1}) \cdot (1 + t_{j-1})^{p-i-1}, & j > 1 \end{cases} \quad (16)$$

Where, per unit of installed power, VI_a is the standard value of the undertaken initial investment, Ing_i and $Cexp_i$ are the standard mean total income and operating cost for $i < p$, sm is the number of years of j and $Vajdm_{i,j-1}$ is a coefficient adjusting the deviations of Pm_i .

Ing_i and $Cexp_i$ are computed as follows:

⁴ For $j=1$, $p=2014$.

$$Ing_i = Pm_{e_i} \cdot Nh_{e_i} \quad (17)$$

$$Cexp_i = C_{Exp_{e_i}} \cdot Nh_{e_i} \quad (18)$$

Where, for a year i and per unit of generated energy, Pm_{e_i} and $C_{Exp_{e_i}}$ represent the revenue from energy sales and the standard operating cost, respectively, under the regulatory frameworks prior to RD 413/2014⁵, and Nh_{e_i} is the number of standard equivalent operating hours for that particular period.

With respect to $Vajdm_{i,j-1}$, it is intended to compensate the deviations between Pm_i and Pmf_i . Thus, Pm_i is checked against two upper limits ($LS1_{i,j}$, $LS2_{i,j}$) and two lower limits ($LI1_{i,j}$, $LI2_{i,j}$) defined around Pmf_i . The comparison may result in an surplus or in a deficit that will correct $VNA_{j,a}$ in the following half-period, as shown in Equation (16). Specifically, $Vajdm_{i,j-1}$ is determined as follows:

$$Vajdm_{i,j} = \begin{cases} Nh_{i,j} \cdot 0,5 \cdot (LS1_{i,j} - LS2_{i,j}) + Nh_{i,j} \cdot (LS2_{i,j} - Pm_i), & Pm_i > LS2_{i,j} \\ Nh_{i,j} \cdot 0,5 \cdot (LS1_{i,j} - Pm_i), & LS1_{i,j} \leq Pm_i \leq LS2_{i,j} \\ 0, & LI1_{i,j} \leq Pm_i \leq LS1_{i,j} \\ Nh_{i,j} \cdot 0,5 \cdot (LI1_{i,j} - Pm_i), & LI2_{i,j} \leq Pm_i \leq LI1_{i,j} \\ Nh_{i,j} \cdot 0,5 \cdot (LI1_{i,j} - LI2_{i,j}) + Nh_{i,j} \cdot (LI2_{i,j} - Pm_i), & Pm_i < LI2_{i,j} \end{cases}$$

(19)

⁵ As an exception, for $i=2013$ Ing_i must also include the term $SR_{Revenue_i}$, since the facilities perceived revenue from the RD 413/2014 framework as well.

Regarding t_j , the reasonable profitability before taxes was defined by the RDL 9/2013 as the average yield during determined period of the 10-year Spanish bonds in the secondary market (SB_j) plus a differential (Δt_j)⁶:

$$t_j = SB_j + \Delta t_j \quad (20)$$

Finally, the last factor in Equation (12) will be noted as K_j for ease of reference in the analysis that will follow:

$$K_j = \frac{t_j \cdot (1 + t_j)^{VR_j}}{(1 + t_j)^{VR_j} - 1} \quad (21)$$

2.3. The regulatory parameters of the RD 413/2014 framework

The description of the RD 413/2014 economic and regulatory framework carried out in the section 2.2 evidences the great complexity introduced by the new remuneration scheme. This intricacy becomes even more evident when comparing the RD 413/2014 new economic structure with the former RD 661/2007 framework (see Figure 1).

FIGURE 1

In the Figure 1, the RD 661/2007, the RD 661/2007 plus its subsequent amendments and the RD 413/2014 frameworks are represented using blocks that receive as inputs parameters of economic, physical and regulatory nature. Inside the blocks it has been placed a

⁶ For the existing facilities and for $j=1$, SB_j would be computed over the last 10 years prior to the entry into force of the RDL 9/2013 and Δt_j would be set to 300 basis points, resulting $t_j = 7.395\%$. For $j>1$, SB_j would be computed over the last 24 months prior the first month of May previous to the beginning of j .

simplified representation of the scheme processing these parameters⁷, rendering as a result the revenue of the facilities. It is significant that while the former frameworks required at most three regulatory parameters, the new RD 413/2014 framework requires twelve. The uncertainty about the future evolution of these parameters adds still more complexity to the new remuneration scheme. With the exception of VI_a and VU , all the regulatory parameters can be reviewed at the end of the six-year regulatory period. Among them, Pfm_i and those related to the calculation of $C_{j,a}$ can even be reviewed at the end of every regulatory half-period j .

The MO IET 1045/2014 established an equivalence between the classification of the GCPVS under the former frameworks RD 661/2007 and RD 1578/2008 and the standard facilities referred to in the new framework RD 413/2014. A total number of 576 standard facilities were defined to encompass all the existing GCPVS, with different sets of regulatory parameters for determining their remuneration. A representative example of the equivalence between the former and the new classification of the GCPVS is shown in the Figure 2.

FIGURE 2

The upper subplot labelled a) in the Figure 2 shows the cumulative installed power and the number of GCPVS in Spain prior to the entry into force of the RD 413/2014. As can be seen, nearly three quarters of the installed power and above 80% of the number of facilities were under the RD 661/2007 framework. Therefore, being the largest and most representative group of GCPVS in Spain, it has been selected to illustrate the classification of the facilities under the new RD 413/2014 framework.

In the Figure 2.b the installed power under the RD 661/2007 is segmented in a pie chart by the year a obtaining the operating permit. As can be seen, near 80% of the installed power

⁷ For a detailed explanation of the parameters and the structure of the RD 661/2007 framework and its subsequent amendments, see [34].

under the RD 661/2007 obtained the operating permit in 2008, hence this preponderant segment has been considered in the remainder of the figure. Thus, the power installed in 2008 has been represented by a block placed at the centre of the Figure 2.b. In turn, this block has been subdivided in two sections of different P_n , according to the categories established in the RD 661/2007. The first section corresponds to facilities up to 100 kW and the second one to facilities ranging between 100 kW and 10 MW. Arrows coming out from each section point to the new classification under the RD 413/2014.

Thus, the GCPVS obtaining the permit in a given year a are now sorted following a more comprehensive classification, with more P_n steps⁸ and distinguishing between fixed, single-axis and double-axis solar tracker facilities (noted as Fij, S1E and S2E in the Figure 2.b, respectively). Each of the GCPVS standard facilities is identified by a code starting with IT-00XXX.

3. Cost containment as a new energy target: the RD 413/2014 economic framework and its energy policy implications

3.1. Model formulation: deconstructing the economic framework

The intrinsic complexity of the RD 413/2014 framework, with a great number of parameters and the uncertainty associated to their future evolution, severely hampers understanding its effects on the economic results of the GCPVS. To clarify this issue, a simplified economic model is proposed below.

⁸ Due to a loophole in the RD 661/2007, some large facilities with $P_n > 100$ kW were registered as multiple smaller facilities with $P_n \leq 100$ kW in order to access the highest FIT [22]. The new classification of the RD 413/2014 has corrected this approach in specific cases (see Figure 2.b).

The considered simplified model is based on the formulation in a year i of the earnings before interest, taxes, depreciation and amortization of the facilities ($EBITDA_i$), which can be expressed as:

$$EBITDA_i = Revenue_i - Operating_Cost_i \quad (22)$$

The $Operating_Cost_i$ comprises all the amounts associated with running the facility, and can be expressed as the product of the real operating cost per unit of energy ($C_Eexp_real_i$) by E_i .⁹

$$Operating_Cost_i = C_Eexp_real_i \cdot E_i \quad (23)$$

In turn, $C_Eexp_real_i$ can be written as the sum of C_Eexpf_i and an excess over C_Eexpf_i (ΔC_Eexpf_i):

$$C_Eexp_real_i = C_Eexpf_i + \Delta C_Eexpf_i \quad (24)$$

Obviously, in order to maximise their economic results, the facilities would be forced to reduce the difference between the real and the standard operating cost to the minimum. To the extent that ΔC_Eexpf_i tends to be cancelled, the following simplifying expression will hold:

⁹ In the MO IET 1045/2014 all the operating costs are considered as linearly dependent on the energy production. This simplifying approach is justified by the predominance of the energy dependent operating costs over the fixed operating costs. In fact, the introduction in 2013 of a 7% tax on the gross revenue from electricity production [34] alone accounts for near 50% of the total current operating costs, with the remainder being shared between fixed and energy dependent operating costs."

$$C_Exp_real_i \cong C_Expf_i \quad (25)$$

Assuming that d_i is equal to one, and combining the equations (1)-(3), (5), (7) and (11), the $EBITDA_i$ can now be expressed as follows:

$$EBITDA_i = E_i \cdot (Pm_i + Ro_i - C_Expf_i) + P_n \cdot Rinv_{j,a} \quad (26)$$

On the simplifying assumption that Pm_i is roughly equal to Pmf_i , and substituting the equation (10) into (26), it is obtained:

$$EBITDA_i \cong P_n \cdot Rinv_{j,a} = P_n \cdot C_{j,a} \cdot VNA_{j,a} \cdot K_j \quad (27)$$

Taking into account the physical meaning of $C_{j,a}$ (see section 2.2), it has been considered equal to one through all the VU of the GCPVS. Therefore, the $EBITDA_i$ is finally expressed as:

$$EBITDA_i \cong P_n \cdot VNA_{j,a} \cdot K_j \quad (28)$$

The equations (27) and (28) reveal that the $EBITDA_i$ is essentially proportional to $Rinv_{j,a}$, or to the product of $VNA_{j,a}$ by K_j . The mechanism of action of these regulatory functions will be discussed below in detail.

The Figure 3.a graphically represents the calculation of $VNA_{j,a}$ in the case $j=1$ for a facility obtaining the operating permit in $a=2008$ (see Equation (16)). As shown in the upper subplot, the value of VI_{2008} is first updated to the year $p=2014$. However, the VI_{2014} obtained in

this way must be augmented by the sum of all the updated $Cexp_i$ incurred before 2014 (see the central subplot) and reduced by the sum of all the updated Ing_i received before 2014 (see the lower subplot). The value of $VNA_{1,2008}$ obtained as a result will rule throughout $j=1$.

FIGURE 3

For the subsequent values of j , the $VNA_{j,a}$ is calculated according to the second expression in Equation (16). Nevertheless, a simpler approximation can be obtained applying the same hypothesis exposed in the above paragraphs. Thus, taking Pm_i equal to Pmf_i and substituting (10), (14) and (15) into the second expression of (16) it is obtained:

$$VNA_{j,a} \cong VNA_{j-1,a} \cdot (1 + t_{j-1})^3 \quad (29)$$

As the Equation (29) shows, the $VNA_{j,a}$ that applies throughout a determined j is roughly equal to the updated value of $VNA_{j-1,a}$. This idea has been illustrated in the upper subplot of the Figure 3.b, where the example of the facility obtaining the operating permit in $a=2008$ is continued and a constant t_j equal to t_1 has been assumed for simplicity. It can be seen that $VNA_{j,a}$ remains constant during the complete term of j and is not updated until the beginning of $j+1$.

For comparison purposes, it has been represented in the central subplot of the Figure 3.b how an annually updated $VNA_{j,a}$ would evolve. Also, a tri-annually and an annually updated $VNA_{j,a}$ have been jointly represented in the lower subplot of the Figure 3.b, for the case of a constant t_j equal to 7% and on a normalised basis. The dark brown and the light brown bars correspond to the normalised values of a tri-annually and an annually updated $VNA_{j,a}$,

respectively. As can be observed, the growth profile of the annual update is exponential whereas the tri-annual update follows a stepped exponential trend.

As regards K_j , the Figure 4.a represents the locus of its possible values for SB_j ranging between 1% to 9% and for Δt_j ranging between 0% to 8%, at the beginning of the regulatory lifetime of a GCPVS ($j=1$ and $VR_1=30$). The obtained surface has been subdivided into coloured areas, corresponding to the different ranges of K_j values specified in the legend of the Figure 4.a. By way of example, two reference points have been highlighted. The point labelled P_1 corresponds to $SB_j=2\%$ and $\Delta t_j=2\%$ and is located in the red-coloured region $0.05 \leq K_j \leq 0.1$. On the other hand, the point labelled P_2 corresponds to $SB_j=2\%$ and $\Delta t_j=7\%$ and is located in the green-coloured region $0.1 \leq K_j \leq 0.15$. As may be noted, K_j increases as SB_j and Δt_j go up.

FIGURE 4

The effect on K_j of the progressive reduction of the GCPVS lifetime is demonstrated in the Figure 4.b. For the same considered range of SB_j and Δt_j , the declining VR_j values result in an exponential increase of K_j . This effect is more clearly appreciated in the Figure 4.c., where the exponential trend of K_j as a function of VR_j is represented for several t_j values.

It should be noted that K_j acts as a capital recovery factor, i.e., converts the $VNA_{j,a}$ that cannot be recovered with the market revenue ($C_{j,a} \cdot VNA_{j,a}$) into a stream of annual payments $Rinv_{j,a}$ of constant value throughout j . Due to the nature of the aforementioned functions, the stream of annual payments results are highly increased in the last years of the VU of the facilities.

3.2. The expected regulatory activity for cost containment

The simplified model presented in the section 3.1 has made it easier to understand the effects on the economic results of the GCPVS of the RD 413/2014 regulatory parameters. Once their mechanism of action has been unveiled, it is possible to formulate what will be probably

the future regulatory activity and its accompanying economic scenarios for the GCPVS. In this regard, being the financial sustainability of the SES a declared target of the last regulatory changes, it can be presumed that the regulatory decisions in the near future are going to be taken under the most strict cost containment criteria.

In this line, the cost to the SES of a GCPVS in a year i ($Cost_i$) is equal to $SR_Revenue_i$, and taking into account (5) can be formulated as follows:

$$Cost_i = SR_Revenue_i = (Op_R_i + Inv_R_i) \cdot d_i \quad (30)$$

In accordance to the very nature of the GCPVS, the following applies:

$$Inv_R_i \gg Op_R_i \quad (31)$$

Consequently, assuming d_i equal to one and taking into account (11) and (27), the $Cost_i$ can be approximated as:

$$Cost_i \cong P_n \cdot Rinv_{j,a} \cong EBITDA_i \quad (32)$$

Given the dependence of $Rinv_{j,a}$ on Δt_j and Δt_{j-1} (see (12),(13),(16),(20)), the most direct way to limit the cost to the SES of the GCPVS is to reduce or even cancel this regulatory parameter in future half-periods j .

Additionally, there is the closely related cost containment mechanism already referred to in the section 2.2., whereby $Rinv_{j,a}$ would be set to zero for the facilities reaching the reasonable profitability before the end of their regulatory life. It has not yet been declared the value of this

reasonable profitability for the GCPVS project as a whole, nor has any methodology for its determination been designated. The lack of specificity regarding this provision leaves a great deal of room for manoeuvre to limit the future cost to the SES of the existing GCPVS facilities. This issue will be discussed in detail in section 4.1.

4. The economic impact on the GCPVS of the RD 413/2014 new remuneration scheme: case study of a 100 kW facility

In this section, the impact of the RD 413/2014 on the economic results of the GCPVS and on their cost to the SES will be illustrated by means of a case study. With the aim of covering the most representative group of GCPVS in Spain it has been selected a 100 kW facility obtaining the operating permit in 2008 under the RD 661/2007 (see Figure 2). Specifically, a facility of the type IT-00030 has been chosen, as this type may represent GCPVS sited at roof or at ground. The main characteristics of the considered facility and the assumptions for the economic parameters used in the profitability analysis can be found in the Table 1 and 2, respectively.

TABLE 1

TABLE 2

Despite the core of the analysis is focused on the effects of the RD 413/2014, the economic performance of the facility under the former RD 661/2007 regulatory framework has also been studied for comparison purposes. The parameters of the RD 661/2007 needed for this analysis are provided in the Table 3. Regarding the regulatory parameters for the facility of the type IT-00030 under the RD 413/2014 new framework, these are provided in the Table 4.

418

TABLE 3

419

TABLE 4

420 *4.1. A preliminary question: the reasonable profitability cost-containment*
421 *mechanism*

422 In the undertaken analysis, the parameter Δt_j has been set to zero, which is the worst
423 case from the point of view of the facilities. It has also been considered a set of possible
424 scenarios with different values for the Spanish Treasury Bond SB_j . For each of the scenarios it
425 has been assumed that SB_j remains constant during the entire VU of the facility. Despite this
426 simplifying assumption, the SB_j values used in the analysis ranging from 1% to 8% are
427 consistent with the historical SB_j cap and floor in the last ten years (see Figure 5). Therefore, the
428 considered scenarios can include the best and the worst experienced cases.

429

FIGURE 5

430

Figure 5. Historical data for SB_j in the last ten year period 2006-2015

431 In the Figure 6.a it has been depicted the evolution of the discounted $EBITDA_i$ values
432 of the case study facility through all its VU , taking $a=2008$ as the base year and assuming a
433 discount rate of 5% (see Table 2). Lines of different colours have been employed to distinguish
434 the considered SB_j scenarios.

435

FIGURE 6

436

437 As can be observed, the exponential growth of the $EBITDA_i$ inherent to the remuneration
438 mechanism is especially relevant in the last regulatory half-period. In addition, this exponential
439 growth is extremely boosted for the higher SB_j scenarios, being the case with $SB_j=8\%$ the most
440 favourable for the $EBITDA_i$ of the facility.

In the same Figure 6.a, it has been included a subplot presenting in red columns the cumulative $EBITDA_i$ for the entire VU of the facility. Each of the columns considers a different SB_j scenario under the RD 413/2014 framework, apart from the first column which corresponds to the former RD 661/2007 framework. It can be seen that the RD 413/2014 scenario with $SB_j=8\%$ set against the former RD 661/2007 framework represents an increase in the cumulative $EBITDA_i$ of more than two and a half million Euros.

Complementarily, in the Figure 6.b other indicators widely used in the profitability analyses have been presented for the former RD 661/2007 framework and for the different SB_j scenarios under the new RD 413/2014 framework. Thus, the Project NPV (Net Present Value) and the Free Cash Flow NPV have been represented using dark blue and red columns, respectively, whereas the cumulative cost to the SES has been depicted in light blue columns. These quantities are expressed in Euros and are to be read on the left vertical axis. On the other hand, the Project IRR (Internal Rate of Return) and the Equity IRR are presented in green and purple lines, respectively. They are expressed in percentage and are linked to the right vertical axis of the figure. The increase in the cumulative $EBITDA_i$ presented in the Figure 6.a results in an increase of the cost to the SES, amounting over two million Euros when the former RD 661/2007 framework is set against the $SB_j=8\%$ scenario under the new RD 413/2014 framework (see Figure 6.b).

The intensified exponential growth of the $EBITDA_i$ - and hence also of the cost to the SES- towards the end of the VU of the facility evidences the need to apply the cost containment mechanism that cancels $Rinv_{j,a}$ once the GCPVS has reached the reasonable profitability. Given the current lack of specificity about the value of the reasonable profitability and the methodology to check if it has been attained, a plausible hypothesis on these issues will now be formulated so that the prospective analysis can be continued.

It will be assumed that the profitability actually attained up to the year i is calculated in the same manner as an IRR up to the year i (IRR_i):

$$NPV_i = 0 = -VI_a \cdot P_n + \sum_{i=a+1}^{i=VU+a} \frac{Cash_Flow_i}{(1 + IRR_i)^{i-a}} \quad (33)$$

Were the IRR_i is the discount rate at which the sum of present value of the cash flows up to the year i equals the initial investment. Depending on the specific type of cash flow employed in (33) a particular IRR_i variant is obtained (consider for example the project IRR or the equity IRR illustrated in the Figure 6.b). The particular cash flow employed here for the IRR_i calculation will be the $EBITDA_i$, i.e., purely the difference between the standard revenue and the standard operating cost (see (22), (26)). The selection of this cash flow is in line with the approach followed in the new framework for setting the remuneration levels that result in a reasonable profitability before taxes: only the standard operating cost are taken into account. It must be pointed out that this proposal for checking whether the reasonable profitability has been met corresponds to the worst possible methodology from the facility point of view, but the best option for reducing the cost to the SES. The choice of any other cash flow type accounting for factors other than the operating costs (i.e., financial expenses, taxes) would render results more consistent with the actual economic performance of the facility.

Next, the IRR_i calculated in this way is checked against a certain reasonable profitability level (L_R). The result of this comparison determines the existence or lack of $Rinv_{j,a}$ in the year i :

$$\begin{cases} Rinv_{j,a} = C_{j,a} \cdot VNA_{j,a} \cdot \frac{t_j \cdot (1 + t_j)^{VR_j}}{(1 + t_j)^{VR_j} - 1} & , IRR_i < L_R \\ Rinv_{j,a} = 0 & , IRR_i \geq L_R \end{cases} \quad , \forall i \in j \quad (34)$$

4.2. The economic analysis results

This section is intended to provide a clear insight on the economic impact that the 2014 new Spanish renewable energy policy might have on the existing GCPVS.

In this regard, one of the most relevant effects on the economic management of the facilities might be the liquidity problems. In order to identify whether the 2014 new regulatory scheme might be responsible for such problems and under what circumstances, the evolution of the treasury has been one of the analyzed financial figures. Additionally, and according to the principle of protection of the legitimate expectations [58], financial metrics such as the Project IRR, Project NPV, Project IRR decrease and Project NPV decrease have been selected as objective elements for assessing to what extent the economic expectations of the facilities might have been reduced.

The deconstruction of the regulatory scheme performed in the section 3.1 led to identify the most relevant regulatory parameters influencing the economic results of the facilities, namely, SB_j and L_R . Results have been collected for different scenarios with SB_j ranging from 1% to 8% and L_R ranging from 4% to 8%, respectively, being the reasonable profitability cost containment mechanism incorporated to the economic model of the RD 413/2014 framework. As done in the previous section 4.1 it has been assumed again that SB_j remains constant during the entire VU of the facility for each of the scenarios and that the parameter Δt_j is set to zero.

The effect of L_R in the treasury can be seen in the Figure 7, for the different SB_j scenarios. As shown in the Figure 7.a, $L_R=4\%$ can led to a bankruptcy situation towards the end of the VU of the facility. Nevertheless, this bankruptcy problem disappears increasing L_R to 5%, as represented in the Figure 7.b. This result accentuates the importance of this regulatory parameter and its economic effects on the viability of the facilities.

FIGURE 7

In the Figure 8.a, it has been represented the effect on the project IRR¹⁰ of SB_j and L_R values ranging from 1% to 8% and from 4% to 8%, respectively. The project IRR evolves over a surface that has been subdivided into coloured areas corresponding to the different ranges specified in the legend of the Figure 8.a.

As the Figure 8.a shows, $L_R=4\%$ results in negative values of the project IRR for all the SB_j scenarios, while for $L_R=5\%$ positive values of the project IRR begin to appear. It can be observed that the project IRR is predominantly driven by L_R , whereas the influence of SB_j is weaker. Values of the project IRR around 5% can be only be obtained with $L_R=8\%$. This figure is noticeably lower than the project IRR of 6.9% correspondent to the former RD 661/2007 framework. In other words, the transition from the RD 661/2007 to the RD 413/2014 has involved a loss of profitability for the GCPVS. This can be seen in the Figure 8.b, where the decrease in the project IRR with respect to the former RD 661/2007 framework is reflected for all the scenarios analysed in the Figure 8.a. The loss of profitability varies from a minimum of 1.6% with $L_R=8\%$ to a maximum of 15.1% with $L_R=4\%$.

FIGURE 8

The inclusion of the reasonable profitability cost containment mechanism also has a negative impact on the project NPV. As shown in the Figure 9.a, positive values for the project NPV are only obtained for $L_R=8\%$ and for SB_j ranging from 1% to 4% and also for $SB_j=8\%$. The maxim value achieved for the project NPV is 17600 €, which corresponds to $L_R=8\%$ and $SB_j=2\%$. Nevertheless, this result falls far short of the project NPV of near 150000 € related to the

¹⁰ Being the project IRR a widely used indicator in the profitability analyses, it has been selected for illustrating the effect of the RD 413/2014 provisions on the economic results of the GCPVS. The project IRR is calculated from the project cash flow, and must not be confused with the particular IRR_t determined from the EBITDA proposed in the section 4.1. for checking if L_R had been attained.

former RD 661/2007 framework (see Figure 6.b). The generalized decrease in the project NPV results with respect to the RD 661/2007 framework is represented in the Figure 9.b.

FIGURE 9

The Figure 10.a. shows the cumulative discounted cost to SES of the considered facility, for different SB_j and L_R scenarios. As in the case with the other indicators represented in the Figures 6 to 9, the cost to the SES is mainly driven by L_R . The reduction in the cost to the SES due to the transition from the RD 661/2007 to the new 413/2014 framework is shown in the Figure 10.b. As indicative data the threshold $L_R = 5\%$ that renders positive project IRRs, results in reduction of the cost to the SES of around 30% for all SB_j the scenarios, with respect to the former RD 661/2007 framework.

FIGURE 10

Consistent with the outlined above, the value finally given to L_R will have the key to reconcile the conflicting interests of the earnings of the facilities and their cost to the SES. The particular case study here analysed does not allow inferring a generalized optimal L_R value for all the GCPVS types. Notwithstanding, this analysis highlights the critical impact of L_R above other parameters such as SB_j on the economic results of the facilities. It is clearly demonstrated the need to particularly determine the L_R value to apply to each type of GCPVS in order to prevent their bankruptcy. According to the National PV Energy Producer's Association [59], more than one third of the GCPVS are currently bearing negative returns and the vast majority of the producers have been pushed to refinance their bank debt under more burdensome terms. It is expected that this analysis might contribute to properly forecast the economic results of the GCPVS under the new RD 413/2014 framework, despite the various regulatory aspects pending definition.

5. Conclusions

This paper has analysed the RD 413/2014 new economic and regulatory framework for RES-E producers in Spain, placing the focus on its impact on the economic results of the existing GCPVS.

In order to undertake this analysis, a detailed description and a precise formulation of the RD 413/2014 new economic model have been provided. The great number of regulatory parameters involved and the very complex nature of the new remuneration scheme have revealed as the main factors that hamper getting a clear view of its effects on the economic performance of the facilities.

So as to overcome this initial difficulty, it has been proposed a simplified model that provides a clear insight on the economic dynamics of the new RD 413/2014 regulatory framework. This simplified model has proven to be a useful tool to assess not only the evolution of the economic results of the facilities but also what could be the most plausible future Governmental regulatory activity for reducing the economic burden to the SES of the GCPVS. Likewise, the simplified model has revealed which are the regulatory parameters having a greater influence on the economic performance of the facilities and, consequently, has helped to properly define the set of scenarios to be considered in the analysis.

Once the intricacies of the new RD 413/2014 remuneration mechanism have been unveiled, its impact on the economic results of a case study facility is assessed using the widely employed indicators NPV and IRR along with the treasury evolution and the cost to the SES. In order to obtain more general results, the selected case study has been taken from the most representative group of GCPVS in Spain - those under the former RD 661/2007 framework and entering into operation in the year 2008.

The figures obtained have illustrated the crucial effect on the economic results of the facilities of the reasonable profitability L_R cost containment mechanism, above all the other regulatory parameters of the new RD 413/2014 framework. In the case studied facility, only for

$L_R \geq 5\%$ positive IRR values were obtained and the risk of bankruptcy was avoided. In the case of the NPV, negative values were obtained unless $L_R \geq 8\%$, using a typical 5% discount ratio.

It has also been assessed the profitability reduction caused by the RD 413/2014 new remuneration scheme in the case studied facility, with respect to the former RD 661/2007 framework. For the $L_R = 8\%$ threshold resulting in positive NPV values, IRR decreases ranging from 1.6% to 2.5% and NPV reductions from around 133000€ to 173000 € were achieved.

Although the particular case study here analysed does not allow inferring general L_R thresholds valid for all the GCPVS types, its value lies in highlighting the critical impact of L_R above all the other regulatory parameters. It is expected that this analysis can contribute to diminish the uncertainty on the evolution of the economic results of the facilities under the new highly complex remuneration scheme, further increased by the current lack of specificity about the L_R value finally applied to the different GCPVS types.

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771 **Acronyms**

772 RD: Royal Decree

773 EU: European Union

774 FIT: feed-in tariff

775 GCPVS: grid connected photovoltaic systems

776 IRR: Internal Rate of Return

777 MO: Ministerial Order

778 NPV: Net Present Value

779 PV: photovoltaic

780 RDL: Royal Decree-Law

781 RES-E: electricity from renewable energy sources

782 SES: Spanish Electricity Sector

783 SR: Specific Retribution

784 **Variables:**

785 a : the year in which the operating permit is obtained

786 $C_{j,a}$: coefficient representing the investment cost of a GCPVS obtaining the operating permit in
787 the year a that cannot be recovered with the market revenue within j

788 $C_{exp,i}$: standard mean total operating cost for $i < p$ per unit of installed power [€/MW]

789 C_{expf_i} : future estimated cost per unit of installed power within the year i [€/MW]

790 C_{Expf_i} : standard operating cost per unit of generated energy in the year i [€/MWh]

791

792 C_{Exp_ei} : standard operating cost per unit of generated energy in the year i under the regulatory
frameworks prior to RD 413/2014 [€/MWh]

793

$C_{Exp_real_i}$: real operating cost per unit of energy [€/MWh]

794 d_i : coefficient correcting the annual revenue according to Nh_inst_i

795 E_i : total energy generated within the year i [MWh]

796 $EBITDA_i$: earnings before interest, taxes, depreciation and amortization of the GCPVS in the
797 year i [€]

798 E_{max_i} : maximum value of E_i eligible for perceiving the Ro_i [MWh]

799 Ing_i : standard mean total income for $i < p$ per unit of installed power [€/MW]

800 $Ingf_i$: future estimated operating income per unit of installed power within the year i [€/MW]

801 Inv_R_i : the remuneration for the investment in the year i [€]

802 j : three-year half-period

803 K_j : capital recovery factor

804 K_R : the yearly degradation rate [%]

805

L_R : reasonable profitability level

806 $LI1_{ij}, LI2_{ij}$: lower limits for the calculation of $Vajdm_{ij}$

807 $LS1_{ij}, LS2_{ij}$: upper limits for the calculation of $Vajdm_{ij}$

808 $Market_Revenue_i$: market revenue perceived in the year i [€]

809 Nh_{ij} : standard equivalent operating hours within the year i of j [h]

810

811 Nh_{e_i} : standard equivalent operating hours for the year i under the regulatory frameworks prior
to RD 413/2014

812 Nh_{inst_i} : number of equivalent operating hours within the year i [h]

813 $Nh_{max(Ro)_i}$: maximum value of Nh_{inst_i} eligible for perceiving the Ro_i [h]

814 Nh_{min_i} : minimum value of Nh_{inst_i} that does not entail a reduction of $SR_Revenue_i$ [h]

815 Op_R_i : the remuneration for the operation in the year i [€]

816

$Operating_Cost_i$: total cost for running the facility [€]

817 p : first complete year of j

818 P_{peak} : installed capacity of the PV panels, considered at the inverter DC input [MW_p]

819 P_n : nominal power, considered at the inverter AC output [MW]

820 Pm_i : yearly average energy market price per unit of generated energy in the year i [€/MWh]

821 Pmf_i : estimated future market price per unit of generated energy for the year i [€/MWh]

822

823 Pm_{e_i} : revenue per unit of generated energy from the energy sales in the year i under the
regulatory frameworks prior to RD 413/2014 [€/MWh]

824 $Revenue_i$: total revenue perceived in the year i [€]

825 $R_{inv,j,a}$: remuneration for the investment per unit of installed power for every year i within j of a
826 GCPVS obtaining the operating permit in the year a [€/MW]

827 Ro_i : the remuneration for the operation per unit of generated energy in the year i [€/MWh]

828 sm : number of years of j

829 SB_j : average yield during determined period of the 10-year Spanish bonds in the secondary
830 market within j

831 $SR_Revenue_i$: SR revenue perceived in the year i [€]

832 t_j : per unit discount rate within j corresponding to the reasonable profitability

833 Uf_i : threshold of Nh_inst_i for perceiving $SR_Revenue_i$

834 $Vajdm_{ij}$: coefficient adjusting the deviations of Pm_i

835 $VNA_{j,a}$: net value per unit of installed power within j of a GCPVS obtaining the operating permit in
836 the year a [€/MW]

837 VR_j : remaining number of years at the beginning of j to the end of the facility VU [years]

838 VI_a : standard value of the initial GCPVS investment per unit of installed power [€/MW]

839 VU : regulatory lifetime [years]

840 ΔC_Eexpf_i : differential over C_Eexpf_i [€/MWh]

841 Δt_j : basis points differential added to SB_j for determining t_j

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Table 4. Values of the regulatory parameters for a GCPVS of type IT-00030. Source: self-elaboration based on [41].

Table 1. Main characteristics of the case study facility. Source: self-elaboration.

Year obtaining the operating permit (a)	Nominal power (P_n) [kW]	Peak power [kW _p]	Type of facility	Energy average 2009-2011 (E_i) [kWh/year]	Operating time average 2009 -2011 (Nh_{inst_i}) [h/year]	Province and climatic zone	Installation cost [€]
2008	100	104	On floor. No solar tracker. South oriented. Slope 30°	134836	1296	Girona Zone III	689134.60

Table 2. Assumptions for the economic parameters used in the profitability analysis. Source: self-elaboration.

Investment scenario	
Equity	30%
Bank debt	70%
Loan repayment system	Linear method
Loan fixed interest rate	5,5%
Loan grace period	First year
Term of the loan	15 years
Other data	
Operation cost (C_{exp})	62 €/kWp
Inflation rate (CPI)	3%
Wholesale market price of electricity (P_{m_i})	Government forecast
Yearly degradation (K_R)	0,8%
Tax rate	25%
Discount rate	5%
Access tariff for electricity producers (RDL 14/2010)	0,5 MW/h
Electricity production tax (Law 15/2012)	7%

Table 3. Variables and parameters for the GCPVS under RD 661/2007 and its subsequent modifications. Source: self-elaboration based on [9], [22].

Variables and Parameters	Definition	Value evolution
$FIT_{i,a}Cost_{(k,i,n)}$	FIT in the year i for a GCPVS obtaining the operating permit in the year a (RD 661/2007)	$FIT_{i,a} = FIT_{i-1,a}(1 + CPI_{i-1} - r_i)$
r_i	Parameter for the update of $FIT_{i,a}$ set by RD 661/2007 (RD 661/2007)	25 basis points until 2012 and 50 basis points from 2013 onwards
CPI'_i	CPI_i at constant tax and excluding unprocessed food and energy products, for the update of the retribution of the activities of the electric sector (RDL 2/2013)	$CPI'_i = CPI_i - \Delta CPI_i$
ΔCPI_i	Difference between CPI'_i and CPI_i	0,5%
RHE	Reference equivalent hours (RDL 14/2010)	1492 [h/year]

Table 4. Values of the regulatory parameters for a GCPVS of type IT-00030. Source: self-elaboration based on [41].

Code	<i>a</i>	<i>VU</i> [years]	<i>VI</i>₂₀₀₈ [€/MW]	<i>C</i>_{1.a}	<i>Rinv</i> (2014-2016) [€/MWh]	<i>Nh_max</i>(<i>R₀</i>) [h]	<i>Nh_min</i>(2014-2016) [h]	<i>Uf_min</i>(2014-2016) [h]		
IT-00030	2008	30	7065614	1	576047	1648	989	577		
Regulatory parameters	<i>Pm_ei</i> [€/MWh]	<i>C_Eexp_ei</i> [€/MWh]	<i>Pfm_i</i> [€/MWh]	<i>C_Eexpfi</i> [€/MWh]	<i>Nh_ei</i> [h]	<i>Nh_{ij}</i> [h]	<i>LS2_{ij}</i> [€/MWh]	<i>LS1_{ij}</i> [€/MWh]	<i>LI1_{ij}</i> [€/MWh]	<i>LI2_{ij}</i> [€/MWh]
2009	466.48	31.62			1553		61.242	57.192	48.994	44.911
2010	469.66	32.35			1526		61.242	57.192	48.994	44.911
2011	381.93	32.72			1577		61.242	57.192	48.994	44.911
2012	397.96	32.66			1617		61.242	57.192	48.994	44.911
2013	485.01	68.05	52.35	61.63	844	772	61.242	57.192	48.994	44.911
2014			49.21	63.29		1648	61.242	57.192	48.994	44.911
2015			50.55	63.68		1640	61.242	57.192	48.994	44.911
2016			50.78	64.34		1632	61.242	57.192	48.994	44.911
2017			53.08	65.00		1623	61.242	57.192	48.994	44.911