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Electricity costs in irrigated agriculture: A case study for an irrigation scheme in Spain

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ABSTRACT

Electricity prices have risen sharply in Spain in recent years, to the point where they are now among the highest in the EU. The scant competition between power utilities, changes in the law, and the tariff deficit (accumulated debt in favour, mainly, of the electricity firms), have driven up the cost of electricity, affecting numerous other industries such as irrigated agriculture, a sector that has significantly increased its electricity consumption as a result of modernization processes over the past twenty-five years. We examine these issues through a case study of an irrigation scheme in Spain that provides irrigation water and infrastructure to 58 farming communities in north-eastern Spain, and is highly representative of the Ebro Valley. Based on the results of direct estimations and simulations of different tariffs, we propose the lowering of capacity-based tariffs to reduce sector problems and cut energy costs, especially for farmers. We also raise the possibility of increasing self-consumption, a complementary measure for many farmers and for medium-size firms.

1. Introduction

Electricity is key to the functioning of the Spanish, and of course every other, economy: industries cannot function without power. This is nowhere more true than in the case of irrigated agriculture, a sector that has considerably increased its energy consumption to pump and distribute water as a result of the modernization of the last thirty years (see Jackson et al. [1], Jiménez-Bello et al. [2], and Plappally and Lienhard [3]). A nationwide process of modernization over this period has raised farm output and competitiveness to unprecedented levels, significantly improving farmers' incomes. However, the resulting structure of irrigation systems is highly sensitive to energy costs, and the continuous increases and variability of energy prices in recent years have become a significant obstacle to the sustainability of agricultural earnings.

The link between energy and water has generated a global interest in this issue, with the objective of reducing consumption, especially, of conventional energy sources (which have many environmental impacts), particularly for irrigation applications. Gopal et al. [4] carry out a literature review on this topic, and there are several studies of alternative energy sources for pumping water (see Haddad [5], Bataineh [6], Chandel et al. [7], Ali et al. [8], and Purohit and Kandpal [9]).

The electricity industry in Spain faces serious problems: the lack of competition between power utilities, the premiums on renewable energy, the high dependence on gas and imported coal, and deficiencies in the grid. These problems have been further aggravated by the issue of the *tariff deficit* (accumulated debt in favour, primarily, of the electricity firms), resulting in a sharp rise in the cost of electricity in Spain, which has adversely affected the country's competitiveness.

In this context, our study examines these rising energy costs as they affect irrigated farming. Prior studies have analysed the impact of energy costs on agriculture, including Lecina et al. [10] and Rodríguez et al. [11], who observed a 400% increase in the costs incurred by one irrigation scheme in Andalusia, after the modernization of the infrastructure and technology. Our aim goes beyond the study of energy costs in irrigated farming to propose viable options to reduce the burden, in a context of increasing costs due to modernization.

One of the objectives of this study is, therefore, to analyse the Spanish electricity system in order to determine the effects of the different tariff systems on irrigated farming. We look at the *Upper Aragon Irrigation Scheme* (CGRAA in its Spanish acronym), which brings together 58 communities of farmers in the province of Huesca, in north-eastern Spain. The CGRAA irrigates more than 133,000 ha of land, which is very representative of irrigated agriculture in the Ebro Valley, and it is the largest irrigation scheme in Spain. Moreover, our ideas on this issue could be applied to other EU irrigation systems. The case of France is relevant, where there is a special green tariff for irrigation (see JORF [12]) that includes a capacity tariff, but this capacity tariff is very low compared to the one in Spain.

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Energy costs in the CGRAA have mushroomed in recent years, the result of growing energy needs on one hand, due to the modernization of irrigation systems (see Sánchez Chóliz and Sarasa [13]), and rising energy prices on the other.

We use data on electricity generation, consumption and supply provided directly by the CGRAA. Official electricity tariffs for both energy consumed and capacity contracted are published periodically in the Official Journal of the Spanish State (BOE in its Spanish acronym), allowing for the calculation of costs and observation of its growth, in particular due to price hikes. On this basis, we have calculated energy consumption and costs for the period 2010–2013 and estimated them for 2014. This period corresponds with the establishment of major electricity reforms in Spain. Moreover, despite the economic crisis, the first cause of increasing electricity consumption in agriculture is linked to water needs for irrigation that boost the modernization processes, with Spanish irrigated agriculture being one of the sectors least affected by the crisis. This makes this case study very suitable for the objective of our work, as the CGRAA presents water constraints that are addressed through improvements in technology (see Philip et al. [14]).

Additionally, based on the results of direct estimations and simulations of different tariffs, we propose to remove or, at least, to reduce the capacity-based tariffs to respond to the observed problems and to cut energy costs, especially for farmers. We also highlight the possibility of increasing self-consumption as a complementary measure.

In Section 2, we describe the Spanish electricity system and highlight its main problems. Section 3 examines the specific case of the CGRAA in terms of output and power consumption, and Section 4 proposes some possible solutions to the issues identified. The paper ends with some brief concluding remarks.

2. The Spanish electricity system

2.1. Competition issues

The electricity market began to be liberalized in several countries in the 1980s (see Erdogdu [15], Pollitt [16], and Slabá et al. [17]). In 1997, the Spanish Electricity Industry Act of the Spanish Government (see BOE [18]) was designed to foster competition between power utilities. To this end, it decoupled generation, transportation, distribution, and marketing, and prohibited any single company from engaging in more than one of these businesses.

At the time, it was believed that this unbundling would establish the conditions in which competition could flower. Today, however, we can question whether this measure has been a success, and if so in what ways. From the standpoint of economic theory, there is no particular reason why this vertical splitting should encourage competition. Furthermore, decoupling does not always work in practice, in spite of the legal separation of generation and distribution firms, because the shareholders often overlap and they avoid competing with each other and tend to cooperate in pursuit of common goals.

Power is sold at auction in a daily market, which operates by matching supply and demand so that the marginal price is the final price. The system is seriously flawed in terms of competition, among other reasons because a minimum guaranteed output is applied to nuclear power, while renewable energies like solar and wind power enjoy preferential access to the grid. Also, generating conditions allow producers of nuclear power to offer very low prices in the market in order to boost their sales. There can be no doubt, then, that this auction system creates winners (nuclear plants and wind farms) and losers (combined-cycle plants, which use two thermodynamic cycles: gas turbine and steam turbine), as can be observed in Table 1. Moreover, in this line, certain authors also suggest penalizing less combined plants (see Cardoso and Fuinhas [20]).

Table 1
Daily market power output by generating technology, January and February 2014. *Source*: OMIE [19].

	Daily market – January		Daily market – February	
	GW h	%	GWh	%
Oil-Gas	0	0.0	0	0.0
Thermal (subsidized)	300	1.3	250	1.2
Coal	1,238	5.6	108	0.5
Combined cycle	251	1.1	210	1.0
Nuclear	4,559	20.5	4,703	22.6
Hydroelectric	3,891	17.5	5,259	25.2
Imports	1,324	6.0	892	4.3
Wind	6,592	29.6	5,967	28.6
Cogeneration/Waste/ Small hydro	4,982	18.4	3,462	16.6
TOTAL	22,236	100.0	20,851	100.0

In addition, the transmission system suffers from a dearth of connections with Europe, and large areas of Spain itself are burdened by connection deficiencies, with the result that there is not enough external and internal competition. Moreover, in Spain, the distribution conditions are unquestionably optimized by the existence of a single grid, given the very large infrastructure investments required, the general use of the system, and its geographic extent, and for these reasons it would be quite justifiable for Government to take over management of the grid. By contrast, while the Spanish state could manage electricity distribution (not to be confused with marketing) and the upkeep of the grid directly, so far, it has preferred in practice to entrust responsibility to private firms, paying them the costs incurred in this activity and a guaranteed margin so that profits are assured. Under these conditions, there is little incentive to compete and firms have a clear interest in colluding to demand all they can from Government, increasing the upward pressure on electricity prices.

Finally, competitive conditions in electricity marketing are likewise questionable, in view of the market shares of the utilities involved. In reality, the market is an oligopoly in which just two firms account for most of the pie, as shown in Yusta [21].

2.2. The tariff deficit

As in the management of electricity distribution and the upkeep of the grid, so the Spanish Government has established by law a number of regulated activities for which the power utilities receive incomes as compensation for the regulated costs that they bear (see references in Table 2). The tariff deficit is the difference between the regulated income received and the regulated costs. The tariff problem first arose in 1997 as a consequence of intense lobbying (then as now) by the electricity industry. Given the clearly oligopolistic nature of the electricity market in the 1990s, the power utilities were able to wield significant social, media, and political influence in Spain. The Government at the time was keen to freeze the rising energy costs paid by consumers, as any hike in electricity bills would have been deeply unpopular among the general public and electricity prices already had a major impact on the economy and growth. In this light, the Government resolved in 1997 to freeze consumers' electricity bills, and this was the origin of the tariff deficit. It was decided that the electricity price would be split into two parts, one of which would be payable directly in cash through the electricity bill, and the other part deferred as a debt owed by the electricity system (guaranteed by the Spanish Government) to the utilities. This debt was the germ of the tariff deficit, which has since grown each year to become a massive cumulative burden, more than €35 billion in 2013 (see Fig. 1). The immediate result of the Government's decision was to rein in Spain's current electricity bill,

Table 2
Tariff deficit, 2009–2013.
Source: CNE [22,23,24,25], and CNMC [26].

(thousands of euros)	2009	2010	2011	2012	2013
A. Gross regulated income	**13,824,138**	**12,716,222**	**12,905,933**	**14,120,906**	**14,364,200**
Income from customers at tariff prices	7,299,390				
Income from access tariffs	6,524,748	12,716,222	12,757,933	13,858,906	14,177,200
Income from generators' grid access tolls			148,000	142,000	127,000
Surplus on last resort tariffs (TUR)				120,000	60,000
B. Earmarked charges	**1,816,714**	**1,369,133**	**1,189,815**	**433,306**	**392,782**
Island and non-mainland weightings	1,295,213	897,240	760,654		
System operators	37,517	38,267	39,032	39,618	
Market operator	11,140				
National Energy Commission (CNE) charge	19,746	22,892	23,876	25,536	20,997
Nuclear moratorium	3,000	100,228	54,463	54,661	75,460
2nd part of nuclear fuel cycle			129	138	140
Financing of Radioactive Waste Plan	71,047	127			
2005 Income deficit surcharge	379,051	310,379	311,661	313,352	296,185
C. Net regulated income (C=A−B)	**12,007,424**	**11,347,088**	**11,716,118**	**13,687,601**	**13,971,418**
D. Special regime premium	**4,808,563**	**5,888,099**	**6,019,145**	**7,013,581**	**9,050,000**
E. Cost of Electricity delivered to tariff customers	**4,291,714**				
F. Regulated activities settlement income (F=C−D−E)	**3,707,147**	**5,458,989**	**5,696,973**	**6,674,020**	**4,921,418**
G. Regulated costs	**8,632,357**	**8,649,213**	**9,802,917**	**10,059,110**	**9,925,475**
Transport	1,344,021	1,397,104	1,534,426	1,722,434	1,672,136
Distribution and marketing	5,384,477	5,201,642	5,457,149	5,692,748	5,474,444
Settlement income differences	900,369	1,252,905	1,309,324	788,776	673,610
Island and non-mainland generating differences	188,989	280,643	165,553	473,206	
Elcogas, S.A. viability plan	64,501	66,919			
Securitization fund				948,817	1,632,195
Temporary deficit for 2009			814,465		
Market interruption system		450,000	522,000	561,499	748,900
Capacity payments system deficit/surplus	750,000			−268,000	−275,810
H. Deficit/Surplus (H=F–G)	**−4,925,210**	**−3,190,224**	**−4,105,944**	**−3,385,090**	**−5,004,057**
I. Other costs for settlement					**550,500**
Financing of social rebates					292,500
Estimated 2011 island and non-mainland system (SEIE) cost overruns					58,000
Estimated final interest cost					200,000
J. External income from access tolls					**5,571,468**
Law 15/2012					2,921,468
CO_2					450,000
Extraordinary credit					2,200,000
K. Settlement deficit/surplus (H−I+J)					**16,911**

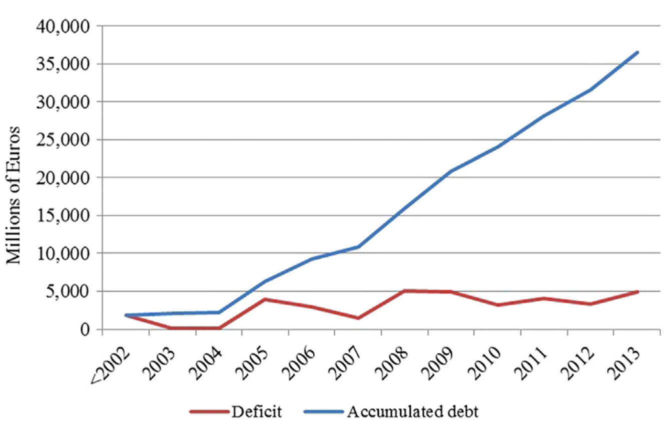

Fig. 1. Tariff deficit and cumulative debt.
Source: Own work based on CNE data.

but the utilities' revenues (in which the Government-backed debt was included *de facto*) swelled, regardless of any economic rationale for rising prices, and ignoring the woeful lack of competition in the electricity market.

In order to understand the reasons for the significant growth in the tariff deficit, we need to look at the way in which regulated income and costs are settled. Table 2 shows an estimate of settlements in the period 2009–2013.

Clearly, the settlement of regulated income and costs includes certain items that should not, by their nature, be treated as regulated costs, as they are only indirectly attributable to the electricity industry and consist rather of expenses and costs originating from political decisions (so that they would be more appropriately allocated to the national budget).[1] These items include the earmark for the "Nuclear moratorium", the "Island and non-mainland weightings", the "Special regime premiums" and the "Capacity payments system deficit/surplus".

As explained in Martínez [27], the "Nuclear moratorium" consists of financial compensation paid to the promoters of nuclear plants authorized in the late 1970s and early 1980s – but never built, because of the suspension of the nuclear programme by the Spanish Government in 1984. It may well be asked, why should electricity consumers be required to pay for such a clearly political decision directly. "Island and non-mainland weightings" consist of compensation paid for the extra costs ostensibly incurred by conventional generating plant situated in the Balearic and Canary Islands, and in the non-mainland enclaves of Ceuta and Melilla, on the north coast of Morocco (CNE [22]). It may also well be asked, why a cost originating from the Government's inter-regional budget redistribution policy should be charged directly to consumers' electricity bills. "Special regime premiums" represent incentives paid for renewables, co-generation, and waste-to-energy generation. Finally, the "Capacity payments system deficit/surplus" is

[1] We are aware that there are only three options for financing these expenditures: tariffs, the treasury, or default (in this case, perhaps the result of court litigation). Our proposal is to transfer these expenditures to the national budget, and we maintain that the treasury should assume these political costs.

designed to incentivize the construction of generating plant to ensure that there is sufficient power available at peak hours. However, the economic rationale for these payments is debatable, in view of the surplus capacity of existing plant in Spain.

In summary, and as a consequence, this situation involves an increasing debt that must be paid by final consumers; more concretely, an annual cost of more than €6.5 billion, due to industrial policy incentives, territorial quotas, and business errors, must be paid by final users in the coming years. The adding of these four items amounts to 6,857, 6,886, 6,800, and 8,850 million, from 2009 to 2013 respectively, with the 2013 figure being around 45% of the total regulated costs.

In this context, we do not necessarily consider that the described costs are unreasonable; they may indeed be perfectly justifiable in terms of economic policy. What we do question is whether they should be directly included in energy prices. For example, it is undeniably reasonable for the Government to establish incentives for the use of renewables (see Ballester and Furió [28]), but it is nonetheless open to question whether such incentives should be financed via the system of premiums applied in recent years, which were not only very high, but were also passed on directly to consumers via their electricity bills and the tariff deficit. It is clear, in the first place, that incentives for renewable energy sources should foster innovation (in generation and energy storage technologies), but not output, and still less installed capacity, as has hitherto been the case. Second, these incentives should not be financed out of the settlement of regulated costs and income. The most logical and socially responsible solution would be to fund incentives for renewables directly from the national budget.

In the case of the “Island and non-mainland weightings compensations”, in addition to being an inter-regional policy that should not be included as a regulated cost to be paid by direct users, it has been suggested that this extra cost could be reduced by implementing the correct measures (see Guerrero-Lemus et al. [29]).

2.3. Recent reforms

The welter of energy legislation in recent years has caused much legal uncertainty. As a result, private companies, and especially foreign investors, have either reduced their investments in Spain or begun to consider them much more carefully. In line with other authors, such as del Río and Mir [30], we maintain that changes in energy policy should be gradual and predictable in order to avoid investors leaving Spain.

Although there is a significant trend of changing energy legislation in Spain (see del Río [31]), the legislative riot began with the Spanish Electricity Industry Act, 1997 (BOE [18]). However, we shall focus here on the key changes made in 2012 and 2013, the breadth and nature of which have heightened the industry's qualms.

A number of changes were made to the regulation of the Spanish electricity industry in 2012, including the removal of incentives for plant capacity, the definition of new criteria for the compensation of regulated activities, the creation of new taxes, and an increase in tolls and *last resort tariffs* (BOE [32,33,34]).

Meanwhile, incentives for renewables were first tweaked, and then removed in 2013, and a new *voluntary small-consumers' price* was created to replace the former *last resort tariff* (BOE [35,36,37]). Let us note here that the *last resort tariffs* modified in 2012 were removed in 2013, changing prices twice in less than 12 months.

Royal Decree 9/2013 implemented one of the most significant reforms, seeking to resolve the problem of the tariff deficit once and for all. This decree had its greatest impact on the compensation of special regime generating plant, which was slashed. Apart from eroding the profits of non-conventional generating companies, this measure also had adverse environmental outcomes, insofar as incentives for renewables helped reduce atmospheric CO_2 emissions. As a matter of particular interest to this case study, the CGRAA lost revenue from the premiums received for the operation of its six small hydroelectric plants. The value of its premiums was around €2,802 million, 49.91% of its 2013 electricity costs, which amounted to €5,615 million. In addition, the reform of August 2013 sharply raised the capacity tariff, a charge payable per kW of power contracted by electricity customers, regardless of their actual consumption. Unfortunately, this last measure will increase a more wasteful energy use in the medium term, because it will weaken users' sensitivity to the cost effects of increased consumption.

2.4. Price hike

Electricity prices have risen inexorably in Spain in recent years, as a direct consequence of the matters described in Sections 2.1–2.3, to the point where they are now among the highest in Europe, although they were among the lowest not ten years ago. By contrast, generating costs in Spain are close to the EU average. This development is reflected in Figs. 2 and 3, which show the electricity prices paid by domestic and industrial consumers, respectively.

This is because the price paid by the consumer is affected mainly by the general lack of competition between utilities, the deficiencies of the distribution network, the low level of international connections, and a costly grid access toll, which is decided by the Spanish Government. Moreover, the Government has successively raised this toll in an effort to cover the tariff deficit.

This hike in energy prices has had serious consequences throughout the economy, undermining its competitiveness in general, and it has hurt farmers in particular because the modernization of irrigation systems has led to a significant increase in energy use. In the specific case of the CGRAA, costs have soared because of increases both in the energy consumed per hectare and in the number of hectares irrigated, which has expanded continuously in recent years.

3. Generation and energy use in the CGRAA

In this section, we use actual data to show that rising energy costs are basically attributable to the increase in grid-access tariffs. To this end, we focus on irrigated agriculture in the CGRAA, a scheme in the north of Aragon (Spain) with more than 133,000 ha of irrigated land.

The CGRAA is both an energy producer, generating power from small hydroelectric dams situated on its canals and reservoirs, and a major consumer, using large amounts of electricity since the modernization of its irrigation systems in a process that has been particularly intense over the last decade.

This study was prepared using detailed information, for the period 2010–2013, both on the output of hydroelectric plants and

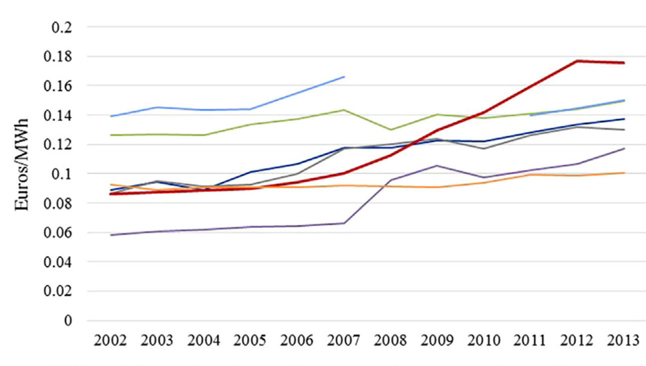

Fig. 2. Domestic prices (Euros/MWh).
Source: Own work based on EUROSTAT [38,39].

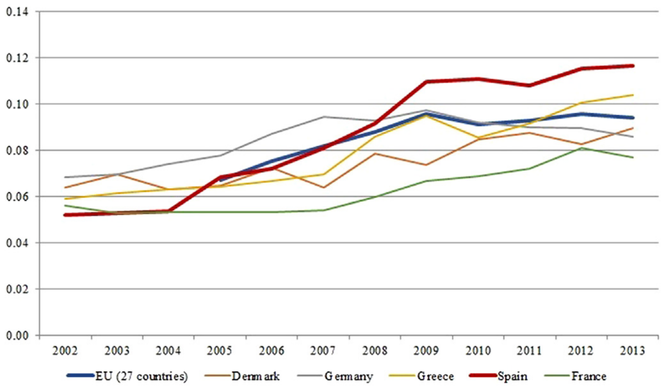

Fig. 3. Industrial prices (Euros/MWh).
Source: Own work based on EUROSTAT [38,39].

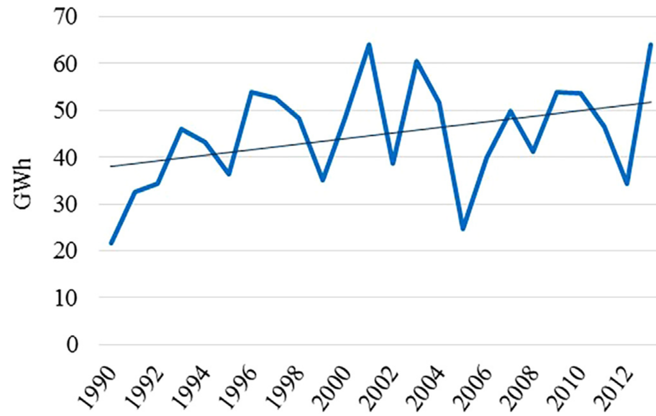

Fig. 4. CGRAA energy output.
Source: Own work based on CGRAA data, available on request.

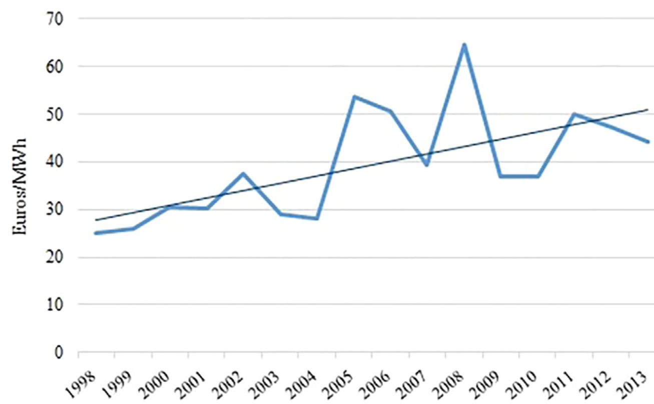

Fig. 5. Mean OMIE price (€/MWh).ws.
Source: Own work based on OMIE data, http://www.omie.es/files/flash/ResultadosMercado.swf.

on energy use at the various supply points (power contracted, consumption, and hourly and monthly consumption schedules). All of this data was supplied directly by the CGRAA. Meanwhile, we obtained energy prices from the data published on the official website of the Iberian Energy Market Operator (OMIE in the Spanish acronym), while the premiums paid are detailed in the Official Journal of the Spanish State (BOE), which also lists the tariffs applicable to the capacity contracted and energy consumed.

3.1. Generating activity

It is not usual for irrigation schemes to operate their own generating plant. However, the CGRAA chose in the 1980s to invest in small hydroelectric plants to generate power for sale in the wholesale market.

The Valdespartera and La Sotonera hydroelectric plants, each of which has generating capacity of 5,000 kW, were opened in 1989, and the Berbegal and Odina plants with respective capacities of 2,300 and 630 kW (which we shall hereafter treat as a single facility) came on stream in 1991. Finally, the Montanera (1145 kW), Piracés (1135 kW) and Torrollón (893 kW) small hydro plants were inaugurated in 2000. The CGRAA thus has six small hydroelectric generating plants.

The original aim of building these small plants was to earn additional revenues as part of the CGRAA's operations, but as shown in Fig. 4, their overall output has grown over the years. This, and the rise in energy prices (see Fig. 5) have recently led the CGRAA to consider the self-consumption alternative. Such a course could be justified because the total power generated is in fact greater than the scheme's total consumption, as reflected in Tables 3 and 4, which show that the CGRAA could easily generate enough power to supply all of its own needs. However, this strategy is conditioned by transmission factors and serious current legal barriers to self-consumption.

As shown in Fig. 5, average energy prices began to rise around 1998. Table 5 shows the CGRAA's generating revenues per year, and per hydro plant, resulting from the positive trend in daily market prices and rising output in kW h terms. The Table also reflects the incentives received by generating concerns until the recent reform, which accounted for almost half their income.

3.2. Tariffs and energy consumption

The energy price comprises two parts, namely the capacity contracted and the energy consumed. The capacity component is fixed by Government in the form of access tariffs per kW contracted. This charge does not depend on the amount of electricity actually consumed, and although it is paid by the consumer to the supplier, the utilities in fact act merely as intermediaries, passing on to the State the amounts collected, which are used to cover the regulated costs. The energy component consists of a charge per kW h consumed. It is agreed with the electricity utilities and it consists of various items, including the energy consumption access tariff. The problem with tariffs in the Spanish system resides in the very significant increase in the capacity charge in recent years. In the following discussion, we refer to the tariff types usually contracted by farmers, although the arguments made apply equally to others.

Table 3
Annual CGRAA power output and consumption (GWh).
Source: Own work based on CGRAA data, available on request.

	2010	2011	2012	2013
Power generated	53.67	46.41	34.33	63.96
Power consumed	36.1	46.7	41.5	46.2

Since the electricity market was liberalized, and the special electricity tariffs applied to agriculture were removed in July 2008 (BOE [40,41]), the CGRAA has normally contracted tariffs named 3.1 A and 6.1. Over the years, however, tariff 6.1 has been the most widely contracted and it is the one most commonly used at the supply points with the highest energy consumption. This tariff divides the day into six four-hour scheduling periods and it is applicable to installations with a voltage of between 0 and 36 kV, provided the capacity contracted is greater than or equal to 450 kW. Figs. 6 and 7 show the evolution of the capacity component and the energy access tariff of tariff 6.1.

Table 4
Monthly data, 2013 (GWh).
Source: Own work based on CGRAA data, available on request.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Power generated	4.17	4.78	5.32	7.39	7.75	7.72	8.03	8.17	5.72	2.19	1.15	1.57	63.96
Power consumed	2.97	0.38	0.74	3.63	3.18	6.04	10.36	11.97	5.46	0.95	0.24	0.29	46.2

Table 5
Market income and premiums (Euros).
Source: Own work based on CGRAA data, available on request.

		Sotonera	Valdespartera	Berbegal and Odina	Montanera	Piracés	Torrollón	Total
2010	Market	476,697	737,158	341,996	148,787	87,943	43,753	1,836,337
	Premiums	983,377	901,021	404,576	176,107	85,451	41,462	2,591,997
	Total	1,460,075	1,638,179	746,573	324,894	173,395	85,215	4,428,335
2011	Market	508,933	1,020,142	431,043	179,313	135,234	59,391	2,334,058
	Premiums	379,981	788,751	292,500	105,986	78,679	33,501	1,679,401
	Total	888,914	1,808,893	723,543	285,299	213,914	92,893	4,013,460
2012	Market	307,095	823,035	351,436	147,384	68,033	27,609	1,724,594
	Premiums	247,213	675,940	251,951	92,347	41,787	16,056	1,325,297
	Total	554,309	1,498,976	603,388	239,731	109,820	43,665	3,049,892
2013	Market	874,577	1,288,297	375,319	159,070	70,494	44,713	2,812,473
	Premiums	948,912	1,215,827	397,067	153,854	52,244	34,485	2,802,390
	Total	1,823,489	2,504,125	772,387	312,925	122,738	79,198	5,614,863

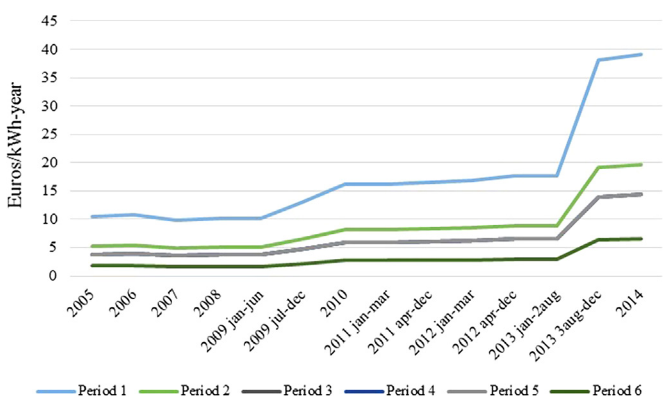

Fig. 6. Capacity component (Capacity access tariff) (€/kW-year) The capacity contracted in periods 3, 4 and 5 is the same.
Source: Own work based on data published in the Official Journal of the Spanish State (BOE).

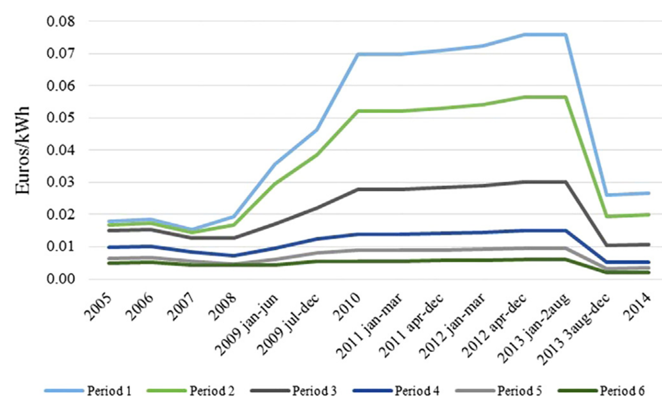

Fig. 7. Energy access tariff (€/kW h).
Source: Own work based on data published in the Official Journal of the Spanish State (BOE).

The capacity component of tariff 6.1 has increased continuously since 2005, resulting in a medium-term loss of energy efficiency because of the relative increment in the fixed cost inherent in the electricity bill, compared to the variable cost. Moreover, the energy access tariff of the electricity bill has actually fallen since August 2013, further accentuating this effect. Tariffs 3.1 A and 6.2 contracted for irrigation have also followed this path.

Access tariffs generate income for the state and provide a means of covering the cost of regulated activities. However, Government should consider all aspects of economic, environmental, and growth policy, and not just revenue and opportunities to cut the tariff deficit. This does not appear to be the case. As explained above, the trend has been to increase capacity and cut energy tariffs, thereby benefitting the largest consumers at a given level of power (as consumption per kW h is cheaper). This provides a negative incentive for efficient energy use and has regressive environmental effects. This is just one of the several arguments we make below for removing, or at least seriously reducing, capacity tariffs.

In addition to access tariffs, we have also obtained data on the energy prices. Aggregating the two components, we can obtain the total energy cost incurred by the CGRAA, as explained in Section 3.3 below.

According to the data reflected in Table 4, the CGRAA consumes the most energy between May and October. However, the scheme is obliged to contract capacity all year round, which increases its costs. This irregular consumption pattern has led farmers to propose *seasonal contracts*, which would make summer consumption cheaper, arguing that the need to contract power at the same level on a year-round basis is an unwarranted expense, and that this penalty should be compensated for by cuts in the energy price in summer. The proposal we make below would also solve this problem.

3.3. Energy costs

Having analysed both energy consumption and prices, let us move on to consider the CGRAA's energy costs in 2010–2013. This analysis was performed individually at each of the scheme's supply points, but we shall here describe only the overall energy costs incurred.

Table 6 shows the capacity contracted (mean for all supply points), the energy consumed by CGRAA, and the total cost under tariff 3.1 A. As may be observed, energy consumption in scheduling

Table 6
Power, energy and cost, 2010–2013, Tariff 3.1 A.
Source: Own work based on CGRAA data, available on request.

	Mean capacity contracted (kW)			Energy consumed (kW h)[a]				Cost (Euros)
	P1	P2	P3	P1	P2	P3	Total	Total
2010	60	175	175	96,249	603,553	1,042,910	1,742,712	229,054
2011	60	170	170	114,856	675,163	1,280,758	2,070,777	228,671
2012	60	150	160	92,741	605,833	1,151,808	1,850,382	229,669
2013	55	160	160	55,605	699,079	1,086,250	1,840,934	390,425

[a] Tariff 3.1 A only has three daily periods.

Table 7
Capacity, energy and cost, 2010–2013, Tariff 6.1.
Source: Own work based on CGRAA data, available on request.

	Mean capacity contracted (kW)						Energy consumed (kW h)							Cost (Euros)
	P1	P2	P3	P4	P5	P6	P1	P2	P3	P4	P5	P6	Total	Total
2010	380	670	680	680	700	855	1,397,621	2,423,264	449,776	1,401,409	2,172,704	26,512,749	34,357,523	3,433,277
2011	375	715	720	720	720	930	1,588,367	3,192,995	470,313	1,636,054	2,781,834	35,437,538	45,107,101	4,035,201
2012	315	650	655	655	700	940	900,812	2,195,129	533,830	1,668,506	1,505,481	32,604,768	39,408,526	4,401,254
2013	340	765	770	770	810	1035	1,179,937	3,329,836	492,293	1,888,034	1,863,571	34,795,021	43,548,692	5,775,541

period 1 (the most expensive) fell sharply over the time horizon of the study and increased gradually in period 2, remaining practically constant in period 3. Despite the diminution in the power contracted and the limited (5.63%) growth in energy consumption, however, the total cost increased from €229,054 in 2010 to €390,425 in 2013, mostly because of the rise in capacity access tariffs.

Table 7 reflects the capacity contracted, the energy consumed, and the cost incurred at the supply points under contracting tariff 6.1 in the period 2010–2013. As may be observed, the capacity contracted in the cheapest scheduling period (period 6) increased over the time horizon from 855 to 1035 kW, but in period 1, which is the most expensive, it dropped from 380 to 340 kW. The increase in the capacity contracted in certain periods is mainly due to rising demand from modernized irrigation facilities. Meanwhile, consumption trended downwards in periods 1 and 5, and rose in periods 2, 3 and 6, so that the total energy consumed in all scheduling periods increased overall, though only by 26.75%. The main reason for this overall increment is, once again, increased demand from upgraded and recently-modernized irrigation facilities. Despite the diminution in the capacity contracted in the most expensive scheduling periods, however, and the fact that consumption increased by only 26.75% over the time horizon, costs climbed every year, rising by 68.21%, from €3,433,277 in 2010 to €5,775,541 in 2014. Hence, it is clear that the growth in costs is due principally to soaring energy prices driven, above all, by the increase in capacity tariffs.

The above tables reflect the trends found in the CGRAA, revealing that the capacity contracted in the early scheduling periods is significantly lower than in periods 5 and 6, whose capacity tariffs are also much lower. Meanwhile, over 70% of consumption occurs in period 6, when the cost per kW h is lowest, although these are not daytime hours. Where any of the supply points do not follow this pattern, this is due to structural and infrastructure problems, which may make it necessary to consume more energy than may initially be desired in other periods (mainly periods 2, 4 and 5).

The energy costs for 2014 were estimated based on the CGRAA's energy consumption and the capacity contracted in 2013, as the 2014 figures were not yet available when the study was carried out. However, we were able to obtain the necessary information on the prices agreed with electricity utilities. On this basis, the estimated total cost to all of the irrigation schemes included in the CGRAA in 2014 was €6,986,074, showing that the upward trend continues (the total cost was €3,662,331 in 2010, €4,263,331 in 2011, €4,630,923 in 2012, and €6,269,858 in 2013). Furthermore, the cost of contracted capacity in 2014 was €3,521,172 compared to a cost of €2,252,443 in respect of energy consumed, revealing the inexorable rise in the share of the electricity bill represented by capacity.

3.4. Simulation based on different tariffs

In order to confirm that the increase in costs is indeed due mainly to hikes in access tariffs, we perform a simulation of the energy cost at different tariffs, assuming actual levels of contracted capacity and energy consumed. Six simulations were addressed based on the applicable tariffs per BOE [42,43,44,45,46,47]. In all cases, the cost per month and scheduling period at each one of the irrigation scheme supply points were taken into consideration, as well as the power and energy figures for 2013. These data were obtained directly from the CGRAA.

As can be observed in Table 8, the general cost trend is increasing.[2] We show the costs for the communities that contract tariff 6.1 because it is the most representative. When we compare the tariffs applicable in January 2010 [42] and February 2014 [47], for example, we find that the total cost rises from €4,380,281 to €6,092,780, an increase of 40.88%, most of which was generated by the tariff changes introduced by the August 2013 reform [46]. It results in an increase of 14.79% in costs, from €5,307,704 to €6,092,780 (mainly due to the rise in the capacity tariff). To make matters worse, this increase is even more acute in the most expensive periods. Specifically, the total cost in scheduling period 1 would have been €679,352 in 2013, 73.31% of which (€498,031) consists of capacity charges, up from 49.99% with the tariffs of 2010. Moreover, the upward trend in capacity costs does not appear likely to change, as this component makes up 73.71% of the estimated cost for 2014. The results simulated for scheduling period 2, again one of the most expensive periods, are similar. Based on the BOE [42] tariff, the capacity cost would have represented around 24.92% of the total cost, much smaller than the 41.96% with the August 2013 reform.

[2] Note that the costs in Table 7 are not the same as those in Table 8 (even when we talk about the same year), because Table 7 take's into account the tariff changes throughout the year, and in the simulation of Table 8 we used annual fixed tariffs.

Table 8
Simulation of CGRAA costs in Tariff 6.1 for different electricity tariffs (Euros).
Source: Own work.

	P1	P2	P3	P4	P5	P6	Total
BOE [42]							
Capacity cost	212,647	237,693	174,710	174,710	184,637	107,177	1,091,573
Power cost	212,731	511,696	58,376	187,331	171,374	2,147,201	3,288,708
Total cost	425,378	749,389	233,086	362,040	356,011	2,254,378	4,380,281
% of capacity by total	49.99%	31.72%	74.96%	48.26%	51.86%	4.75%	24.92%
BOE [43]							
Capacity cost	216,900	242,447	178,204	178,204	188,329	109,321	1,113,404
Power cost	214,821	516,100	58,723	187,993	171,796	2,152,157	3,301,591
Total cost	431,721	758,547	236,927	366,197	360,125	2,261,478	4,414,996
% of capacity by total	50.24%	31.96%	75.21%	48.66%	52.30%	4.83%	25.22%
BOE [44]							
Capacity cost	221,238	247,296	181,768	181,768	192,096	111,507	1,135,672
Power cost	243,418	564,538	69,452	222,272	189,844	2,531,171	3,820,695
Total cost	464,656	811,833	251,220	404,040	381,940	2,642,678	4,956,367
% of capacity by total	47.61%	30.46%	72.35%	44.99%	50.29%	4.22%	22.91%
BOE [32]							
Capacity cost	231,135	258,358	189,899	189,899	200,689	116,495	1,186,475
Power cost	256,990	592,278	70,885	226,168	196,178	2,778,730	4,121,230
Total cost	488,125	850,636	260,784	416,066	396,867	2,895,226	5,307,704
% of capacity by total	47.35%	30.37%	72.82%	45.64%	50.57%	4.02%	22.35%
BOE [46]							
Capacity cost	498,031	556,689	409,179	409,179	432,429	251,014	2,556,521
Power cost	181,321	431,114	58,376	201,038	180,394	2,484,017	3,536,259
Total cost	679,352	987,803	467,555	610,217	612,822	2,735,031	6,092,780
% of capacity by total	73.31%	56.36%	87.51%	67.05%	70.56%	9.18%	41.96%
BOE [47]							
Capacity cost	511,589	571,845	420,318	420,318	444,201	257,848	2,626,120
Power cost	182,442	433,517	58,576	201,468	180,700	2,488,255	3,544,959
Total cost	694,032	1,005,362	478,895	621,787	624,901	2,746,103	6,171,079
% of capacity by total	73.71%	56.88%	87.77%	67.60%	71.08%	9.39%	42.56%

4. Possible alternatives

In this section, we set out two possible alternatives, which could help cut the energy costs paid by consumers in general and farmers in particular, and would foster competitiveness and efficiency in the electricity industry. The first of these alternatives consists of removing, or at least sharply reducing, capacity tariffs to link the cost to the energy actually consumed. In most countries, connection charges are used to recover the cost of investments in the distribution grid, although other financing sources do exist. Moreover, governments usually fund the lion's share of the capital expenditures required. This is the way that our proposal would take place in Spain. The other alternative would be to encourage energy self-consumption that is partially a complementary measure to the previous one. Therefore, though they are technically separate, the ideal would be to move forward with both measures at the same time.

4.1. Reduction of capacity tariffs

Our first proposal to reduce the impact of capacity tariffs on electricity costs would change the current system applied to the compensation of the electricity industry, by removing or cutting the payments made by users for the capacity contracted. This would involve, at the same time, moving towards charges linked to the energy consumed and the true transmission cost, which would depend on distances, and the distribution systems used. Let us look at this option in more detail.

In order to analyse the effects of the removal of the capacity-based tariff, we present the following four scenarios for 2013 in the CGRAA (results are shown are Table 9). The energy (kW h) and capacity (kW) contracted are the same in the four scenarios, i.e. the 2013 figures.

We simulate the four scenarios based on the fact that, in 2013, the unjustified expenditures are supposed to be around 45% of total capacity cost (see Section 2.2). Thus, this 45% is assumed by the Government in the four scenarios. We propose alternative payments of the remaining 55%.

The first scenario consists of removing the capacity-based tariffs and keeping the energy tariffs that we had previously. In this case, the consumer's cost would only include the energy cost, as the transport and distribution costs are assumed by the Government and paid from the State budget (in other words, the remaining 55% is also assumed by the Government). In this case, the total cost would be around €3,536,259, approximately 58% of the 2013 costs.

The second scenario is based on transferring one third of the 55% of the capacity cost to the energy cost. For that, we must increase the energy tariff by 13.25%. The other two thirds of the capacity cost would be assumed by the Government. When we compare this measure with the current situation, we observe that the CGRAA saving would be more than €2 million, with respect to the current situation. Note that the total electricity cost using the tariffs of August of 2013 for the CGRAA was €6,092,780.

In the third scenario, the capacity-based tariff is reduced by 100%. In this case, 2/3 of the remaining 55% are applied to the energy tariff and 1/3 is assumed by the Government. The CGRAA would save more than €1.5 million, taking into account the 2013 costs.

Finally, the fourth scenario transfers the remaining 55% of the capacity cost to the energy cost. In this case, we would increase the power tariff by 39.76%. The saving for CGRAA would be in excess of €1 million (the costs would be €4,942,346).

4.1.1. Covered and lower costs and environmental gains

The proposals in these four scenarios would cause no additional tariff deficit and could address the different types of

Table 9
Simulation of CGRAA costs in Tariff 6.1 with our proposal (Euros).
Source: Own work.

Periods	P1	P2	P3	P4	P5	P6	Total
Current situation							
Capacity cost	498,031	556,689	409,179	409,179	432,429	251,014	2,556,521
Power cost	181,321	431,114	58,376	201,038	180,394	2,484,017	3,536,259
Total cost	679,352	987,803	467,555	610,217	612,822	2,735,031	6,092,780
% of capacity by total	73.31%	56.36%	87.51%	67.05%	70.56%	9.18%	41.96%
Scenario 1: Capacity 0							
Power cost = total cost	181,321	431,114	58,376	201,038	180,394	2,484,017	3,536,259
Scenario 2: Capacity 0, power increases in 13.25%							
Power cost = total cost	205,353	488,254	66,113	227,683	204,303	2,813,248	4,004,955
Scenario 3: Capacity 0, power increases in 26.51%							
Power cost = total cost	229,385	545,393	73,850	254,329	228,212	3,142,479	4,473,650
Scenario 4: Capacity 0, power increases in 39.76%							
Power cost = total cost	253,418	602,533	81,588	280,974	252,122	3,471,711	4,942,346

payments established. The differences are the role played by Government, which covers the regulated cost in total in the first alternative and a significant part in the others, and the energy price paid by consumers. So, this option cannot be rejected on the grounds that it would be financially insufficient to cover costs.

The hikes in capacity tariffs in recent years have considerably increased energy costs. As we can see in Table 9, as expected, if we apply our four proposals, the user's energy costs would be lower than they are now because a part is paid by Government. And, in any case, the user payments are proportional to the energy used.

On the other hand, recently the cost of energy presents an ever-diminishing share of the total cost, so that Spain is heading towards something like a flat-rate charge, a situation in which energy use is increasingly irrelevant compared to the capacity contracted. This has clearly negative environmental consequences in the long run. Our four proposals would disentangle consumer reactions, as users would be able to associate cost and consumption more directly, providing a clear signal that would foster savings because rising energy use would bring with it a concomitant increase in costs, and this increase would offer a first incentive for all consumers to rein in their energy use. At the same time, energy savings would translate into lower costs for the consumer and in the long run would mitigate adverse environmental outcomes.

4.1.2. *Capacity outcomes*

In a system such as currently exists in Spain, especially since the recent hike in access tariffs, the fact that consumers pay for the capacity contracted means they seek to adjust this component, with the result that they tend to contract the lowest possible amount of power in order to avoid costs. In our proposal, as users would not have to pay a capacity charge, each consumer would be more free to contract adequate capacity and install plant based on their actual energy needs. This would, to a great extent, remove the influence of cost concerns in contracting capacity and would prevent bad choices, because decisions would be taken in view of technological and safety factors, rather than being dictated by cost. We believe that the availability of capacity up to 4,500 kW in households reduces the risk of fire and ensures more rational use. In general, linking cost to consumption would ensure the installation of adequate, safe levels of capacity, which would in turn provide gains for the transport and distribution grid, and for consumers. Additionally, it could help foster technological development.

4.1.3. *Seasonal consumption*

Importantly, our proposal would de-penalize seasonal patterns of energy use, because users would pay for consumption rather than the capacity of their installations. In light of the data provided by the CGRAA (see Table 4), irrigation schemes use energy most intensively between May and October. Under the current billing system, such seasonal consumption is penalized over the year as a whole, because farmers must pay tariffs for the capacity they contract year round, although they use very little energy in the winter months. The alternative we propose would remove this problem, because billings would be closely tied to the energy consumed. In the case of irrigation, farmers would thus pay most of their total energy costs in summer, which is when they use the most electricity. The effect would be similar to the so-called *seasonal contract* or to *the French green tariff* (although the approach is different). This is very important to irrigation, but also in other industries, such as tourism and, indeed, in the case of second homes, and the implementation of consumption-based billings would encourage efficient energy use in all cases.

4.1.4. *Implementation*

One simple way to implement this alternative could be based on the current cost structure: it would be sufficient merely to increase the charge for energy actually consumed, to replace the part of the capacity tariff paid by users. This tariff could then be gradually cut and the charges for regulated activities which should not be included in the electricity bill, could be removed.

As commented at the beginning of Section 4.1, different tariffs are possible, depending on the distribution grid or system used. It is a technical reality that not all transmission and distribution facilities entail the same costs per kW h. Low voltage and urban grids usually suffer higher levels of wastage and their structure is generally larger in spatial terms, which creates other specific costs. In this light, we propose that, if the Government does not cover the total capacity cost, each different type of user pay depending on the type (or types) of distribution infrastructure used based on the energy consumed. For example, exporters and importers who only use the high-voltage grid and transformers should pay for the cost of this infrastructure per kW h exported. Likewise, if households purchase their power from nearby utilities, they should not be asked to pay for long-distance transmission grids. This is, of course, a complex matter, but it would not be impossible to analyse infrastructure construction and maintenance costs and allocate them to consumers in such a way that each would pay for their own use.

4.1.5. *Public grid*

A keystone of this proposal is the existence of a truly public distribution grid, so that energy producers, industrial users, and domestic consumers would simply be users of the necessary infrastructure to transmit or receive electricity. This grid should be operated as a non-profit and treated rather as a national infrastructure, like the road and rail networks. Government should fund the construction and maintenance of new electricity transmission and distribution infrastructure in total (Scenario 1) or partially (Scenarios 2, 3 and 4). In this last case, the Government could fix a charge based on three basic parameters, namely kW h consumed, distance between the source and the point of consumption of the energy, and the type of distribution infrastructure utilized. In any event, the criteria established should be completely transparent and conditions should be the same for all regions in order to facilitate economic and social integration and foster competition.

Moreover, any entity paying the fixed toll would have full and unrestricted access to the grid. This would mean that the Government would no longer be a passive player, becoming a true regulator and a facilitator, at the same time guaranteeing the minimum or basic electricity supply.

This public grid could also solve two other serious current problems, to wit, international interconnections, and access to the grid from any geographical point in Spain. The first issue is fundamental to raising competitiveness by broadening the market and opening it up to foreign utilities and providers. This would improve matters for many other industries, thereby fostering growth, and it would also make the alternative of self-consumption much easier, again providing a spur to growth. Moreover, such a national grid would weaken the separation between generation and marketing, which has not proved an effective driver of competition in Spain.

4.2. Self-consumption

In light of the CGRAA's annual and monthly electricity generation and consumption figures (Tables 3 and 4), it would be possible to cover much of the scheme's energy use out of its own energy output, if generating schedules could be properly aligned and measures were taken to facilitate transmission. Beyond the CGRAA, numerous other generating facilities are in a similar position. The main problem is the need for an institutional and legal framework that would foster and facilitate generation of this kind.

In general terms, the self-consumption option consists of generating the energy consumed, or at least a significant part of it. This could prove to be a very interesting option for irrigation schemes because they have the water needed for hydroelectric generation in their canals and reservoirs, and the land needed to site solar plants, which would allow them to consume their own power in their operations and sell any surplus. There can be little doubt that self-consumption provides efficiency gains due to proximity and encourages competition by increasing the number of suppliers.

At present, two drafts exist for a Royal Decree to regulate self-consumption. In both cases, only consumers contracting capacity of 100 kW or less per supply point would qualify for authorization to consume their own energy, and even then, only if they had an internal electricity generating facility earmarked for self-consumption.

The first is the *Draft Royal Decree on the regulation of photovoltaic self-consumption or the net energy balance in Spain* (see MINETUR [48]). The fundamental feature of this net balance is that producers can feed a given quantity of kW h into the grid and can acquire the amount of energy they require when they wish. At the end of the year, a settlement would be prepared, in which producers would pay if the kW h consumed were higher than the kW h generated, and would receive a price for their surplus energy otherwise. Meanwhile, an "access toll" would be charged for use of the network, but no tariff would be applied for the capacity contracted.

It is no easy task to evaluate draft legislation before it is actually published, but we see at least three weaknesses in the current text. To begin with, constraints are placed on the size of the generating plant, which makes little sense from the standpoint of an open market, as industries should not be shut out by legislation prohibiting their operations, but by the efficiency with which they are able to generate electricity. Furthermore, the draft Royal Decree (surprisingly) fails to address the geographic reach of the distribution grid, which forms the basis for any system of self-generation because it is to be expected that a producer-consumer will be systematically exposed to energy shortfalls and surpluses. Finally, the draft is unforthcoming about the concept of the "access toll" and other associated payments, leaving the door open to the inclusion of all of the currently-existing regulated costs.

The other and most recent legislative blueprint is the one shown in MINETUR [49], which establishes the access tolls.

Surprisingly, this draft is prey to almost exactly the same weaknesses as the previous one. It maintains size constraints via the regulation of installed capacity, and it fails to move towards a public grid that would be largely autonomous of energy utilities.

Table 10 shows the data on the simulation of self-consumption. We estimate what the savings would be for the CGRAA if self-consumption was implemented. First, as is shown in Tables 3 and 4, we can see that the difference between the kW h produced, around 64 million kW h, and consumed, around 47 million kW h, is positive, so, it is possible to cover the CGRAA consumption with its own production. Moreover, more than 17 million kW h could be sold to the market. We are assuming that the savings would be the difference between the expenditure for the electricity consumption and the income from selling the production of this 47 million kW h to the market. In Table 10, we can observe that the expenditure for electricity consumption in 2013 was €6.3 million; and, if we only take into account the expenditure for power consumption (and not for capacity contracted), the expenditure was a little more than €4 million. For our simulation, we could only consider (discounting from the savings) the income from selling the 47 million kW h. As we can also see in Table 10, the CGRAA income from selling the 47 million kW h in 2013 was a little more than €4 million in total, including premiums, which are recently removed; then, the expected income from production is around €2 million (coming from the market, without premiums). The difference between the power consumed and the income from selling without premiums (taking into account only the 47 million kW h consumed) is €1,950,991, which is a first estimation of the savings. Now, taking into account the access costs for paying the tolls, which would be[3] €472,705, the costs for transporting the kW h to the consumption points. When we take these costs into account, the total savings would be €1,478,286. This is without considering the capacity costs, which in 2013 were €2,353,713. In a real situation, only the 50% of this capacity cost should be paid by a self-consumption supplier; in that case, the actual savings would approach €2.5 million.

Finally, we should not ignore the fact that self-consumption could actually improve the supply of energy and facilitate management of the system, because it would decentralize generating. However, the main challenge, which the draft legislation discussed above should address, is to raise competition between firms and ensure that all of them, whether large or small, can provide capacity to cover Spain's energy needs.

5. Key conclusions

As we have seen, the energy industry in Spain is prey to major problems, including a lack of competition between firms, the tariff deficit, and the latest round of legislative reform, the sheer volume of which has significantly increased legal uncertainty, while its content will produce adverse environmental effects over the long

[3] We calculate the transport costs taking into account the access tolls established in MINETUR (2013).

Table 10
Self-consumption simulation for 2013.
Source: Own work.

	Total
kW h produced	63,957,170
kW h consumed	46,845,638
Difference between kW h produced and consumed	17,111,532
Expenditure for 2013 consumption (Euros)	6,364,709
Expenditure for 2013 power consumption (Euros)	4,010,996
2013 income for the 46,2 GW h (Euros)	5,614,863
2013 income without premiums (Euros)	2,812,473
Access toll cost (Euros)	472,705
2013 expenditure for consumption – 2013 income without premiums (Euros)	1,198,523
Saving taking into account access toll costs	725,818

run. All of this has driven up Spanish electricity prices, which represents a serious challenge to the country's growth and modernization, increasing energy costs for industry of all kinds and for irrigated farming in particular. These price hikes are largely a result of the sharp increase in capacity tariffs in an effort to reduce the tariff deficit. While we would not wish to deny that these reforms have certain positive aspects, none of them addresses energy-saving incentives as a principal goal, or the use renewables, at least in the short to medium term.

This paper presents some alternatives, specifically with regard to tariff criteria, which we believe would help Spain progress in the right direction. We have based our study on the experience of the CGRAA because of the availability of data on both energy consumption and generation in this major irrigation scheme.

Observing the CGRAA's own electricity use, we may note that rising energy consumption has been accompanied by tariff hikes, which has significantly increased the scheme's energy costs, particularly since August 2013. As is well known, energy consumption is closely associated with the modernization of irrigation systems. The increase in prices and costs described in this paper is not confined to irrigated agriculture but has also affected all sectors of the Spanish economy and their competitiveness. The prices paid by both industry and households have shot up from relatively low or medium levels compared to Spain's EU partner countries, to become among the most expensive in Europe.

In the period 2010–2013, the capacity contracted by the CGRAA stayed practically unchanged, and even fell in the most expensive scheduling periods, while energy consumption rose, but not as fast as costs. Energy consumed under tariff 6.1 (the most commonly used by the CGRAA, accounting for much of its energy use) increased by 26.75% between 2010 and 2013, but costs soared from €3,433,277 to €5,775,541, or 68.21%, clearly revealing that the phenomenon is largely attributable to price effects.

To demonstrate this, we perform a simulation of the CGRAA's energy costs under different electricity tariffs, based on the actual levels of consumption and power contracted. We develop this simulation for tariff 6.1, which is the most common in irrigation. Where costs totalled €4,380,281 with the tariff of January 2010, they had risen to €6,171,079 by February 2014, an increase of 40.88%. This increase was caused mainly by the reform of August 2013, which alone resulted in a 14.79% increase, from €5,307,704 to €6,092,780. This once again demonstrates that the growth in costs is due to the tariff increase.

In this light, we propose possible measures to reduce energy costs. Our first proposal, to reduce the impact of capacity tariffs on electricity costs, would change the current system applied to compensation of the electricity industry, by removing or cutting the payments made by users for the capacity contracted and moving towards charges linked more closely to the energy consumed and the true transmission cost, which would depend on distances and the distribution systems used. In order to analyse this measure, we propose four scenarios, which differ in the part of the capacity cost paid by users through proportional increases in the power access tariff.

For the reasons explained in Section 2.2, we assume that around 45% of the capacity cost is not justified, and that expenditures would be paid by the State budget. Thus, our first assumption is reducing the capacity cost by 45%. The difference in the four scenarios will be the financing of the remaining 55% of the capacity cost. In the first, the 55% is also assumed by the Government. Scenario 2 proposes that the consumers would pay one third of this 55% through the power tariff. In scenario 3, consumers would pay two thirds of this 55% of the capacity cost through the power tariff. And, finally, in scenario 4, consumers would pay the whole 55% through the power tariff.

Our proposal could, in any case, cover the costs of the distribution grid, but crucially it would incentivize energy savings, because cost would be linked to electricity consumption rather than capacity contracted. Furthermore, it would encourage a more rational approach to the choice of the capacity to contract for a given installation, thereby reducing the risk of power overloads and short circuits, and it would increase competition between energy firms, because the final electricity bill would be less conditioned by distribution costs. Meanwhile, the penalty incurred for irregular or seasonal consumption would be removed, which would clearly be fairer, because the consumers would pay according to their consumption. Quite probably, this would also indirectly encourage self-consumption, a measure mooted by both farmers and many other industries for some time now, especially if there existed a public, inexpensive grid that would allow more economical, or even free, access to the distribution grids.

An alternative (and complementary) measure proposed is the implementation of self-consumption. As shown in Table 10, the savings for the CGRAA would be positive if self-consumption was implemented. In addition, the CGRAA could sell the difference between its energy produced and consumed (positive difference) in the daily market.

Unfortunately, the two draft Royal Decrees in the pipeline to regulate self-consumption in Spain are restricted to small generating facilities and neither addresses the need to develop the grid or to cut access costs, which in practice would hobble growth in energy availability and favour competition between energy firms.

To conclude, returning to the convenience of expanding the electricity grid, which should be considered as a public service: competition within the industry could be enhanced by improving and upgrading the grid, which would increase alternative supply options and broaden the market by allowing energy to be bought and sold in times of surplus or deficit. This measure would also solve the serious current problems of international interconnection (which again increases competition and fosters the entry of foreign firms and providers) and easier access to the grid from anywhere in the country.

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