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SPANISH REGULATED SCENARIOS FOR RENEWABLE ENERGY AND CSP PLANTS

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ABSTRACT

Spanish legislation evolution has followed the dynamics of deregulation that allowed the evolvement of the installed power capacity on renewable resources in parallel with the development of the technologies on renewable resources. This depends directly on technical and legislative factors related to the economic support to the investment for the construction of this type of power generation systems. The strengths and weaknesses of each stage of regulation can be analyzed following the Spanish energy model. The first phase of liberalization of the market for the production of electric power has been funded. Here technologies used for the generation of installed power from renewable sources have not observed criteria of availability of renewable resources and efficiency in electricity production, as much as expected. The demand for electric energy should match efficient generation, as peaks of consumption demand higher production of electricity. Thus, there should be no need to have installed total power several times greater than the electrical power required. The evolution of electric generation systems according to relevant legislation demonstrates that optimizing the choice of energy mix from renewable sources must prioritize the implementation of concentrating solar thermal plants.

Keywords: Spanish electric legislation, renewable energy regulation, solar thermal power plant, feasibility.

LEGAL REGULATION AND ITS INFLUENCE ON RENEWABLE ENERGIES WITHIN THE SPANISH ELECTRICAL MARKET

Applicable Legislation

Throughout the last two decades, the European directives have laid the basics of a support system to renewable resources. Nowadays, the European policy in this area is aimed at a phase of stabilization of resources and sustainability of the generation systems achieved, maintaining the objectives set for 2020.

The control of energy consumption in Europe and the increased use of energy from renewable sources, together with the energy savings and greater energy efficiency, have been an important part of the package of measures to comply with the Kyoto Protocol to the United Nations Framework Convention on Climate Change [1], and other commitments of international community. In addition, these factors have played an important role in promoting the security of energy supply, technological development and innovation. This provides opportunities for employment and regional development, especially in rural and isolated areas.

The directive 2001/77/EC [2] defined the different types of energy from renewable sources. The Directive 2003/54/EC [3] established definitions applicable to the electricity sector in general for the sake of legal certainty and clarity.

The Council of Europe (March 2007) reaffirmed the commitment of the Community with the development of energy from renewable sources (EU-wide) beyond 2010. It approved the mandatory target to reach a market share of 20% of energy proceeding from renewable sources in the entire consumption of EU energy in 2020.

Regarding production sustainability, different directives from 2009 [4] have established convenience that energy prices reflect their external costs, including production, consumption, environmental, social and health costs.

That is the reason why public aid is needed to achieve the objectives of the Community, with a view to the expansion of electricity production from renewable energy sources. In particular, electricity prices in the national market reflect neither all costs nor the environmental and social benefits of the used renewable sources.

To ensure the achievement of the overall national mandatory targets, Member States have designed a progressive national plan of action on the subject of renewable energy, which would allow them to achieve its compulsory final targets. According to the EU directives mentioned, each Member State must evaluate their forecasts of gross energy final consumption, and establish the contribution that energy efficiency and energy saving make to their national targets. Member States must take into account the optimal combination of technologies and renewable resources to improve energy efficiency.

The Spanish System of Electricity: Transposition of European Directives for Reduction of Energy Costs

The transposition of European directives to the Spanish legislation has caused the evolution toward the appropriate legislation and strict observance of the principle of reasonable profitability of the facilities, while ensuring the financial sustainability of the system.

The Spanish normative (including investment policies of generation using renewable resources) is described below in a chronological order. This has led towards technological development and implementation of

some generation technologies whose effects are discussed in subsequent sections of this work.

The Law 54/1997 [5] has been the main norm for the regulation of these aspects. It included the special scheme for electric power production. It contained the set of specific rules that applied to the electricity generated by renewable energy sources, cogeneration with high energy efficiency and waste.

These legal provisions were developed in successive regulatory standards. The first one was the Royal Decree 2818/1998 [6], which regulates the production of electrical energy from renewable resources. This legal provision was later modified by the Royal Decree 841/2002 [7], which regulates the facilities for production of electrical energy in special regime, obligations of its production forecasts, and the acquisition by the marketers of its electrical energy produced. Both Royal Decrees were repealed by the Royal Decree 436/2004 [8], which sets out the methodology for updating and systematization of the legal and economic regime of the electric energy production in special regime.

Subsequently, the Royal Decree 661/2007 [9] regulates the activity of electricity production in special regime, which also repealed the existing regulations contained in the Royal Decree 436/2004. This Royal Decree has been applied until the approval of the next Royal Decree-Law 2/2013 [10], taking urgent measures to ensure the financial stability of the electrical system.

The measures from 2009 to 2011 have not been sufficient for the achievement of the purposes, committing the own financial sustainability of the system. Under this circumstance the Royal Decree-Law 1/2012 [11] considered the suspension of the procedures of pre-allocation and economic incentives for new production facilities of electricity from cogeneration, renewable energy sources and waste. Subsequently, Royal Decree-Law 2/2013 [10] introduced urgent measures in the electrical and in the financial sector, which amended the Royal Decree 661/2007 [9], deleting the market price plus premium options for those technologies. This determined the remuneration pursuant to tariff of all facilities of the special regime. At the time, this Royal Decree changed the parameters of the remuneration of the regulated power system activities.

In that context, the need to ensure the financial sustainability of the electricity system consolidated the continuous adaptation that the regulation had undergone to ensure the strict and proper application of the principle of reasonable profit. It also undertook a review of the regulatory framework that would allow its better adaptation to the reality of the sector-defining events having been made patent by the Royal Decree-Law 2/2013 [10]. Urgent measures were adopted in this Royal Decree-Law to ensure the financial stability of the power system. This has been an important measure in the reform process of the electricity sector, because it includes a mandate to the Government to approve a new legal regime for existing installations of electricity production from renewable energy sources, cogeneration and waste. This mandate refers explicitly to functioning principles of special regime applicable to these facilities on terms that have been subsequently incorporated into Law 24/2013 [12] about the Electricity Sector, and which are developed by this Royal Decree. Both rules assume one of the fundamental principles collected from their original wording in the Law 54/1997 [5], namely that the payment systems that are articulated must allow such facilities cover the costs needed to compete in the market on a level of equality with the rest of technologies.

From a technological perspective the regulatory development has been, after a first phase of design and implementation, the support for the commercialization of decentralized renewable energy production technologies. This progressive shift towards decentralized energy production means numerous advantages, such as the use of local energy sources, greater security of the local power supply, shorter transport routes and minor losses in the transmission of power. Such decentralisation also promotes development and the cohesion of the community, providing sources of income and creating jobs at the local level [13].

RENEWABLE ENERGY MIX FOR OPTIMIZATION OF THE POWER INSTALLED

As described in the beginning of this article, the justification of our work is supported by the need of adaptation of the regulatory regime and legislation in the energy field. This adaptation considers the real potential of generation and energy consumption, as well as the resources available with the minimum economic impact.

To reach this adaptation a single scenario that will provide optimal results does not exist. It is necessary to join all criteria to create a set of alternatives and supplementary solutions.

For the realization of this study, Spain's energy production and economic data have been considered to obtain an optimized model of electricity production. A full year data (2014) concerning demand for power and prices, according to the current legislation through electrical network of Spain, have been taken for this research [14].

Known data on prices and production allow us to validate the production model, which would not be feasible through the values got from prediction tools.

After this first assumption, it is necessary to study the availability and potential of the different renewable resources for their integration into production and energy consumption curves.

Table-1 shows the classification of technologies and resources based on their capacity factor in Spain at the end of 2013 [14]. It is related to technologies leading towards a scenario of generation using renewable resources. They have reached a total installed power several times higher than expected in Spain by the most optimistic estimations made several years ago.

Table-1. Classification of technologies and resources and their capacity factor. Spain 2013.

TECNOLOGY	Installed Power (MW)	Generated Energy (GWh)	Capacity Factor
Solar Thermal	2.300	4.853	71,90%
Wind Power	22.949	55.767	61,73%
PV Azimuth	4.711	8.258	85,57%
Biomass	658	3.789	71,98%
Hydroelectric	19.650	36.780	50,84%
Biogas	223	907	50,84%
Waste	276	595	26,95%

The capacity factor of a power plant is the ratio of its output over a period of time to its potential output if operation continuously over the same period of time were possible. The capacity factor should not be confused with the availability factor of the power plant, as the amount of time that it is able to produce electricity over a certain period, divided by the amount of the time in the period. Figures-1 and 2 below show the evolution of the renewable energy mix in Spain for the last two decades.

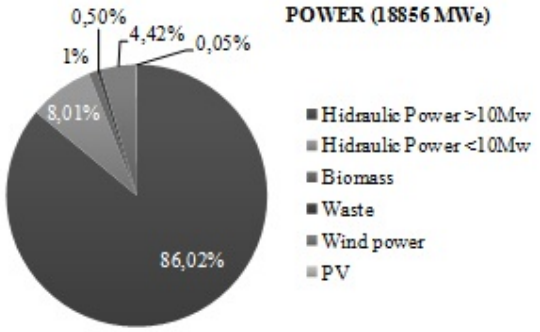

Figure-1a. Evolution of renewable installed power (1998).

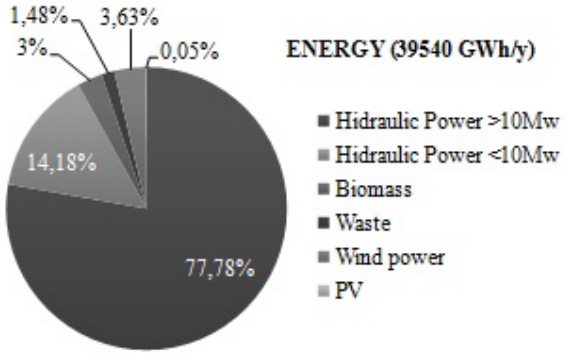

Figure-1b. Evolution of renewable generated energy (1998).

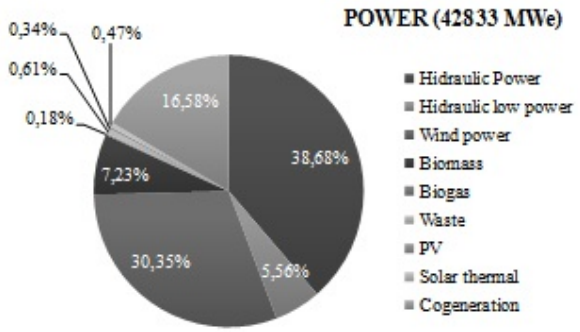

Figure-2a. Evolution of renewable installed power (2008).

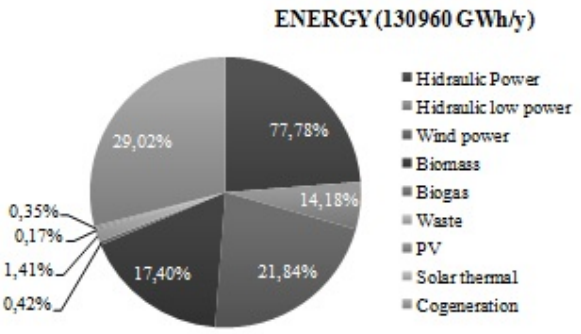

Figure-2b. Evolution of renewable generated energy (2008).

This energy mix has been the product of the incentive of generation facilities without attention to their capacity factor, by which the power of renewable energy installed must correspond with an energy generation of equal magnitude. This production would give real answer to the requirements of energy demand of the national power grid.

Thus, starting from a roof of generation shown in Figure-3, which marks the limits on the availability of renewable resources, the model of energy mix that is proposed in Figure-4 corresponds to a balanced distribution between installed power, energy resource available, energy generated and real demand of the set of consumers connected to the network [14].

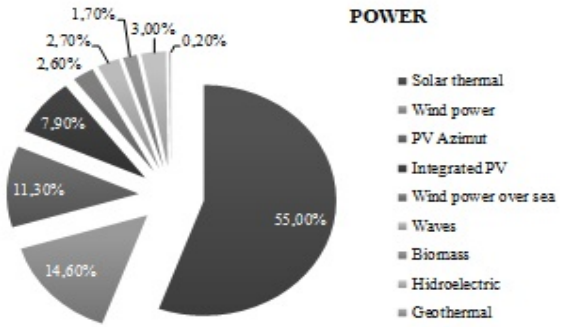

Figure-3. Potential of generation for renewable resources [14].

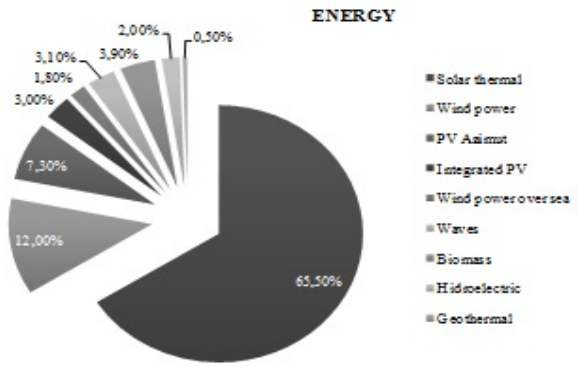

Figure-4. Proposal for a technological mix (supply 100% of the total energy demand in Spain) [14].

Here it can be observed how the strengthening of solar plants concentration would increase the capacity factor of the set of technologies through renewable resources to cover 55% of the installed power, as well as 100% of the electrical power demand.

STATUS OF THE LEGISLATION FOR THE OPTIMAL DEPLOYMENT OF CONCENTRATING SOLAR THERMAL PLANTS

Implantation, Pay-off periods, and Influence of the Regulation in the Development of Plants CSP

According to the current normative frame described above, it is possible to receive the incentives during the regulative useful life of the generation plant. Additionally to this, economical compensation for the sale of the energy valued at the cost of the market can be received. A specific payment covers the investment costs for every installation type that could not recover by the sale of the energy on the market. A different compensation to the operation covers the difference between the costs of development and the income for the market share of production of the above mentioned installation type.

For the calculation of the compensation to the investment and from the compensation to the operation it is considered to be (for an installation standard type) the income by the sale of the energy valued at the cost of the market, the standard costs of development necessary to do the activity, and the standard value of the initial investment. This is carried out by an efficient and well-managed company. There a set of remunerative parameters is established, approved by order of the Minister of Industry, Tourism and Commerce, for each facility type [13]. It is able to segment the facilities according to its technology, electrical system and power. The costs or investments for administrative acts are not considered. In the same way, only the activity of the production of electricity is considered in the Spanish territory.

The remuneration to the investment and to the operation allows, according to the current Spanish legislation, to cover the increased costs of the facilities of production from renewable energy sources, high-efficiency cogeneration and waste, so that they can compete on equal terms with other technologies and be able to obtain a reasonable return on investment.

With this legislation, the concept of reasonable pay-off on project is introduced. This concept is related with the obligations of the State for ten years in the secondary market, preceding the start of the regulatory period increased with a differential.

In order to reduce the uncertainty about the price of energy in the market upper and lower limits are defined to this estimate. These limits are applied in the calculation of the parameters restorative that directly affects the reward obtained by sale of the energy generated. When the average annual price of the daily and intraday market falls outside these limits, a positive or negative balance (calculated on a yearly base) is generated. This balance is called value adjustment for deviations in the market price and is compensated along the power plant life.

The previously summarized legislation has brought a dynamic implementation and use of renewable resources that, in less regulated scenario, would follow a different path, as shown in the Figure-5. Here it can be seen that the Spanish legislation enables the intensive development of power with renewable sources, especially CSP plants, although this development was not accompanied by the appropriate capacity factor, getting a lower power production than expected.

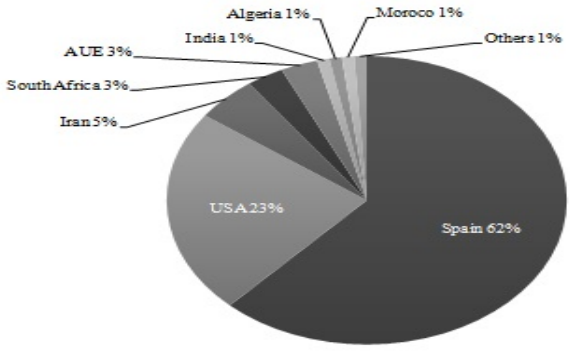

Figure-5. Power distribution for CSP plants around the World [14].

Once the regulatory systems of lower economic support was implanted, the power plants owners have chosen to improve their capacity factor by taking advantage of the available technology and implementing measures. Thermal storage is an option to accommodate the curve of production to the demand for electricity as shown in Figure-6.

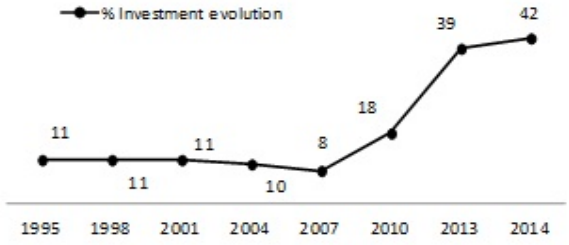

Figure-6. Evolution of thermal storage investment [14].

The new law on the electricity sector [12] develops the principle of economic and financial sustainability of the system where the ability to meet all costs is referred. The electrical system revenues and costs are defined. It also establishes two fundamental principles: on the one hand, the revenues of the system will be sufficient to meet the entire cost of the electrical system. On the other hand, to keep the costs and income roofs, every regulatory measure in relation to the electricity sector (involving an increase of costs for the electrical system or a reduction in revenue) should incorporate other items of cost reduction or an equivalent increase of income to ensure the balance of the system. This new law sets a single regime of energy production with facilities to improve regulation, while establishing a specific remuneration scheme for generation by renewable resources.

Operation Cost and Feasibility of Exploitation in non-regulated Systems

The requirement for competitive concurrency procedures for renewable energy power plants, as well as the promotion of these technologies in the market on an equal condition with the rest of technologies, comes from EU guidelines and policies to support the renewable energy and to protect the environment.

The incentives of this regulated market, until its disappearance, have been established through the market operator, with a base rate and lower and upper limits on this basis depending on the premiums.

In Figure-7 the general structure of operation and players in the national electricity market is shown, including the participation of producers in regulated regime of remuneration (e.g. plants of concentrating thermal generation in high temperature) [12].

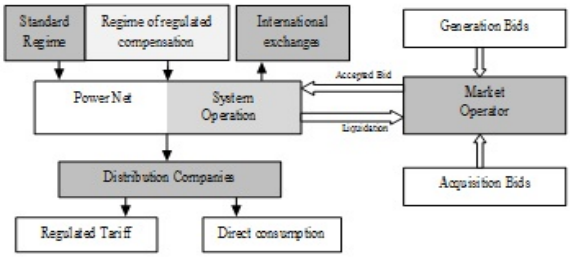

Figure-7. Participation in the Spanish electricity market [12].

In this market system, the producers are entering the market for purchase and sale of energy with the same technical restrictions, although with sale priorities for the producers of energy from renewable resources established from the different rules of the market operator and the state legislation in this area.

For concentrating solar plants, in addition to the market factors, another can be found that influences the operation and improvement of the economic viability of the plant. The use of storage technologies and oversizing of solar fields allows us to match the production of electricity and the solar resource available to the energy demand and the selling price.

After the study of structures, components and modes of operation for CSP plants, it is necessary to evaluate this option for the optimization of energy production. For this analysis a basic model of simulation has been created by using SIMULINK V2010 simulation tool in the MATLAB R2010a programming environment. A summary of the results of simulation of implantation and production options are shown in table 2. These results, as well as the operating conditions, will allow to draw conclusions about the suitability of direct operation, thermal storage, and sale of electricity. Different production options depend on the change of the rules of production, which have forced CSP plant operators to optimize the production according to the dynamics of the plant to consider the sale of energy in either free market (prices vary depending on generation and demand) or regulated market with stable prices and improvable benefits.

Through a system of plant structural simulation [15] comparisons can be made in economic operation of plant and results in terms of constructive parameters, sizing and operation strategies. In Figure-8 a functional model of the plant and process of simulation used for this evaluation is shown.

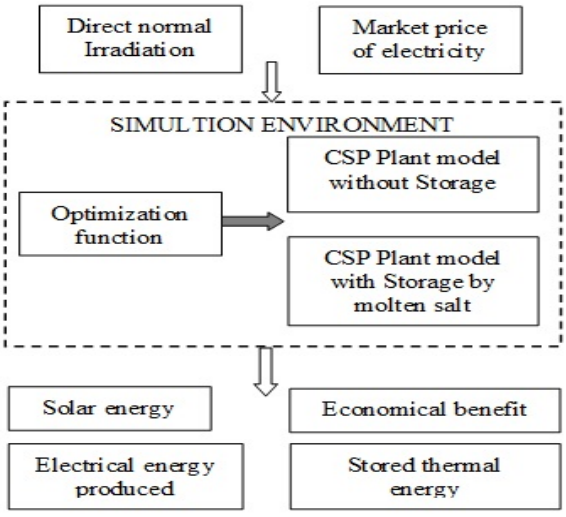

Figure-8. Functional model for CSP Plants [15].

With this process of simulation, we can get a set of results of production and economic viability that, aided by the legislation in the field of sustainability and incentive to production using renewable resources, show the scene of feasibility of different technologies for CSP plants.

After simulation of solar thermal plant and its integration in the power net, it is possible to show the highlights as a summary of our results and its adaptation for CSP plants to the optimal model for energy production.

Table-2 shows the comparative results of production for different options for the construction of a CSP plant, direct production without storage, storage direct thermal and thermal storage tanks by fluid [15].

Table-2. Numerical results for three options of thermal management: Double Direct Tank, direct production of electricity without storage and Increased Overflow Tank.

CSP plant with 7h TES	
Energy (GWh)	3,668.32
Energy Value (Mio.€)	1,014.61
After Tax Cash-flow (Mio.€)	610.82

CSP plant without thermal Storage	
Energy (GWh)	2,884.33
Energy Value (Mio.€)	797.77
After Tax Cash-flow (Mio.€)	462.66

CSP plant with greater overflow tanks	
Energy (kWh)	3,527.82
Energy Value (Mio.€)	975.75
After Tax Cash-flow (Mio.€)	573.61

This analysis shows that the technology of thermal storage can raise the capacity factor of a plant increasing the production of electricity, as well as reduce their dependency on the incentives to production from established legislative entities and specific directives.

The technology of energy production from renewable resources and, in particular, the one used in CSP plants has technological maturity enough to adapt the generation of energy to regulatory states and needs of production and consumption in every country.

The detailed study of the needs of production adapted to the dynamics of energy consumption allows to integrate efficient production technologies; to help authorities in the adoption of incentive measures that do not punish the production; to reduce dependencies of limited resources; and, finally, to promote more sustainable patterns of energy production.

The example of production and development policy in Spain, commented throughout this work, can serve as an example of a result of greater sustainability through an improved regulatory road production. This model and its changes have meant a weaker technological development as well as better sustainability, as shown in the Figures 2 and 5 on current state and forecast in the medium term.

CONCLUSIONS

This work has analyzed the legislative developments toward deregulation as the optimization option of the energy production factor in the Spanish sector of renewable energy, and its origin in the European directives.

The liberalization of the market of electric power has been developed with economic support where the technologies used for the generation of installed power from renewable sources have not observed availability criteria of renewable resources and efficiency in electricity production expected. This phenomenon has led to the creation of an energy mix with oversized power factor and reduced production, given the scarcity of renewable resource for generation.

This study, with the optimization of this mix through the change of generation technologies, has shown the way of attaining an efficient generation that meets the demand for electric power. Contrary to the initial conception of the renewable energy model, photovoltaic technologies have not offered a capacity factor according to the existing energy needs.

To get the optimization of the energy mix from renewable sources, prominence be given to the introduction of concentrated solar thermal power plants with storage technology. This kind of generation offers higher regulatory power and adaptation, with lower costs of production and operation, thus improving the economic viability of the investment.

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