UNIVERSIDAD PONTIFICIA COMILLAS

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

OFFICIAL MASTER'S DEGREE IN THE ELECTRIC POWER INDUSTRY

Master's Thesis

THE COST OF REDUCING CO_2 EMISSIONS BY INCENTIVIZING THE USE OF RENEWABLE ENERGY IN THE SPANISH ELECTRIC SECTOR

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Abstract

Renewable energy has become a key instrument to obtain the environmental objectives set by the European Union due to its contribution to Greenhouse gases emissions reduction. This research work quantifies the cost of reducing emissions as a result of the incentives received by wind and solar technologies in Spain. An ex-post analysis is applied to the period 2005-2013 based on a cost/benefit comparison. To calculate the incentives pay by the government to generators has been followed the methodology introduced by the Royal Decree 413/2014. All the costs and savings from the generation side are divided by the amount of CO2 emissions offset to obtain an economic value per ton. The results reveal that the cost of reducing emissions does not differ greatly from the EU ETS price in the case of wind technology while solar technology is out of the range of any possible price. The cost of incentives to wind energy could be justified by its substantial contribution to environmental goals at a reasonable cost.

Resumen

La energía renovable se ha convertido en un instrumento clave para lograr los objetivos medioambientales fijados por la Unión Europea debido a su contribución a la reducción de las emisiones de gases de efecto invernadero. Este trabajo de investigación cuantifica el coste de reducir emisiones como resultado de los incentivos recibidos por las tecnologías eólica y solar en España. Para ello, se aplica un análisis ex-post al período 2005-2013 basado en una comparación de coste/beneficio. Para el cálculo de los incentivos pagados a los generadores por el gobierno, se ha seguido la metodología establecida por el Real Decreto 413/2014. Todos los costes y los ahorros incurridos en la actividad de generación se dividen por la cantidad de emisiones de CO2 evitadas para obtener un valor económico por tonelada. Los resultados revelan que el coste de reducir las emisiones no difiere en gran medida del precio en el ETS de la UE en el caso de la tecnología eólica, mientras que la tecnología solar fotovoltaica está fuera del alcance de cualquier precio posible. El coste de los incentivos a la energía eólica podría ser justificado por su importante contribución a los objetivos medioambientales a un coste razonable.

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Table of contents

Chapter 1. Introduction 7
1.1. Research objective 8
Chapter 2. Problem statement 10
2.1. Electricity system in Spain 10
2.1.1. Energy efficiency and renewable energy penetration in Spain. 11
2.1.2. Capacity installed and electricity generation 14
2.1.3. Evolution of renewable energy in Spain 16
2.2. Regulatory framework of Renewable energy 18
2.2.1. Regulatory framework of Renewable energy in Europe. 18
2.2.2. Regulatory framework of Renewable energy in Spain 20
2.3. Renewable energy: energy potential and main characteristics (costs and cost savings associated to renewable generation) 24
2.3.1. Costs associated to renewable generation: Balancing and cycling costs. 25
2.3.2. Benefits associated to renewable generation: Fuel and carbon savings 28
2.3.3. Other effects associated to renewable energy 29
Chapter 3. State of the art 31
3.1. RES-E support mechanisms for Renewable energy in the EU 31
3.1.1. EU electricity sector framework 32
3.1.2. Support instruments to renewable technologies in the EU Member States 35
3.1.3. Effeticveness of support policies 51
3.2. Literature Review 53
Chapter 4. Methodology 56
4.1. Data base description 57
4.1.1. Facilities included in the Royal Decree 661/2007 58
4.1.2. Facilities included in the Royal Decree 1578/2008 58
4.2. Data treatment 60
4.2.1. Estimation of the remuneration obtained by generators 61
4.2.2. Additional costs and cost savings estimation 65
Chapter 5. Results 68

Chapter 6. Conclusion and further research 75
6.1. Conclusion 75
6.2. Further research 77
Annexes 78
Annex 1. Classification of the installed capacity 78
Annex 2. Calculation of the annual retribution to generators.. 94
Bibliography 103

Table of figures

Figure 1. Wind production relative to installed wind capacity………………………...25

Figure 2. Wind power generation variability…………………………………………..26

Figure 3. Wind forecast error, Spain (02/11/08)……………………………………….27

Figure 4. Wind forecast evolution, 2005-2008………………………………………...27

Figure 5. CCGT starts in a six week period……………………………………………28

Figure 6. Renewable energy injection effect on the wholesale market………………...30

Figure 7. Comparison between annual remuneration and equalized remuneration……64

Figure 8. Evolution of annual and equalized remuneration for wind energy…………68

Figure 9. Evolution of the annual and equalized remuneration for solar energy………69

Table of Graphs

Graph 1. Evolution of primary energy consumed in Spain by source, 1990-2012…….12

Graph 2. Evolution of the final energy consumption by source, 1990-2012…………..13

Graph 3. Evolution of the internal energy production……………………………......14

Graph 4. Spanish peninsula electricity demand coverage, 2013…………………........14

Graph 5. Installed capacity in Spain, 2013…………………………………………..16

Graph 6. Evolution of renewable energy in Spain……………………………….......17

Graph 7. Annual wind and solar capacity additions, Spain 2001-2012……………..….23

Graph 8. Share of renewable energy in gross final energy by country……………..….33

Graph 9. Gross electricity generation from renewable energy sources, EU-27 1990-2011……………………………………………………………………….…………34

Graph 10. RES support levels by main technology and country, 2011………………..….35

Graph 11. Policy effectiveness for onshore wind power in the period 2004-2010…....52

Graph 12. Effectiveness of RES-E support policies by technology, EU-27…………...52

Graph 13. GHG emissions by country, 2011……………………………………………...53

Graph 14. Evolution of CO2 emissions allowances price…………………….....……53

Graph 15. Cost and avoided costs per tCO2 reduced by wind technology……………72

Graph 16. Cost and avoided costs per tCO2 reduced by solar technology…………..…72

Graph 17. Cost and avoided costs per MWh generated by wind technology…………73

Graph 18. Cost and avoided costs per MWh generated by solar technology…………..73

Graph 19. Evolution of EU ETS allowances prices vs. cost of reducing emissions through incentives……………………………………………………...…………….74

Table of Tables

Table 1. Premium to renewable, combined cycle and waste technologies…………......18

Table 2. Generation capacity in the EU, 1980-2010…………………………………...32

Table 3. Support mechanism to RES in the EU………………………………………..39

Table 4. Level of FiT in Germany……………………………………………………...40

Table 5. ROCs/MWh in UK……………………………………………………………43

Table 6. Italy's renewable electricity quota obligations………………………………..46

Table 7. Fee paid by consumer regarding to the grid level in Austria…………………49

Table 8. RES-E support instruments by country and technology in UE………………50

Table 9. Displaced generation, and CO2 emissions and fuel avoided……………......66

Table 10. Annual and equalized remuneration for wind energy……………………....68

Table 11. Annual and equalized remuneration for solar energy…………………...…..68

Table 12. Costs and avoided costs associated to wind and solar technology………...70

Table 13. Cost of reducing CO2 emissions by wind and solar generation……………71

Chapter 1. Introduction

To encourage the expansion of renewable technologies, Spain has performed an investing effort in subsidizing the installation of new renewable capacity. A *Feed in Tariff* support scheme based on a fix rate or market price plus a premium has been developed to attract investors by assuring a certain level of profits. The Spanish government has shown a strong commitment with these objectives.

In this framework, it becomes necessary to analyze the implications of this new energy generation mix, the needs imposed by the system as balancing requirements and their influence on the overall market.

The severity of the problem of climate change has led countries to find solutions to fight global warming. The Kyoto Protocol was a first step to control greenhouse gases, providing a basic framework for action to reduce GHG (Greenhouse gases) emissions. It forced many industrialized countries to implement policies and institutions necessary to achieve emissions reduction. The main objectives set by the European Union on the electricity sector are the reduction of CO2 emissions and the promotion of renewable energies through economically sustainable measures. In Europe the most used options to achieve these goals are: RES-E Support Schemes (Renewable Energy Sources - Electricity Support Schemes) and EU ETS (European Union Emission Trading System) (Saenz de Miera et al., 2008).

Agosti and Padilla (2010) argue that, although the Spanish system, resulting from those incentives, can be considered effective in general by encouraging participation of these technologies in the national electricity mix, it has not been sufficiently effective since the subsidies received are very high in relation to production costs.

Delgado (2013) maintains that promotion incentives to renewables could be justified by the inadequacy of the price of CO2 to promote alternative energy sources. Moreover, he proposes that the premium should be linked to the price of CO2, so that the higher the CO2 price is, the lower the premium received by RES generators (or when the CO2 reaches a certain price).

In this line, to study the level of equivalence between both schemes and the efficiency of renewable technology in emissions reduction it will be obtained the cost of reducing CO2 emissions using incentive mechanisms to renewable energy.

The study is set in Spain due to its position as one of the leading countries in renewable energy support and penetration degree into the generation mix of the country, and focused in wind and solar energy for the significant growth experienced by them. It will follow the methodology used by Marcantonini and Ellerman (2013).

Regulatory framework: Renewable energy in Spain

The Law 54/1997 established a subsidiary system, Special Regime, to support the development of renewable energy. Its regulation has undergone substantial changes over the years. As part of the implementation of the Law 54/1997, the Royal Decree 2818/1998 established a mechanism by which special regime generators could sell their power to the distributor in their area. Subsequently, regulation has been approved to improve the efficiency of the remuneration system applied to renewables, and control the production and investment in new plants.

The development of the Royal Decrees 436/2004 and 661/2007, not only allowed the access to electricity networks to new facilities but also, through a dual system of rates and production premium, encouraged the significant investments that have been produced in the generation of renewable energy since that time. However, the economic problems facing by the country during the last years, have made necessary the introduction of new more restrictive measures. Currently, it has being developed a new Royal Decree for 2014 which eliminates the premium system for renewable energies and replaces it by a fee-based investment standards and operating costs and introduces a reduction in the incentives perceived by renewables technologies.

1.1. Research objective

In the definition of energy policy should be included the environmental objectives that renewable contribute to meet as well as the costs derived from adopting this new technology. To this end, we consider the possibility to generate an economic value associated to the reduced emissions equivalent to the total price of carbon tons not emitted traded in the current carbon market.

Thereby, the aim of this study is to assess the efficiency of the deployment of renewable energy in Spain regarding to the reduction of emissions achieved by them and the cost associated to it. In addition, this cost is compared to the allowances price in the EU ETS.

Chapter 2 provides an overview of the Spanish electric sector, the role of renewable energy in the system and the evolution of the regulation. Chapter 3 reviews the support mechanisms to renewable energy applied in the EU and the previous literature related to emissions reduction and the costs associated to it. The methodology applied in the study is explained in chapter 4 and the results obtained are shown in chapter 5. Chapter 6 presents the conclusions and further research recommendations.

Chapter 2. Problem statement

This chapter presents the situation of the Spanish electric system, especially the evolution of renewable energy sources and their contribution to demand coverage. The regulatory framework where this evolution has taken place is analysed in section 2.2. Section 2.3. explains the cost and cost savings associated to renewable energy.

2.1. Electricity system in Spain

Historically, domestic energy production has been predominantly based on coal and hydro. After the eighties, nuclear power grew significantly and renewable energies improved its position since the mid-nineties. The commitment of the country to meet the objectives established by the European Union for 2020 (to reduce a 20% greenhouse emissions regarding to 1990 levels, to increase the percentage of renewable energy sources in the final consumption up to a 20% and to improve in a 20% the energy efficiency) has contributed to the development of renewable energy. Between 1990 and 2010, it was achieved a great diversification of Renewable Energy Sources (RES), becoming the principal investment destination of the country with an increment of 58% during that period (APPA, 2012). Due partially to the international economic situation, renewable energies and natural gas units have been able to reduce the gap regarding conventional energy sources (fossil fuel and coal).

Given the lack of competitiveness of renewable energy compared to conventional energies, governments have been forced to support the renewable sector (Sevilla Jiménez et al., 2013). Thus, Spain became the country offering a major level of support to this sector surpassing even Germany not only in the degree of penetration in the energy mix of this technologies (about 30%) but also on the average cost of such support (Sallé Alonso, 2012).

2.1.1. Energy efficiency and renewable energy penetration in Spain.

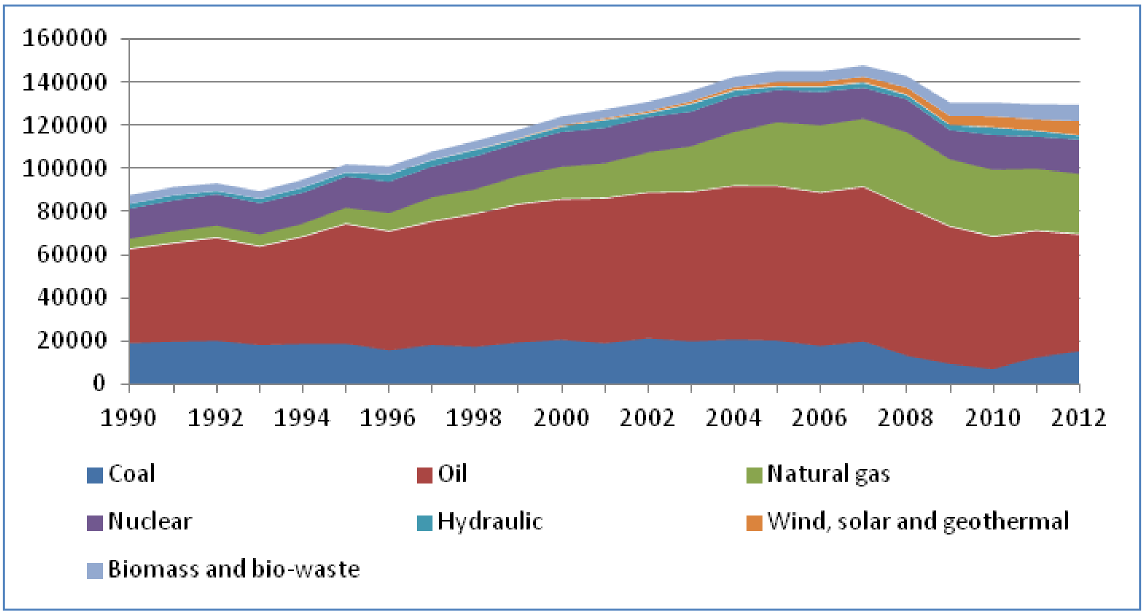
The national energy demand has experienced an increase in the diversification of energy sources according to their structure in the past decades. This transformation is particularly evident from the second half of the ‘90s when energy sources such as natural gas and renewables began to gain prominence against products that had been usually presented in the Spanish energy supply such as oil and coal. Graph 1 illustrates this evolution.

In 2008 and 2009, the effects of the crisis are reflected on the primary energy demand which fell by 8.56%, keeping a constant and downward trend. In 2012, the demand fell by 0.76% over the previous year (MINETUR[1], 2012). This result contributed to the decline in oil consumption (7.08%) and natural gas (2.57%), which together accounted for 64.3% of the demand. This decrease has been largely offset by the increased consumption associated to carbon (17.92%), renewable energy (7.57%) and nuclear (6.31%), whose demands accounted for 36.4% of the global demand.

During 2012, although the hydraulic availability decreased compared to the previous year, the contribution of other renewable energy sources shows an upward trend, especially in the case of wind and solar energy, whose contributions to primary energy demand were increased respectively by 15.8% and 77.9% (MINETUR, 2012).

[1] Ministerio de Industria, Energia y Turismo de España/Industry, Energy and Tourism Ministry of Spain

Graph 1: Evolution of primary energy consumed in Spain by source, 1990-2012 (ktep[2])



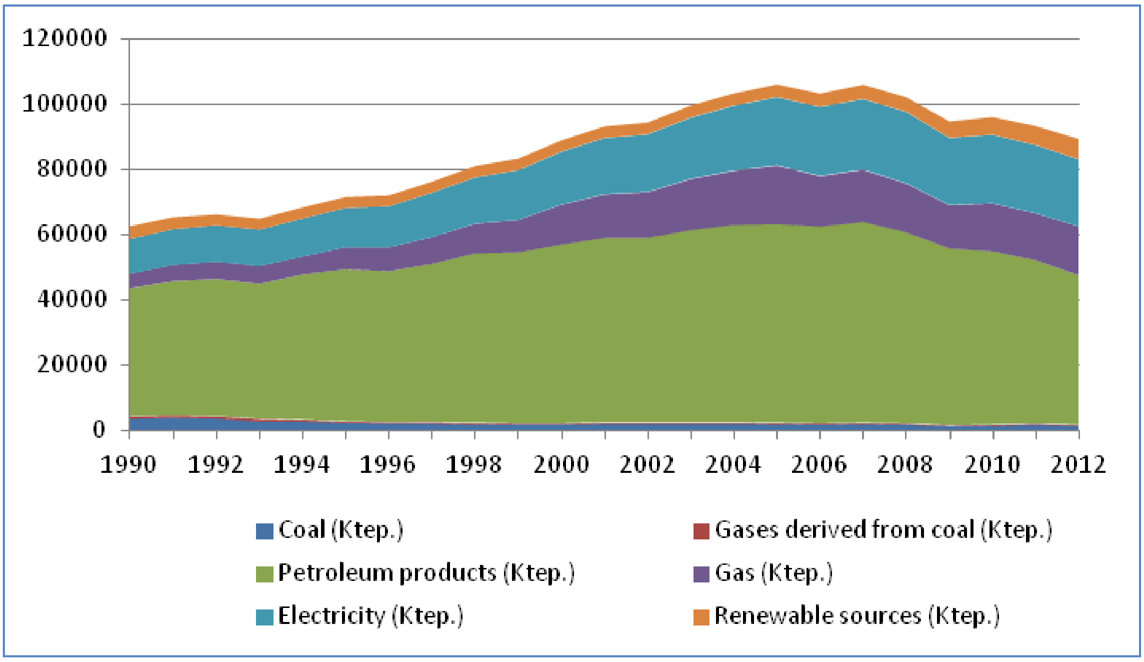
Source: own elaboration with data from MINETUR

In terms of final energy, almost all energy sources experienced a retracement of its final demand, except for renewable energy and natural gas which increased their demand by 9.38% and 6.41% respectively in 2012. Electricity is the second most consumed final energy behind petroleum products as shown in Graph 2.

Regarding renewable energy sources, all the technologies represent improvements with exception of biogas. In relative terms, it is included biofuels, geothermal and solar thermal energy for being the facilities with the highest activity recorded.

[2] 1 Mwh = 0.086 tep

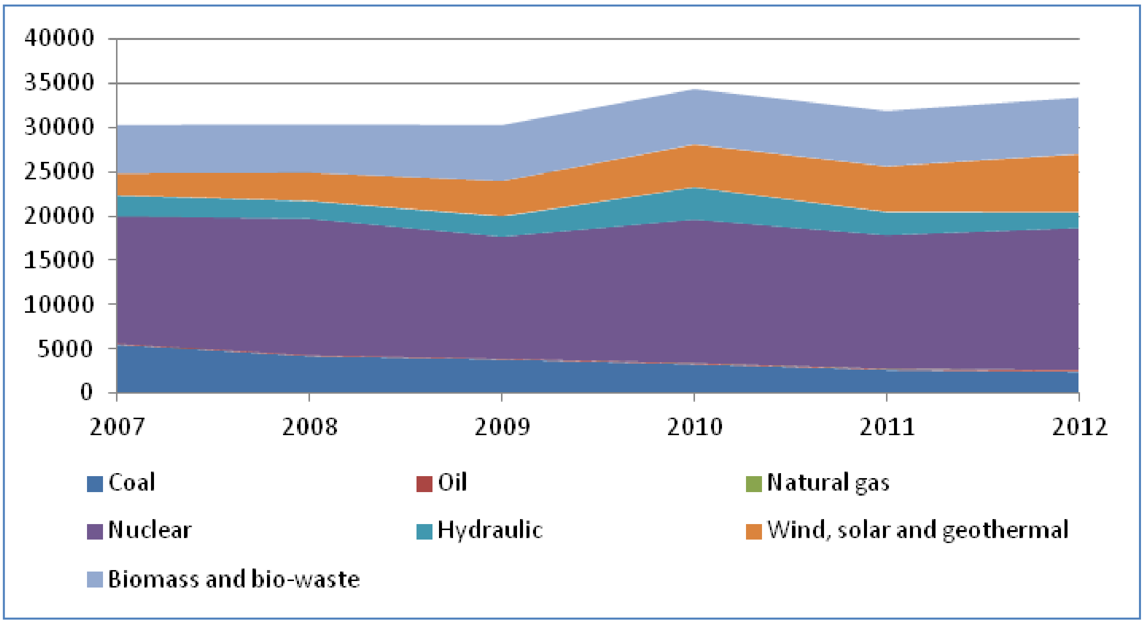
Graph 2: Evolution of the final energy consumption by source, 1990-2012



Source: own elaboration with data from MINETUR

Historically, one of the factors that have limited the economic development of Spain has been the shortage of energy resources which has led to a high dependence on foreign energy. However, it is remarkable the evolution that has been observed since 2007, coinciding with a significant increase of the renewable energy in the primary energy consumption. Graph 3 shows the evolution of the energy generation by type of source in the Spanish system.

Graph 3: Evolution of the internal energy production (ktep)



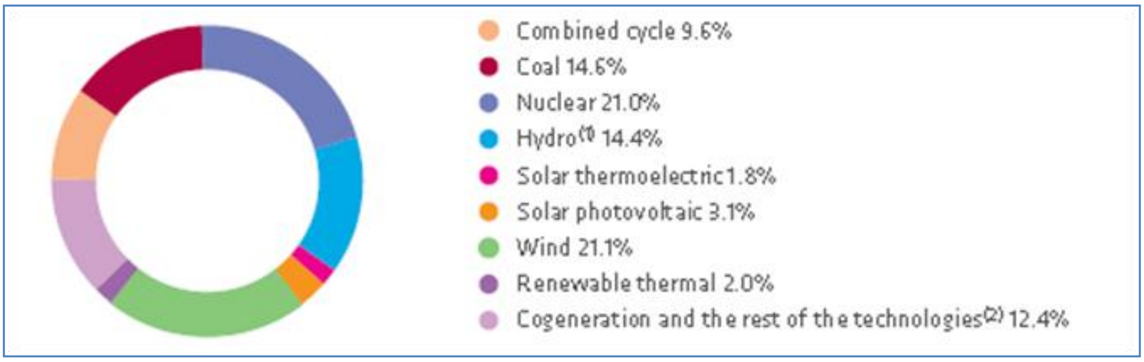
Source: own elaboration with data from MINETUR

2.1.2. Capacity installed and electricity generation

Wind energy has been the main source of energy in Spain, ahead of nuclear in 2013. It represented a 21.1% of the total energy produced last year.

According to the transmission system operator (REE), renewable sources continue its positive development. By the end of 2013 they represented a total of 42.4% of the coverage of the electricity demand, 10.5% more than in 2012. Graph 4 shows the participation of each technology in the coverage of the electricity demand in Spain.

Graph 4: Spanish peninsula electricity demand coverage, 2013



Source: REE (2013): "Preliminary report: The Spanish Electricity System"

The technology with a major presence in the Spanish system is natural gas combined cycles which represented a 24.8% of the total installed capacity in the country. It is followed closely by wind technology (22.2%) and hydro (19.4%) as shown in Graph 5.

In 2013, there were 1,325 wind facilities with an installed capacity around 22,800 MW, representing 58% of the total renewable energy, cogeneration and waste capacity, and an energy fed to the system of 48,328 GWh in 2012 (50% of the energy generated by renewable sources, cogeneration and waste). Although wind farms have been installed continuously from 1994 to the present, more than 70% were commissioned in the last decade in terms of capacity.

In the case of combined cycles, the capacity installed were 5,963 MW (15% of total renewable sources, cogeneration and waste capacity) with 985 power plants in 2013 and an energy produced of 26,782 GWh in 2012 (22% of the total energy generated by renewable sources, cogeneration and waste facilities).

Photovoltaic facilities reached an installed capacity of 4,600 MW (12%) with 60,000 plants in 2013 and 8,160 GWh of generated energy (8%). In 2008, the commissioned facilities experienced a greater increased with more than 2,600 MW.

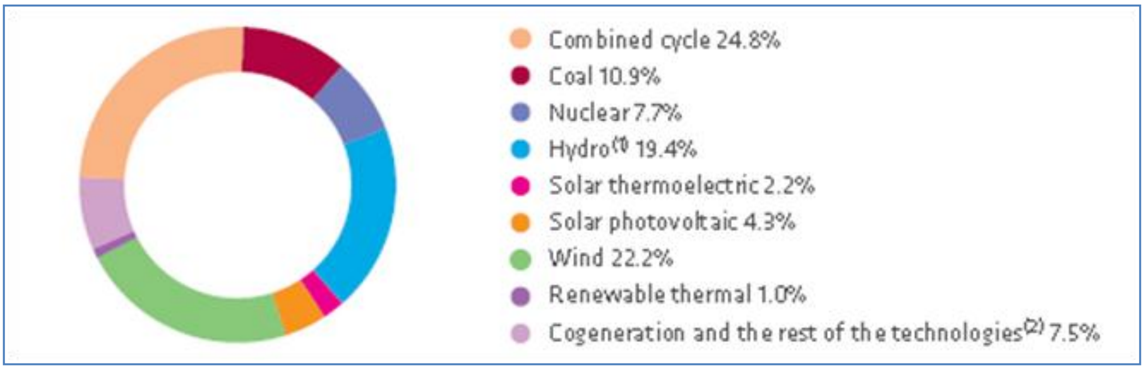
Solar thermoelectric power plants accounted for 50 installations with a capacity installed of 2,300 MW in 2013 (5.8%). In 2012, they generated 3,433 GWh (3.3%).

The hydro power plants included in the Special Regime[3] were 1,000 with a capacity installed of 2,070 MW in 2013.

Biomass power plants accounted for a capacity of 519 MW (1.3%) with 63 installations in 2013 and an energy produced of 2,678 GWh (2.7%).

[3] The concept of Special Regime is explained in section 2.2.2.

Graph 5: Installed capacity in Spain, 2013



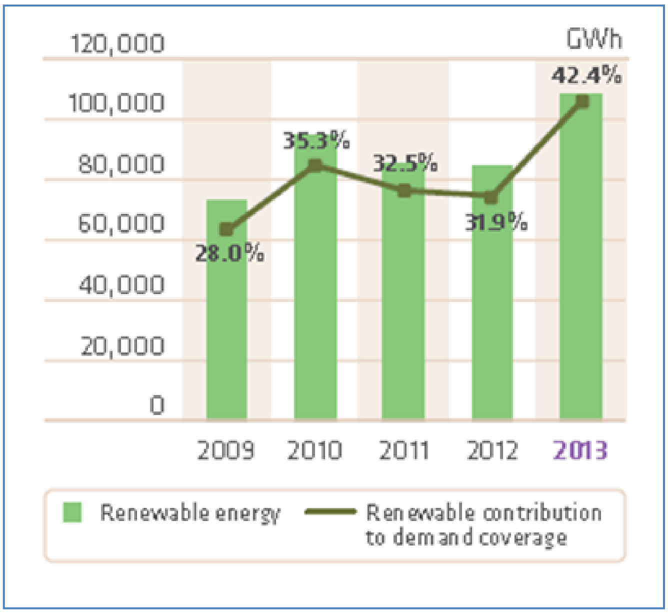
Source: REE (2013): "Preliminary report: The Spanish Electricity System"

2.1.3. Evolution of renewable energy in Spain

The spectacular growth of the Renewable Energies (RE) in Spain has contributed to achieve the environmental objectives as well as to decrease the energy dependence from conventional forms of generation. The path followed by Spain has been considered as an international reference model due to the level of RE deployment achieved.

Renewables have doubled their participation in the last five years (as shown in Graph 6), together with the increase in natural gas which have resulted in a reduction of oil energy sources achieving a greater diversification.

Graph 6: Evolution of Renewable energy in Spain



Source: REE (2013): "Preliminary report: The Spanish Electricity System"

According to PANER 2011-2020 the development of renewable energy has been a priority for the Spanish energy policy in recent years to meet its objectives for the energy sector regarding efficiency improvement, lowering the dependence on foreign energy and reducing greenhouse gas emissions.

Among the positive aspects of renewable energies it can be included the sustainability of their sources, reduced level of emissions and the possibility of moving towards distributed generation. As said before, wind generation has taken the lead to nuclear. This fact, together with the increase of the production of nuclear power plants and hydropower, has been a significant reduction in greenhouse gas emissions. Last year, emissions reached 61.4 million tons, 23.1% less than in 2012. However, renewable technologies also have higher development costs than conventional technologies and which are very different. Moreover, wind technology is shown as the only one that can be competitive with conventional technologies.

Regarding to the support received from the government, from 1998 to 2013 the economic incentives to electricity production facilities from renewable energy sources, cogeneration and waste amounted up to more than €50,000 million. This figure increased by more than 800% since 2005 until 2013 where the premia for such plants reached about €9,000 million. Table 1 displays the quantities paid by the government per year.

Table 1: Premium to renewable, combined cycle and waste technologies (billion of €)

<2003	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013[4]
2,000	1,017	1,209	1,054	1,394	2,522	3,338	6,214	7,067	6,985	8,639	9,000

In 2012, combined cycle power plants received €1,961 million, photovoltaic plants accounted for €2,600 million, €925 million for solar thermoelectric, €2,000 million were obtained by wind facilities, hydro got €200 million and biomass perceived €240 million[5].

The premium for these technologies have been substantially financed by electricity consumers through their bill. In addition, from the 1st of January 2013 a portion of these costs for the promotion of renewable energies are financed by the State Budget.

2.2. Regulatory framework of Renewable energy

This section reviews the policy implemented by the European Union and Spain in relation to renewable energy, especially the evolution of the Spanish legislation and its consequences.

2.2.1. Regulatory framework of Renewable energy in Europe.

The European Union has made a significant commitment to renewable energy as a solution not only to the high emissions of greenhouse gases but also as a necessary measure to reduce energy dependence.

In 2001, it was approved the first directive on renewable energy, Directive 2001/77/EC of 27th of September, on the promotion of electricity produced from renewable energy sources in the electricity market. This Directive fixed the legal basis to increase up to 12% the share of renewable energies in gross primary consumption in the EU and 22.1% with respect to the contribution of these technologies to power consumption in 2010. This overall target of 22.1% resulted in national indicative targets

[4] Estimated premium for 2013
[5] According with data from the Industry, Energy and Tourism Ministry of Spain

for all Member State and in the case of Spain it was set a share of 29.4% of electricity from renewable energy sources for 2010.

In 2009, The European Union adopted the Directive 2009/28/CE which established the national objectives and the guidelines for their achievement. The package on Renewable Energy and Climate Change forced the 27 member countries of the European Union to meet the 2020's targets:

- Reducing emissions of greenhouse gases by 20% regarding to the values of 1990.
- Increasing energy efficiency by 20% over the baseline evolution.
- A 20% of gross final consumption in the EU must come from renewable sources.

This proposal emphasizes on efficiency measures and energy savings and includes a set of legislative tools to achieve the goals of promoting renewable energy and meet the Kyoto Protocol embraced in the United Nations Convention on Climate Change, as well as other European and international commitments. To ensure the accomplishment of these objectives, Member States were required to develop national action plans on renewable energy including information on the objectives set by sector and the support mechanism to be applied to each technology. Moreover, Member states had to establish either a priority access or a guaranteed access to the grid system of the electricity produced from renewable energy.

In 2013, it was announced a new package of measures to face the tough situation for the electricity companies and the challenge of increasing the competition level of the industry. Its aim was to reduce the support level to electrical generation since it represented €60,000 million in 2011 (€26,000 million for fossil fuels and €30,000 million to renewable sources)[6]. The European Commission appealed for a higher market exposure for renewable energies and a reform of the market.

In April of 2014, The European Commission adopted a new regulation for the incorporation of future renewable projects in the Member states which will be enter in force in July 2014. The new regulation opts for a gradual introduction of market

[6] Source: " Europa ultima su reforma: Cambia la retribución de las renovables" Available at: <http://www.eleconomista.es/interstitial/volver/carmpc/energia/noticias/5280203/11/13/Europa-ultima-su-reforma-Cambia-la-retribucion-de-las-renovables.html#.Kku8rJTZnV14J5a> Retrieved on 20th April 2014

mechanisms for renewable facilities considering that some technologies are ready to be integrated into the electricity market. It proposes that public support to the less competitive renewable energies will be through tendering processes. Some countries such as France have already applied auction mechanisms for solar power plants.

Furthermore, the package establishes the substitution of the Feed-in tariff (FiT) system by Feed-in premium to make renewable facilities more responsive to market signals and avoid extra costs (already applied in countries such as Germany, France, Portugal and UK).

Another goal of the EU is the designing of a "Single European Energy Market" and increasing the energy exchanges between countries. The energy exchange represents one of the main issues to integrate renewable energy in Europe[7]. To promote the competitiveness of the European industry, the European Commission has determined that sector with a high energy consumption will be exempt of paying the fees to the promotion of renewable energies included in the electricity bill in several countries (e.g. some companies in Germany do not pay this fee[8]).

The new rules will be applied progressively, with a pilot phase between 2015 and 2016 in which Member States may try these new tendering procedures for aid to RES on a small part of its new electricity production capacity. From 2016 it will be applied generally, although the Member States have leeway to take into account national peculiarities[9].

2.2.2. Regulatory framework of Renewable energy in Spain

Characteristics of facilities subject to the special regime

Under the denomination of Special Regime it is covered a set of generation technologies that have in common the use of inexhaustible renewable energy sources,

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[7; 3] Source: " La Comisión Europea adopta nuevas reglas sobre la incorporación de las renovables" Available at: <www.pv-magazine-latam.com/noticias/detalles/articulo/la-comisin-europea-adopta-nuevas-reglas-sobre-la-incorporacin-de-las-renovables_100014853> Retrieved on 26th of April 2014

[9] Source: "Bruselas aprueba nuevas reglas que restringirán las ayudas públicas a las energías reovables" Available at <www.europapress.es/economia/noticia-bruselas-aprueba-nuevas-reglas-restringiran-ayudas-publicas-energias-renovables-20140409150248.html> Retrieved on 29th of April 2014

residues from different production processes or the exploitation of the combined production of heat and electricity with high energetic performance.

Although at the first stage (seventies) these technologies were promoted based on their autochthonous nature and the imported fuel savings associated, subsequently they have been promoted on the grounds that they all have in common a reduced environmental impact because they do not emit greenhouse gases (CO2) (or it is not emitted more than the pre-set in the fuel in the case of biomass). It has also been incorporated into this Regimen those technologies that reduce the environmental impact using either polluting substances as fuel (e.g., industrial waste incinerators) or using different technologies to treat and reduce waste (e.g., sludge treatment plants).

Historical review

The Special Regime was established with the Law 82/80 of Conservation of Energy for the development of small renewable energy installations and high energy-efficient plant, which regulated two basic aspects: the right to sell surplus energy to the grid and at statutorily defined prices.

The Royal Decree (RD) 2366/94 established that the facilities could give their surplus to the nearest power distribution company which must acquire it compulsory when it was technically feasible. The selling price of this energy was fixed based on the electric rates depending on the capacity and type of installation.

In 1997, it was approved the Law 54/97 of the Power Sector which established the possibility for producers covered by the Special Regime to incorporate their surplus energy to the system or to participate directly in the production market. In the first case, the facilities perceived the final average market price plus a premium. In the second case, besides of the premium, they perceived the hourly marginal price plus a compensation for the guaranteed power and ancillary services that might correspond to them. They were also charged if the case, the cost of deviations between the energy matched in the market and its actual production.

The effective commitment to support renewable energy took place after the approval of the RD 2818/1998 whereby a tariff for each type of technology consistently in a fixed premium over the market price of electricity. The adoption in 1999 of the Development Plan of Renewable Energy and the approbation of the Royal Decree-Law

(RDL) 6/00 of 23rd of June introducing a requirement for facilities of RD 2366/94 with a capacity over 50 MW to participate in the production market, supposed a major involvement in the final production of energy of these technologies. This fact led to a change in the regulation by the RD 436/2004. Through this RD, producers were allowed to sell their production to distribution companies at a fixed rate or sell in the market at market price plus a premium or with greater incentives in some cases. As a result of this measure, most of the producers opted for the second alternative from that time as it meant larger subsidies to their generation (Sevilla Jiménez et al., 2013).

In 2005, it was approved the Renewable Energy Plan 2005-2010 (REP) to promote investment in new projects.

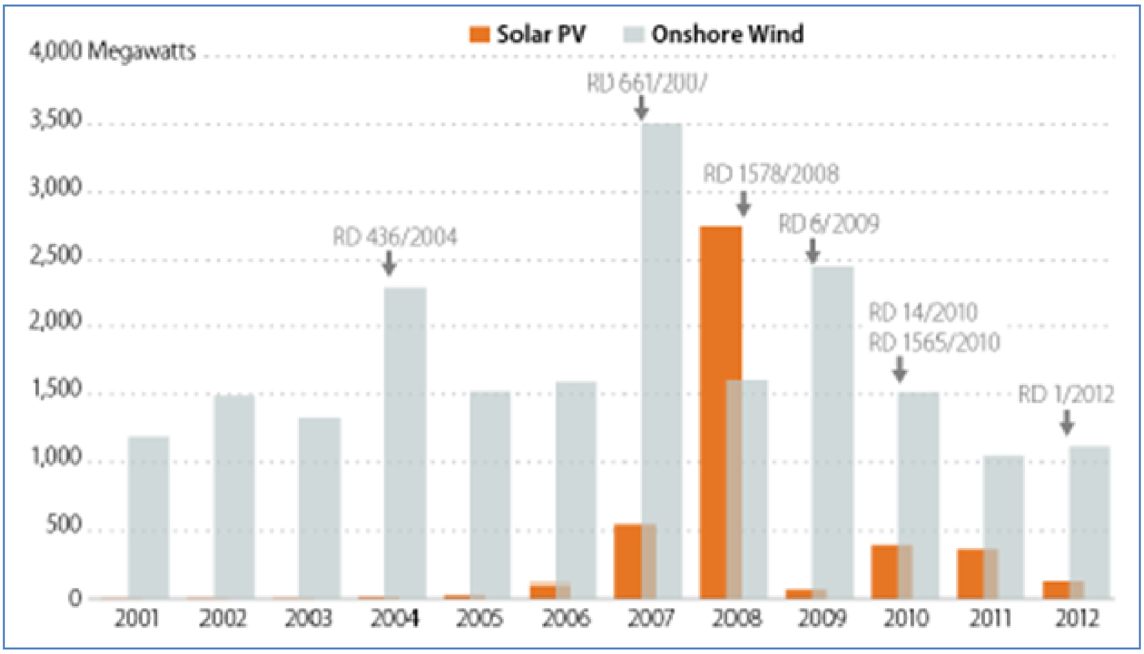
The RD 661/2007 of 25th of May which regulated the electricity production in the Special Regime, introduced higher subsidies to generators. The most significant change associated to this decree was that the premium was determined regardless of the market price, eliminating uncertainty about the price and facilitating the access for new projects. A common practice was to divide photovoltaic parks in sets of modules of low power to obtain greater remunerations (Mir, 2012).

This increase in the incentives, specially to photovoltaic technology (0.44038 €/kWh), led to a "boom" in the capacity installed which experienced an increase of 424% in 2008 reaching 3,207 MW in 2008. In the case of wind energy, it went from 13,529 MW in 2007 to 15,977 MW in 2008. This situation required the approval of the RD 1578/2008 to adjust the retribution system to lower levels (0.32 €/kWh for photovoltaic plants of type I.2).

Given the impossibility to maintain the existing support system due to the economic situation facing by the country, it was approved the RDL 1/2012 of 27th of January. It introduced the suspension of the pre-allocation procedure and the removal of economic incentives for new facilities for the production of electricity from cogeneration, renewable energy sources and waste in order to avoid new costs to the electrical system.

Graph 7 illustrates the effect of the Spanish policy on the progression of the capacity installed. It is observable the high decrease of photovoltaic capacity in 2009 due to the capacity limits and restrictions introduced by the government.

Graph 7: Annual wind and solar capacity additions, Spain 2001-2012



Source: Brown, P., 2013: "European Union Wind and solar electricity policies: Overview and Considerations", CRS Report for Congress.

Current situation

Currently, The Renewable energy sector in Spain faces a regulatory uncertainty. The Regulatory changes experienced since 2009 that aimed to reduce the remuneration of renewable energies, made it difficult for some technologies to compete in the market.

As mentioned above, in 2012 this situation became more severe with the approbation of the RD 1/2012. In the same line, it entered in force the RDL 9/2013 of 12th of July, which adopted urgent measures to guarantee the stability of the Spanish electricity market. It determined the basis for a new regulatory framework to allow to generation facilities from renewable sources, cogeneration and waste cover the costs to compete in the market on equal level with other technologies and obtain a reasonable return on profits[10]. Therefore, this RD established several aspect to be taken into account on the design of the retribution scheme for each type of technology: (1) the revenues from the sale of the energy generated valued at the market price; (2) the standard exploitation costs necessary to carry out the activity; (3) the value of the initial investment of type of installation. It encouraged a retributive regimen based on standard

[10] Average yield in the secondary market of the ten-year State bonds during the ten years prior to the entry into force of the RDL 9/2013 (the period between the 1st of July 2003 and the 30th of June 2013).

parameters regarding the types of installation determined for an "efficient and well-managed business".

The law 24/2013 of 26th of December, specified the criteria and revision procedure of the retribution parameters, setting regulatory periods with a duration of six years starting from the 12th of July 2012 (date of entry into force the RDL 9/2013).

The new regulation path has been reflected in the RD 413/2014 of 6th of June, for the regulation of the energy production from renewable sources, cogeneration and waste which will be applied retroactively.

In the new scheme, the retribution does not depend on the energy generated by the power plants but rather on the installed capacity. It embraces an incentive which will complement the revenues from the sale of the electricity into the market depending on the investment and operating costs incurred by the plant.

All the facilities included in the Special Regimen will be regulated by the new retributive system independently of the RD that covers them initially.

The National Market and Competition Commission (NMCC) estimate that the new retributive parameters would involve reducing the regulated revenues for all affected facilities around €1.7 billion in 2014[11].

2.3. Renewable energy: energy potential and main characteristics (costs and cost savings associated to renewable generation)

From the point of view of integration in the electrical system, the main feature of wind and photovoltaic solar technology is that its operation depends on the weather conditions at each area. These local weather conditions are extremely variable which made the generation also variable.

A consequence of this behavior is that the capacity factor of these technologies, the relationship between the energy produced over a period of time and the energy that would have been produced by the facility at full power during the same period of time,

[11] Source: <http://www.suelosolar.es/newsolares/newsol.asp?id=9306>

is low. In the case of wind generation the capacity factor is around 25% in the Spanish parks and about 20% for photovoltaic plants.

Renewable have several negative characteristics for its exploitation, such as:

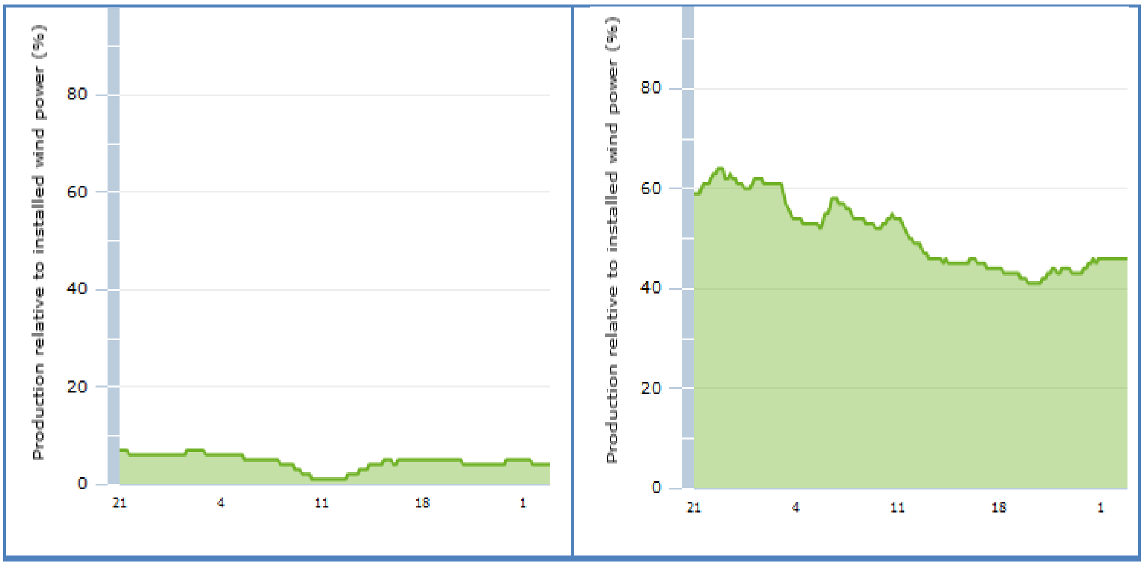
- Low intensity.
- Intermittency.
- Unpredictability.
- The factual impossibility of storage, unless they have undergone a transformation, such as biomass or hydro reservoirs.

2.3.1. Costs associated to renewable generation: Balancing and cycling costs.

The introduction of RES into the system brings unpredictability to power generation and as a consequence, additional balancing services to face forecast errors and a greater amount of reserves to assure the stability of the grid.

Figure 1 shows the variation of wind generation between two days with similar demand in Spain. The contribution to demand coverage on the 17th September of 2012 at 10:00 am was 1% while the 24th on the same month it was 37%.

Figure 1: wind production relative to installed wind capacity (%)

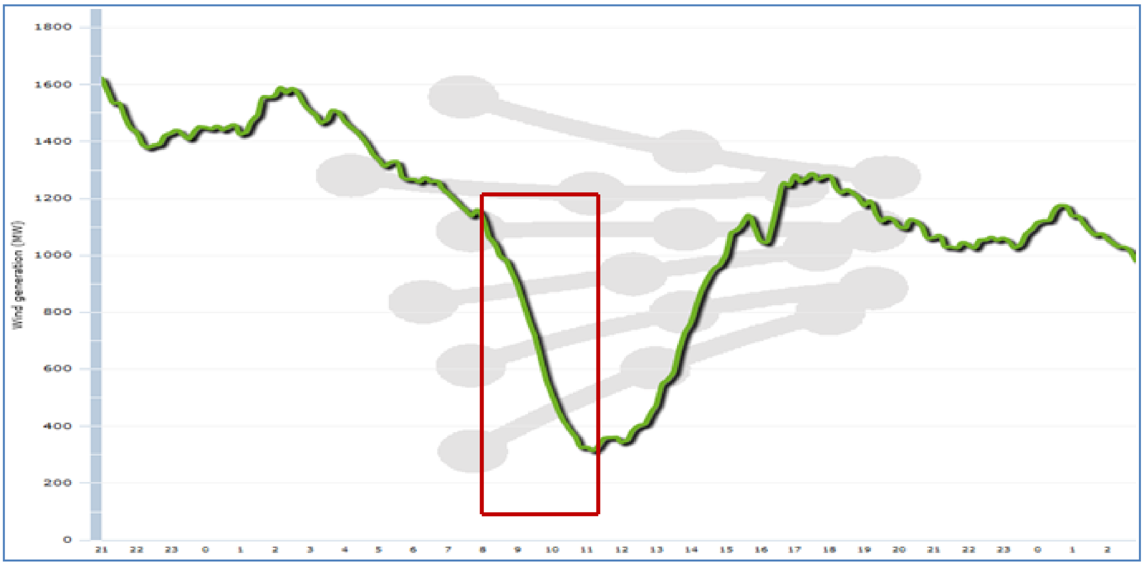


Source: REE

Flexible generation plants have to be kept in a state of readiness (Pérez-Arriaga and Batlle, 2012) adding costs and uncertainty into the system. Moreover, it may be needed conventional generators running at lower load to respond to the requiring upward/downward regulation.

Figure 2 illustrates the wind generation curve of the Spanish system during the 17th September of 2009. It can be observed a decrease in wind generation from 1,131 MW to 326 MW in 3 hours (from 8:00 am to 11:00 am).

Figure 2: Wind power generation variability



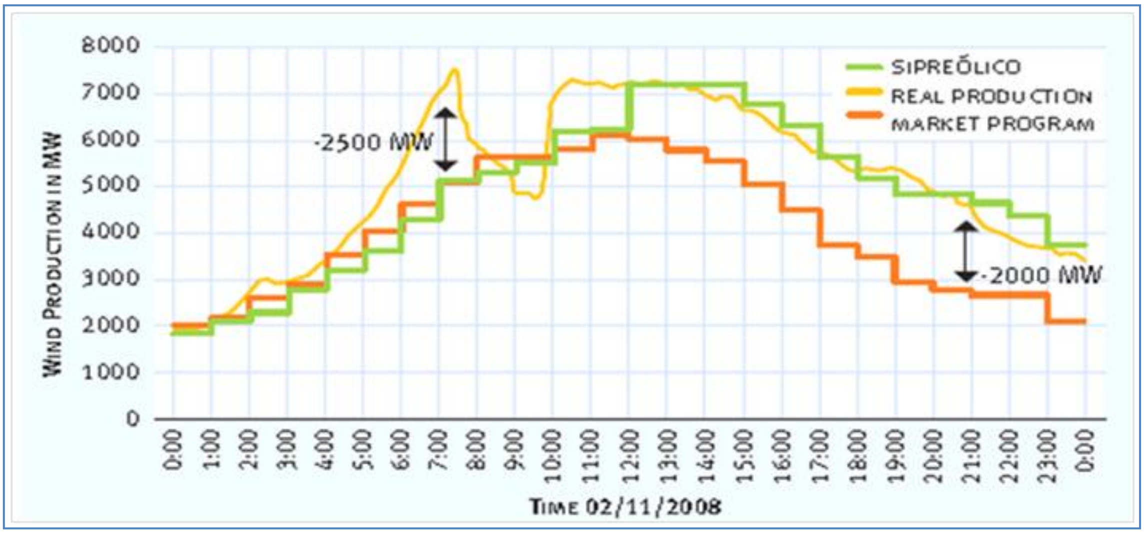
Source: REE

This situation reduces the efficiency of the plants compared to their use at full load and increase the operation and maintaining costs (Pérez-Arriaga and Batlle, 2012). A CCGT plant can experience a reduction in the efficiency level of 20% with a reduction in its load to 50%. Thus, in turn, increase the polluting level per MW produced of these facilities (Eurelectric, 2011). Although this argument is out of the scope of this study, it should be taken into consideration for future work on CO2 emissions avoided by RES injection.

The low predictability of wind energy and its lack of firmness, as well as high penetration levels of wind generation, increase the back-up capacity that needs to be available in order to keep the system in balance. Figure 3 presents a case of wind forecast error in the Spanish system which required to curtail wind generation. However, the forecast methods have improved along time encouraged by the RD

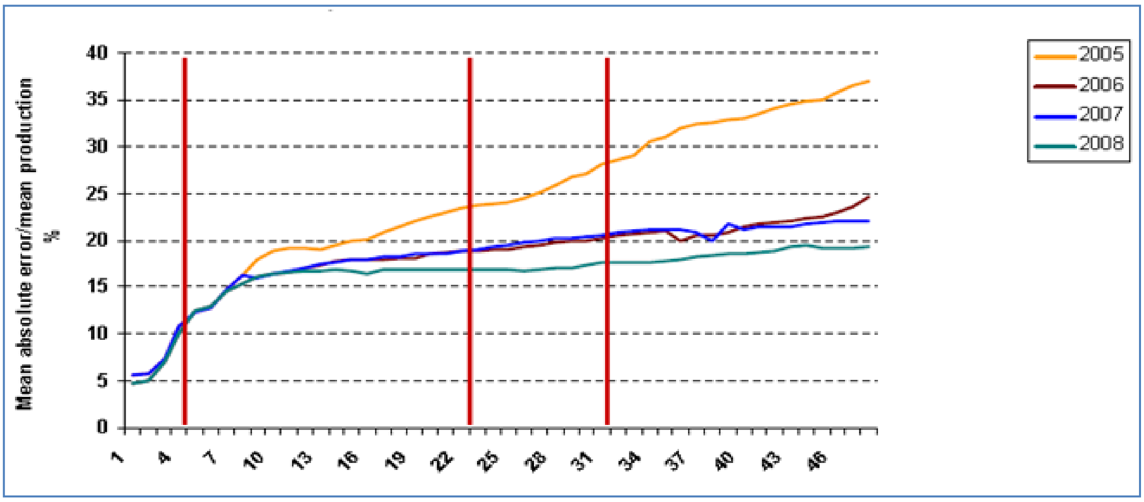
436/2004 of 12th March which established penalties for deviations to wind farms predictions. In Figure 4 can be observed the decrease on the forecast errors from 2005 to 2008.

Figure 3: Wind forecast error, Spain (02/11/08)



Source: REE

Figure 4: Wind forecast evolution, 2005-2008

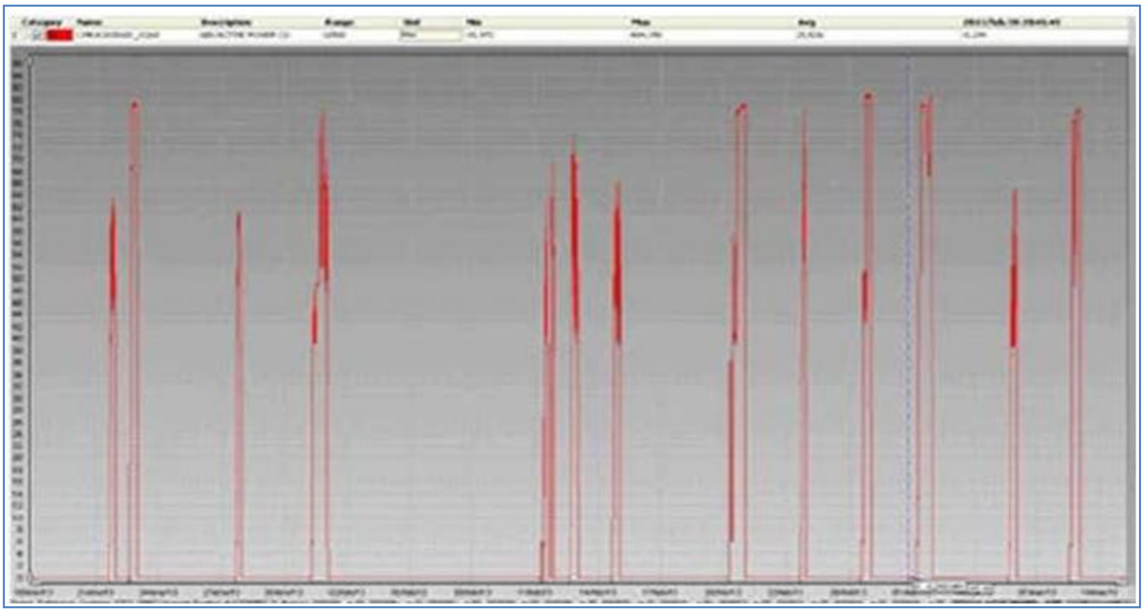


Source: REE

Beside of this improvement, on average only 2.5% of the wind capacity installed in Spain has a level of firmness of 95% and around 50% a level lower than 5%

(Eurelectric, 2010). The study of Eurelectric[12] about the impact of the integration of intermittent sources into the system claims that although RES incorporation in the generation mix contribute to avoid expenditure on fuel, it does not mean that the need to invest on firm capacity is displaced, being still needed investments in new plants. Moreover, the high level of intermittent and irregular generation of this type of sources increase the number of start-ups of conventional facilities which increment its operation and cycling costs. The lack of correlation between wind generation and demand and the priority of dispatch principle change the dispatching schedule of thermal facilities (Pérez-Arriaga and Batlle, 2012). Thermal units are forced to lowered their production or shut down, mostly during night when wind energy is higher, to be star-up just a few hours later and running for a short period of time. Figure 5 shows this effect in a six week period.

Figure 5: CCGT starts in a six week period



Source: UNESA

2.3.2. Benefits associated to renewable generation: Fuel and carbon savings

The reduction of CO2 emissions due to the introduction of RES into the system has been widely study in previous literature. It is accepted that renewable energy reduces greenhouse gas emissions that would have been emitted by conventional facilities otherwise. The quantity of the emissions avoided depend on the type of fossil

[12] Eurelectric (2010): "Integrating intermittent renewable sources into the EU electricity system by 2020. Challenges and solutions".

fuel generator displaced (Cullen, 2011; Luickx et al., 2009). Novan (2011) relates the amount of pollution avoided with the level of electricity demand in the Texas electricity market, introducing a location factor. The author argues that pollution varies depending on the location where the renewable generator is placed and the point in time in which it produces.

Abrell and Weigt (2008) explain that reducing the share of conventional power plants implies a reduction on emissions allowances demand and thus a decrease in emission costs in the EU ETS framework. Bräuer et al. (2001) maintain that support mechanisms such as Feed-in tariffs lead to an increase of RES's share and a reduction on emission allowances required, and therefore its price.

The quantity of fuel employed in generation also change with the introduction of RES generation into the system. The fossil fuel that is not longer needed to generate the electricity supplied by renewable facilities is considerated a cost saving to the system. This saving varies depending on the fuel price.

As mentioned before, thermal units suffer a detriment in efficiency due to the variability of renewable facilities. Thus, the consumption of fuel is higher than when they operate at full load as well as when the cycling increase (Denny, 2007).

2.3.3. Other effects associated to renewable energy

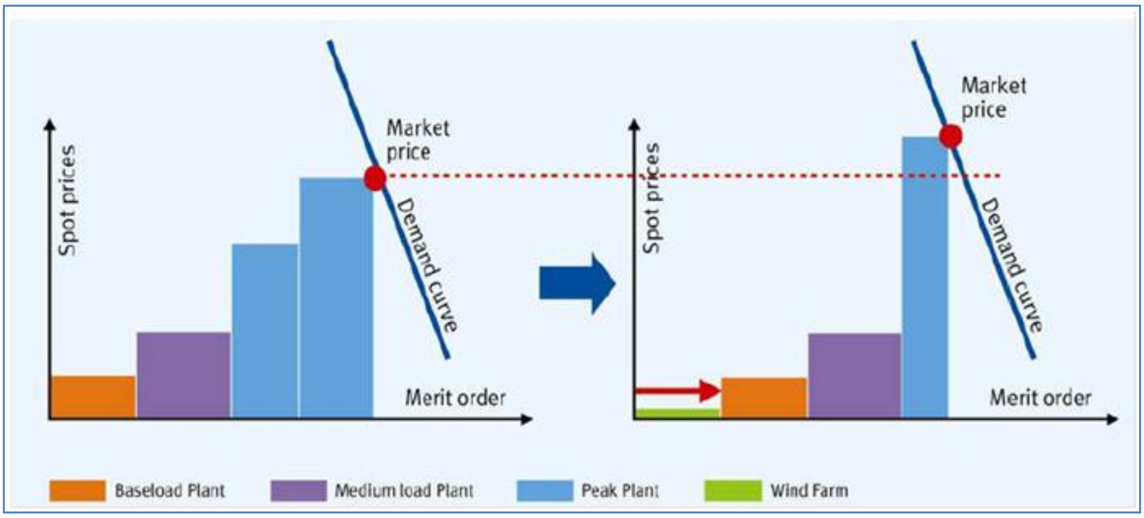
There are some relevant effects of RES injection beyond the generation activity that, although they will not be included in this study, need consideration.

It has been argued that generation with renewable energies implies a reduction on the wholesale electricity market price. The conventional energy that is displaced by renewable sources has a higher marginal cost associated which would rise the prices on the market.

In the electricity market, the price is fixed at the intersection point between the supply and demand curves in organized short-term markets. The supply curve conforms accumulating the generation bids in an ascendant order depending on their declared cost in a hourly basis giving priority on the dispatch to the cheaper plants. In this process, the plants with higher marginal cost will be pushed out of the market (Eurelectric, 2010) lowering the electricity price. In some cases, where the supply is higher than the demand, conventional facilities may be "forced" to bid negatives prices in order to keep running and avoid extra start-ups costs.

However, this effect is less significant in European markets due to the presence of a high number of CCGTs power plants which often set the hourly marginal price (Pérez-Arriaga and Batlle, 2012). Furthermore, the increase on start-up costs due to the variability of renewable sources have to be recover during few hours, increasing the marginal price of these technologies (Eurelectric, 2010). Figure 6 illustrates this effect on the market price.

Figure 6: Renewable energy injection effect on the wholesale market



Source: Eurelectric (2010)

Some studies have argued the role played by renewable energy in the development of the economy of the country through the contribution of the sector to the GDP. The study carry out by the Institute for Diversification and Energy Saving (IDAE) in collaboration with Deloitte (2011) finds a positive impact and an annual growth from 2005 to 2009. Another impact assessed has been the contribution of renewable energy growth to the employment rate of the sector obtaining positive results and to security of supply decreasing dependency from importations.

Chapter 3. State of the art

This Chapter reviews the support mechanisms for renewable energy sources applied by the European Union's Member States and previous literature related with the cost of reducing emissions by implementing these instruments. Section 3.1. describes the European electric frame, the different promotion instruments applied by European counties and their efficiency. Section 3.2. is devoted to previous research works.

3.1. RES-E support mechanisms for Renewable energy in the EU

Governments' participation is necessary in the initial phase of implementation of renewable forms of energy to ensure its development and to protect them from direct competition from conventional technologies. This government support can be justified for the presence of market and regulatory failures: deficient internalization of negative externalities resulting from the use of fossil fuels and the need to stimulate technical change (Menanteau et al., 2003). Its optimal performance in terms of cost and reliability will be achieved gradually as a result of the learning process with their implementation (learning by doing) (Dosi, 1988). Hence the need for the establishment of a promotion system that allows solving their disadvantaged position compared with other technologies in the system. The European Commission also points out an unfair competition with other fuels in the form of subsidies for fossil fuels and nuclear energy[13].

About a 20.4% of the EU gross electricity generation came from renewable sources in 2011[14] (increasing a 50% between 2000 and 2011). National promotion policies have enabled this growth. EU electricity markets and utilities are changing as a result of the EU's policy goals, especially to reach the EU's 20 % renewables and greenhouse emissions reduction targets by 2020.

[13] See Commission staff working documents SWD (2013) 439 final report.
[14] Source: Eurostat, 2013: "2013 monitoring report of the EU sustainable developnment strategy" Available at: <epp.eurostat.ec.europa.eu> Retrieved on 11th April 2014

RES facilities have experienced a considerable deployment since the nineties and are the largest area for investment in terms of capacity.

3.1.1. EU electricity sector framework

The available capacity of renewable electricity generation has increased significantly over the last 20 years. Wind power capacity had already begun to increase rapidly in the late ‘90s and from 2005 there was a boom in solar generation capacity. Additional capacity increases for other renewables sources were much more modest than for these two.

As mentioned above, solar and wind generation are intermittent energy sources and their utilization rate is much lower than for those renewables used in conventional thermal power stations (as well as compared with fossil fuels and nuclear power). Pumped-storage hydropower plants can be reliably used to deal with surplus electricity generation from intermittent sources. However, the capacity of pumped-storage hydropower plants did not increase at the same rate as solar and wind. The evolution of the renewable energy generation capacity is displayed in Table 2.

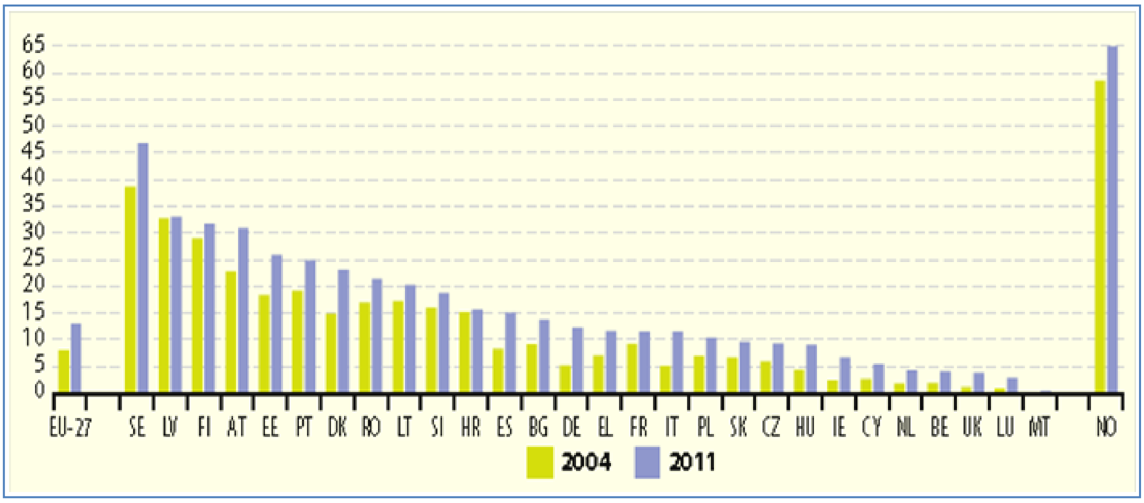
Table 2: generation capacity in the EU, 1980-2010

	1980	1990	2000	2007	2008	2010
Hydro	101,589	119,317	128,875	133,182	134,162	152,464
Solar	0	4	90	4,818	10,176	22,588
Geothermal	432	502	604	698	702	706
Wind	4	502	12,747	55,731	64,013	83,355
Biogas	0	230	991	3,36	3,86	3,681
Biomass	932	1,448	3,16	9,18	9,711	12,208
Waste	5	746	3,152	3,968	5,679	4,529
Other	354	453	649	324	169	222
TOTAL RES capacity	103,316	123,382	150,268	211,262	228,472	279,753

Source: Eurelectric

In 2011, the share of renewable energy of the EU represented a 13% in the gross final energy consumption becoming the world's biggest renewable energy investor. Graph 8 shows the share that renewable energy represents in the final energy consumption, ranging from 46.8% in Sweden to 0.4% in Malta.

Graph 8: Share of renewable energy in gross final energy consumption by country (%)

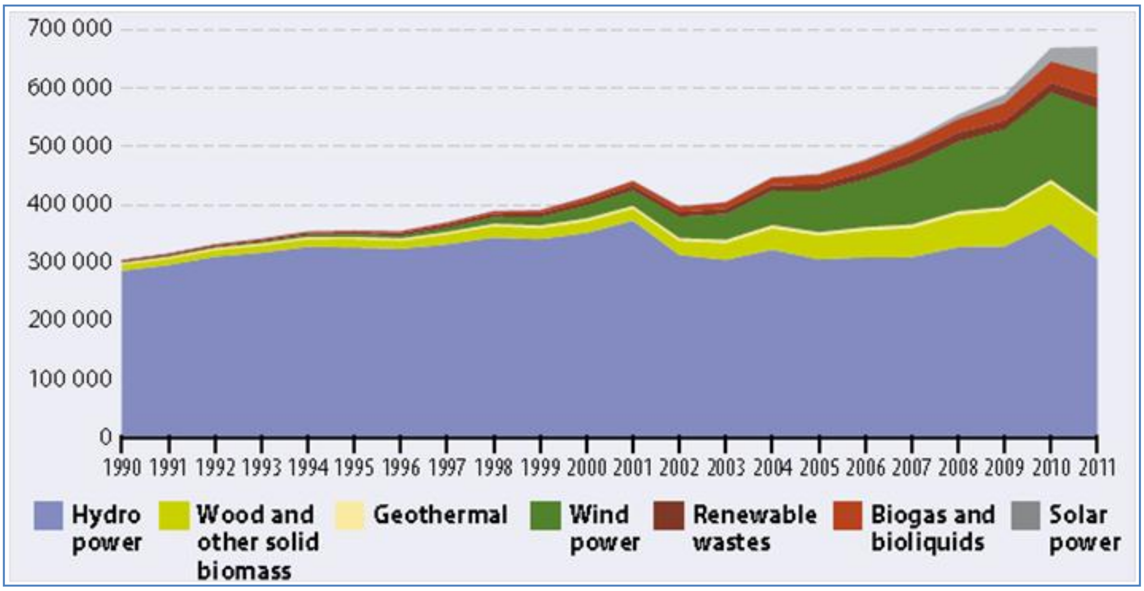


Source: Eurostat (online data code: tsdcc110)

Hydro generation represents the largest portion on the total renewable electricity generated in the EU with a 45.8%, wind generation reaches a 26.7%, biomass and biogas contributes a 17%, solar energy a 6.9%, renewable wastes only account for a 2.7% and the smallest proportion is from geothermal energy with 0.9%. Wind power has showed the major growth during the last decade. The technological advance experienced by wind and solar installations has allowed these technologies to start being economically viable without subsidies, where conditions are propitious[15]. Graph 9 illustrates the evolution of the share of renewable energies on the electricity generation in the EU-27 from 1990 to 2011.

[15]Eurostat, 2013: "2013 monitoring report of the EU sustainable development strategy" Available at: <epp.eurostat.ec.europa.eu> Retrieved on 11th April 2014

Graph 9: Gross electricity generation from renewable energy sources, EU-27 1990-2011 (GWh)



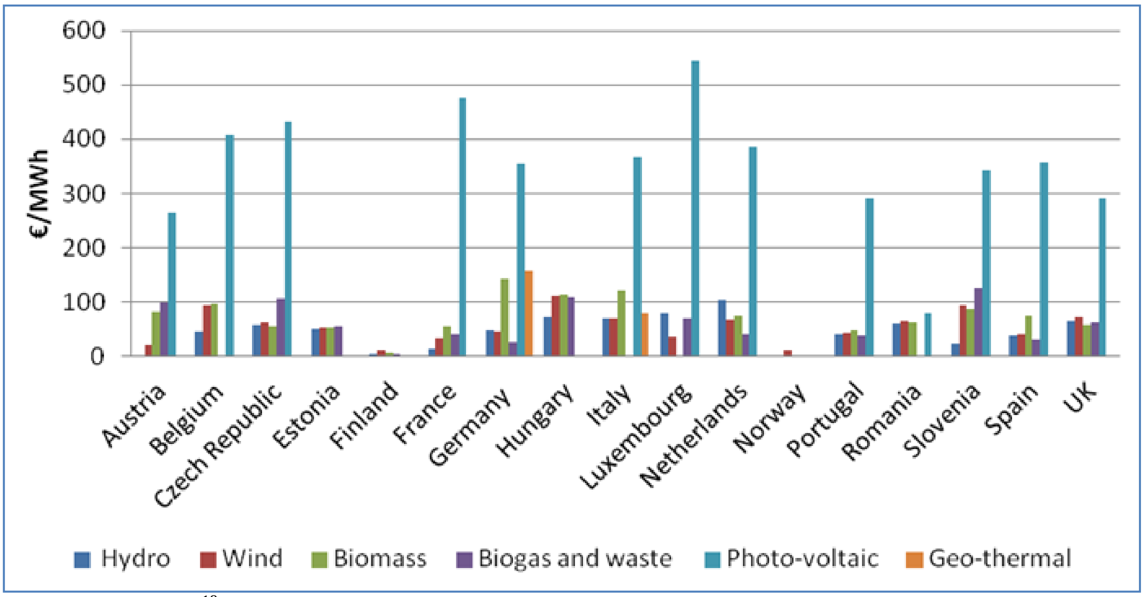
Source: Eurostat (online data code: nrg_105a)

Currently, all the Members States have implemented different mechanisms to support this expansion of renewable energies in Europe. However, the budget that each country has diverted to support actions vary across the EU. In Graph 10 it can be appreciated the unit support levels by technology for 2011. It has been obtained a considerable diversification of the power mix but the chosen path has not been the most adequate in some cases[16] and the level of development has been different in each country due to the regulatory uncertainty associated to some countries. Poor design and implementation of government intervention has led to avoidable distortions with regard to energy production, trade and investment in renewables[17].

[16] Euroelectric, 2013: "Power statistics and trends 2013" <www.eurelectric.org/power-generation/renewables> Retrieved on 11th April 2014

[17] See Commission staff working documents SWD(2013) 439 final report.

Graph 10: RES support levels by main technology and country , 2011



Source: CEER, 2013[18]

3.1.2. Support instruments to renewable technologies in the EU Member States

The RES-E Support Schemes are considered direct mechanisms to promote the deployment of renewable energy, while the instruments for reducing emissions as the EU ETS are considered indirect mechanisms which are focus on improve the long-term competitiveness of renewable energy making more expensive the fossil generation (Haas et al, 2011). In addition, mechanisms to support renewable energy can be directed to finance investment and reduce operating costs.

Similarly, the support mechanisms for renewable energy and emissions reduction can be classified into quantity instruments or price instruments: (a) quantity instruments indicate the amount of use of renewable energy or the emissions reduction that should be achieved, allowing the price to be determined by the market; while (b) price instruments are measures that fix the price perceived in the market exogenously (De Jonghe et al., 2009).

The regulatory treatment of renewable energies in the European Union's countries is not identical. The renewable energy capacity and energy mixes vary from

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[18] CEER, 2013: " Status review of renewable and energy efficiency support schemes in Europe" Availabla at: <www.ceer.eu> Retrieved on 2nd May 2014

one Member State to another which determines the required action to comply with the European guidelines. Therefore, the Directive 2009/77/EC allowed to each Member State to choose the support mechanism for renewable energy that best suited its characteristics.

A review of such measures in the EU highlights the establishment of six types of mechanisms: 1) feed-in tariff; 2) premium; 3) competitive auctions; 4) quota obligation and tradable green certificates; 5) fiscal incentives and investment grants; and 6) tax exemptions.

As mentioned, EU countries have implemented different mechanisms to support renewable production technologies with no consensus on which one is the most appropriate (Vera, 2012). However, it has been argued that a premium system ensuring an attractive ratio of returns for renewable installations is effective in promoting the expansion of renewable energies (García-Álvarez et al., 2012).

Germany was one of the first countries to design a legal framework to support renewable energy based on feed in tariffs and special conditions of access and connection to the network, achieving a significant penetration of these technologies in the energy mix. The Spanish and Danish support mechanisms are similar to the German and have also favored a spectacular development of these technologies in recent years. The good results obtained have turned these countries to be the main reference models in Europe. Greece and France have also adopted these instruments.

Other countries have chosen to establish a system of quota obligations or green certificates. Certificates are issued by the National Authority to generators of electricity from renewable sources creating a market between them and the suppliers of energy which can trade two commodities: electricity and the green certificates as an attribute of the environmental benefits associated with each MWh. UK was the first country to establish a market for green certificates but, despite these efforts, the results have not been as pronounced as in Germany, Denmark and Spain. Italy and Sweden have also chosen this quota system to exploit its renewable resources and meet the objectives of the European directive on renewables.

Types of renewable support mechanisms

- Direct support mechanisms

a) Feed in Tariff (FIT): generators from renewable sources receive a fixed price for the electricity produced instead of the electricity market price. This is the main support system in the European Union.

According to this system, generators of electricity from renewable sources have the right to sell all their production at a price already known (total regulated rate). Usually, the transmission system operator (TSO) plays the role of the buyer. In most countries where it is applied, the FiT payment is guaranteed for a period of time ranging from a minimum of 15 years and a maximum which coincides with the lifetime of the installation.

Investors have to face a lower risk since they receive a fixed level of support than using other systems.

This scheme is in force in countries such as Germany, Spain, Austria, France, Portugal, Greece Ireland, Luxembourg, Hungary, Bulgaria, Slovakia, Cyprus, Malta, Latvia and Lithuania.

b) Feed-in premium: Generators receive an additional return to the price of the kWh in the electricity market. The premium is based on expectations on generation costs of renewable energy. This system implies less certainty and a higher risk for investors than FiTs.

Denmark and the Netherlands use this scheme as the main support mechanism. Other countries such as Spain, Estonia, Slovenia and Czech Republic have adopted this mechanism in parallel to FiT (ECOFYS, 2011).

c) Green Certificates and quotas: This support system for renewable energy is characterized by the legal imposition on consumers, suppliers or generators, of the requirement that a certain percentage or quota of their electricity supplied or produced must come from renewable sources.

At the end of each period, usually one year, the parties obliged by the quota shall demonstrate its compliance through the virtual delivery to the relevant National Regulatory Authority for an amount equivalent to the fixed Green certificates quota. A green certificate usually equals one MWh of renewable energy.

The green certificates are free and previously granted by the National Regulatory Authority to generators of electricity from renewable sources according to their production and generally following the proportion of a green certificate for each MWh generated.

United Kingdom, Italy, Belgium, Poland, Rumania and Sweden have adopted this instrument.

d) Auctions/ Tenders: Promoters are invited to submit offers for a limited amount of power or energy in a given period. The companies that offer a lower cost for the delivery of electricity win long-term contracts, usually over a period of 15-20 years. Auctions allow competition between promoters allowing the increase of efficiency.

Countries such as Denmark, UK, Spain and the Netherlands have applied this process to allocate offshore wind projects (ECOFYS, 2011).

e) Investment grants: Some countries grant aid as a percentage of the cost of investment in some technologies, reducing the cost of capital of the power plants. This option is the only support available in Finland.

f) Fiscal incentives: Different methods are used to encourage the generation of renewable energy with fiscal instruments, such as the application of a reduced VAT, tax exemptions on dividends generated by these investments, accelerated depreciation, etc. Germany, Malta, Netherlands, Estonia, Poland and Bulgaria employ this support.

Table 3 summarizes the different support mechanisms applied to RES.

Table 3: Support mechanism to RES in the EU

	Regulated Prices	**Regulated quantities**
Based on investment	Investment grants Tax incentives	Auctions/Tenders
Based on generation	FiT / Premium	Green certificates and quotas

- Indirect support mechanism

In addition to the strategies described above, there are others that may have an indirect impact on the proliferation of renewable energy. The most important are:

- Green taxes to electricity produced from non-renewable sources.
- CO2 policies such as fees or allowances.
- Reductions in subsidies to nuclear or fossil energy.

The promotion of renewable energy through taxes on energy or environmental taxes can take two forms: (a) exemption from such taxes; or (b) the reimbursement for the total amount or part of it to renewable plants.

Additionally, there are voluntary support mechanisms based on the will of certain consumers, commercial or industrial companies to pay more if the electricity consumed comes from renewable energy sources.

Renewable promotion mechanisms by country

- *Germany*

The Renewable Energy Sources Act (EEG) was approved in 2000, which established specific tariffs for renewable energy sources based on their generation costs.

Generators are entitled to a fixed compensation for the delivery of energy to the grid based on the investment and operation costs of the plant. These feed-in tariffs (FiT) are gradually reduced (digression) to encourage a reduction in costs from technological development. The amount established in the year of commissioning of the plant remains in effect throughout its life and depends on the type of energy source. The degree of maturity and market penetration are also taken into account: the most efficient technologies (e.g. wind) receive a compensation more close to market prices than the installations less efficient (e.g. solar) which is more expensive to promote their technological development.

In general, all renewable energy facilities are entitled to receive regulated rates for a period of 20 years from the date of commissioning. From 2012, photovoltaic technologies are applied a monthly digression while for the other types the change is annual.

The feed-in tariff received by solar and biomass facilities varies according to the capacity of the plant. Therefore, to avoid the division of a single installation on several smaller plants with the purpose of obtaining a higher remuneration, all the plants located on the same parcel or very close are considered as a single one. These plants meet the condition of generating from the same renewable source and have been commissioned with a difference of less than twelve months.

The levels of FiT provided by the Renewable Energy Act, Erneuerbare-Energien-Gesetz (EEG), in 2013 are shown in Table 4. Geothermal and photovoltaic are in the higher range while onshore wind moves within a narrower range.

Table 4: Level of FiT in Germany

Source of energy	Feed-in tariff
Photovoltaic	11.78-17.02 cent €/kWh
Biomass	5.88-14.01 cent €/kWh
Geothermal	25.00-30.00 cent €/kWh
Landfill gas	5.80-8.47 cent €/kWh
Offshore wind	3.50-19.00 cent €/kWh
Onshore wind	4.80-9.27 cent €/kWh
Hydro	3.37-12.57 cent €/kWh

Source: Source: CMS, 2013: “Renewable Support Mechanisms Across Europe” Available at: <www.cms-hs.com>

The 2012 EEG introduced the option for renewable energy to receive a market premium instead of FiT. Under this system, the generators receive the difference between the monthly average electricity price in the wholesale market and the FiT. In addition, they may also obtain a management fee for the costs of participating in the market.

The TSO is obliged to connect the renewable energy plants to the grid and pay the FiT. The plants have priority in the use of the network as long as they do not jeopardize the safety and functionality of the network and taking into account the capacity and network management.

The costs are financed by consumers through the electricity bill.

- *Denmark*

In general, operators of renewable energy power plants receive the market price plus a premium. The sum of both may not exceed a certain limit and therefore the premium vary depending on the market price.

Normally, this compensation has a duration of 10 years from the date of commissioning of the installation. The maximum duration is 20 years. All the technologies are promoted with exception of geothermal.

In the case of offshore wind facilities, it was established a tender procedure to develop new projects. The Danish state assures a stable price to generators through a premium in the case that market price is lower than the settling price.

The RES support schemes entered into force in Denmark in 2008 and are managed by the Danish Energy Agency.

The costs are borne by consumers through the electricity bill which include a charge that is transferred to the company in charge of monitoring the process and paying premia to renewable energy facilities[19].

The electricity generated from renewable energy sources have priority in the use of the network, reducing the production from conventional installations if necessary.

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[19] RE-Shaping, 2012, “Renewable Energy Policy Country Profiles” Available at: <http://www.reshaping-res-policy.eu/downloads/RE-Shaping_CP_final_18JAN2012.pdf> Retrieved on 16th April 2014

- *United Kingdom*

a) Green certificates

In 2002, it was introduced a Renewable Obligation system (RO) in UK to incentivize the electricity generation from renewable sources.

Suppliers have to prove that a certain amount of energy supplied was generated from renewable energy sources by submitting certificates (renewable obligation certificates) to Ofgem (the regulator). The ROCs are awarded to generators in proportion of the renewable energy that they generate. Suppliers can buy green certificates directly to generators, either separately or packaged with renewable electricity or green certificates can be purchased separately in a green certificate market that starts simultaneously to the electricity market. It has been devised a system known as "headroom" which determines the mandatory quota of suppliers adding 10% to the planned renewable energy, so that the demand for green certificates is always greater than the supply and it protects the price of the green certificate of falling.

From 2009, it was introduced a banding regime for the ROCs per MWh of electricity awarded. The proposed banding levels of ROCs awarded to generators for 2013 are displayed in Table 5.

Table 5: ROCs/MWh in UK

Renewable electricity technologies		Proposed level of support (ROCs/MWh)
Solar PV		Banding proposals subject to re-consultation. Closure of band to new projects at or below 5 MW, from 1 April 2013, subject to consultation.
Landfill gas		— 0 for open landfill sites — 0.1 for new Waste Heat to Power band at open and closed sites — 0.2 for closed sites
Biomass	Co-firing of biomass (standard)	— Solid and gaseous biomass (less than 50% biomass co-fired in a unit): 0.3 (proposed) in 2013/14 and 2014/15; 0.5 from 2015/16 — Bioliquids (less than 100% biomass co-fired in a unit): 0.3 (proposed) in 2013/14 and 2014/15; 0.5 from 2015/16
	Co-firing of biomass (enhanced)	— Mid-range co-firing (50-less than 85%): 0.6 — High-range co-firing (85-less than 100%): 0.7 in 2013/14; 0.9 from 2014/15
	Co-firing of biomass with CHP (standard and enhanced)	0.5 ROC uplift in addition to prevailing ROC support available to new accreditations until 31 March 2015 (prevailing ROC support = 1)
	Biomass conversion	1
	Dedicated biomass	1.5 until 31 March 2016; 1.4 from 1 April 2016
	Biomass conversion with CHP	1.5 in 2013/14 and 2014/15
	Dedicated biomass with CHP	2 in 2013/14 and 2014/15
Sewage gas		0.5
Advanced and standard gasification/pyrolysis		2 in 2013/14 and 2014/15; 1.9 in 2015/16 and 1.8 in 2016/17
Wind	Offshore wind	2 in 2013/14 and 2014/15; 1.9 in 2015/16 and 1.8 in 2016/17
	Onshore wind	0.9
Hydro	Hydro-electricity	0.7
	Tidal impoundment (range) – tidal barrage (< 1GW)/Tidal impoundment (range) – tidal lagoon (< 1 GW)	2 in 2013/14 and 2014/15; 1.9 in 2015/16 and 1.8 in 2016/17
	Tidal stream/Wave	5 up to a 30 MW project cap; 2 ROCS above the cap
Energy from waste with CHP		1
Geopressure		1
Energy crops	Co-firing of energy crops (standard)	0.5 ROC uplift in addition to prevailing ROC support for co-firing of biomass (standard) (prevailing ROC support = 1). No uplift available for mid-range or high-range co-firing
	Dedicated energy crops	2 in 2013/14 and 2014/15; 1.9 in 2015/16 and 1.8 in 2016/17
	Dedicated energy crops with CHP	2 in 2013/14 and 2014/15; 1.9 in 2015/16 and 1.8 in 2016/17
	Co-firing of energy crops with CHP (standard)	0.5 ROC uplift in addition to prevailing ROC support for co-firing of energy crops (standard) (prevailing ROC support = 1.5). Band not available for mid-range or high-range co-firing
Anaerobic digestion		2 in 2013/14 and 2014/15; 1.9 in 2015/16 and 1.8 in 2016/17
Geothermal		2 in 2013/14 and 2014/15; 1.9 in 2015/16 and 1.8 in 2016/17
Micro-generation		2 in 2013/14 and 2014/15; 1.9 in 2015/16 and 1.8 in 2016/17

Source: CMS, 2013: "Renewable Support Mechanisms Across Europe. Available at: <www.cms-hs.com>

From 2017, it will be applied another support mechanism to new renewable generation plants, the so-called Contract for Difference (CfD). The national System Operator and the Secretary of State will be responsible for allocating the CfD.

b) Feed-in tariffs

The Energy Act 2008 introduced a FiT scheme for some generators with a maximum capacity of 5 MW. The scheme started in 2010 to support small-scale generation and it is composed for two payments to generators: (1) a generation tariff for the electricity produced; and (2) an optional export tariff for the electricity exported to the grid resulting unused.

The quota system is financed by customers through electricity bills.

c) Climate Change Levy

The climate change levy (CCL) only taxed suppliers from conventional energy sources to non-domestic end-users, renewable energy sources are exempted. For consumers of renewable energy to be exempted from paying this tax must sign a contract with the supplier that includes a Renewable Source Statement. In turn, those suppliers must reach an agreement (New Electricity Trading Agreement) with producers who must present certificates (Levy Exemption Certificates) issued by the Office of Gas and Electricity Markets.

The costs of the tax exemptions are provided for the national budgets.

d) UK carbon price floor

In 2013, the UK introduced a carbon price floor to encourage the investment in more “eco-friendly” technologies in the power sector. The government aims to reach a price of GBP 30 per ton of CO2 by 2020 (CMS, 2013).

- *France*

The operator of the distribution network is required to sign a contract to purchase the energy produced from renewable energy sources at the price established in the decrees (arrêtés) of each technology.

Furthermore, each technology receives a FiT established by the Minister of Economy, Industry and Employment. Generators are assured that all the energy produced will be sold at a fixed price (CMS, 2013). The Ministerial Order of 2013 established three types of FiT according to the capacity and the type of installation.

Moreover, in order to meet capacity targets set in the Annual Plan, the promoters may submit proposals for the construction of renewable energy facilities and projects selected to receive financial assistance. Tender processes fund, for example, photovoltaic plants with a capacity above 100 kW which are no longer covered by FiTs.

Renewable energy also counts with tax incentives: (1) up to a 40% of tax credits; and (2) a 5.5% applied to residential energy equipment.

Costs of these tax benefits are provided in the national budgets.

- *Italy*

In 2011, Italy became the main installer of solar PV modules in the world taking the place of Germany.

a) Green certificates

Producers and importers of energy have to prove that a certain amount of the total energy produced or imported comes from renewable sources through Green Certificates. Green Certificates are issued by the Electrical Service Manager for each MWh produced from renewable energy.

Political intervention in the green certificates price has reached its highest expression in Italy where it has been the system operator itself (GTRN) which directly fixes the reference price. Even GTRN itself acts on that market because, first, it buys green certificates that remain unsold on the market when the demand determined by the quota has not been enough, and on the other hand, it offers green certificates into the market in the years in which demand exceeds the supply.

There are several ways to obtain certificates to meet the mandatory share of renewable: self generation of electricity from renewable energy sources, purchasing the certificates to other plants or buying certificates in the market. If generators do not meet the quota may be punished. The required proportion of electricity to be generated from RE is shown in Table 6.

Table 6: Italy's Renewable Electricity Quota Obligation

Year	Renewable electricity quota
2002	2.00%
2003	2.00%
2004	2.35%
2005	2.70%
2006	3.05%
2007	3.80%
2008	4.55%
2009	5.30%
2010	6.05%
2011	6.80%
2012	7.55%

Source: RE-Shaping (2012)

The price of these certificates was fixed opaquely by the regulator, theoretically based on the average costs of production of the facilities subject to a previous grant program called CIP6.

The purchase of certificates required to meet the mandatory quota increase the costs for producers and importers and these costs are reflected in the price of electricity in the market. Therefore, consumers are ultimately bearing the cost of this support mechanism for renewables.

Although the Green Certificates were applied to all renewable energy sources, most of the investments were dedicated to wind technology. To promote other technologies as photovoltaic it was necessary to develop other specific support systems[20].

b) Feed in tariffs

In 2012, it was approved a new Decree which established a new regime for those wind farms in operation from the year 2013.

This decree proposed that all plants over 5 MW would be paid a feed-in tariff which would be defined through an auction. The auctions would be annual unless the auction does not cover more than the 20% of the fixed amount, in which case it would be hold another in the following six months. It was expected to be auctioned 500 MW per year of onshore wind capacity from 2013.

The 2012 Decree also provided incentives to hydro, biomass, geothermal and sustainable bio-fuels. Plants with a capacity below 1 MW receive an all-include feed-in tariff including the remuneration for the electricity generated and the incentive. Plants with a capacity above 1 MW receive a premium tariff for the electricity fed into the grid which is calculated as the difference between the hourly zone price and the specific FiT. In average the tariffs are received during 20 years and depend on the type and capacity of the plant.

The feed-in scheme for photovoltaic plants is known as Conto Energia. For plants with a capacity below 1 MWp, it is applied an all-inclusive feed-in tariff for all the electricity fed into the grid. Facilities with a capacity above 1 MWp receive the difference between the relevant all-inclusive FiT less the hourly zone price. Rates range from € 0.36 and € 0.49 per KWh, and vary depending on the size of the facility being the highest those dedicated to the integration of PV in buildings.

c) Off-take scheme

Another scheme is available to RE generators which is the simplified off-take scheme (ritiro dedicato) and from 2013 is not compatible with other FiTs. The system operator acts as an intermediary between RE producers and the market selling. The price obtained by the generators is based on the hourly zonal price.

[20]Source: "Cambio de paso en Italia: de certificados verdes a subastas" Available at: <www.energias-renovables.com> Retrieved on 14th April 2014

d) Net-metering

In 2013, Italy moved forward into a new promotional scheme, net-metering (Scambio sul Posto), aiming to bring solar incentive plants closer to the costs of conventional energy. This policy is based on measuring the excess of energy that is delivered to the network with respect to the energy consumed, ie, measuring in both directions. It allows a consumer to install small RE systems in their own home or business, and sell the excess of electricity to the grid or to the electricity supplier. The net-metering scheme is available for facilities with a capacity below 20 kW (200kW for plants commissioned after 2007).

This system might offers benefits for both the supplier of electricity and the consumer, because the excess of electricity produced during peak hours can improve system load factors and offset the need for peak generation plants[21].

- *Austria*

The Green Electricity Act (GEA) was approved in 2003 and introduced a uniform FiT support scheme for RE.

In 2006, It was created a settlement centre, the Abwicklungsstelle für Ökostrom (OeMAG), which is in charge of the payment of FiTs to generators of green energy.

The Clearing and Settlement Agency is responsible for the purchase of electricity from renewable sources to resale it to traders, who are forced to buy the amounts assigned to them by the agency at a price (transfer price) determined by the law, which exceeds the price of energy on the market.

The criteria for determining such compensation is the average cost of production of the most efficient plants and employing the latest technologies, so these amounts are gradually being reduced.

The costs are borne by customers, covering the difference between the market price and the transfer price established by law and paying the "support fee" to the network operator. The fee depends on the grid level to which the consumer is

[21] Source: "Mecanismos de apoyo a las Fuentes de energías renovables" <www.cubasolar.cu/biblioteca/Energia> Retrieved on 25th May 2014

connected, independently of the actual consumption. Table 7 displays the fee applied to consumers.

Table 7: Fee paid by consumer regarding to the grid level in Italy

Grid level	Fee
High voltage levels 1 to 4	€ 35,000 per annum
High voltage level 5	€ 5,200 per annum
High voltage level 6	€ 320 per annum
High voltage level 7	€ 11 per annum

Soure: CMS (2013)

- *Belgium*

In 1999, it was established a Green Certificate system based on an obligation (quota) and penalties for the part not accomplished. Suppliers have to prove that a certain amount of the energy was generated from renewable energy sources.

Three bodies are responsible for the certification of the generating units as well as the grant of the Green Certificates: VREG in Flanders, CWaPE in Wallonia and Brussels Environment in Brussels (Van Stappen et al., 2003). In 2013, the annual quotas fixed for suppliers in each region were 19.4% in Wallonia, and 3.5% in Brussels, while in Flanders it depends on the level of electricity produced and consumed (CMS, 2013). If the supplier does not meet these quotas, it will be applied a penalty for each missing green certificate.

Offshore wind farms also receive a specific promotion support. Within the green certificate system, transmission system operator (TSO) is obliged to buy green certificates at a guaranteed minimum price (based on the profitability of the plant), and later sell them in the market. Such certificates are issued per MWh of electricity (excluding consumption of the plant itself). The TSO has to buy the certificates at 107 €/MWh for the first 216 MW generated and 90 €/MWh for the rest (during 20 years) (CMS, 2913).

The costs from the quota system are borne by consumers.

There are also applied tax reductions for some investments in RES and energy efficient houses (real estate prepayment).

Table 8 summarizes the different support mechanisms used by the EU's countries classified by type of technology.

Table 8: RES-E support instruments by country and technology in EU

Member state	Hydro	wind	Biomass and Waste	Biogas	Photovoltaic	Geothermal
Austria	Investm. Grants, FiT	FiT	FiT	FiT	Investm. Grants, FiT	FiT
Belgium	GC with guaranteed minimum price	GC with guaranteed minimum price	GC with guaranteed minimum price	GC with guaranteed minimum price	GC with guaranteed minimum price	GC with guaranteed minimum price
Czech Republic	FiT/ Premium	FiT/ Premium	FiT/ Premium	FiT/ Premium	FiT/ Premium	FiT/ Premium
Estonia	Premium	Premium	Premium	Premium		
Finland	Excise tax return	Excise tax return	Excise tax return	Excise tax return		
France	FiT	FiT, Call for tenders	FiT, Call for tenders	FiT	FiT, Call for tenders	FiT
Germany	FiT, Direct Marketing, Premium	FiT, Direct Marketing, Premium	FiT, Direct Marketing, Premium		FiT, Direct Marketing, Premium	FiT, Direct Marketing, Premium
Hungary	FiT	FiT	FiT	FiT	FiT	FiT
Italy	Green certificates, FiT	Green certificates, FiT	Green certificates, FiT	Green certificates, FiT	Premium	Green certificates, FiT
Lithuania	FiT	FiT	FiT	FiT	FiT	
Luxembourg	FiT/ Premium	FiT/ Premium		FiT/ Premium	FiT/ Premium	

Netherlands	Premium	Premium	Premium		Premium	
Norway		Investment grants				
Portugal	FiT	FiT, Tendering process	FiT, Tendering process	FiT	FiT	
Romania	Green certificates	Green certificates	Green certificates	Green certificates	Green certificates	
Slovenia	FiT	FiT	FiT	FiT	FiT	
Spain	FiT or Premium	FiT or Premium	FiT or Premium	FiT or Premium	FiT (PV), FiT or Premium (CSP)	
UK	Green certificates , FiT	Green certificates , FiT	Green certificates		Green certificates, FiT	

Source: CEER (2013)

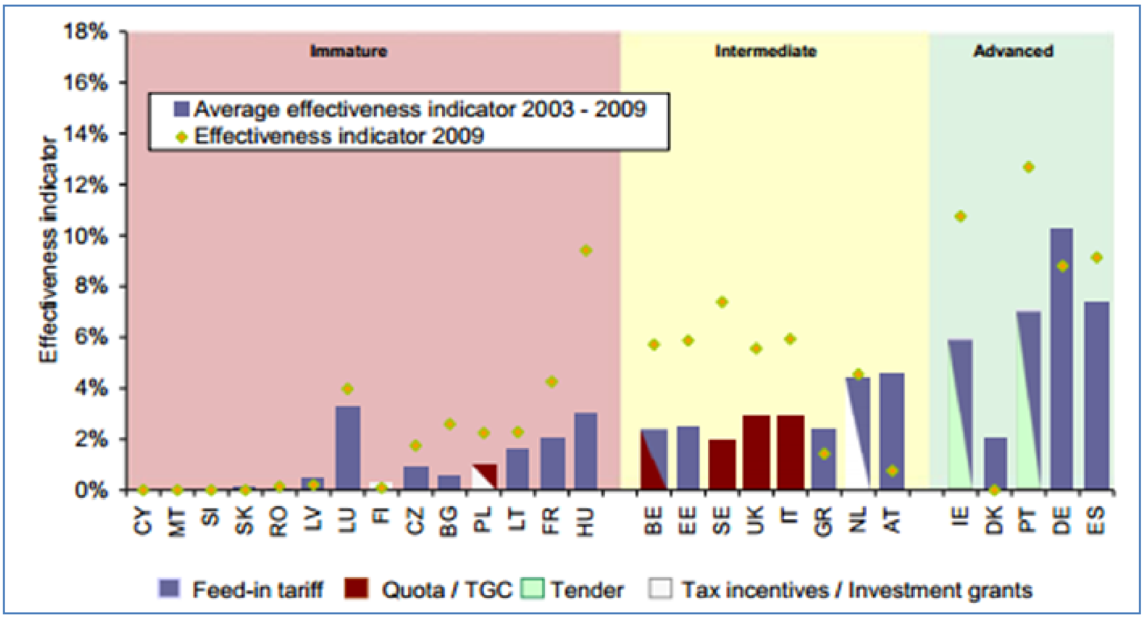
3.1.3. Effectiveness of support policies

As mentioned in the previous section, RES support schemes are wide spread between the EU's countries. FiT/premium and quota obligations are the most common mechanisms implemented. However the effectiveness[22] on reaching the environmental targets of these mechanisms varies considerably among member states. All the member states have carry out a financial effort to develop incentives to attract investments on renewable technologies. However, the investment level should be doubled compared to 2008 to reach the targets (Jager et al., 2011). An ex-post evaluation of the performance of incentive schemes contribute to assess the correlation between the efficiency of support instruments and the expenditure level on them. Graph 11 shows the effectiveness level of support mechanisms in the EU' member states in the case of wind generation. It can be observed that countries with a higher level of policy performance are the countries applying FiTs. Graph 12 compares the level of effectiveness by type of

[22]By effectiveness we mean high level of RES deployment at low cost for consumers.

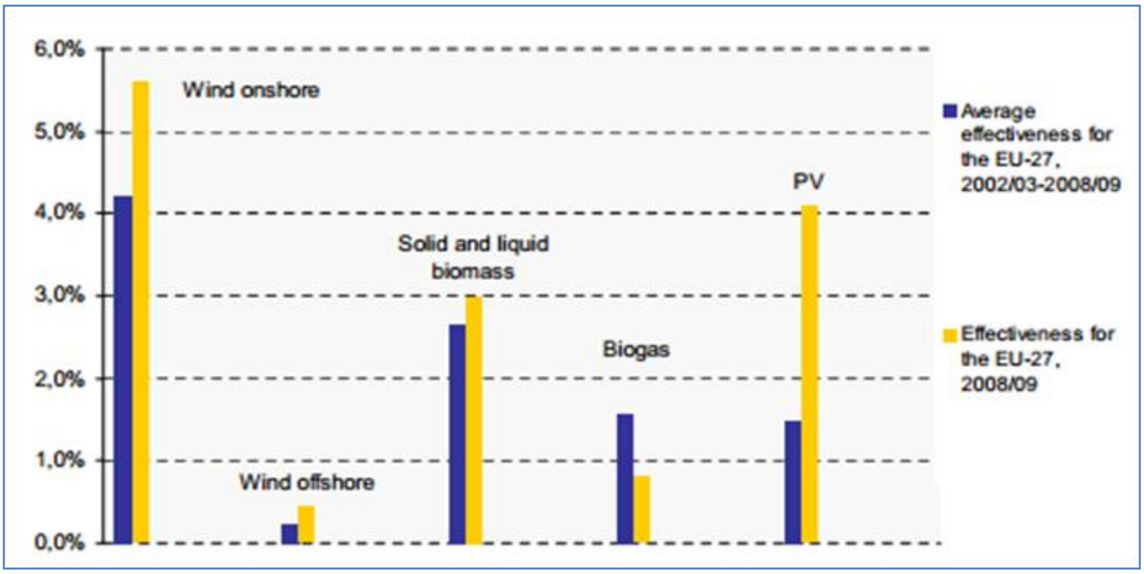
technology in years 2003-2009. It can be observed that wind presents the higher policy performance.

Graph 11: Policy effectiveness for onshore wind power in the period 2004-2010



Source: RE-Shaping (2013)

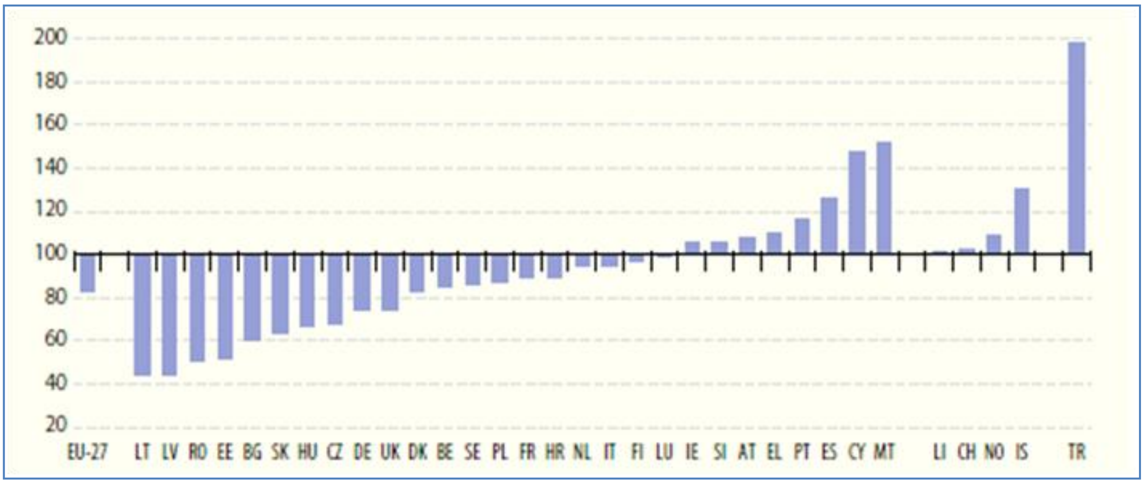
Graph 12: Effectiveness of RES-E support policies by technology, EU-27



Source: Klessmann (2012)

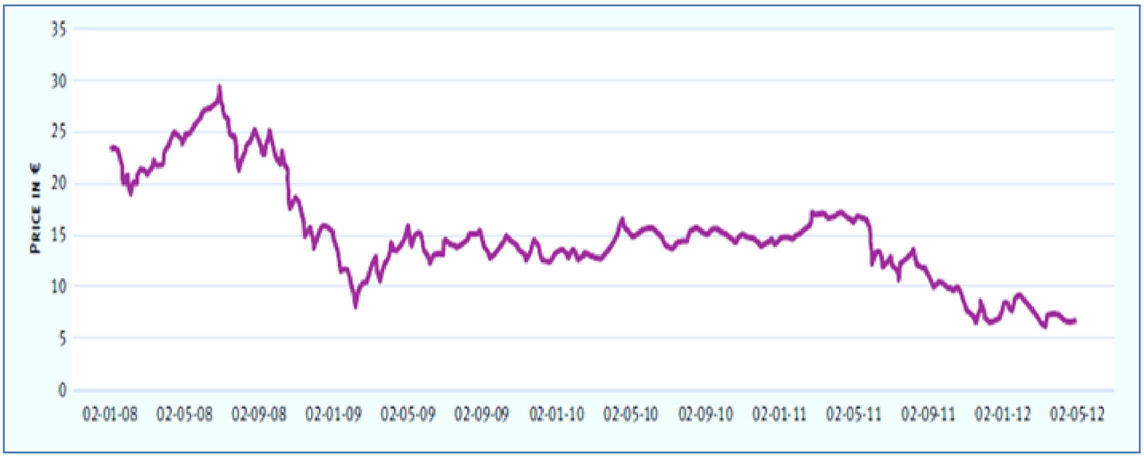
The majority of the European countries have reduced greenhouse emissions between 1990 and 2011 (Graph 13). The implementation of RES support schemes has allowed the reduction in the overall EU's emissions level, although the generation from coal plants has increased to serve as back-up capacity. However this reduction has been lower than expected due to the fact that CO2 price has undergoing a decrement with the introduction of RES incentives. Graph 14 shows the path followed by CO2 allowances price.

Graph 13: GHG emissions by country, 2011



Source: Eurostat (2012)

Graph 14: Evolution of CO2 emissions allowances price



Source: Eurelectric (2013)

3.2. Literature Review

The important role that renewable energies play in the CO2 emissions reduction objectives and the significant deployment experienced by them during the last years, has been widely discussed in the literature. Several authors have analysed the effect of RES injections into the system on emissions reductions achievements as Denny and O'Maley (2006) in the case of wind generation. Also Weigt et al. (2012) estimate the reduction of emissions as a result of RE injection into the German electricity sector finding a reduction of 10%-16% from 2006 to 2010 being greater in the presence of a CO2 price. The interaction between RE support schemes and the EU ETS have been included in many studies. Linares et al. (2007) examine the expected effect of both mechanisms on the market prices for electricity. They find that when both systems are combined the permit price decreases. Van den Bergh et al. (2012) carry out an ex-post analysis of the impact of RE penetration on the allowances price and the CO2 emissions in the European power system maintaining these same results.

Regarding to the cost of reducing CO2 emissions, Holttinen (2004) calculates the hypothetical cost of emissions reduction using RES on the Nordic electricity system. The author explains that the reserves to cover the wind' variability increase a 2% with a 10% of wind penetration, ranging the regulation cost from 1€ (10% penetration) to 2€ (20% penetration). Dale et al. (2004) determines the emission abating cost as a result of introducing new wind capacity in the UK electricity market indentifying the extra costs added to electricity generation due to wind energy's intermittency. The study shows that the capacity credit of wind declines as wind generation increases, rising the back-up requirements and balancing costs. Lang (2009) find out that wind generation saves little greenhouse gas emissions when the emissions from the back-up capacity are taken into account in the Australian electric system.

Marcantonini and Ellerman (2013) and Marcantonini and Ellerman (2014) obtain the abatement emissions cost taking into account the cost of FIT in Germany as an ex-post analysis. The authors estate a CO2 emissions reduction cost much higher than the historical EU ETS carbon prices in the case of solar technology.

In general, all the studies found using historical data of the Spanish power system, are focused on the impact of RES on the electricity price. Sáenz de Miera et al. (2008) use historical data to prove that the incorporation of RES into the system reduce the electricity price in the wholesale market, being this amount greater than the cost charged to consumers to support these technologies through FiTs. Gelabert et al. (2011) obtain a reduction of almost 2€ per MWh in the Spanish electricity prices with the introduction of renewable sources and cogeneration. These studies follow the reasoning expressed by

Jensen and Skytte (2002) which hold that a significant reduction on electricity prices compensate the costs of RES promotion.

Chapter 4. Methodology

In this section it will be explained the methodology followed to obtain the costs and savings associated to the introduction of renewable energy sources into the electricity system in Spain.

The cost of reducing C02 emissions using incentive mechanisms to renewable energy will be calculated following the methodology in Marcantonini and Ellerman (2013).

It will be used an ex-post analysis considering only the capacity installed from 1994 to 2011 in the case of wind technology and from 2002 to 2011 for solar photovoltaic facilities (the capacity installed before 2002 is not a very significant amount, therefore, it has been considered as it was installed in this year). This study does not analyse the effect of integrating new renewable capacity into the system in the future. However, it can be observed the consequences of the current installed capacity in a future generation scenario.

For the purpose of this research work, renewable energy is examined from the point of view of the climate objectives, i.e., as a tool to reduce CO2 emissions. It has not been taken into account other effects related to these technologies such as the reduction in energy dependency, the increment on jobs, etc.

The costs to be considered are the remuneration received by the producers of renewable generation or the balancing costs incurred by the system. The cost savings of introducing these technologies are the cost of fossil fuel and carbon whose consumption is avoided (Marcantonini and Ellerman, 2013).

The cost of reducing CO2 emissions through the incentives received by wind and solar technologies in Spain is obtained as the sum of all the costs incurred due to use of these technologies minus the cost savings. Dividing this quantity by the amount of emissions reduced, it is obtained the monetary value of one ton of CO2 avoided in the system.

4.1. Data base description

The data base has been elaborated following the classification proposed by the RD 413/2014 for the capacity installed. This legislation for renewable energy, cogeneration plants and generation from waste, establishes a retributive regime based on standard parameters as a function of the different types of facilities determined. The new retributive regime will be applied to the facilities that are not able to achieve a minimum level of "reasonable return on profits" to cover exploitation costs and be competitive on the market. The scheme sets a compensation to cover the investment costs not recovered through the participation in the market and a retribution to cover the difference between the exploitation costs of the power plant and the market price, if necessary. The main change introduced is that this compensation is calculated based on the installed capacity of the power plant rather than the energy generated.

This study considers an approximation of the current capacity installed for each standard plant type for wind and solar photovoltaic technologies.

The classification of wind technology is based on the year when the facility is authorised to operate and which range from 1994 to 2013.

Solar photovoltaic technology has been classified depending on the Royal Decree by which the facilities are covered. For facilities covered by the RD 661/2007 of 25th of May, the different types of plants have been defined based on its power range registered according to the RD 661/2007, the power range attributed by the RD 413/2014 and the solar tracking technology (fixed structure, one-axis solar tracking and two-axis solar tracking). From each case it is generated a standard plant per year of commissioning.

The facilities included in the Royal Decree 1578/2008 of 26th of September have been classified according to the category (I.1, I.2, II), the call for pre-allocation in which they were registered (category I.1), the power range (category I.2), the solar tracking technology (category II), the climatic area in which they are installed and the year of commissioning.

The initial data on capacity installed has been retrieved from the Market and Competition National Commission (MCNC) webpage. Information on the capacity registered in each call for pre-allocation is obtained from a website specialised on solar technology[23].

In the case of solar photovoltaic technology, the initial data have been modified to achieve an approximation of the capacity installed per standard facility.

4.1.1. Facilities included in the Royal Decree 661/2007

The capacity installed per power range of the RD 413/2014 for each year has been obtained from the MCNC. Since, the capacity installed per type of solar tracking technology was not public at the date of this study, it is assumed that 75% of the capacity installed has a fixed structure and 25% is classified as solar tracking technology (this percentage is divided between one-axis and two-axis in the same proportion). This division is derived from the information included in the report of MCNC from 10th September of 2010 related to the operating hours of each category (I.1, I.2, II) during 2009. We also assume that 90% of this capacity was assigned to the initial range ≤100kW in the RD 661/2007 and a 10% for the initial range 100kW<P≤10MW[24]. This last division responds to the speculative behaviour of the owners of solar farms discussed in a previous section.

4.1.2. Facilities included in the Royal Decree 1578/2008

The capacity registered in each call for pre-allocation from year 2009 to 2011 is classified according to the province where the plant is inscribed and the category (I.1, I.2, II) assigned to it. In a second step the capacity registered in each call for pre-allocation finally installed is obtained. The data published by the MCNC provides only the total installed capacity by year.

We assign a proportional part of the capacity installed during the year to each call for pre-allocation, obtaining equal amounts for each of them. In a first stage we obtain the assumed capacity not installed for each call and which is added to the capacity pending of installation in the following call and so on until the 4th call of 2011[25]. In a second stage, the capacity pending of installation is

[23] <www.suelosolar.es>
[24] For capacity above 100kW
[25] In the cases where the difference between the capacity registered in the call and the capacity installed results negative, it is assumed that all the capacity was installed at the end of the year (4th call).

discounted from the last call of the year to the previous call to infer the origin of this capacity.

The provinces are allocated according to the different climate areas related to the average solar radiation in Spain as established by the RD 314/2006 of 17th of March.

Annex 1 displays the final classification of the installed capacity according to this procedure.

In order to provide more details about the procedure followed to classify the data, it will be showed the results of each step taking as an example the group b.1.1 covered by the RD 1578/2009, type I.1.

- Capacity registered in each call for pre-allocation.

Province	Type I.1 - Nominal capacity registered in call for pre-allocation (MW)				
	1C 2009	2C 2009	3C 2009	4C 2009	Total I.1
COMUNIDAD VALENCIANA	Alicante	0.0505	0.3650	0.1611	0.3836
	Castellón	0.0441	0.1499	0.1697	0.1340
	Valencia	0.1065	0.7290	0.4323	0.4537
	Total	0.2010	1.2439	0.7631	0.9712
EXTREMADURA	Badajoz	0.0275	0.0675	0.0525	0.1625
	Cáceres	0.0480	-	-	0.0650
	Total	0.0755	0.0675	0.0525	0.2275

- Assignment of the capacity finally installed from each call for pre-allocation.

ALICANTE	C1 09	C2 09	C3 09	C4 09	C1 10	C2 10	C3 10	C4 10	C1 11	C2 11	C3 11	C4 11
Reg. Cap.[26]	0.0505	0.3650	0.1611	0.3836	0.4521	0.1242	0.1388	0.2229	0.1596	0.3443	0.2853	0.2926
Inst. Cap.[27]	0.0421	0.0421	0.0421	0.0421	0.2390	0.2390	0.2390	0.2390	0.1124	0.1124	0.1124	0.1124
Difference	0.0084	0.3312	0.4502	0.7917	1.0047	0.8899	0.7897	0.7736	0.8207	1.0525	1.2254	1.4056

[26] Registered capacity in each call of pre-allocation.
[27] Capacity finally installed in each call of pre-allocation.

Province	Area	Call.	Reg. Cap.	Inst. Cap. per year of commissioning			
				2009	2010	2011	>2011
ALICANTE	IV	1C 09	0.0505	0.0505			
		2C 09	0.3650	0.1180	0.247		
		3C 09	0.1611		0.1611		
		4C 09	0.3836		0.3836		
		1C 10	0.4521		0.1644	0.28767	
		2C 10	0.1242			0.1242	
		3C 10	0.1388			0.0379	0.10092
		4C 10	0.2229				0.2229
		1C 11	0.1596				0.1596
		2C 11	0.3443				0.3443
		3C 11	0.2853				0.2853
		4C 11	0.2926				0.2926

- Allocation of provinces to the climate areas.

Area	Call	Installed capacity per commissioning year			
		2009	2010	2011	>2011
Z4	1C 09	0.5799	0.0311	0.0000	0.0000
Z4	2C 09	0.6688	1.1722	0.0000	0.0000
Z4	3C 09	0.0549	1.2496	0.0019	0.0000
Z4	4C 09	0.0511	1.6457	0.1530	0.0315
Z4	1C 10	0.0000	1.0615	1.5478	0.0050
Z4	2C 10	0.0000	0.1638	1.2283	0.0783
Z4	3C 10	0.0000	0.0309	1.6269	0.6684
Z4	4C 10	0.0000	0.0000	0.5856	1.5558
Z4	1C 11	0.0000	0.0000	0.0961	2.0221
Z4	2C 11	0.0000	0.0000	0.0000	2.4214
Z4	3C 11	0.0000	0.0000	0.0000	1.6926
Z4	4C 11	0.0000	0.0000	0.0000	2.0972

4.2. Data treatment

This section describes the procedure followed to calculate the costs and avoided costs from associated to wind and photovoltaic technologies.

4.2.1. Estimation of the remuneration obtained by generators

The remuneration to generators has been calculated from the historical values listed on the proposal of the Energy Ministry from 1994 to 2013 for wind facilities and from 2003 to 2013 for photovoltaic plants. From 2013 it is applied the new criteria established in the 2013's reform.

- Remuneration before 2013

Before the entry into force of the Law 24/2013 and the publication of the proposed RD 413/2014, the premia were based on the production of the plants. The historical values for the income received have been multiply by the estimated installed capacity per type of technology and the historical working hours for each year from the year of commissioning.

- Remuneration from 2013

From 2013 it has been applied the criteria to calculate the retribution to generators proposed by the RD 413/2014. As mentioned in a previous section, this criterion is based on the capacity installed and comprises two components: investment retribution (Rinv) and operation retribution (Ro). This retribution will complement the income from the participation in the market in the cases where it is necessary to assure the "reasonable return on profits". The Ro will be perceived by the producer only in the case where the exploitation costs are highest than the income obtained from participation in the market. Therefore, this component varies every year and it is obtained as the difference between the market price and the operation cost.

The Rinv is updated every three years (half regulatory cycle). The formula applied to obtain the Rinv is the following.

$$Rinv = C * NAV * \frac{T * (1+T)^{RL}}{(1+T)^{RL} - 1}$$

Where:

C: adjustment factor for the installation type (between 0 and 1).

NAV: net asset value of the installation type (per capacity unit).

T: remuneration rate at the beginning of each regulatory period (updated every 6 years).

RL: residual life of the installation (useful life of the installation minus the years passed from the commissioning year till the beginning of the regulatory period).

In this study it has been considered that the coefficient C remains constant along the useful life of the installation and equal to the value fixed by the Ministry for the period 2014-2016. Furthermore, the remuneration rate is considered also constant and equal to the predetermined value for the first regulatory period (7.39%).

The useful life of the installations has been defined by the Ministry (20 years for wind facilities and 30 years in the case of photovoltaic plants).

The NAV is determined with the following expression for the first period.

$$NAV = IV * (1+T)^{p} - \sum_{i=1}^{p} (Inc_i - Exp.C_i) * (1+t)^{p-i}$$

Where:

IV: initial investment value of the installation type (per capacity unit).

P: years passed from the commissioning year until the actualization year.

Inc: total income per capacity unit of the installation type in year i, starting on the following year to the commissioning year.

Exp. C: exploitation cost per capacity unit of the installation type in year i, starting on the following year to the commissioning year.

In the following three-year periods it is applied the following formula to obtain the NAV.

$$NAV = NAV_{j-1} * \left(1 + T_{j-1}\right)^3 - \sum_{i=1}^{3} (Inc_i - Exp.C_i - Vadjm_i) * \left(1 + T_{j-1}\right)^{3-i}$$

Where:

j: half- period of regulation for which is made the calculation.

NAV (j-1): net asset value in the previous half-period.

T (j-1): retribution rate for the previous half-period.

i: years of the previous half-period.

Inc/ Exp. C (i): total income and exploitation cost per capacity unit of the installation type in year i estimated in the previous half-period.

Vajdm(i): income adjustment in the wholesale market for the year i.

The investment values are predetermined by the Ministry for the different types of technologies.

To obtain the remuneration for 2013 and the period 2014-2016 it has been used the parameters determined in the annex II of the Proposal published by the MCNC for the Rinv, Ro and the market price. However, it has been necessary to adopt additional assumptions for the remaining years.

It is considered an increase of 2% per year for the market price and the exploitation costs (calculated on the basis of the annual rate of change of the Harmonized Consumers Price Index for the period 2002-2013[28]).

The operating hours of the installations have been considered constant. They have been obtained as the average annual working hours from the data published by the MCNC for the equivalent premium and incentives to renewable energy sources liquidation in years 2011, 2012 and 2013, in the case of wind technology. For solar facilities, it has been applied the same average working hours used in the calculation of the percentages to divide the installed capacity between fixed structure and solar tracking technology.

[28] Data from Eurostat website: <http://epp.eurostat.ec.europa.eu>

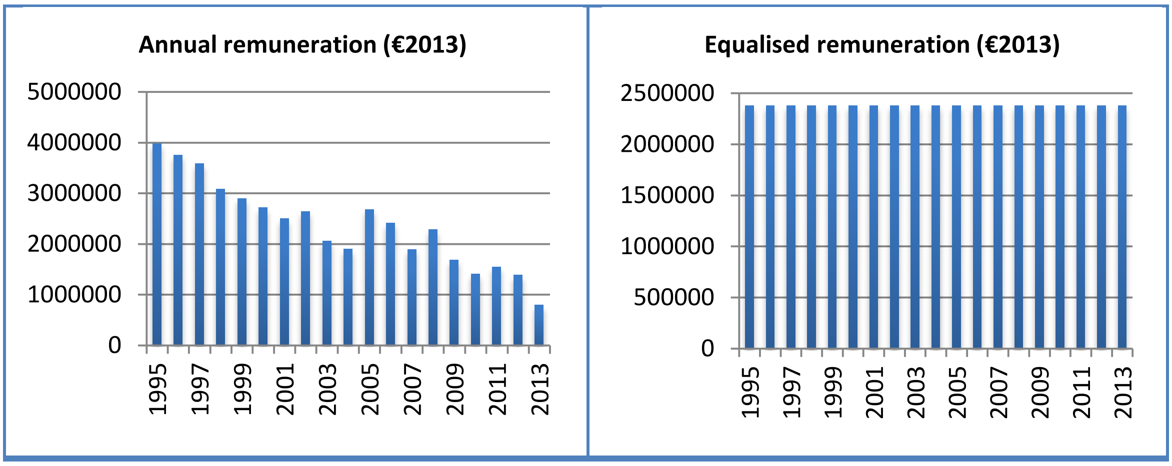
These average annual working hours have been assigned to area 5 and they have been reduced in the same proportion as the equivalent reference hours established by the RDL 14/2010 of 23rd of December for the rest of the areas.

The maximum working hours subject to perceive the retribution have been established by the Ministry for the first regulatory period. These hours are assumed constant until the end of the useful life of the plant in this study. In the cases where the operating hours assigned are higher than the maximum hours predetermined, it will be taken the lower of both figures.

The Vajdm (i) has not been taken into account.

The annual retribution obtained from the commissioning year up to the end of the lifetime of the installations is actualized to 2013 using the same actualization rate and redistributed over the lifetime to obtain equalized annual remunerations. In the case of power plants (mostly wind power) which are forgoing the remuneration due to the application of the RD 413/2014 and have not reach the end of their useful lifetime, the total payment is redistributed over the years receiving the incentives. Given that the remuneration to generators tends to decrease over time, analyzing the payments in specific years would lead to misleading results. The following graphs show the effect of equalization in the wind capacity installed in 1994.

Figure 7: Comparison between annual remuneration and equalised remuneration



Source: Own elaboration

The annual expenditure on incentives to renewable sources is obtained by the sum of all the equalized payments to all the facilities in that year.

Annex 2 shows the results in more details for each technology.

4.2.2. Additional costs and cost savings estimation

To estimate the costs and cost savings associated to the electricity generation from wind and solar photovoltaic sources, it has been used a simplistic approximation approach to identify the technology displaced by the introduction of wind and solar photovoltaic generation. The analysis compares two scenarios representing the actual market outcome and the simulation of the generation dispatch without wind and photovoltaic production for the period considered. The method is based on the average emission rate for each technology displaced due to the introduction of wind and photovoltaic generation. Emissions avoided and fuel reduction are obtained from the difference between both scenarios.

This approach has been selected over other methods, such as modeling software, since some of the data required for these other methods is private and mostly unavailable for public consultation. Therefore, the results would have been less transparent and accessible.

To determine the technology substituted by wind and photovoltaic injection, it has been identify the less economically efficient technologies in terms of fuel consumption in relation to energy produced. Coal plants and CCGTs are the technologies identified as displaced.

The average fuel consumption rates are 2.26 (te/kWh) for coal plants and 1.32 (te/kWh) for CCGTs. The emission rates are 1.003 (t/MWh) for coal plants and 0.371 (t/MWh) for CCGTs[29], based on the carbon content of each fuel and efficiency. These rates are considered constant along the period under study.

To determine the energy displaced, it has been used the national electricity balance by year and type of technology provided by REE. For each year, the wind and photovoltaic demand coverage has been proportionally distributed among the displaced

[29] Data facilitates by Endesa, S.A.

technologies identified to obtain the amount that would otherwise have been produced by them in absence of the generation accounted by these sources. Perfect competition and no transmission constraints have been considered. Table 9 displays the generation displaced by wind and photovoltaic technologies, as well as the amount of emissions and fuel consumption avoided.

Table 9: Displaced generation, and CO2 emissions and fuel consumption avoided

Wind												
Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Displaced generation (GWh)												
Coal	8675	9706	11421	12783	11665	13988	10687	11445	11016	19438	28235	33335
CCGT	585	2014	4333	8074	11547	13624	21473	26808	32529	23028	20273	21373
Total	9259	11720	15754	20858	23212	27612	32160	38253	43545	42465	48508	54708
Avoided CO2 emissions (Mt)												
Coal	9	10	11	13	12	14	11	11	11	19	28	33
CCGT	0	1	2	3	4	5	8	10	12	9	8	8
Total	9	10	13	16	16	19	19	21	23	28	36	41
Avoided fuel (Mtep)												
Coal	2	2	3	3	3	3	2	3	2	4	6	8
CCGT	0	0	1	1	2	2	3	4	4	3	3	3
Total	2	2	3	4	4	5	5	6	7	7	9	10

Solar												
Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Displaced generation (GWh)												
Coal	4	7	13	25	53	239	829	1818	1630	3343	4679	4959
CCGT	0	2	5	16	53	245	1669	4254	4793	4082	3523	3365
Total	5	9	18	40	106	484	2498	6072	6423	7425	8202	8324
Avoided CO2 emissions (kt)												
Coal	4.3	7.4	12.9	24.6	53.1	239	831	1824	1635	3353	4694	4974
CCGT	0.1	0.6	1.8	5.8	19.8	91	620	1580	1780	1516	1308	1250
Total	4.4	8.0	14.8	30.4	73.0	330	1451	3404	3415	4869	6002	6224
Avoided fuel (ktep)												
Coal	1.0	1.7	2.9	5.5	12.0	54	187	411	368	755	1057	1120
CCGT	0.0	0.2	0.6	2.1	7.1	32	221	563	634	540	466	445
Total	1.0	1.9	3.6	7.6	19.0	86	408	974	1002	1295	1523	1565

Emission allowances prices are the annual average historic values from the European Energy Exchange (EEX). The annual average carbon price is the ARGUS coal API4 and for gas is the IPE natural gas. These prices are multiply by the amount of emissions and fuel avoided to obtain the savings.

The level of extra cost of imbalance in Spain is between 15-20% of the day-ahead market price. For a wind farm, it means around 2-3 €/MWh (Eurelectric, 2014). In this study, it has been considered 2€/MWh. Cycling costs are not representative and have been neglected[30].

[30] According to Van den Bergh and Delarue (2014), cycling costs of conventional facilities are very small in comparison with fuel cost savings.

Chapter 5. Results

As mentioned in previous chapters, the economic support to renewable energies by the government has been an important driver of their growth. Tables 10 and 11 show the remuneration received by wind and solar (photovoltaic) generators. Figure 8 and 9 illustrate the evolution in the annual remuneration due to the variation on the amount of energy generated and the introduction of the different RDs. The equalized remuneration remains lower than the annual remuneration except in 2013 for wind energy when the remuneration is significantly reduced by the introduction of the new legislation.

Table 10: Annual and equalised remuneration for wind energy

Wind (M€)												
Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Annual remuneration	1,178	1,325	1,563	2,739	3,153	2,969	4,294	3,592	3,769	3,983	3,965	2,972
Equalised remuneration	900	1,273	1,572	2,090	2,247	2,427	2,688	2,859	3,094	3,165	3,265	3,372

Figure 8: Evolution of annual and equalised remuneration for wind energy

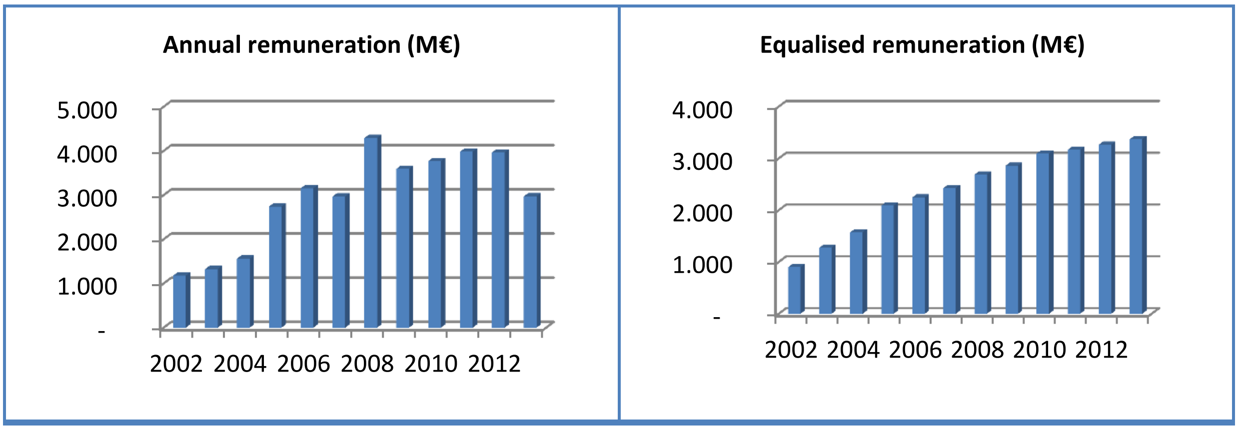
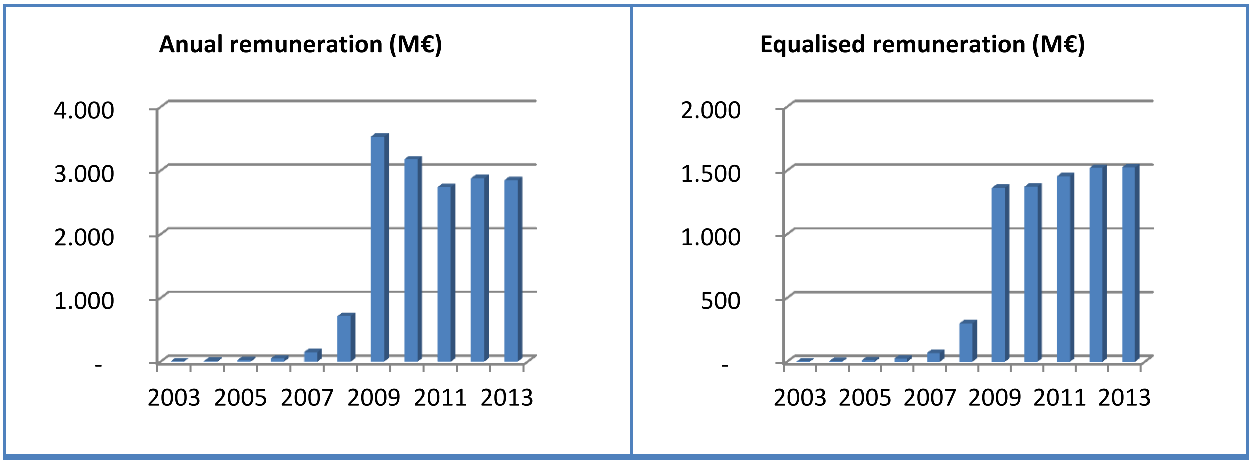


Table 11: Annual and equalised remuneration for solar energy

Solar (M€)											
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Anual remuneration	4	10	23	47	150	716	3,533	3,176	2,742	2,880	2,849
Equalised remuneration	2	5	12	24	69	300	1,365	1,374	1,456	1,521	1,525

Figure 9: Evolution of the annual and equalised remuneration for solar energy



As discussed in section 2.3., the introduction of RES into the system contributes to reduce CO2 emissions and fuel consumption and, therefore their costs. On the other hand, it has to be bear additional balancing cost in the case of wind energy. Table 12 present the cost and cost savings associated to wind and solar injection into the system. The carbon savings vary from year to year depending on EU ETS price. For instance, for years 2007 and 2008 with similar amount of emissions, the carbon saving in year 2007 is much lower than 2008 due to the high decrease in the emission allowances price observed in that year.

It has to be considered that the allowances price taken into account in this study undergoes the reduction effect caused by the introduction of RES generation in a cap-and-trade system (Weigt et al., 2012) reducing the marginal cost of emissions (Linares et al., 2007). Therefore, the carbon cost avoided would be higher if this effect is contemplated. Future research needs to introduce the interdependency between both systems in the cost-efficiency analysis of renewable technologies.

The higher fuel savings are observed in gas in both technologies, and are significantly higher that the additional balancing costs associated to wind's intermittency.

Table 12: Costs and avoided costs associated to wind and solar technologies

Wind									
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
Carbon savings									
EU ETS price	20.07	17.24	0.67	22.07	13.15	14.32	12.69	7.39	4.35
Avoided carbon cost (M€)	318	276	13	413	282	331	356	265	180
Fuel savings									
Coal price (€/t)	36.98	40.43	45.43	81.56	46.49	69.17	83.57	72.32	60.55
Avoided cost (M€)	153	152	205	281	172	246	524	659	651
Gas price (€/MMbtu)	6.10	6.70	4.41	7.77	3.59	4.83	6.72	7.30	7.90
Avoided cost (M€)	259	406	316	877	505	826	813	777	887
Avoided fuel cost (M€)	411	559	521	1,158	677	1,072	1,337	1,436	1,538
Balancing costs									
Balancing cost (€/MWh)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Additional cost (M€)	42	46	55	64	77	87	85	97	109

Solar									
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
Carbon savings									
EU ETS price	20.07	17.24	0.67	22.07	13.15	14.32	12.69	7.39	4.35
Avoided carbon cost (M€)	0.61	1.26	0.22	32.03	44.77	48.89	61.79	44.33	27.06
Fuel savings									
Coal price (€/t)	36.98	40.43	45.43	81.56	46.49	69.17	83.57	72.32	60.55
Avoided cost (M€)	0.29	0.69	3.50	21.81	27.27	36.37	90.14	109.20	96.89
Gas price (€/MMbtu)	6.10	6.70	4.41	7.77	3.59	4.83	6.72	7.30	7.90
Avoided cost (M€)	0.50	1.88	5.69	68.15	80.15	121.68	144.14	135.00	139.66
Avoided fuel cost (M€)	0.79	2.57	9.19	89.96	107.42	158.05	234.27	244.20	236.55

Table 13 shows the annual cost of reducing CO2 emissions by introducing wind and solar generation into the Spanish electric system. *Net cost* is the result of summing up the costs and avoided costs[31]. *Cost of reducing CO2 emissions* is the economic value of reducing one ton of CO2. The higher contribution to costs comes from the remuneration to generators and the avoided fuel cost is the higher saving.

[31]Positive amounts represent costs and negative amounts savings.

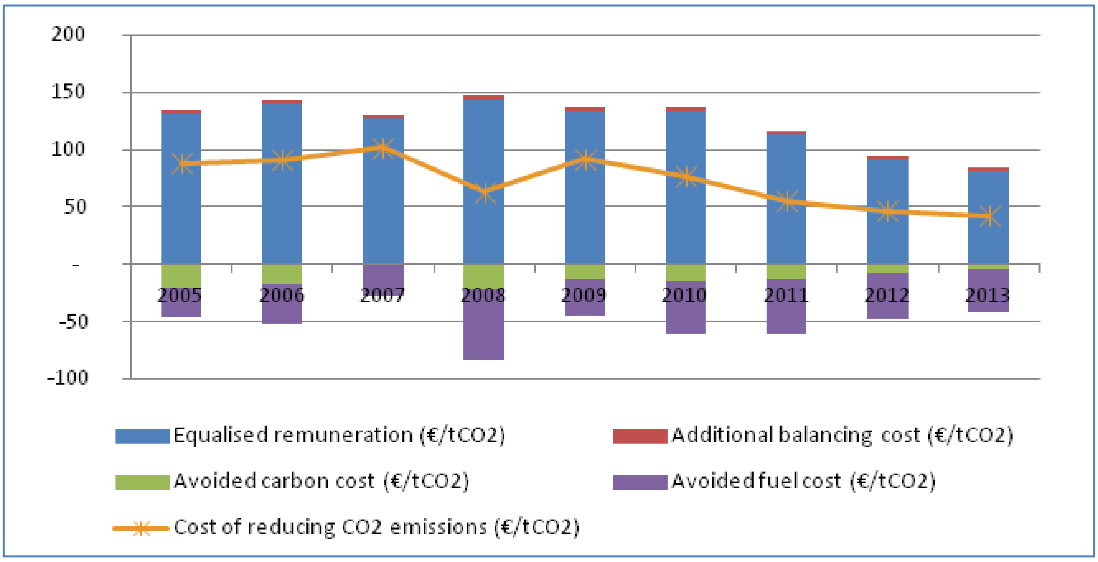
Table 13: Cost of reducing CO_2 emissions by wind and solar generation

Wind									
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
Equalised remuneration (M€)	2,090	2,247	2,427	2,688	2,859	3,094	3,165	3,265	3,372
Additional balancing cost (M€)	42	46	55	64	77	87	85	97	109
Avoided carbon cost (M€)	-318	-276	-13	-413	-282	-331	-356	-265	-180
Avoided fuel cost (M€)	-411	-559	-521	-1158	-677	-1072	-1337	-1436	-1538
Net cost (M€)	1,402	1,459	1,948	1,182	1,977	1,779	1,557	1,661	1,763
CO2 emissions avoided (Mt)	16	16	19	19	21	23	28	36	41
Cost of reducing CO2 emissions (€/tCO2)	**88.64**	**91.23**	**102.05**	**63.21**	**92.21**	**76.89**	**55.50**	**46.33**	**42.61**

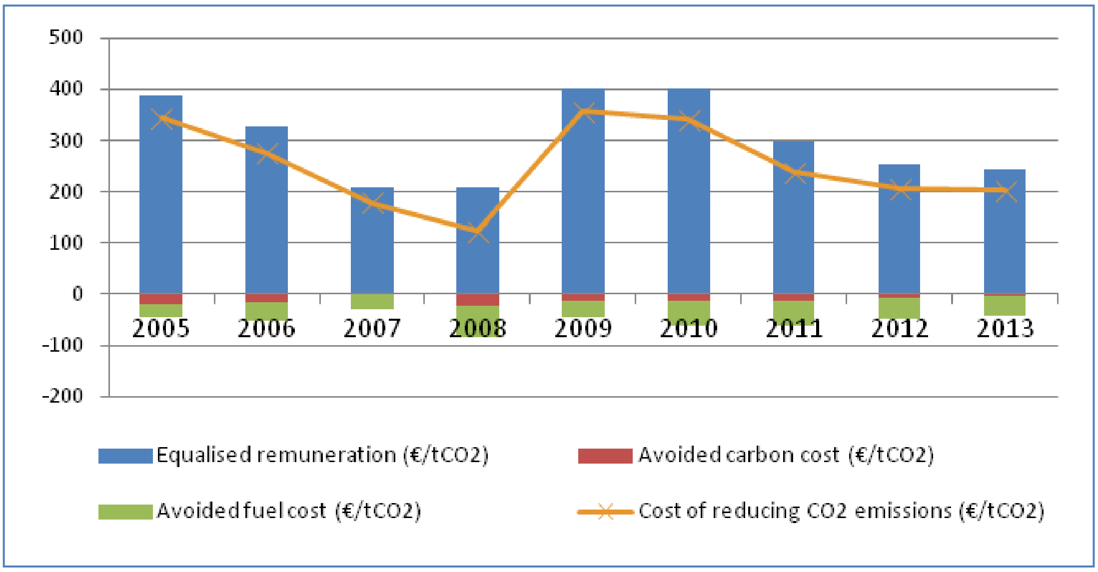
solar									
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
Equalised remuneration (M€)	12	24	69	300	1365	1374	1456	1521	1525
Avoided carbon cost (M€)	-0.61	-1.26	-0.22	-32.03	-44.77	-48.89	-61.79	-44.33	-27.06
Avoided fuel cost (M€)	-0.79	-2.57	-9.19	-89.96	-107.42	-158.05	-234.27	-244.20	-236.55
Net cost (M€)	10	20	59	178	1213	1167	1159	1233	1261
CO2 emissions avoided (Mt)	0.03	0.07	0.33	1.45	3.40	3.41	4.87	6.00	6.22
Cost of reducing CO2 emissions (€/tCO2)	**344**	**276**	**179**	**123**	**356**	**342**	**238**	**205**	**203**

Solar energy results to be less efficient than wind energy in Spain. Both in terms of emissions reduction and energy generation, solar technology seems to be more expensive than wind. Graphs 15 and 16 illustrates the cost and avoided costs associated to wind and solar energy per ton of CO_2 reduced and per energy generated are shown in Graphs 17 and 18.

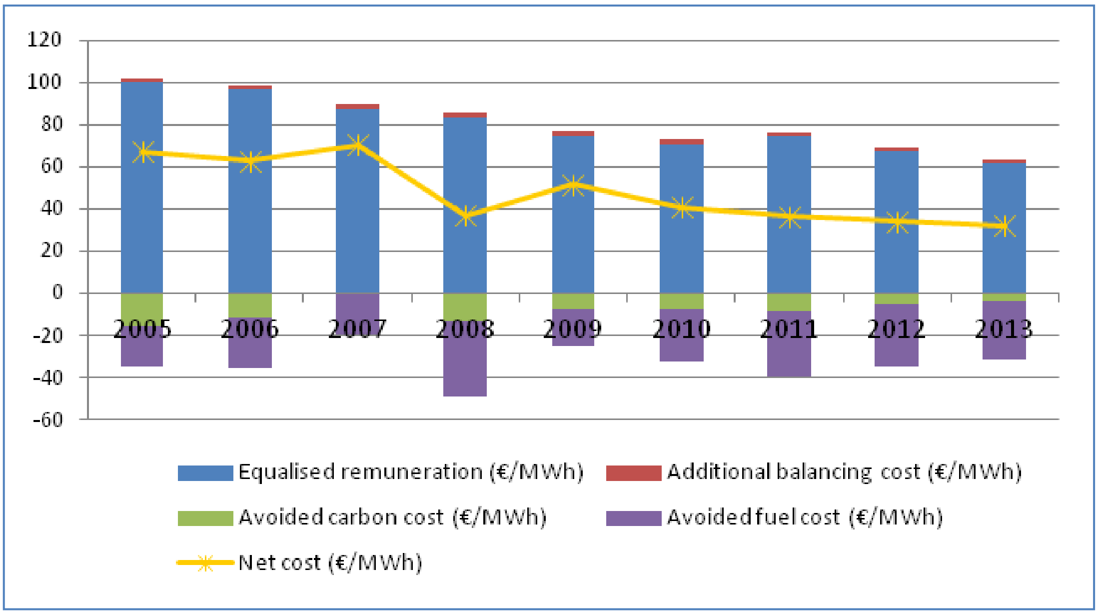
Graph 15: Cost and avoided costs per tCO2 reduced by wind energy



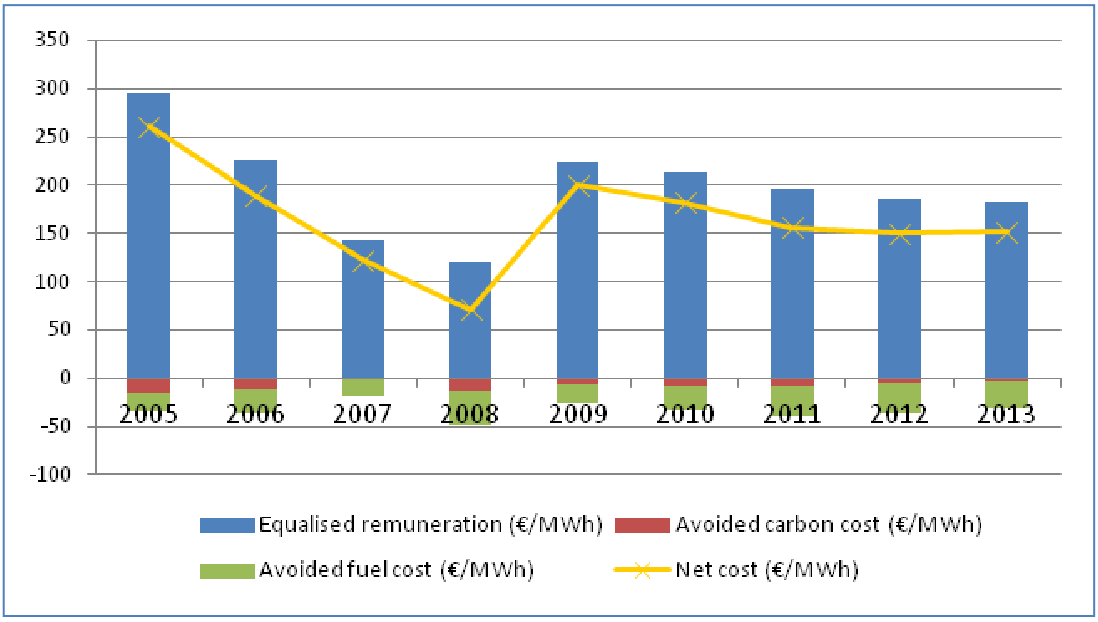
Graph 16: Cost and avoided costs per tCO2 reduced by solar energy



Graph 17: Cost and avoided costs per MWh generated by wind technology

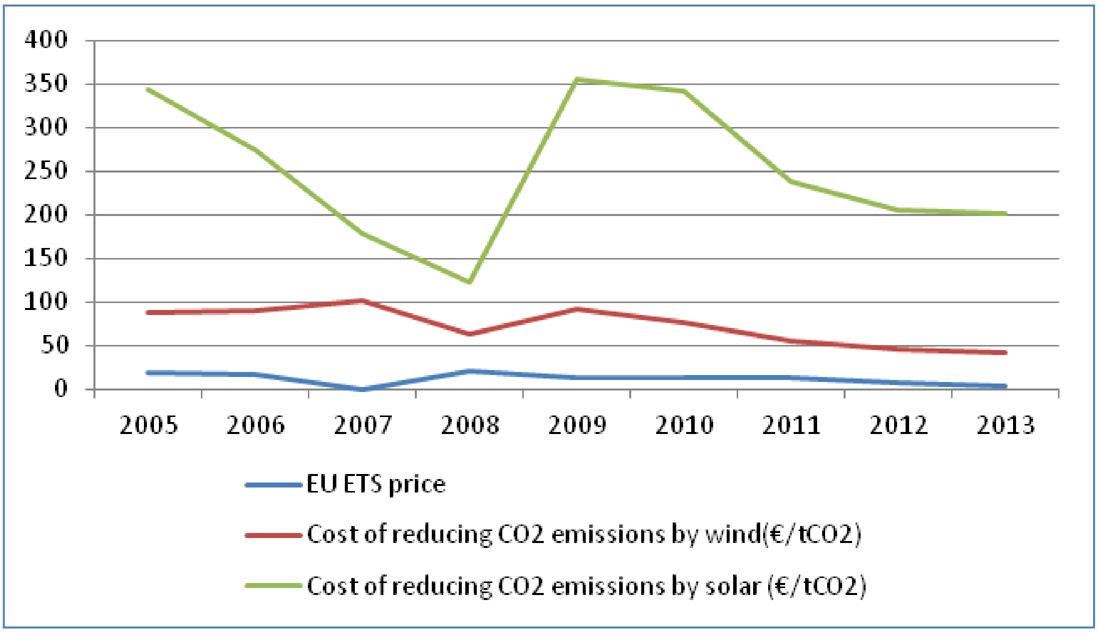


Graph 18: Cost and avoided costs per MWh generated by solar technology



The cost of reducing emissions through incentives to renewable energy (wind and solar) tends to be higher than the EU ETS price along the period studied. However, it can be appreciated an approximation between both prices in 2008 in the case of wind energy. In that year, the allowances price reached its maximum annual average price (€22.07) and fuel savings were considerably high. This effect is illustrated in Graph 19.

Graph 19: Evolution of EU ETS allowances price vs. cost of reducing emissions through incentives



In comparison to the EU ETS price, the cost of reducing emissions for wind energy does not differ as much as solar energy, keeping a reduced gap between both prices.

Chapter 6. Conclusion and further research

This research work provides an estimation of the cost of reducing emissions through the use of wind and solar photovoltaic technologies. It also provides an overview of the components that influenced this cost.

While other studies have focused on the amount of emissions reduced and the avoided cost, this work assesses how much it cost to reduce CO2 emissions using incentives to RES-E in Spain for the period 2005-2013.

6.1. Conclusion

Spain has become one of the countries with the highest level of RES integration during the last decade. This development has been possible due to a favorable regulatory framework which has incentivized the expansion of renewable technologies, especially wind and solar photovoltaic facilities and which has implied an important economic effort.

The FiT system is the most common support mechanism adopted among EU member states and it is financed by the consumers in most of the cases. The FiT scheme has demonstrates a good performance incentivizing the deployment of RES and contributing to the reduction of CO2 emissions.

The results obtained show that developing technologies such as photovoltaic, which have not yet reached a sufficient degree of maturity, have led to a higher cost in the emissions reduction process.

In the case of wind energy, the cost/benefit analysis reveals a substantial contribution to the environmental objectives at a reasonable cost. The cost of incentives could be justified by this fact, however, it does not mean that this system is the less expensive.

Given the dependency of the abatement cost to CO2 prices, it suggests that the carbon savings would be higher in the presence of higher prices leading to a lower cost of emissions reduction. The results would also vary depending on the technology displaced by renewable generation.

The benefit obtained from RES injection has been reduced by the additional balancing costs caused by wind generation variability. Although the forecast error has been reduced during last years, the need of back-up capacity is still present in the system. However, this cost is considerably small in comparison with the savings associated to wind energy.

The remuneration to generators is the main cost item. However, it has experienced a reduction by the application of the RD 413/2014. The major cost saving is provided by the avoided fuel consumption.

Regulators should learn from this study and consider the results to improve the environmental policy design of the country in terms of cost-efficiency. In this sense, wind energy performs efficiently achieving a balance between the costs and benefits associated to it. On the other hand, photovoltaic energy seems to be less efficient reaching a lower level of emissions reduction in relation to the cost incurred.

It suggests that more mature technologies are more cost effective and therefore, the subsidy level required for them should be lower. The results of this study imply that the promotion system should be able to adapt to the changes in the support level needed to avoid economic inefficiency and extra costs allocation.

From the point of view of consumers, the promotion scheme to renewable energy is financing by them through a charge on the electricity bill. Therefore, an inefficient policy design may have a negative impact on households, especially to the individuals with lower levels of income who usually spend a significant portion of their budget to electricity consumption, increasing the inequality and creating a negative distributional effect.

6.2. Further research

Further research should include the carbon savings that would have been reached taking into account the effect of RES implementation on the emissions allowances price. Additionally, transmission grid constraints could be incorporated as well as other sources of renewable energy such as geothermal or biomass technologies.

Annexes

Annex 1. Classification of the installed capacity

➢ Classification of installed capacity covered by RD 661/2007

Group	Subgroup	Year	Code assigned by the RD 413/2014	Installed capacity (MW)
b.2	b.2.1	1994	IT-01016	8
b.2	b.2.1	1995	IT-01017	57
b.2	b.2.1	1996	IT-01018	129
b.2	b.2.1	1997	IT-01019	193
b.2	b.2.1	1998	IT-01020	466
b.2	b.2.1	1999	IT-01021	800
b.2	b.2.1	2000	IT-01022	610
b.2	b.2.1	2001	IT-01023	1212
b.2	b.2.1	2002	IT-01024	1558
b.2	b.2.1	2003	IT-01025	1258
b.2	b.2.1	2004	IT-01026	2208
b.2	b.2.1	2005	IT-01027	1562
b.2	b.2.1	2006	IT-01028	1802
b.2	b.2.1	2007	IT-01029	2640
b.2	b.2.1	2008	IT-01030	1786
b.2	b.2.1	2009	IT-01031	2538
b.2	b.2.1	2010	IT-01032	845
b.2	b.2.1	2011	IT-01033	1363
b.2	b.2.1	2012	IT-01034	1567
b.2	b.2.1	2013	IT-01035	140

Group	Subgroup	Capacity range RD 661/2007	Capacity range RD 413/2014	Solar tracking technology	Commisioning year	Code assigned by RD 413/2014	Installed capacity (MW)
b.1	b.1.1	≤ 100 kW	≤ 5kW	FIJ	≤2002	IT-00437	2.2479
b.1	b.1.1	≤ 100 kW	≤ 5kW	FIJ	2003	IT-00438	2.4767
b.1	b.1.1	≤ 100 kW	≤ 5kW	FIJ	2004	IT-00439	5.3720
b.1	b.1.1	≤ 100 kW	≤ 5kW	FIJ	2005	IT-00440	5.3498
b.1	b.1.1	≤ 100 kW	≤ 5kW	FIJ	2006	IT-00441	9.4662
b.1	b.1.1	≤ 100 kW	≤ 5kW	FIJ	2007	IT-00442	17.5063
b.1	b.1.1	≤ 100 kW	≤ 5kW	FIJ	2008	IT-00443	10.6061
b.1	b.1.1	≤ 100 kW	≤ 5kW	S1E	≤2001	IT-00444	0.0729
b.1	b.1.1	≤ 100 kW	≤ 5kW	S1E	2002	IT-00445	0.3017
b.1	b.1.1	≤ 100 kW	≤ 5kW	S1E	2003	IT-00446	0.4128
b.1	b.1.1	≤ 100 kW	≤ 5kW	S1E	2004	IT-00447	0.8953
b.1	b.1.1	≤ 100 kW	≤ 5kW	S1E	2005	IT-00448	0.8916
b.1	b.1.1	≤ 100 kW	≤ 5kW	S1E	2006	IT-00449	1.5777
b.1	b.1.1	≤ 100 kW	≤ 5kW	S1E	2007	IT-00450	2.9177
b.1	b.1.1	≤ 100 kW	≤ 5kW	S1E	2008	IT-00451	1.7677
b.1	b.1.1	≤ 100 kW	≤ 5kW	S2E	≤2001	IT-00452	0.0729
b.1	b.1.1	≤ 100 kW	≤ 5kW	S2E	2002	IT-00453	0.3017
b.1	b.1.1	≤ 100 kW	≤ 5kW	S2E	2003	IT-00454	0.4128
b.1	b.1.1	≤ 100 kW	≤ 5kW	S2E	2004	IT-00455	0.8953
b.1	b.1.1	≤ 100 kW	≤ 5kW	S2E	2005	IT-00456	0.8916
b.1	b.1.1	≤ 100 kW	≤ 5kW	S2E	2006	IT-00457	1.5777
b.1	b.1.1	≤ 100 kW	≤ 5kW	S2E	2007	IT-00458	2.9177
b.1	b.1.1	≤ 100 kW	≤ 5kW	S2E	2008	IT-00459	1.7677
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	FIJ	≤2002	IT-00460	0.7550
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	FIJ	2003	IT-00461	0.6666
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	FIJ	2004	IT-00462	2.8625
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	FIJ	2005	IT-00463	13.0891
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	FIJ	2006	IT-00464	63.4129

b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	FIJ	2007	IT-00465	375.5471
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	FIJ	2008	IT-00466	1603.4618
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	S1E	≤2004	IT-00467	0.7140
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	S1E	2005	IT-00468	2.1815
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	S1E	2006	IT-00469	10.5688
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	S1E	2007	IT-00470	62.5912
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	S1E	2008	IT-00471	267.2436
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	S2E	≤2001	IT-00472	0.0721
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	S2E	2003	IT-00473	0.1111
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	S2E	2004	IT-00474	0.4771
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	S2E	2005	IT-00475	2.1815
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	S2E	2006	IT-00476	10.5688
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	S2E	2007	IT-00477	62.5912
b.1	b.1.1	≤ 100 kW	5kW < P ≤ 100kW	S2E	2008	IT-00478	267.2436
b.1	b.1.1	≤ 100 kW	100kW < P ≤ 2MW	FIJ	≤2003	IT-00479	1.1880
b.1	b.1.1	≤ 100 kW	100kW < P ≤ 2MW	FIJ	2004	IT-00480	0.2775
b.1	b.1.1	≤ 100 kW	100kW < P ≤ 2MW	FIJ	2006	IT-00482	0.7200
b.1	b.1.1	≤ 100 kW	100kW < P ≤ 2MW	FIJ	2007	IT-00483	3.7193
b.1	b.1.1	≤ 100 kW	100kW < P ≤ 2MW	FIJ	2008	IT-00484	100.7033

b.1	b.1.1	≤ 100 kW	100kW < P ≤ 2MW	S1E	≤2004	IT-00485	0.2396
b.1	b.1.1	≤ 100 kW	100kW < P ≤ 2MW	S1E	2006	IT-00487	0.1080
b.1	b.1.1	≤ 100 kW	100kW < P ≤ 2MW	S1E	2007	IT-00488	0.6888
b.1	b.1.1	≤ 100 kW	100kW < P ≤ 2MW	S1E	2008	IT-00489	16.7839
b.1	b.1.1	≤ 100 kW	100kW < P ≤ 2MW	S2E	≤2004	IT-00490	0.2396
b.1	b.1.1	≤ 100 kW	100kW < P ≤ 2MW	S2E	2006	IT-00492	0.1080
b.1	b.1.1	≤ 100 kW	100kW < P ≤ 2MW	S2E	2007	IT-00493	0.6199
b.1	b.1.1	≤ 100 kW	100kW < P ≤ 2MW	S2E	2008	IT-00494	16.7839
b.1	b.1.1	≤ 100 kW	2MW < P ≤ 10MW	FIJ	2007	IT-00497	12.6833
b.1	b.1.1	≤ 100 kW	2MW < P ≤ 10MW	FIJ	2008	IT-00498	264.8228
b.1	b.1.1	≤ 100 kW	2MW < P ≤ 10MW	S1E	2007	IT-00500	2.3488
b.1	b.1.1	≤ 100 kW	2MW < P ≤ 10MW	S1E	2008	IT-00501	44.1371
b.1	b.1.1	≤ 100 kW	2MW < P ≤ 10MW	S2E	2007	IT-00503	2.1139
b.1	b.1.1	≤ 100 kW	2MW < P ≤ 10MW	S2E	2008	IT-00504	44.1371
b.1	b.1.1	100 kW < P ≤ 10 MW	100kW < P ≤ 2MW	FIJ	≤2002	IT-00510	0.1320
b.1	b.1.1	100 kW < P ≤ 10 MW	100kW < P ≤ 2MW	FIJ	2007	IT-00513	0.4133
b.1	b.1.1	100 kW < P ≤ 10 MW	100kW < P ≤ 2MW	FIJ	2008	IT-00514	11.1893
b.1	b.1.1	100 kW < P ≤ 10 MW	100kW < P ≤ 2MW	S1E	≤2006	IT-00515	0.0386
b.1	b.1.1	100 kW < P ≤ 10 MW	100kW < P ≤ 2MW	S1E	2008	IT-00516	1.8649

b.1	b.1.1	100 kW < P ≤ 10 MW	100kW < P ≤ 2MW	S2E	≤2006	IT-00517	0.0386
b.1	b.1.1	100 kW < P ≤ 10 MW	100kW < P ≤ 2MW	S2E	2007	IT-00518	0.0689
b.1	b.1.1	100 kW < P ≤ 10 MW	100kW < P ≤ 2MW	S2E	2008	IT-00519	1.8649
b.1	b.1.1	100 kW < P ≤ 10 MW	2MW < P ≤ 10MW	FIJ	≤2007	IT-00520	1.4093
b.1	b.1.1	100 kW < P ≤ 10 MW	2MW < P ≤ 10MW	FIJ	2008	IT-00521	29.4248
b.1	b.1.1	100 kW < P ≤ 10 MW	2MW < P ≤ 10MW	S1E	2008	IT-00523	4.9041
b.1	b.1.1	100 kW < P ≤ 10 MW	2MW < P ≤ 10MW	S2E	≤2007	IT-00524	0.2349
b.1	b.1.1	100 kW < P ≤ 10 MW	2MW < P ≤ 10MW	S2E	2008	IT-00525	4.9041

- Classification of installed capacity covered by RD 1578/2008

Group	Subgroup	Category	Call of pre-allocation	Area	Commisioning year	Code assigned by RD 413/2014	Installed capacity (MW)
b.1	b.1.1	I.1	1C 2009 I1	Z1	2009	IT-00528	0.2278
b.1	b.1.1	I.1	1C 2009 I1	Z2	2009	IT-00530	0.0999
b.1	b.1.1	I.1	1C 2009 I1	Z2	2010	IT-00531	0.0110
b.1	b.1.1	I.1	1C 2009 I1	Z3	2009	IT-00532	0.2099
b.1	b.1.1	I.1	1C 2009 I1	Z3	2010	IT-00533	0.0281
b.1	b.1.1	I.1	1C 2009 I1	Z4	2009	IT-00534	0.5799
b.1	b.1.1	I.1	1C 2009 I1	Z4	2010	IT-00535	0.0311
b.1	b.1.1	I.1	1C 2009 I1	Z5	2009	IT-00536	0.4339
b.1	b.1.1	I.1	1C 2009 I1	Z5	2010	IT-00537	0.0475
b.1	b.1.1	I.1	2C 2009 I1	Z1	2009	IT-00538	0.1075
b.1	b.1.1	I.1	2C 2009 I1	Z1	2010	IT-00539	0.0713

b.1	b.1.1	I.1	2C 2009 I1	Z2	2009	IT-00540	0.2135
b.1	b.1.1	I.1	2C 2009 I1	Z2	2010	IT-00541	0.0608
b.1	b.1.1	I.1	2C 2009 I1	Z3	2009	IT-00542	0.2745
b.1	b.1.1	I.1	2C 2009 I1	Z3	2010	IT-00543	0.1761
b.1	b.1.1	I.1	2C 2009 I1	Z4	2009	IT-00544	0.6688
b.1	b.1.1	I.1	2C 2009 I1	Z4	2010	IT-00545	1.1722
b.1	b.1.1	I.1	2C 2009 I1	Z5	2009	IT-00546	0.4844
b.1	b.1.1	I.1	2C 2009 I1	Z5	2010	IT-00547	0.4018
b.1	b.1.1	I.1	3C 2009 I1	Z1	2010	IT-00549	0.2256
b.1	b.1.1	I.1	3C 2009 I1	Z1	2011	IT-00550	0.0002
b.1	b.1.1	I.1	3C 2009 I1	Z2	2009	IT-00551	0.0439
b.1	b.1.1	I.1	3C 2009 I1	Z2	2010	IT-00552	0.1167
b.1	b.1.1	I.1	3C 2009 I1	Z3	2010	IT-00554	0.2742
b.1	b.1.1	I.1	3C 2009 I1	Z4	2009	IT-00555	0.0549
b.1	b.1.1	I.1	3C 2009 I1	Z4	2010	IT-00556	1.2496
b.1	b.1.1	I.1	3C 2009 I1	Z5	2009	IT-00557	0.1829
b.1	b.1.1	I.1	3C 2009 I1	Z5	2010	IT-00558	0.6307
b.1	b.1.1	I.1	4C 2009 I1	Z1	2010	IT-00560	0.2727
b.1	b.1.1	I.1	4C 2009 I1	Z1	2011	IT-00561	0.0185
b.1	b.1.1	I.1	4C 2009 I1	Z2	2010	IT-00563	0.4242
b.1	b.1.1	I.1	4C 2009 I1	Z2	2011	IT-00564	0.0098
b.1	b.1.1	I.1	4C 2009 I1	Z3	2010	IT-00566	0.6774
b.1	b.1.1	I.1	4C 2009 I1	Z3	2011	IT-00567	0.0301
b.1	b.1.1	I.1	4C 2009 I1	Z4	2009	IT-00568	0.0511
b.1	b.1.1	I.1	4C 2009 I1	Z4	2010	IT-00569	1.6457
b.1	b.1.1	I.1	4C 2009 I1	Z4	2011	IT-00570	0.1530
b.1	b.1.1	I.1	4C 2009 I1	Z5	2010	IT-00572	1.1308
b.1	b.1.1	I.1	4C 2009 I1	Z5	2011	IT-00573	0.2166
b.1	b.1.1	I.1	1C 2010 I1	Z1	2010	IT-00574	0.1068
b.1	b.1.1	I.1	1C 2010 I1	Z1	2011	IT-00575	0.2307
b.1	b.1.1	I.1	1C 2010 I1	Z2	2010	IT-00576	0.4587
b.1	b.1.1	I.1	1C 2010 I1	Z2	2011	IT-00577	0.0300
b.1	b.1.1	I.1	1C 2010 I1	Z3	2010	IT-00578	0.4625
b.1	b.1.1	I.1	1C 2010 I1	Z3	2011	IT-00579	0.6051
b.1	b.1.1	I.1	1C 2010 I1	Z4	2010	IT-00580	1.0615
b.1	b.1.1	I.1	1C 2010 I1	Z4	2011	IT-00581	1.5478
b.1	b.1.1	I.1	1C 2010 I1	Z5	2010	IT-00582	0.5837
b.1	b.1.1	I.1	1C 2010 I1	Z5	2011	IT-00583	0.9116

b.1	b.1.1	I.1	2C 2010 I1	Z1	2010	IT-00584	0.1068
b.1	b.1.1	I.1	2C 2010 I1	Z1	2011	IT-00585	0.2307
b.1	b.1.1	I.1	2C 2010 I1	Z2	2010	IT-00586	0.4587
b.1	b.1.1	I.1	2C 2010 I1	Z2	2011	IT-00587	0.0300
b.1	b.1.1	I.1	2C 2010 I1	Z3	2010	IT-00588	0.4625
b.1	b.1.1	I.1	2C 2010 I1	Z3	2011	IT-00589	0.6051
b.1	b.1.1	I.1	2C 2010 I1	Z4	2010	IT-00590	1.0615
b.1	b.1.1	I.1	2C 2010 I1	Z4	2011	IT-00591	1.5478
b.1	b.1.1	I.1	2C 2010 I1	Z5	2010	IT-00592	0.5837
b.1	b.1.1	I.1	2C 2010 I1	Z5	2011	IT-00593	0.9116
b.1	b.1.1	I.1	3C 2010 I1	Z1	2010	IT-00594	0.0264
b.1	b.1.1	I.1	3C 2010 I1	Z1	2011	IT-00595	0.1163
b.1	b.1.1	I.1	3C 2010 I1	Z2	2010	IT-00596	0.0669
b.1	b.1.1	I.1	3C 2010 I1	Z2	2011	IT-00597	0.6916
b.1	b.1.1	I.1	3C 2010 I1	Z3	2010	IT-00598	0.0823
b.1	b.1.1	I.1	3C 2010 I1	Z3	2011	IT-00599	1.4536
b.1	b.1.1	I.1	3C 2010 I1	Z4	2010	IT-00600	0.0309
b.1	b.1.1	I.1	3C 2010 I1	Z4	2011	IT-00601	1.6269
b.1	b.1.1	I.1	3C 2010 I1	Z5	2011	IT-00603	1.4037
b.1	b.1.1	I.1	4C 2010 I1	Z1	2010	IT-00604	0.0030
b.1	b.1.1	I.1	4C 2010 I1	Z1	2011	IT-00605	0.1959
b.1	b.1.1	I.1	4C 2010 I1	Z2	2010	IT-00607	0.0180
b.1	b.1.1	I.1	4C 2010 I1	Z2	2011	IT-00608	0.7368
b.1	b.1.1	I.1	4C 2010 I1	Z3	2011	IT-00611	0.9817
b.1	b.1.1	I.1	4C 2010 I1	Z4	2011	IT-00614	0.5856
b.1	b.1.1	I.1	4C 2010 I1	Z5	2011	IT-00617	0.7120
b.1	b.1.1	I.1	1C 2011 I1	Z1	2011	IT-00619	0.0548
b.1	b.1.1	I.1	1C 2011 I1	Z2	2011	IT-00621	0.2186
b.1	b.1.1	I.1	1C 2011 I1	Z3	2011	IT-00623	0.2180
b.1	b.1.1	I.1	1C 2011 I1	Z4	2011	IT-00625	0.0961
b.1	b.1.1	I.1	2C 2011 I1	Z2	2011	IT-00631	0.0397

Group	Subgroup	Category	Call of pre-allocation	capacity range RD 413/2014	Area	Year of commissioning	Code assigned by RD 413/2014	Installed capacity (MW)
b.1	b.1.1	I.2	1C 2009 I2	20kW < P ≤ 1MW	Z1	≤2009	IT-00667	0.0960
b.1	b.1.1	I.2	1C 2009 I2	20kW < P ≤ 1MW	Z1	2010	IT-00668	0.0340
b.1	b.1.1	I.2	1C 2009 I2	20kW < P ≤ 1MW	Z2	≤2009	IT-00669	0.4740
b.1	b.1.1	I.2	1C 2009 I2	20kW < P ≤ 1MW	Z2	2010	IT-00670	0.2700
b.1	b.1.1	I.2	1C 2009 I2	20kW < P ≤ 1MW	Z3	≤2009	IT-00671	1.7519
b.1	b.1.1	I.2	1C 2009 I2	20kW < P ≤ 1MW	Z3	2010	IT-00672	0.2070
b.1	b.1.1	I.2	1C 2009 I2	20kW < P ≤ 1MW	Z4	≤2009	IT-00673	5.9651
b.1	b.1.1	I.2	1C 2009 I2	20kW < P ≤ 1MW	Z4	2010	IT-00674	2.0966
b.1	b.1.1	I.2	1C 2009 I2	20kW < P ≤ 1MW	Z5	≤2009	IT-00675	2.2922
b.1	b.1.1	I.2	1C 2009 I2	20kW < P ≤ 1MW	Z5	2010	IT-00676	0.4020
b.1	b.1.1	I.2	2C 2009 I2	20kW < P ≤ 1MW	Z1	2010	IT-00678	0.2869
b.1	b.1.1	I.2	2C 2009 I2	20kW < P ≤ 1MW	Z2	≤2009	IT-00679	1.7065
b.1	b.1.1	I.2	2C 2009 I2	20kW < P ≤ 1MW	Z2	2010	IT-00680	1.2125
b.1	b.1.1	I.2	2C 2009 I2	20kW < P ≤ 1MW	Z3	≤2009	IT-00681	1.3835
b.1	b.1.1	I.2	2C 2009 I2	20kW < P ≤ 1MW	Z3	2010	IT-00682	2.5972
b.1	b.1.1	I.2	2C 2009 I2	20kW < P ≤ 1MW	Z4	≤2009	IT-00683	1.1231
b.1	b.1.1	I.2	2C 2009 I2	20kW < P ≤ 1MW	Z4	2010	IT-00684	9.5356

b.1	b.1.1	I.2	2C 2009 I2	20kW < P ≤ 1MW	Z4	2011	IT-00685	0.5072
b.1	b.1.1	I.2	2C 2009 I2	20kW < P ≤ 1MW	Z5	≤2009	IT-00686	2.2539
b.1	b.1.1	I.2	2C 2009 I2	20kW < P ≤ 1MW	Z5	2010	IT-00687	2.6780
b.1	b.1.1	I.2	2C 2009 I2	20kW < P ≤ 1MW	Z5	2011	IT-00688	0.0000
b.1	b.1.1	I.2	3C 2009 I2	20kW < P ≤ 1MW	Z1	≤2009	IT-00689	0.1335
b.1	b.1.1	I.2	3C 2009 I2	20kW < P ≤ 1MW	Z1	2010	IT-00690	0.2760
b.1	b.1.1	I.2	3C 2009 I2	20kW < P ≤ 1MW	Z2	≤2009	IT-00691	0.0000
b.1	b.1.1	I.2	3C 2009 I2	20kW < P ≤ 1MW	Z2	2010	IT-00692	2.3310
b.1	b.1.1	I.2	3C 2009 I2	20kW < P ≤ 1MW	Z3	≤2009	IT-00693	0.0517
b.1	b.1.1	I.2	3C 2009 I2	20kW < P ≤ 1MW	Z3	2010	IT-00694	5.5496
b.1	b.1.1	I.2	3C 2009 I2	20kW < P ≤ 1MW	Z4	≤2009	IT-00695	0.6415
b.1	b.1.1	I.2	3C 2009 I2	20kW < P ≤ 1MW	Z4	2010	IT-00696	14.1014
b.1	b.1.1	I.2	3C 2009 I2	20kW < P ≤ 1MW	Z5	≤2009	IT-00697	0.0120
b.1	b.1.1	I.2	3C 2009 I2	20kW < P ≤ 1MW	Z5	2010	IT-00698	8.0510
b.1	b.1.1	I.2	4C 2009 I2	20kW < P ≤ 1MW	Z1	≤2010	IT-00699	0.4990
b.1	b.1.1	I.2	4C 2009 I2	20kW < P ≤ 1MW	Z2	≤2009	IT-00700	0.0000
b.1	b.1.1	I.2	4C 2009 I2	20kW < P ≤ 1MW	Z2	2010	IT-00701	1.8289
b.1	b.1.1	I.2	4C 2009 I2	20kW < P ≤ 1MW	Z2	2011	IT-00702	0.4591
b.1	b.1.1	I.2	4C 2009 I2	20kW < P ≤ 1MW	Z3	≤2009	IT-00703	0.0000

b.1	b.1.1	I.2	4C 2009 I2	20kW < P ≤ 1MW	Z3	2010	IT-00704	5.8058
b.1	b.1.1	I.2	4C 2009 I2	20kW < P ≤ 1MW	Z3	2011	IT-00705	0.9804
b.1	b.1.1	I.2	4C 2009 I2	20kW < P ≤ 1MW	Z4	≤2009	IT-00706	0.1111
b.1	b.1.1	I.2	4C 2009 I2	20kW < P ≤ 1MW	Z4	2010	IT-00707	13.7051
b.1	b.1.1	I.2	4C 2009 I2	20kW < P ≤ 1MW	Z4	2011	IT-00708	0.9611
b.1	b.1.1	I.2	4C 2009 I2	20kW < P ≤ 1MW	Z5	≤2009	IT-00709	0.0000
b.1	b.1.1	I.2	4C 2009 I2	20kW < P ≤ 1MW	Z5	2010	IT-00710	12.5315
b.1	b.1.1	I.2	4C 2009 I2	20kW < P ≤ 1MW	Z5	2011	IT-00711	4.0241
b.1	b.1.1	I.2	1C 2010 I2	20kW < P ≤ 1MW	Z1	≤2010	IT-00712	0.4705
b.1	b.1.1	I.2	1C 2010 I2	20kW < P ≤ 1MW	Z1	2011	IT-00713	0.2345
b.1	b.1.1	I.2	1C 2010 I2	20kW < P ≤ 1MW	Z2	≤2010	IT-00714	2.0925
b.1	b.1.1	I.2	1C 2010 I2	20kW < P ≤ 1MW	Z2	2011	IT-00715	1.0270
b.1	b.1.1	I.2	1C 2010 I2	20kW < P ≤ 1MW	Z3	≤2010	IT-00716	3.6142
b.1	b.1.1	I.2	1C 2010 I2	20kW < P ≤ 1MW	Z3	2011	IT-00717	4.0158
b.1	b.1.1	I.2	1C 2010 I2	20kW < P ≤ 1MW	Z4	≤2010	IT-00718	8.7256
b.1	b.1.1	I.2	1C 2010 I2	20kW < P ≤ 1MW	Z4	2011	IT-00719	11.2649
b.1	b.1.1	I.2	1C 2010 I2	20kW < P ≤ 1MW	Z5	≤2010	IT-00720	3.7881
b.1	b.1.1	I.2	1C 2010 I2	20kW < P ≤ 1MW	Z5	2011	IT-00721	12.6427
b.1	b.1.1	I.2	2C 2010 I2	20kW < P ≤ 1MW	Z1	≤2010	IT-00722	0.0909

b.1	b.1.1	I.2	2C 2010 I2	20kW < P ≤ 1MW	Z1	2011	IT-00723	0.0905
b.1	b.1.1	I.2	2C 2010 I2	20kW < P ≤ 1MW	Z2	≤2010	IT-00724	1.7169
b.1	b.1.1	I.2	2C 2010 I2	20kW < P ≤ 1MW	Z2	2011	IT-00725	1.4791
b.1	b.1.1	I.2	2C 2010 I2	20kW < P ≤ 1MW	Z3	≤2010	IT-00726	0.0000
b.1	b.1.1	I.2	2C 2010 I2	20kW < P ≤ 1MW	Z3	2011	IT-00727	5.4411
b.1	b.1.1	I.2	2C 2010 I2	20kW < P ≤ 1MW	Z4	≤2010	IT-00728	0.4066
b.1	b.1.1	I.2	2C 2010 I2	20kW < P ≤ 1MW	Z4	2011	IT-00729	18.9778
b.1	b.1.1	I.2	2C 2010 I2	20kW < P ≤ 1MW	Z5	≤2010	IT-00730	0.0000
b.1	b.1.1	I.2	2C 2010 I2	20kW < P ≤ 1MW	Z5	2011	IT-00731	12.5788
b.1	b.1.1	I.2	3C 2010 I2	20kW < P ≤ 1MW	Z1	≤2010	IT-00732	0.0000
b.1	b.1.1	I.2	3C 2010 I2	20kW < P ≤ 1MW	Z1	2011	IT-00733	0.0800
b.1	b.1.1	I.2	3C 2010 I2	20kW < P ≤ 1MW	Z2	≤2010	IT-00734	0.1600
b.1	b.1.1	I.2	3C 2010 I2	20kW < P ≤ 1MW	Z2	2011	IT-00735	2.4468
b.1	b.1.1	I.2	3C 2010 I2	20kW < P ≤ 1MW	Z3	≤2010	IT-00736	0.0000
b.1	b.1.1	I.2	3C 2010 I2	20kW < P ≤ 1MW	Z3	2011	IT-00737	4.3758
b.1	b.1.1	I.2	3C 2010 I2	20kW < P ≤ 1MW	Z4	≤2010	IT-00738	0.0000
b.1	b.1.1	I.2	3C 2010 I2	20kW < P ≤ 1MW	Z4	2011	IT-00739	16.1192
b.1	b.1.1	I.2	3C 2010 I2	20kW < P ≤ 1MW	Z5	≤2010	IT-00740	0.0000
b.1	b.1.1	I.2	3C 2010 I2	20kW < P ≤ 1MW	Z5	2011	IT-00741	10.1603

b.1	b.1.1	I.2	4C 2010 I2	20kW < P ≤ 1MW	Z1	≤2010	IT-00742	0.0000
b.1	b.1.1	I.2	4C 2010 I2	20kW < P ≤ 1MW	Z1	2011	IT-00743	1.5999
b.1	b.1.1	I.2	4C 2010 I2	20kW < P ≤ 1MW	Z2	≤2010	IT-00744	0.1400
b.1	b.1.1	I.2	4C 2010 I2	20kW < P ≤ 1MW	Z2	2011	IT-00745	2.0366
b.1	b.1.1	I.2	4C 2010 I2	20kW < P ≤ 1MW	Z3	2011	IT-00748	1.4095
b.1	b.1.1	I.2	4C 2010 I2	20kW < P ≤ 1MW	Z4	2011	IT-00751	5.8835
b.1	b.1.1	I.2	4C 2010 I2	20kW < P ≤ 1MW	Z5	≤2010	IT-00753	0.0900
b.1	b.1.1	I.2	4C 2010 I2	20kW < P ≤ 1MW	Z5	2011	IT-00754	4.0761
b.1	b.1.1	I.2	1C 2011 I2	20kW < P ≤ 1MW	Z1	≤2011	IT-00756	0.1735
b.1	b.1.1	I.2	1C 2011 I2	20kW < P ≤ 1MW	Z2	≤2011	IT-00758	3.1561
b.1	b.1.1	I.2	1C 2011 I2	20kW < P ≤ 1MW	Z3	≤2011	IT-00760	0.0100
b.1	b.1.1	I.2	1C 2011 I2	20kW < P ≤ 1MW	Z4	≤2011	IT-00762	0.6344
b.1	b.1.1	I.2	1C 2011 I2	20kW < P ≤ 1MW	Z5	≤2011	IT-00764	0.1898
b.1	b.1.1	I.2	2C 2011 I2	20kW < P ≤ 1MW	Z5	≤2011	IT-00774	0.2132
b.1	b.1.1	I.2	1C 2009 I2	P > 1MW	Z2	≤2010	IT-00804	2.0000
b.1	b.1.1	I.2	1C 2009 I2	P > 1MW	Z4	≤2010	IT-00805	5.2350
b.1	b.1.1	I.2	2C 2009 I2	P > 1MW	Z4	≤2009	IT-00807	2.6000
b.1	b.1.1	I.2	2C 2009 I2	P > 1MW	Z4	2010	IT-00808	4.4000
b.1	b.1.1	I.2	2C 2009 I2	P > 1MW	Z5	≤2010	IT-00809	1.2000

b.1	b.1.1	I.2	3C 2009 I2	P > 1MW	Z4	≤2010	IT-00810	1.7600
b.1	b.1.1	I.2	3C 2009 I2	P > 1MW	Z5	≤2010	IT-00811	0.6000
b.1	b.1.1	I.2	4C 2009 I2	P > 1MW	Z2	≤2010	IT-00812	0.0000
b.1	b.1.1	I.2	4C 2009 I2	P > 1MW	Z3	≤2010	IT-00813	8.7470
b.1	b.1.1	I.2	4C 2009 I2	P > 1MW	Z4	≤2010	IT-00814	6.1060
b.1	b.1.1	I.2	1C 2010 I2	P > 1MW	Z3	≤2011	IT-00817	3.5042
b.1	b.1.1	I.2	1C 2010 I2	P > 1MW	Z4	≤2011	IT-00818	3.3970
b.1	b.1.1	I.2	1C 2010 I2	P > 1MW	Z5	≤2011	IT-00820	2.9000
b.1	b.1.1	I.2	1C 2011 I2	P > 1MW	Z5	≤2011	IT-00824	0.9000
b.1	b.1.1	I.2	2C 2010 I2	P > 1MW	Z3	≤2011	IT-00828	3.2600
b.1	b.1.1	I.2	2C 2010 I2	P > 1MW	Z4	≤2010	IT-00829	2.0000
b.1	b.1.1	I.2	2C 2010 I2	P > 1MW	Z4	2011	IT-00830	4.3210
b.1	b.1.1	I.2	2C 2010 I2	P > 1MW	Z5	≤2011	IT-00832	5.5000
b.1	b.1.1	I.2	3C 2010 I2	P > 1MW	Z3	≤2011	IT-00834	0.4978
b.1	b.1.1	I.2	3C 2010 I2	P > 1MW	Z4	≤2011	IT-00835	7.5138
b.1	b.1.1	I.2	3C 2010 I2	P > 1MW	Z5	≤2011	IT-00836	6.0000
b.1	b.1.1	I.2	4C 2010 I2	P > 1MW	Z4	≤2011	IT-00837	2.9150
b.1	b.1.1	I.2	4C 2010 I2	P > 1MW	Z5	≤2011	IT-00839	5.6000

Group	Subgroup	Category	Call for pre-allocation	Solar tracking technology	Area	Year of Commisioning	Code assigned RD 413/2014	Installed capacity
b.1	b.1.1	II	1C 2009 II	FIJ	Z2	≤2009	IT-00854	0.0075
b.1	b.1.1	II	1C 2009 II	FIJ	Z2	2010	IT-00855	3.0113
b.1	b.1.1	II	1C 2009 II	FIJ	Z3	≤2009	IT-00856	0.8910
b.1	b.1.1	II	1C 2009 II	FIJ	Z3	2010	IT-00857	17.0963
b.1	b.1.1	II	1C 2009 II	FIJ	Z4	≤2009	IT-00858	1.8675
b.1	b.1.1	II	1C 2009 II	FIJ	Z4	2010	IT-00859	4.6988
b.1	b.1.1	II	1C 2009 II	FIJ	Z5	≤2009	IT-00860	0.9858
b.1	b.1.1	II	1C 2009 II	FIJ	Z5	2010	IT-00861	21.8217
b.1	b.1.1	II	2C 2009 II	FIJ	Z2	≤2009	IT-00863	4.0000
b.1	b.1.1	II	2C 2009 II	FIJ	Z3	2010	IT-00865	12.7500
b.1	b.1.1	II	2C 2009 II	FIJ	Z4	2010	IT-00867	10.9013
b.1	b.1.1	II	2C 2009 II	FIJ	Z4	2011	IT-00868	0.0675
b.1	b.1.1	II	2C 2009 II	FIJ	Z5	≤2009	IT-00869	3.7800
b.1	b.1.1	II	2C 2009 II	FIJ	Z5	2010	IT-00870	25.8248
b.1	b.1.1	II	3C 2009 II	FIJ	Z3	≤2010	IT-00871	9.0585
b.1	b.1.1	II	3C 2009 II	FIJ	Z4	≤2009	IT-00872	0.1500
b.1	b.1.1	II	3C 2009 II	FIJ	Z4	2010	IT-00873	2.5393
b.1	b.1.1	II	3C 2009 II	FIJ	Z5	2010	IT-00875	39.4830
b.1	b.1.1	II	4C 2009 II	FIJ	Z2	≤2010	IT-00876	0.5070
b.1	b.1.1	II	4C 2009 II	FIJ	Z2	2011	IT-00877	9.8500
b.1	b.1.1	II	4C 2009 II	FIJ	Z3	≤2010	IT-00878	0.4575
b.1	b.1.1	II	4C 2009 II	FIJ	Z3	2011	IT-00879	5.9375
b.1	b.1.1	II	4C 2009 II	FIJ	Z4	≤2010	IT-00880	2.6400
b.1	b.1.1	II	4C 2009 II	FIJ	Z4	2011	IT-00881	2.2500
b.1	b.1.1	II	4C 2009 II	FIJ	Z5	≤2010	IT-00882	28.2011
b.1	b.1.1	II	4C 2009 II	FIJ	Z5	2011	IT-00883	11.2595
b.1	b.1.1	II	1C 2010 II	FIJ	Z2	≤2011	IT-00884	13.3000
b.1	b.1.1	II	1C 2010 II	FIJ	Z3	2011	IT-00886	1.3836
b.1	b.1.1	II	1C 2010 II	FIJ	Z4	≤2011	IT-00887	0.8547
b.1	b.1.1	II	1C 2010 II	FIJ	Z5	≤2010	IT-00888	0.2700
b.1	b.1.1	II	1C 2010 II	FIJ	Z5	2011	IT-00889	24.8399
b.1	b.1.1	II	2C 2010 II	FIJ	Z2	≤2010	IT-00890	0.0100
b.1	b.1.1	II	2C 2010 II	FIJ	Z2	2011	IT-00891	2.7375
b.1	b.1.1	II	2C 2010 II	FIJ	Z3	2011	IT-00893	2.8328

b.1	b.1.1	II	2C 2010 II	FIJ	Z4	≤2011	IT-00894	8.1555
b.1	b.1.1	II	2C 2010 II	FIJ	Z5	2011	IT-00896	20.5142
b.1	b.1.1	II	3C 2010 II	FIJ	Z2	≤2011	IT-00897	1.2173
b.1	b.1.1	II	3C 2010 II	FIJ	Z3	2011	IT-00899	1.7488
b.1	b.1.1	II	3C 2010 II	FIJ	Z4	≤2011	IT-00900	2.0340
b.1	b.1.1	II	3C 2010 II	FIJ	Z5	≤2011	IT-00901	17.9393
b.1	b.1.1	II	4C 2010 II	FIJ	Z2	≤2011	IT-00902	0.3240
b.1	b.1.1	II	4C 2010 II	FIJ	Z3	≤2011	IT-00903	7.7786
b.1	b.1.1	II	4C 2010 II	FIJ	Z4	≤2011	IT-00905	0.0200
b.1	b.1.1	II	4C 2010 II	FIJ	Z5	≤2011	IT-00907	0.0300
b.1	b.1.1	II	1C 2011 II	FIJ	Z4	≤2011	IT-00910	1.8000
b.1	b.1.1	II	1C 2009 II	S1E	Z2	≤2009	IT-00925	0.0013
b.1	b.1.1	II	1C 2009 II	S1E	Z4	≤2009	IT-00926	0.3113
b.1	b.1.1	II	1C 2009 II	S1E	Z5	≤2009	IT-00927	0.1643
b.1	b.1.1	II	2C 2009 II	S1E	Z1	≤2009	IT-00928	0.0000
b.1	b.1.1	II	2C 2009 II	S1E	Z4	≤2010	IT-00929	1.8169
b.1	b.1.1	II	2C 2009 II	S1E	Z5	≤2010	IT-00930	4.9341
b.1	b.1.1	II	3C 2009 II	S1E	Z2	≤2010	IT-00931	15.5970
b.1	b.1.1	II	3C 2009 II	S1E	Z3	≤2010	IT-00932	3.0195
b.1	b.1.1	II	3C 2009 II	S1E	Z4	≤2010	IT-00933	0.4482
b.1	b.1.1	II	4C 2009 II	S1E	Z3	2010	IT-00935	0.0762
b.1	b.1.1	II	4C 2009 II	S1E	Z3	2011	IT-00936	1.9792
b.1	b.1.1	II	1C 2010 II	S1E	Z3	≤2011	IT-00937	0.2306
b.1	b.1.1	II	1C 2010 II	S1E	Z5	≤2010	IT-00938	0.0900
b.1	b.1.1	II	1C 2010 II	S1E	Z5	2011	IT-00939	8.2800
b.1	b.1.1	II	2C 2010 II	S1E	Z3	≤2011	IT-00940	0.4721
b.1	b.1.1	II	2C 2010 II	S1E	Z4	≤2011	IT-00941	2.7185
b.1	b.1.1	II	2C 2010 II	S1E	Z5	≤2011	IT-00942	3.4190
b.1	b.1.1	II	3C 2010 II	S1E	Z2	≤2011	IT-00943	0.4058
b.1	b.1.1	II	3C 2010 II	S1E	Z3	≤2011	IT-00944	0.2915
b.1	b.1.1	II	3C 2010 II	S1E	Z4	≤2011	IT-00945	0.6780
b.1	b.1.1	II	3C 2010 II	S1E	Z5	≤2011	IT-00946	5.9798
b.1	b.1.1	II	4C 2010 II	S1E	Z5	≤2011	IT-00947	0.0100
b.1	b.1.1	II	1C 2009 II	S2E	Z2	≤2009	IT-00954	0.0013
b.1	b.1.1	II	1C 2009 II	S2E	Z2	2010	IT-00955	1.0038
b.1	b.1.1	II	1C 2009 II	S2E	Z3	≤2009	IT-00956	0.2970
b.1	b.1.1	II	1C 2009 II	S2E	Z4	≤2009	IT-00957	0.3113
b.1	b.1.1	II	1C 2009 II	S2E	Z4	2010	IT-00958	1.5663

b.1	b.1.1	II	1C 2009 II	S2E	Z5	≤2009	IT-00959	0.1643
b.1	b.1.1	II	1C 2009 II	S2E	Z5	2010	IT-00960	7.2739
b.1	b.1.1	II	2C 2009 II	S2E	Z3	2010	IT-00962	4.2500
b.1	b.1.1	II	2C 2009 II	S2E	Z5	≤2009	IT-00963	0.6300
b.1	b.1.1	II	3C 2009 II	S2E	Z4	≤2010	IT-00964	0.4482
b.1	b.1.1	II	3C 2009 II	S2E	Z5	≤2010	IT-00965	13.1610
b.1	b.1.1	II	4C 2009 II	S2E	Z2	≤2010	IT-00967	0.1690
b.1	b.1.1	II	4C 2009 II	S2E	Z3	≤2010	IT-00968	0.0762
b.1	b.1.1	II	4C 2009 II	S2E	Z4	≤2011	IT-00969	1.6300
b.1	b.1.1	II	4C 2009 II	S2E	Z5	≤2010	IT-00970	9.4004
b.1	b.1.1	II	4C 2009 II	S2E	Z5	2011	IT-00971	3.7532
b.1	b.1.1	II	1C 2010 II	S2E	Z3	2011	IT-00973	0.2306
b.1	b.1.1	II	1C 2010 II	S2E	Z4	≤2011	IT-00974	0.2849
b.1	b.1.1	II	2C 2010 II	S2E	Z2	≤2011	IT-00975	0.9125
b.1	b.1.1	II	2C 2010 II	S2E	Z3	2011	IT-00977	0.4721
b.1	b.1.1	II	2C 2010 II	S2E	Z5	2011	IT-00979	3.4190
b.1	b.1.1	II	3C 2010 II	S2E	Z3	2011	IT-00981	0.2915
b.1	b.1.1	II	4C 2010 II	S2E	Z2	≤2011	IT-00982	0.1080
b.1	b.1.1	II	4C 2010 II	S2E	Z3	2011	IT-00984	2.5929

<u>Annex 2.</u> Calculation of the annual retribution to generators

➢ Wind technology annual retribution (M€)

Code IT	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
IT-01016	4	4	4	3	3	3	2	3	2	2	3	2	2	2	2	1	2	1	1
IT-01017	-	28	27	24	22	21	19	20	16	14	20	18	14	17	13	11	12	10	6
IT-01018	-	-	61	53	49	45	42	45	35	32	44	41	30	34	29	24	24	23	13
IT-01019	-	-	-	79	72	68	63	66	51	48	65	61	48	57	43	36	40	36	20
IT-01020	-	-	-	-	176	165	152	160	124	116	159	147	116	136	103	91	99	89	51
IT-01021	-	-	-	-	-	281	259	272	210	197	266	247	196	238	177	158	171	153	94
IT-01022	-	-	-	-	-	-	196	205	160	151	192	192	151	181	135	120	132	117	69
IT-01023		-	-			-													

	-			-	-		-	408	319	301	402	383	303	364	269	240	262	234	136
IT-01024	-	-	-	-	-	-	-	-	406	388	500	493	392	470	346	311	328	303	168
IT-01025	-	-	-	-	-	-	-	-	-	313	409	397	316	382	279	251	268	245	138
IT-01026	-	-	-	-	-	-	-	-	-	-	679	689	556	676	490	444	451	429	242
IT-01027	-	-	-	-	-	-	-	-	-	-	-	484	394	478	346	314	340	304	185
IT-01028	-	-	-	-	-	-	-	-	-	-	-	-	452	556	400	365	387	351	237
IT-01029	-	-	-	-	-	-	-	-	-	-	-	-	-	703	585	529	548	512	380
IT-01030	-	-	-	-	-	-	-	-	-	-	-	-	-	-	376	357	322	314	268
IT-01031	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	517	446	453	386
IT-01032	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	151	151	130

IT-01033	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	240	214
IT-01034	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	227
IT-01035	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
Total anual	4	32	91	159	321	584	734	1178	1325	1563	2739	3153	2969	4294	3592	3769	3983	3965	2972

Code IT	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
IT-01016	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IT-01017	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IT-01018	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IT-01019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IT-01020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IT-01021	-	-	-																	

				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IT-01022	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IT-01023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IT-01024	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IT-01025	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IT-01026	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IT-01027	24	22	21	26	24	23	25	24	22	29	27	25	-	-	-	-	-	-	-	-
IT-01028	72	67	62	73	68	63	65	61	57	63	59	55	93	-	-	-	-	-	-	-
IT-01029	186	173	161	166	154	144	142	132	123	125	116	108	122	113	-	-	-	-	-	-
IT-01030	168	156	146	145	135	126	123	114	106	105	98	91	95	89	83	-	-	-	-	-

IT-01031	266	247	230	226	210	196	190	177	165	162	151	140	142	132	123	151	-	-	-	-
IT-01032	87	81	75	74	69	64	62	58	54	53	49	46	46	42	40	43	40	-	-	-
IT-01033	131	122	114	113	106	98	95	89	82	80	75	70	69	64	60	62	57	53	-	-
IT-01034	150	140	130	126	117	109	105	98	91	88	82	76	74	69	65	65	60	56	66	-
IT-01035	13	12	12	11	10	9	9	8	8	7	7	6	6	6	5	5	5	5	5	4
Total anual	1096	1021	951	959	893	831	817	760	708	713	664	618	647	515	374	325	162	114	71	4

➢ Solar technology annual retribution (k€)[32]

Code IT	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
IT-0043	1991	2065	2018	1963	1828	1759	1692	1562	1484	1421	1644	1798	1673	1554	1496	1394	1299
IT-00438	-	2276	2223	2163	2014	1938	1865	1721	1636	1565	1749	1866	1737	1613	1551	1446	1348
IT-00439	-	-	5373	5033	4743	4574	4473	3860	3282	3193	3873	3692	3436	3190	3071	2862	2667
IT-00440	-	-	-	5080	4714	4625	4487	3802	3289	3247	3794	3573	3325	3086	2970	2768	2580
IT-00441	-	-	-	-	9202	9068	8870	7729	6271	6188	6656	5780	5377	4990	4806	4479	4173
IT-00442	-	-	-	-	-	16540	16404	14153	11566	11421	12325	10662	9920	9206	8862	8258	7695
IT-00443	-	-	-	-	-	-	9422	8533	6943	6847	7468	6521	6067	5630	5417	5048	4704
IT-00445	375	423	434	439	425	404	412	343	275	284	257	189	176	163	158	147	137
IT-00446	-	586	602	572	554	529	544	464	377	377	345	256	238	221	214	199	186
IT-00447	-	-	1207	1157	1112	1065	1040	840	726	760	731	631	587	544	525	489	456

[32] Only a sample have been displayed due to the great amount of type of installations that classify the installed solar capacity

IT-00448	-	-	-	1062	1240	1230	1208	882	748	744	677	581	540	501	490	457	425
IT-00449	-	-	-	-	2148	1984	1983	1679	1436	1353	1300	1031	959	890	858	799	745
IT-00450	-	-	-	-	-	2308	2925	2490	2385	2285	2312	2248	2092	1941	1865	1738	1619
IT-00451	-	-	-	-	-	-	1971	1738	1593	1529	1427	1242	1155	1072	1031	960	895
IT-00452	110	110	105	93	94	98	101	76	64	61	62	53	50	46	44	41	38
IT-00453	535	449	475	436	471	463	441	330	272	253	236	181	169	156	156	145	135
IT-00454	-	627	650	608	595	575	572	460	387	367	338	264	245	228	222	207	193
IT-00455	-	-	1409	1340	1292	1240	1262	1061	828	823	747	562	523	485	470	438	408
IT-00456	-	-	-	1331	1348	1332	1244	1088	853	839	754	545	507	470	462	430	401
IT-00457	-	-	-	-	2385	2295	2211	1964	1501	1504	1333	994	924	857	837	780	726
IT-00458	-	-	-	-	-	3932	3955	3439	2787	2718	2478	1992	1853	1718	1655	1542	1437
IT-00459	-	-	-	-	-	-	1937	1821	1647	1554	1485	1313	1221	1133	1090	1015	946

Code IT	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
IT-00437	1248	1163	1084	1047	976	909	887	827	771	772	719	671	793	-	-	-	-	-	-
IT-00438	1293	1205	1123	1082	1009	940	914	851	793	785	732	682	725	676	-	-	-	-	-
IT-00439	2556	2382	2220	2136	1991	1856	1798	1676	1562	1534	1430	1332	1363	1270	1184	-	-	-	-
IT-00440	2470	2302	2145	2061	1921	1790	1730	1612	1502	1468	1368	1275	1278	1191	1110	1319	-	-	-
IT-00441	3994	3722	3468	3329	3102	2891	2788	2598	2421	2355	2195	2046	2028	1890	1761	1877	1749	-	-
IT-00442	7358	6856	6389	6126	5709	5320	5122	4773	4448	4312	4018	3745	3682	3431	3197	3276	3053	2845	-
IT-00443	4495	4188	3903	3739	3484	3246	3121	2908	2710	2620	2442	2275	2224	2072	1931	1939	1807	1684	2006
IT-00445	132	123	115	111	103	96	94	88	82	82	76	71	85	-	-	-	-	-	-
IT-00446	178	166	155	149	139	130	126	118	110	109	101	94	101	94	-	-	-	-	-
IT-00447	437	407	379	365	340	317	308	287	267	263	245	228	234	218	203	-	-	-	-
IT-00448	408	380	354	340	317	295	286	266	248	243	226	211	212	197	184	220	-	-	-
IT-00449	713	664	619	594	554	516	498	464	432	421	392	365	363	338	315	337	314	-	-

IT-00450	1548	1443	1344	1289	1201	1119	1078	1004	936	907	846	788	775	722	673	689	643	599	-
IT-00451	855	797	743	712	663	618	594	554	516	499	465	433	424	395	368	370	344	321	383
IT-00452	37	34	32	31	29	27	26	24	23	23	21	20	24	-	-	-	-	-	-
IT-00453	130	121	113	109	102	95	93	86	80	81	75	70	84	-	-	-	-	-	-
IT-00454	185	172	161	155	144	135	131	122	114	113	105	98	105	98	-	-	-	-	-
IT-00455	391	365	340	327	305	284	276	257	239	236	219	204	210	196	182	-	-	-	-
IT-00456	384	358	333	321	299	278	269	251	234	229	213	199	200	186	173	208	-	-	-
IT-00457	696	648	604	580	540	503	486	453	422	411	383	357	354	330	307	329	306	-	-
IT-00458	1375	1281	1193	1145	1067	994	957	892	831	806	751	700	689	642	598	614	572	533	-
IT-00459	904	843	785	752	701	653	628	585	545	527	491	458	448	417	389	390	364	339	405

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