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Analysis of the Participation of European Countries in the Energy Call of the 7th Framework Programme (2005-2011) with Emphasis in Spain

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Abstract

Renewable energies and, in general, green energy technologies, are an area of a growing interest for mitigating the effects of climate change. The aim of this study is to analyse R & D efforts of European countries in sustainable energies through the analysis of its participation in the Energy Call of the 7th Framework Programme (FP) of the European Union. Results obtained show that Spanish R & D is very important in solar and wind sectors. In addition, public system and companies of the energy sector occupy a very important position in projects funded under the Energy call of the 7th FP. This confirms the innovative potential achieved of Spanish R & D which has managed to establish Spain as one of the leading international references in renewable technologies, particularly in solar and wind energies, while in Europe and worldwide contexts, biofuels are the most important area.

Keywords

R & D, Green Energy Technologies, Renewable Energies, 7th Framework Programme

1. Introduction

The expression "climate change" is the common factor defining a varied set of environmental threats which, at the global scale, have a negative impact on different fields with ecological, health, labour, legislative, economic

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and political implications. In whatever case, industrial activities are largely responsible for climate change as they are based on models of economic growth that are adverse to sustainable development, where production systems and energy consumption are enormously aggressive both for the environment and for socio-economic development. Although the final word has not yet been said and there is widespread agreement that the causes of global warming, their determining factors and the interrelations existing between them are not fully known, intensive research work has now been carried out in the last years in all developed countries. These efforts come not just within the scope of environmental disciplines but also in the technological, health, social and economic sectors, as well as from various multidisciplinary and interdisciplinary perspectives. Scientific policies, such as those promoted under the 7th Framework Programme in the field of *Renewable energies* (*RE*), are necessary for strengthening this sector at European level [1].

At European and national levels, different plans from Renewable Energies have been established, establishing different objectives of primary or final energy consumption coming from these sources. In addition, in 2009, Directive 2009/28/EC on the promotion of the use of energy from renewable resources came into force setting a gross final consumption of renewable energies of 20% for 2020. In the next years, there is a need to increase the share of renewable energies and improve other green energy alternatives such as CO_2 capture and storage, energy efficiency, low energy lighting, etc., which will need extended R & D efforts both at national and European levels.

In the European Union, special mention should be made of investments devoted to funding research in climate change within the framework of the Strategic Energy Technology Plan (SET-Plan) presented in 2007 by the European Commission in order to accelerate the development and implementation of clean technologies [2] [3]. This plan has two phases. A medium-term phase up to 2020 involves: a) the development of biofuels as an alternative to fossil fuels; b) the commercial use of CO_2 capture and storage technologies; c) the improvement of the energy generation capacity of wind turbines, especially offshore wind turbines; and d) the commercial availability of photovoltaic solar energy and solar energy by concentration at industrial scale. On the other side, phase two of the plan involves complete decarbonisation by 2050.

The 7th Framework Programme (FP) is the main mechanism at European level for promoting research and the tool used by the SET-Plan for developing research into renewable energies and other green or clean energy technologies. These research activities have been complemented by other activities coming under specific subprogrammes of the FP, such as those concerned with energy and transport, which have helped to identify and fine-tune measures for mitigating climate change by means of advances in the field of energy efficiency, renewable energies and transport systems more in accord with the needs of sustainability. Together with the research activities forming part of the FPs, the European Research Council (ERC) has carried out intensive work on funding and supporting scientific research in these fields.

In Spain, the National R & D & I Plan for 2008-2011 pay special attention to these issues via its "Energy and Climate Change" strategic line. Its general aim is "the development of a sustainable energy system fed by local resources, especially renewable ones, or which are widely available on the world market, such as clean coal and nuclear energy, as well as of technologies aimed at achieving improvements in energy efficiency, reducing energy consumption and mitigating, anticipating and adapting to climate change". This strategic line aims to develop a common strategy that will avoid duplications and ensure continuity of the priority research lines and the communication of results to public authorities, improve knowledge transfer and excellence of research in this field, promote innovation in the private sector and increase the returns of the 7th FP on energy and climate change.

Altogether, the national R & D plans have granted, growing in importance year by year, the research in climate change and energy systems from the point of view of sustainable development. Nevertheless, the allocated funding is still insufficient, especially if account is taken of the importance of the renewable energies sector in the international context [4].

Green energy technologies represents a thriving sector as highlighted by the changes introduced in recent times in public policies for the promotion of green technologies which have been reflected by a boost in both technological and scientific production [5]. This trend has been identified in other studies, which show that between 1978 and 2005, the percentage of patents related to green technologies rose with respect to the total number of patents [6]. This same trend has also been observed in scientific production in renewable energies at world level [7] [8].

2. Objectives

The aim of this work is a) to analyse the participation of the different European countries in the Energy Call of the 7th FP with special regards to Spain and b) to identify the main agents or entities generating scientific knowledge on green energy technologies.

3. Methodology

The indicators analysed in this study have been obtained from the CORDIS projects database, produced by the European Commission, with the aim of studying Spanish participation and that of other European countries in the Energy call of 7th FP during the period 2007-2011.

The use of these sources of information responds to the need to assess the role played by the private corporate sector in R & D in green energy technologies. Access to funding charged to Framework Programmes constitutes an option that is within the reach of public and private R & D entities and is clearly representative of the trends and capacities in research in both these sectors.

4. Results

During the period 2007-2011, the European Commission approved 220 projects in the Energy call of the 7th FP (**Table 1**). Distribution of total number of projects and total budget by green energy in the Energy Call of FP7 is shown in **Figure 1**.

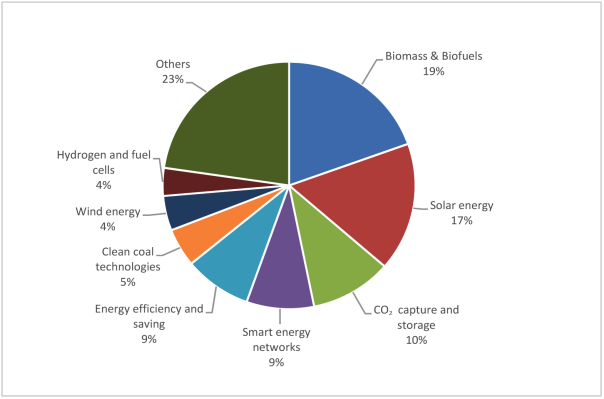
4.1. Projects and Budget Founded by Fields

The most important field is *Renewable electricity generation*, with 61 projects funded in the period 2007-2011, representing a 28.2% of the projects granted and around 30.1% of the total budget. In Renewable electricity generation, outstands *Photovoltaics technology* (23 projects), *Concentrated solar power* (10 projects) and *Wind energy* (10 projects). The rest of fields are: *Biomass* (6 projects), *Ocean* (6 projects), *Cross-cutting issues* (3 projects), *Hydro* (2 projects) and *Geothermal energy* (1 project). Efforts in *Solar energy* (photovoltaics or concentrated solar power) represents more than 50% of total projects in renewable energy generation and a significant amount of the total budget for the field of *Renewable energy generation*.

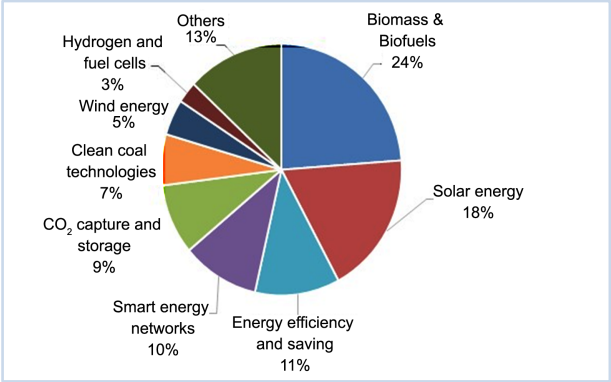
Table 1. Number of projects funded by the 7th Framework Programme by fields.

Technology	Projects[1]	% Total projects	Budget (€)	% Total budget	Average budget (€)
Renewable electricity generation	61	28.2	257,797,411	29.9	4,226,187
Renewable fuel production	35	16.2	155,837,041	18.1	4,452,487
CO_2 capture and storage technologies for zero emission[1]	23	11.1	80,042,962	9.3	3,335,123
Horizontal programme actions	22	10.2	52,698,582	6.1	2,395,390
Energy efficiency and savings	19	8.8	97,790,592	11.4	5,146,873
Smart energy networks	19	8.8	89,391,279	10.4	4,704,804
Clean coal technologies	11	4.6	56,426,256	6.5	5,642,626
Renewable for heating and cooling	9	4.2	27,748,030	3.2	3,083,114
Knowledge for energy policy making	9	4.2	15,821,884	1.8	1,757,987
Hydrogen and fuel cells	8	3.7	23,867,247	2.8	2,983,406
Other	4		4,079,220	0.5	1,998,690
Total	220	100.0	861,500,504	100	3,969,543

[1]Two projects, representing 2.135 million €, are cross cutting actions between activities ENERGY.5 "CO_2 capture and storage technologies for zero emission power generation" and ENERGY.6 "Clean coal technologies", in the field of cross cutting and regulatory issues. Half of the projects and the total budget have been assigned to each field. [2]There are 4 other projects regarding different issues (Energy field): "Preparatory activities of the joint technology initiative for fuel cell and hydrogen", "European Energy Research Alliance (EERA) Secretariat" and "Strategic Energy Technology Plan Conference 2010" and "The European Strategic Energy Technology Plan SET-PLAN towards a low-carbon future".



(a)



(b)

Figure 1. Distribution of total number of projects (a) and total budget (b) by green energy in the Energy Call of FP7.

The second largest field is *Renewable fuel productions* (35 projects), representing a 16.2% of the projects granted and 18.2% of the total budget. In *Renewable fuel production*, outstands the 2nd *generation fuels from biomass* (17 projects), followed by *Bio refinery* (7 projects) and *Cross-cutting issues* (5 projects). The rest of subfields were covered only by 1 or 2 projects, *i.e. Biofuels from energy crops* (2 projects), *Alternative routes to renewable fuel production* (2 projects), 1st *generation fuel from biomass* (1 project) and *Biofuel use in transport* (1 project).

Third most important field is CO_2 *capture and storage technologies for zero emission*, with 23 projects granted, representing an 11.1% of total granted projects and a 9.3% total budget. In the field of CO_2 *capture and storage technologies for zero emission power generation*, a total of 23 projects were founded, with similar number of projects focus in CO_2 *capture* (10 projects) and CO_2 *storage* (12 projects). The other project takes into account the two projects which are cross cutting actions between "CO_2 *capture and storage technologies for zero emission power generation*" and "*Clean coal technologies*", regarding cross cutting and regulatory issues.

Horizontal programmes, *energy efficiency* and *savings and smart energy network* fields have a similar importance (around 20 projects), representing each around 9% - 10% of the projects granted. However, *energy efficiency and savings and smart energy networks* have a similar share of total budget (9% - 11%) but *horizontal programme actions* representing only 6% of total budget. Within the horizontal programme actions, the following subfields were funded: *Novel materials for energy applications* (6 projects), *Future emerging technologies* (FET) (5 projects), *Trans-national cooperation among national contact points* (NCPs) (2 projects) and *other horizontal actions* (9 projects). In *energy efficiency and savings*, the main subfield is *Efficient energy use in the manufacturing industry* (9 projects of the 19 total projects founded), followed by high *Efficiency policy generation* (4 projects) and *Innovative integration of renewable energy supply and energy efficiency in large communities* (CONCERTO) (4 projects) and innovative strategies for clean urban transport (CIVITAS) (1 project). In *Smart energy networks field*, *cross cutting* issues and *technologies* is the most important subfield (14 projects)

while the development of *Inter-active distribution energy networks* and the *Pan-European energy networks* were funded with 4 projects each one.

On the other side, *clean coal technologies*, *renewable for heating and cooling*, *knowledge for energy policy making* and *hydrogen and fuel cells* were the fields with the lowest number of projects funded (ten or less projects), representing together around 15% total budget. In the field of *Clean coal technologies*, 7 projects were funded in the subfield *Conversion technologies for zero emission power generation* were and 4 projects in cross cutting and regulatory issues. In *Renewables for heating and cooling* the 9 projects funded were distributed in the following different subfields as: 7 projects for *Low/medium temperature solar thermal energy* (including 2 projects related with biomass and 1 project related to geothermal energy) and 2 projects in Cross-cutting issues. In the field of *Knowledge for energy policy making*, 6 projects funded knowledge tools for *Energy-related policy making* and 3 projects were funded for *Scientific support to policy*. In the field of *Hydrogen and fuel cells*, 4 projects were related to *Fuel cells* and other 4 related to *Hydrogen supply*.

As it can be seen, *Renewable energy sources* (renewable electricity, renewable fuel productions and renewable for heating and cooling) together represented 48.6% of the number of projects (105 projects) and 51.5% of the total budget (around 441.4 million €). The average budget of the funded projects is 3.969.543 €. *Knowledge for energy policy making and horizontal programme actions* are those fields with the lowest budgets per project, an average of 1.6 and 2.4 million €, respectively. On the other side, fields such as *Clean coal technologies and energy efficiency and savings* are those with the highest budgets: 5.6 and 5.1 million € on average, respectively.

Green energy technologies can be found simultaneously in different FP7 fields. Considering all these fields it can be said that at least these would be the number of projects and total budget of these projects by type of green energy (as there are cross-cutting issues in virtually affecting different subfields):

- Biomass & biofuels (43 projects): 6 projects in renewable electricity generation, 35 projects in renewable fuel production and 2 projects in renewable for heating and cooling.
- Solar energy (37 projects): photovoltaics for renewable electricity generation (23 projects), concentrated solar power for renewable electricity generation (10 projects), low/medium temperature solar thermal energy (4 projects).
- Wind energy (10 projects): renewable electricity generation.
- Hydrogen and fuel cells (8 projects).
- CO_2 capture and storage: 23 projects.
- Smart energy networks: 19 projects.
- Energy efficiency and saving: 19 projects.
- Clean coal technologies: 11 projects.
- Others: 50 projects (geothermal energy, hydro energy, horizontal programme actions, knowledge for energy and policy making, etc.).

It is important to emphasize that the R & D & I approach of the European Commission tend to cover widely and horizontally all the issues that may produce a positive impact for European competitiveness. All the other World regions present strategies oriented to more directional research priorities to address cutting-edge challenges, *i.e.* the China's directionality towards solar technologies [9].

4.2. Projects and Fields by Countries

Table 2 shows the participation rates of the most important countries of the European Union in the different fields of the Energy Call and the % of coordinated projects.

The country with the highest participation rate in energy-related projects under the 7th FP is Germany (**Table 2**), with a participation rate of 70.9% (156 projects). The following countries in terms of participation are France (108 projects), the United Kingdom (107 projects), Netherlands (99 projects), Italy (97 projects) and Spain (85 projects), meaning participation rates between 38.6% (Spain) and 49.1% (France). Other EU-15 countries have the following number of participations: Belgium (75 projects), Denmark (51 projects), Sweden (48 projects), Greece (43 projects), Austria (35 projects), Portugal (34 projects), Finland (25 projects), Ireland (16 projects), Luxembourg (5 projects). Other European countries not in the European Union with importance are Switzerland (78 projects, 35.4%) and Norway (45 projects, 20.4%).

Germany is also the country with the greatest leadership capacity, coordinating 17.7% of the total number of projects. Italy, United Kingdom, France, Spain and Netherlands have similar leadership capacities, ranging from

Table 2. Number of projects of the Energy Call of the 7th FP of the European countries with the highest participation rates by fields.

Technology/number of projects (% respect to total for the field)	Germany	France	UK	Netherlands	Italy	Spain	Total EU-15
Renewable electricity generation	51 (83.6%)	26 (42.6%)	31 (50.8%)	25 (41.0%)	23 (37.7%)	28 (45.9%)	61
Renewable fuel production	21 (60.0%)	12 (34.3%)	16 (45.7%)	18 (51.4%)	11 (31.4%)	12 (34.3%)	35
CO_2 capture and storage technologies for zero emission	16 (72.7%)	17 (77.3%)	16 (72.7%)	16 (71.7%)	9 (40.9%)	8 (36.4%)	23
Horizontal programme actions	14 (63.6%)	11 (50.0%)	11 (50.0%)	11 (50.0%)	14 (63.6%)	7 (31.8%)	22
Energy efficiency and savings	14 (73.7%)	6 (31.6%)	5 (26.3%)	3 (15.8%)	8 (42.1%)	2 (10.5%)	19
Smart energy networks	13 (68.4%)	11 (57.9%)	12 (63.2%)	10 (52.6%)	10 (52.6%)	14 (73.7%)	19
Clean coal technologies	5 (41.7%)	7 (58.3%)	7 (58.3%)	7 (58.3%)	3 (25.0%)	4 (33.3%)	11
Renewable for heating and cooling	1 (0.63%)	1 (0.91%)	0	0	0	0	1
Knowledge for energy policy making	7 (77.8%)	6 (66.7%)	5 (55.6%)	5 (55.6%)	6 (66.7%)	4 (44.4%)	9
Hydrogen and fuel cells	6 (75.0%)	6 (75.0%)	3 (37.5%)	2 (25.0%)	6 (75.0%)	2 (25.0%)	8
Other (undetermined)	1 (25.0%)	2 (50.0%)	0	1 (25.0%)	1 (25.0%)	0 (0%)	12
Projects (total)	157	109	107	99	97	85	220
Participation percentage	70.9	49.1	48.6	45.0	44.1	38.6	-
Coordinated Projects (% respect to the total number of projects from the country)	39 (25.0%)	21 (19.4%)	22 (20.7%)	18 (18.2%)	27 (27.8%)	20 (23.5%)	147
Percentage of coordinated projects vs. total projects in the Energy call	17.7	9.5	10.0	8.2	12.3	9.1	66.5

8.2% (the Netherlands) to 12.3% (Italy), far from Germany. If the number of coordinated projects respect to the total number of projects with participation of each country is considered, the case of Italy and Spain are particularly worth nothing. These countries are those with the lowest participation rates but having similar or even higher percentages of coordinated projects with respect to the total of projects in which they participate (Italy: 27.8%, Spain: 23.5%) compared to Germany (25.0%), United Kingdom (20.7%), France (19.4%) and Netherlands (18.2%). Germany, France, United Kingdom, Netherlands, Italy and Spain coordinated all together 147 of the 220 projects (66.8%) of the FP7 Energy Call during the period 2005-2011. The other 73 projects were coordinated by the other European countries as follows: Belgium (14), Denmark (10), Greece (10), Norway (9), Sweden (7), Finland (7), Switzerland (4), Ireland (4), Portugal (3), Austria (2), Hungary (2) and Iceland (1).

By fields, Germany shows a participation rate of more than 60% in all technologies studied but in clean technologies from coal (41.7%), with an outstanding presence in sources of renewable energies for heating and cooling (participating in the 88.9% of the projects in this area) and generation of electricity from renewable sources (83.6%). In the case of France, its major participation rates are found in CO_2 capture and storage technologies (77.3%) and hydrogen and fuel cells (75.0%), while production of fuel from renewable sources is the area with the lowest participation rate (34.3%). In the case of the United Kingdom, the area with the highest participation rate is CO_2 capture and storage technologies (72.7%) while sources of renewable energies for heating and cooling (11.1%), energy saving and energy yield (26.3%) and hydrogen and fuel cells (37.5%) are the areas with the lowest participation rate. The Netherlands shows the highest participation rate in CO_2 capture and storage technologies and the lowest in sources of renewable energies for heating and cooling (11.1%), energy saving and energy yield (15.8% and hydrogen and fuel cells (25.0%). In the case of Italy, the most important areas are hydrogen and fuel cells (75.0%), sources of renewable energies for heating and cooling (66.7%) and energy policy (66.7%), and the less important areas are clean technologies from coal (25.0%) and production of fuel from renewable sources (31.4%). Finally, in Spain, the areas in which the participation rate is high is intelligent energy networks (73.7%), while the areas with the lowest Spanish participation are energy saving and energy yield (10.5%), hydrogen and fuel cells (25.0%).

A similar analysis can be done by thematic fields. In the field of hydrogen and fuel cells, Germany, France and Italy are the countries with the highest participation (75% participation rate) while the participation rates of United Kingdom (37.5%), the Netherlands and Spain (25% each) are considerably lower. In the field of generation of electricity from renewable sources, Germany is the country with the highest participation rate (83.6%). The rest of countries have similar participation rate, very much lower than Germany, ranging between 37.7% and 50.8%. In the area of production of fuel from renewable sources, Germany is the country with the highest participation rate (60.0%), and the Netherlands and the United Kingdom have slightly lower participation rates, 51.4% and 45.7%, respectively. France, Italy and Spain have very similar participation rates in this field, ranging from 31.4% to 34.3%. In the field of sources of renewable energies for heating and cooling, the highest participation rate is from Germany (8 of the 9 projects in this field), France, Spain and Italy have similar intermediate participation rates (from 4 to 6 projects each) and finally, the participation of the United Kingdom and the Netherlands is rather low (only in one project each). In the field of CO_2 capture and storage technologies, Germany, France, the United Kingdom and the Netherlands are those with the highest participation rates, ranging from 71.2% to 77.3%. The other two countries, Italy and Spain, have very low participation rates: 40.9% and 36.4%, respectively. The participation in clean technologies from coal is very similar with the exception that Germany has slightly lower participation rates (41.7%) than France, the United Kingdom and the Netherlands (58.3% each); Spain and Italy participating in 33.3% and 25.0% of the projects in this field, respectively. In relation to intelligent energy networks, Spain and Germany are the leaders in terms of participation rate, 73.7% and 68.4%, respectively. The other countries have very similar participation rates, ranging from 52.6% to 63.2%. In the field of energy saving and energy yield, Germany is clearly the country with the highest participation rate (73.7%), second is Italy (42.1%) and the rest of the countries have lower participation rates, ranging from 10.5% (Spain) to 31.6% (France). In energy policy, Germany, France and Italy are the countries with the highest participation rates (66.7% - 77.8%), while the participation rates of the United Kingdom, the Netherlands and Spain range from 44.4% to 55.6%. Finally, in horizontal actions, the highest participation rates are from Germany and Italy (63.6%), followed by France, the United Kingdom and the Netherlands (50.0% each), and the lowest participation rate is from Spain (31.8%).

4.3. Type of Entities Participating

It has been also analysed the type of entities involved in the FP7 projects, with special attention to those entities coordinating the projects (**Table 3**). In this sense, a further analysis on the R & D entities coordinating the 220 projects of the FP7 Energy Call reveals the notable role played by private companies, with a coordination rate of 34%, a higher rate than that of universities and public research bodies (26% and 21%, respectively) (**Figure 2**).

Large differences can be found in the type of organisations which coordinate the projects depending on the considered country (**Table 3**). In this regard, special mention must be made of the Spanish case where the participation of private sector companies is very high, with Spanish companies coordinating 67% of Spanish projects

Table 3. Number of projects coordinated by entity and percentage with respect to the total of coordinated projects by country.

Type of organisation	Germany	France	United Kingdom	Netherlands	Italy	Spain	Total
Private company	9 (23%)	2 (10%)	7 (32%)	6 (33%)	4 (15%)	14 (70%)	42 (28.4%)
Public research body	5 (13%)	14 (67%)	3 (14%)	8 (44%)	7 (26%)	0	37 (25.0%)
University	10 (26%)	1 (5%)	10 (45%)	1 (6%)	8 (30%)	5 (25%)	35 (23.6%)
Technology centre	12 (31%)	0	2 (9%)	0	1 (4%)	1 (5%)	16 (10.8%)
Association	1 (3%)	4 (19%)	0	2 (11%)	2 (7%)	0 (0%)	9 (6.1%)
Public authority	1 (3%)	0	0	1 (6%)	3 (11%)	0 (0%)	5 (3.4%)
Foundation	1 (3%)	0	0	0	2 (7%)	0 (0%)	3 (2.7%)
Total	39	21	22	18	27	20	147 (100.0%)

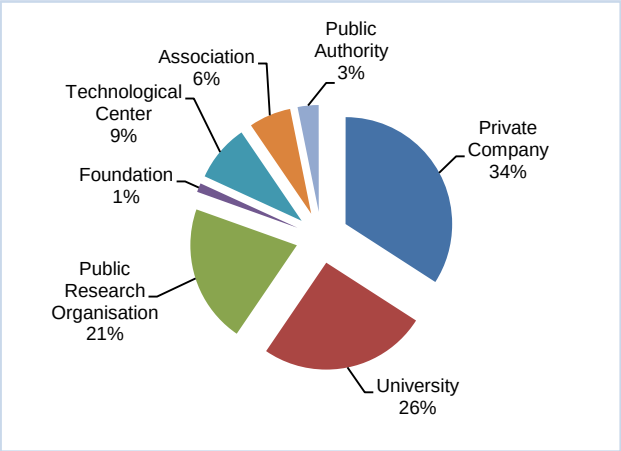


Figure 2. Type of entities coordinating the projects of the FP7 Energy Call 2005-2011 (220 projects).

and 6.4% of all projects in the Energy Programme. Such an outstanding rate is only seen in the Spanish case since in the rest of the countries under study private companies do not exceed 35% of coordinated projects, even 10% in the case of France and 15% in the case of Italy.

Top leadership is held by public research bodies in France, representing a 67.0% of total coordinated projects. Importance of these organizations is moderate in the case of the Netherlands (44%), but not much important in other countries, especially in Spain (0 projects coordinated by public research bodies).

Universities coordinate 45% of projects led by the United Kingdom, and percentages between 24 and 30% in the case of Germany, Italy and Spain. However, only one project in France and other in the Netherlands are coordinated by universities. Technology centres (TC) are important in Germany, where a 31% of the German coordinators of projects are TC. However, in the rest of the countries these entities represent always lower than 10% of the coordinators, even 0% in the case of France and the Netherlands. Finally, Associations coordinate 9 projects, Public Authorities 5 projects and Foundations 4 projects (2 in Italy, 1 in Germany and 1 in Spain).

4.4. Collaboration among Countries

Other indicator which can be obtained from the obtained data is the collaboration patterns between the different European countries in this Energy call. **Figure 3** shows the complex interactions among the European countries. The size of the square is proportional to the participation rate of these countries while the width of the lines connecting the different nodes is proportional to the number of projects in which these two countries participate together.

Germany (participation in 156 projects). The major number of collaborations are with United Kingdom (48), France (45), Netherlands (45), Italy (41), Spain (38) and Switzerland (35). *The country with more collaborations is United Kingdom with around* 30*% of the projects in which Germany participates.*

France (participation in 108 projects). The major number of collaborations are with Italy (51), Germany (45), Spain (44) and United Kingdom (42). Netherlands is 33 and Switzerland 28. *Around* 41% - 47% *of the projects in which French participates, there is a partner from Italy, Germany or Spain.*

United Kingdom (participation in 107 projects). The major number of collaborations are with Germany (48), Netherlands (46), France (42) and Italy (37). Spain is only 26 and Switzerland is 19. *In around* 43% - 45% *of the projects in which United Kingdom participates, there is also a German and/or a Dutch partner.*

Netherlands (participation in 99 projects). The major number of collaborations are with United Kingdom (46), France (44), Germany (38), Italy (36) and Spain (35). Switzerland is 22. *In around* 45% *of the projects in which Netherlands participate, there is also a British and/or a French partner.*

Italy (participation in 97 projects). The major number of collaborations are with France (51), Germany (41), United Kingdom (37), Spain (36). Netherlands is 33 and Switzerland is 24. *In around half of the projects in which Italy participates, there is also a French partner.*

Spain (participation in 85 projects). The major number of collaborations are with France (44), Germany (38),

Italy (36), Netherlands (35). United Kingdom is 26 and Switzerland is 18. *In around half of the projects in which Spain participates, there is also a French partner.*

The collaboration rate with Germany is always around 30% or lower, while other countries such as Italy or Spain have collaboration rates of around 50% with France. There is a strong relationship between Italy and Spain and between France and Spain.

4.5. The Spanish Case

This set of determining factors is now compounded by a global economic and financial crisis. This crisis is far from allowing an increased awareness of the problem and the adoption of measures aimed not just at mitigating the effects of a set of economic models that are scarcely sustainable but also at modifying the production and consumption models lying at the origin of this process of environmental and socioeconomic deterioration (**Figure 4**). Besides, the crisis is also having a very negative influence by blocking or slowing down actions aimed at searching for solutions.

In 2005, the [10] was approved, establishing that 12.1% of primary energy consumption would come from renewable energies in year 2010. In spite of the fact that the use of renewable energies has increased since 2009, when it represented 9.5%, to 11.4% in 2012 (**Figure 1**), it still remains below the set objective. In addition, in 2009, Directive 2009/28/EC on the promotion of the use of energy from renewable resources came into force setting a gross final consumption of renewable energies of 20% for 2020. These data suggest the need to step up Spanish efforts in R & D in issues related to renewable energies and clean technologies.

In Spain, the National R & D & I Plan for 2008-2011 pay special attention to these issues via its "Energy and

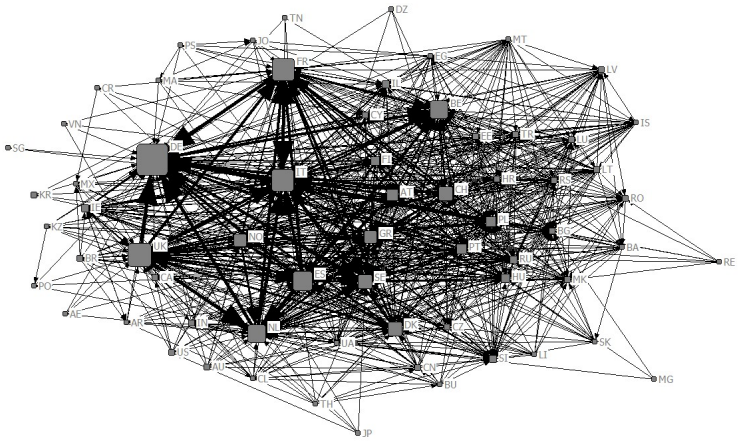


Figure 3. Patterns of collaboration of different European countries in the FP7 Energy Call.

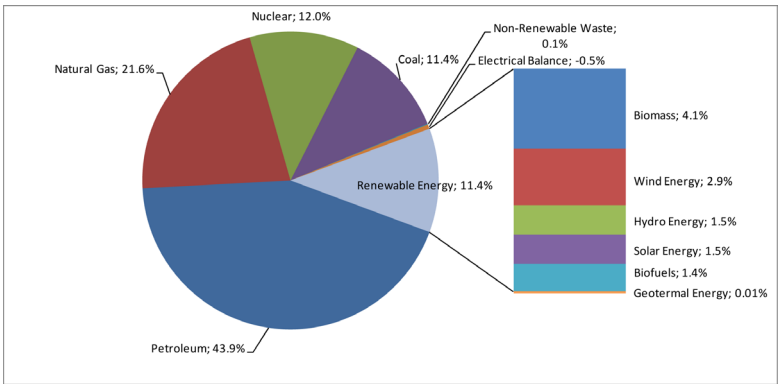


Figure 4. Gross final energy consumption during the period August 2011-July 2012. Source: IDAE (2012) [11].

Climate Change" strategic line. Its general aim is "the development of a sustainable energy system fed by local resources, especially renewable ones, or which are widely available on the world market, such as clean coal and nuclear energy, as well as of technologies aimed at achieving improvements in energy efficiency, reducing energy consumption and mitigating, anticipating and adapting to climate change". Among its specific objectives, this strategic line aims to develop a common strategy that will avoid duplications and ensure continuity of the priority research lines and the communication of results to public authorities, improve knowledge transfer and excellence of research in this field, promote innovation in the private sector and increase the returns of the 7th FP on energy and climate change.

Altogether, the national R & D plans have granted, growing in importance year by year, the research in climate change and energy systems from the point of view of sustainable development. Nevertheless, the allocated funding is still insufficient, especially if account is taken of the importance of the renewable energies sector in the international context [4].

It can be asserted without any doubt that the advance in Spanish scientific research in these fields has been genuinely important, and that the private sector has so far played a fundamental role in said advance, as borne out by the indicators obtained in this study.

However, and in spite of the achievements of research and the development of technologies and energy systems that have been implemented in Spain, the current economic situation—together with the conditioning factors imposed by the need to undertake a truly sustainable development of our economy—makes necessary a determined effort of analysis in order to make the most out of existing scientific and technological resources, as well as of the human capital involved, so that they can eventually be mobilised towards initiatives of economic interest by means of a strategy that will allow an intensification and optimisation of the transfer mechanisms for knowledge and technologies from R & D sectors to the production sectors.

Spain has participated in a total of 85 research projects (38.9% participation) lying in sixth position in the European country ranking, but is ranked second in terms of economic return only behind Germany [12]. In terms of leadership capacity, Spain stands in fifth place with 20 coordinated projects (24.7% of total projects with Spanish participation), behind Germany (39 projects), Italy (27), the United Kingdom (22) and France (21). With regard to the total number of projects resulting from the Energy Call, Spanish participation increased somewhat during the period (**Figure 5**). The participation of private companies in these projects is particularly outstanding, showing an average participation of 57%.

The countries with which Spain has carried out the largest number of joint projects were, in the following order: France (44 projects), Germany (38 projects), Italy (36 projects) and Netherlands (35 projects), United Kingdom (26 projects) and Switzerland (18 projects). As it was expected, most of the collaborations are with the countries with the highest participation rates but it is noticeable the high degree of collaboration with France and the low degree of collaboration with United Kingdom, both countries participating in approximately the same number of projects (108 in the case of France and 107 in the case of United Kingdom). Turning to projects that

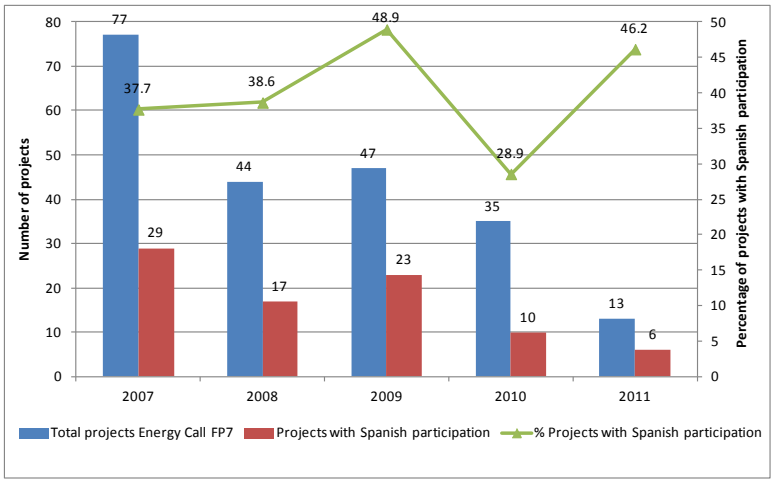


Figure 5. Evolution of Spanish participation in projects resulting from the Energy call of the 7th Framework Programme.

are coordinated by other countries, there is a significant collaboration between Italy and Spain since 14 out of the 27 projects coordinated by Italian entities (51.8%) have at least one Spanish entity participating in them.

The average participation of Spanish entities in the Energy call stands at 2 entities per project. Nevertheless, there is a significant presence of the Research Centre for Energy, Environmental and Technology (CIEMAT) and of the Spanish National Research Council (CSIC) among the organisations with the greatest number of participations in projects (10 and 8 participations, respectively), in spite of the fact that they do not appear as coordinators in any of them.

The Spanish entities with the greatest presence in this call are private companies, with a participation of 50% and coordinating most of the projects with Spanish coordinator (**Table 4**). Universities are the following entity with the greatest leadership capacity, coordinating 23.8% of Spanish projects. It has to be pointed out that the Polytechnic University of Madrid is the Spanish entity showing the highest coordination/participation ratio, being responsible for coordinating all the projects in which it takes part.

In the study on collaboration patterns between private companies and public institutions it has been observed that the most frequent collaboration pairing is between private companies and universities (16 projects). Special attention should also be paid to the fact that there is a large number of projects (13) in which just one Spanish Public Research Body appears.

By technologies, a thematic specialisation in projects related to CO_2 *capture and storage technologies* and *Integrated technologies for electricity production from renewable energies*, such as *Biofuels*, *Solar energy* (photovoltaic and thermoelectric) and wind energy, has been identified for Spain.

Projects related to wind energy are the ones involving the largest number of Spanish participants (30) for only 10 projects directly related to wind power (excluding horizontal actions and other projects), and also the highest average number of Spanish participants per project (3.7). Accordingly, this is the type of project that has been awarded the biggest grants for Spanish organisations (€14,912,632) in spite of being the technology that has received the lowest percentage of funding from the EU with respect to costs (60.0%). This could be due to the higher average number of participants in this kind of project, which in turn are mostly private companies, which makes the difference between costs and funding all the more significant owing to the fact that this kind of organisations receive lesser grants from the EU (around 50% of the project costs). For its part, the higher average grant per participant was obtained by participants in projects related to biomass (€657,726).

In the European context, the outstanding Spanish contribution to projects related to thermoelectric solar energy, exceeded in participation terms only by Germany, should be also highlighted. Besides, it is the technology with the largest number of projects coordinated by Spanish entities, representing 23.5% of Spanish entities participating in projects involving other technologies.

Among the entities that received the largest grants, the presence of four companies among the top five in the ranking is also noteworthy. This fact could be related to their stronger involvement in large-scale projects which are more closely tied to applied research, while the remaining organisations (universities, foundations, public authorities, etc.) receive lower grants, possibly on account of their activity being more related to projects included within the categories of energy policies and basic research concerned with the integration of renewable technologies in the energy system. The company that obtained the largest grant was *Acciona* (7.16%), followed

Table 4. Participation of Spanish entities in projects resulting from the energy call of the 7th Framework Programme.

	Different entities identified	Projects in which they participate	Coordinated projects
Private company	49 (51%)	89 (50%)	14 (70%)
University	16 (16.7%)	28 (15.7%)	5 (25%)
Public research organization	12 (12.5%)	24 (13.5%)	0
Foundation	6 (6.3%)	23 (12.9%)	0 (0%)
Technology centre	5 (5.2%)	4 (2.2%)	1 (5%)
Public authority	4 (4.2%)	4 (2.2)	0
Association	4 (4.2%)	6 (3.4)	0
Total	96	178	20

by *Abengoa* (5.02%), *Iberdrola* (4.12%), *Gamesa* (3.68%) and the *Spanish Research Council* (*CSIC*) (3.57%), referred to the total funds received by Spanish entities in the FP7 Energy Call. This means that only 5 of the 178 entities participating in the Energy Call are receiving around 23.5% of the total funds received by Spanish entities. As it can be noticed, the first four entities with the highest granted received are companies and only the fifth is *CSIC*, the largest public research body in Spain (with almost 13,000 employees, data from 2012).

In terms of the average funding received per project by the organisations, two entities stand out above the others: *Abengoa* and *Gamesa*, which received an average grant per project just short of a million euros (M€0.93 and M€0.91, respectively). Separate mention must be made of the Polytechnic University of Madrid, whose average funding per project was 0.68 million euros, reflecting the size of the projects that it participates in, comparable in grant amounts terms to the funding received by large companies in the sector which take part in a significantly greater number of projects.

From the 20 projects coordinated by Spanish entities: 3 for *Abengoa*, 3 for *Acciona*, 3 for *Polytechnique University of Madrid*, 1 for *Gamesa*, 1 for *Iberdrola*, 1 for *Endesa*, 1 for *Red Electrica de España*, 1 for *University of Zaragoza*, 1 for *T-Solar*, 1 for *Leitat Centro Tecnol*., 1 for *Centro Estudios e Investigaciones Técnicas de Guipuzcoa*, 1 for *Zabala Innovation Consulting*, 1 for *Solintel M & P* and 1 for *Aries*.

It can be asserted without any doubt that the advance in Spanish scientific research in these fields has been genuinely important, and that the private sector has so far played a fundamental role in said advance, as borne out by the indicators obtained in this study.

5. Conclusions

As a consequence of the direct analysis of the results of this study, it can be concluded that scientific activities undertaken by Spanish R & D entities within the Energy field under the 7th Framework Programme offer a set of favourable indicators, in both quantitative and qualitative terms. These indicators not only confirm the trends of recent years and provide evidence of leadership capacity in subsectors such as solar and wind energy, but also highlight the important role played by Spanish companies in the field of applied scientific research.

The private sector is playing a key role in the research and development of technologies in the field of renewable energies. For this reason, it should continue betting for this key sector of the Spanish economy, establishing a framework that not only allows stability in the business field, but also strengthens its capabilities to carry out a greater effort in R & D. To this end, it should intensify cooperation with stakeholders of the Spanish R&D system, as well as streamline the procedures to obtain patents and the quick placing on the market of new products and services.

There should be coordination between our energy and scientific policies. Otherwise, scientific research and innovation will be affected by erroneous decisions which could damage the progress of sustainable energy development. The latter is a key sector of our economy, and is important for the recovery of the labor market, environmental sustainability, and ultimately, to the quality of life.

The two most important Spanish public research bodies (PRBs) dealing with R & D in renewable energy, CIEMAT (Research Center on Energy, Environment and Technology) and CSIC (Spanish Council for Scientific Research), have a significant presence in projects funded by the FP7; however, none of these two entities have been at the forefront of the coordination of any project concerning this discipline. This reveals the ability of scientific leadership of Spanish companies. These entities have coordinated projects on renewable energy, projects in which the aforementioned public research bodies have participated. This fact is quite positive, since the companies in this sector are called not only to play a fundamental role in applied research, but also to transform the results of this activity into new products and services.

In Spain, there can be no denial of the fact that investments in research and development are experiencing a sharp decline as a consequence of austerity measures that are weakening our R & D system and widening the gap between us and other most developed countries. Aside from what might be a legitimate claim in favor of our research sector, what is urgent right now is a creative effort to exploit our base of scientific knowledge, human resources in research and our technologies. Thus, the eco-economy sector will be a pillar to reduce energy spending and to revitalize our economy.

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