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Accompanying the document

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Energy Technologies and Innovation

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The assessment and analysis of European investments in energy RD&D is crucial for better designing energy research and technology development policies and preparing for the commercialisation of specific technologies.

This analysis has been prepared by the Commission's Strategic Energy Technologies Information System (SETIS), specifically by the Institute for Energy and Transport of the JRC. It provides an overview of the public and private RD&D investments in the SET-Plan portfolio of technologies: wind, solar (photovoltaics and concentrated solar power), electricity grids, bioenergy, carbon capture and storage (CCS) and nuclear fission. The concentrated solar power, fuel cells and hydrogen technologies have been partially covered in this report (as only public efforts are accounted for). The assessment year of the present analysis is 2010 due to the two year delay in availability of pertinent data and statistics.

The primary objective is to identify the extent to which public and private efforts were able to satisfy the financing needs of technology development in the SET-Plan, identified in 2009 to be in the range of EUR 5.2 - 5.4 billion per year. This work does not however examine to extent to which the RDD priorities funded match those of the Technology Roadmaps to 2020 as described in SEC (2009) 1295.

The present assessment identifies different sources of finance and maps the capacities at the level of European Member States. Future analysis is needed to assess the extent to which various technology push and market pull policies have been efficient in inducing research and innovation for low-carbon energy technologies. Moreover further analysis will aim to identify sources of competitiveness for the European energy technology leading companies.

Introduction

Since 2008, the EU implements the Strategic Energy Technology Plan (SET-Plan) with the aim to 1) accelerate energy technology development, technology transfer and up-take; 2) maintain EU industrial leadership on low-carbon energy technologies; 3) foster science for transforming energy technologies to achieve the 2020 energy and climate change goals; and 4) contribute to the worldwide transition to a low-carbon economy (COM(2007)723 final; COM(2009)519 final). The implementation of the SET-Plan has led to the establishment of large scale programs, called European Industrial Initiatives (EIIs), which bring together industry, the research community, the Member States and the European Commission in risk-sharing partnerships aiming at the rapid development of key energy technologies at the European level. Six technologies have already been identified as the focal points of the first EIIs (SEC(2009)1295): wind, solar (photovoltaics and concentrated solar power), electricity grids, bioenergy, carbon capture and storage, Fuel Cells and Hydrogen Joint Undertaking and nuclear fission. The Fuel Cells and Hydrogen Joint Undertaking is also considered as part of the SET-Plan. It has been one of the first Joint Technology Initiatives (JTI) of the European Commission, established before the formation of the SET-Plan and its EIIs. Having as goal the elaboration of strategic and permanent collaborations between major research organisations and institutes in the field of energy technology research European Energy Research Alliance (EERA) and its Joint programs (JP) have been set in place since 2009. EERA JPs seek to provide a better coordination of funding with respect to 13 technologies[1-2]. SETIS is the European Commission's Information System for the SET-Plan, and it makes the case for technology options and priorities, monitors, reviews progress regarding implementation, assesses the impact on policy and identifies corrective measures if needed[3].

For the above-mentioned selected technology areas, there is no directly quantifiable link between research expenditures and the value of the results obtained from research. However, to make each low-carbon technology fully cost-competitive, more efficient and proven at the right scale for market roll-out, identifying concrete research, development, demonstration and market replication activities is crucial in maximising the industrial and societal returns. Therefore, part of the broad scope of the SET-Plan focuses on capacities mapping, which aims at providing an assessment of the current public and corporate RD&D investment in low-carbon energy technologies in the EU. The ultimate objective is to offer a benchmark of the current RD&D investments to serve as a basis for the planning of future RD&D investments that will be needed for addressing the key technology challenges identified by the SET-Plan. Unlike the strongly focussed and coordinated energy technology policies in the USA and Japan, pan-European cooperation has been hampered by diverse organisational structures in energy RD&D, ranging from institutional set-ups to programs and public-private partnerships. The SET-Plan addresses these drawbacks through joint planning and implementing at European level by leveraging on the resources and RD&D assets of EU energy technology landscape. In 2009 JRC-SETIS presented an estimation of the public and corporate R&D

[1] The 13 technologies are photovoltaic, wind, geothermal, smart grids, bioenergy, carbon capture and storage, materials for nuclear, AMPEA, concentrated solar power, energy storage, fuel cells and hydrogen, ocean energy and smart cities.
[2] EERA (Coordinating energy research for a low carbon Europe): www.eera-set.eu/index.php?index=13.
[3] Strategic Energy Technology Information System (SETIS): http://setis.ec.europa.eu/.

investment for a series of low-carbon energy technologies and this has been used as a key reference for policy development in the EU (JRC 2009).

Acknowledging the limitations of the present analysis in gathering investment data (both for the private and public sector), this report seeks to provide an estimation of the total European RD&D investment for the year 2010. This includes the EU public sector RD&D investment, Member States' national public sector RD&D investment and corporate RD&D expenditure. By including the current RD&D investment in the SET-Plan technologies from major European companies the report also seeks to identify the extent to which private firms (under)invested in low-carbon technologies.

Information on RD&D investment of the EU Member States is gathered using the IEA RD&D open access statistics database. In order to approximate the corporate RD&D investment for the SET-Plan technologies the methodology developed by JRC-SETIS for the 2009 edition of the Capacities Map has been herein extended. The main data sources used in the analysis for the corporate RD&D were the EU Industrial RD&D Investment Scoreboard, companies' annual reports and patent data from the European Patent Office and WIPO (World Intellectual Patent Organization).

The technological scope of the present analysis mainly focuses on the so-called "SET-Plan technologies": wind energy, solar energy[4], electricity grids, bioenergy (bioethanol, biodiesel and biogas), carbon capture and storage (CCS) and nuclear fission. In addition, fuel cells and hydrogen technologies are also analysed from the point of view of the Member States and EU funding.

To the extent that was possible, the report has compared its findings both at aggregate and sectorial level with other open access sources and found them in good agreement.

[4] Due to missing information for the corporate part, only public efforts are accounted for Concentrated Solar Power, both for private and public R&D investment is assessed for PV technology.

1. Overall assessment

European and national programs and support schemes (i.e. loans) have provided in 2010 considerable funding to the development and deployment of low-carbon energy technologies (see Figure 1). This indicative distribution of financial support does not include the subsidies to RES deployment, which in some countries have also been used to cover capital costs and therefore, have an inducing effect on innovation in renewable energy technologies.

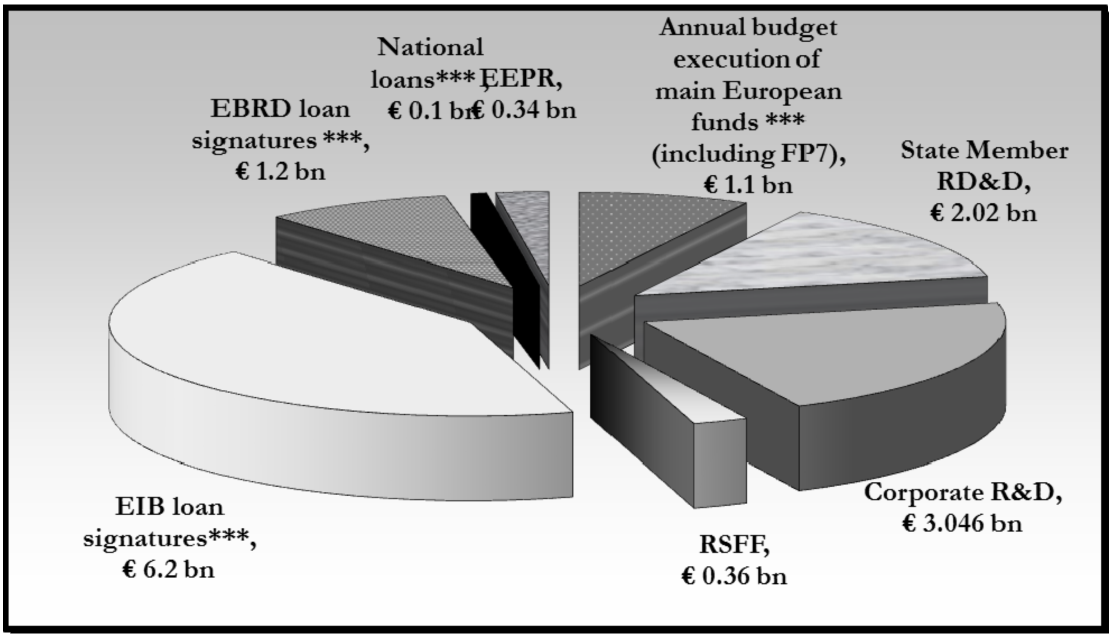


Figure 1. Indicative distribution of the financial support (own investments, grants and loans) of the main bodies involved in financing energy efficiency projects, RES RD&D and deployment programs (European Commission, EIB and EBRD) for the year 2010. RSFF was assumed to be evenly distributed over 6 years and EEPR assessment included only effective payments to CCS and wind projects by the end of 2010. (***) indicate that funding has been used for the support of both research and deployment activities. Data on national programmes may include also direct expenditure in energy-related projects co-funded by the European Union and/or other countries.

In the fiscal year 2010, the aggregated amount of EU (i.e. FP7), corporate and public R&D investment in the six SET-Plan technologies was approximately EUR 5.04 billion[5]. The distribution of investment was not uniform across technologies, with wind and solar energy having benefited from higher shares than the other SET-Plan technologies (see Figure 2a & b). Investments in wind and photovoltaics (PV) were EUR 881.66 and EUR 901.03 million respectively, while for electricity grids and carbon capture and storage (CCS) they were EUR 323.25 and EUR 400.39 million respectively.

[5] This figure excludes the contribution to fuel cells and hydrogen from the EU (EUR 51.41 million) and of the Member States (EUR 211.54 million).

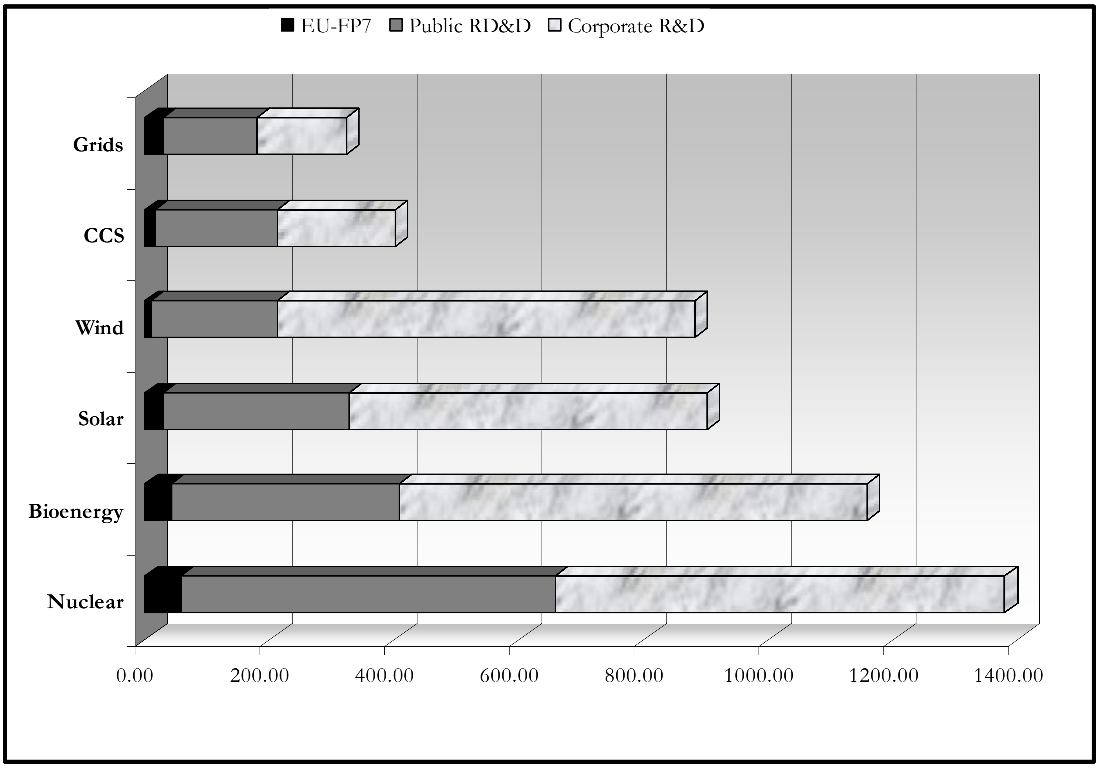


Figure 2a. Estimate of public and corporate R&D by technology and source (2010). EEPR funding is not included.

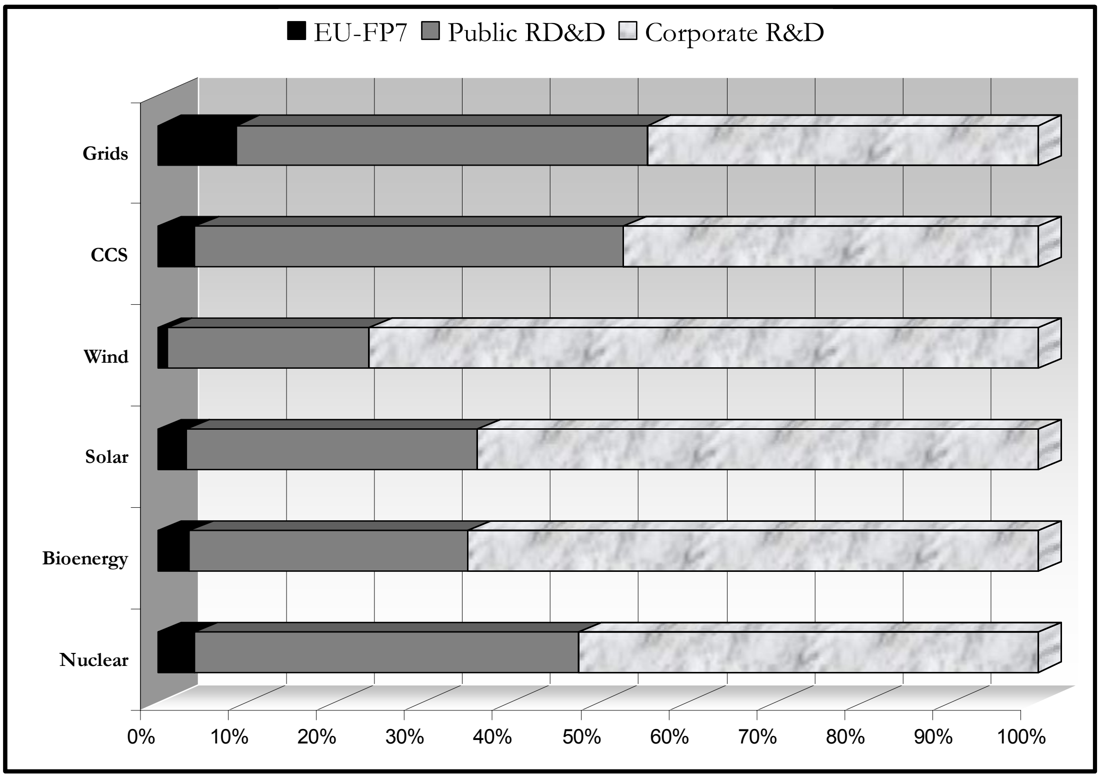
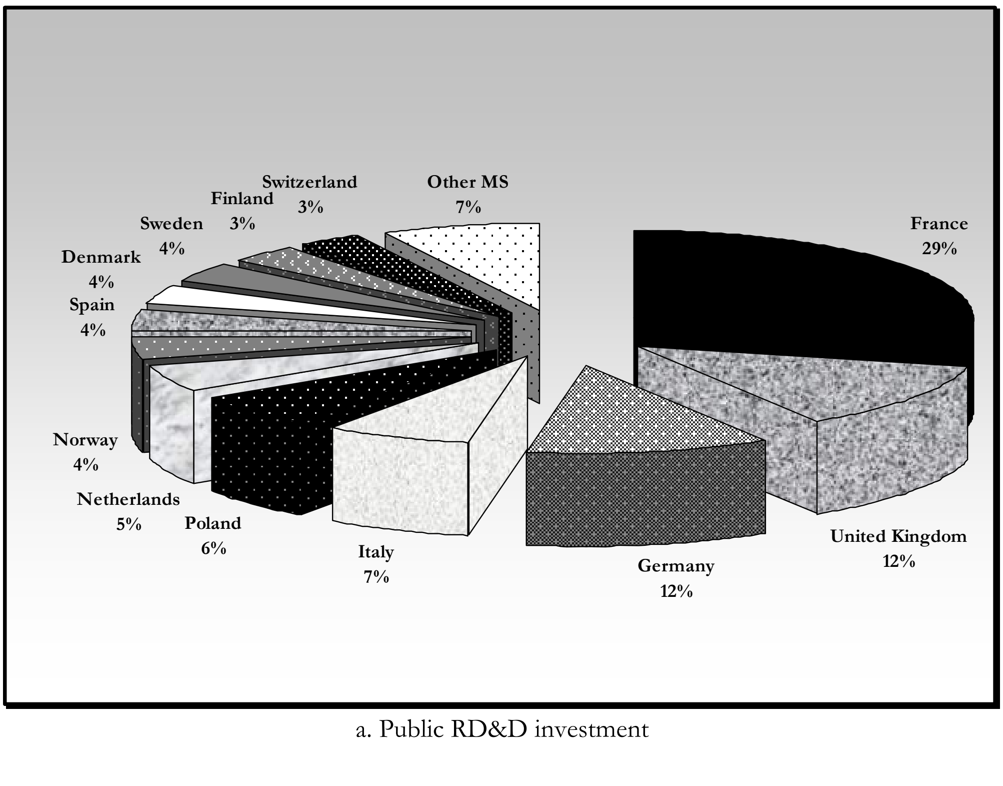


Figure 2b. Shares of public and corporate R&D by technology and source (2010). EEPR funding is not included.

In general, public investment in RD&D was lower than corporate investment. For the nuclear and the bioenergy sectors, the European Union (through FP7) provided higher support than for other SET-Plan technologies, as the nuclear and the bioenergy sectors together accounted for 42% of the funds distributed through FP7. The EEPR funding also provided significant funding to wind and CCS technologies. For example, the EU contribution to CCS technology would increase from 4% (figure 2b) to 15% when the EEPR grant provided to the selected projects in 2010 was also considered along the FP7 grants. For the non-nuclear SET-Plan technologies, corporate R&D was usually higher than public investment (59.2% of total investment). In line with the Lisbon target, the share of corporate investment in wind technology was higher than 67%, while for nuclear technology it was 52%. Investment in nuclear technologies exceeded EUR 1,418.07 million. Fast reactor developments attracted investment of approximately EUR 132.25 million.

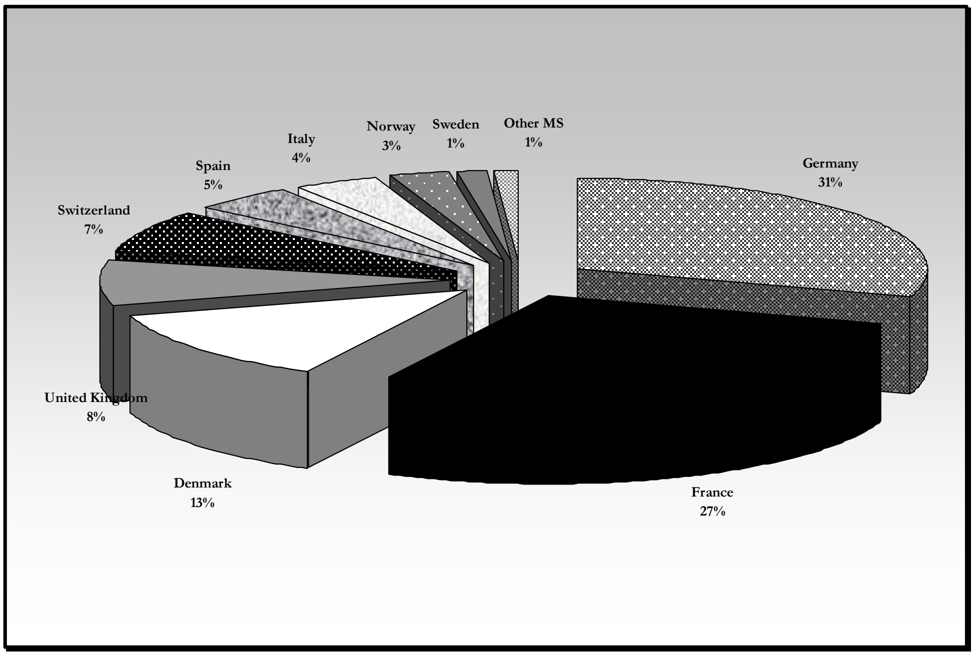
The private sector did play an important role in technology development, especially for mature technologies. For example, this analysis shows that corporate investment of selected companies from the wind energy sector reached 76% of total investment. Also for PV technologies, the participation of the private sector was very significant, where corporate R&D covered 64% of total R&D efforts of the sector. Similarly, 65% of total R&D investments in the bioenergy sector represented private efforts. Overall, corporate R&D funding in non-nuclear energy technologies increased from 2007 levels (EUR 1.24 billion[6]), reaching a total amount of EUR 2.33 billion in 2010[7].



a. Public RD&D investment

[6] Excluding CSP and FCH_2.

[7] This amount reflects JRC-SETIS calculations based on a patent analysis, for the companies that do not provide information about their R&D expenditures. A time lag of one year was used to take into account the delay from the generation of research results until their impact on innovation is visible. This figure may change with future calculations.



b. Corporate R&D investment

Figure 3. Estimate of public RD&D (a) and corporate R&D (b) investment in European Member States for the year 2010. Public RD&D investment under 'Other MS' include those in Austria, Ireland, Belgium, Czech Republic, Hungary, Slovak Republic and Portugal. Corporate RD&D investment under 'Other MS' include those in Belgium, Netherlands, Finland and Austria.

The spatial distribution of public and corporate R&D investment has changed between 2007 and 2010, see Box 1.

Box 1 – Comparison with the 2009 Capacities Map

- In Italy, the R&D public funding share decreased from 16% in 2007 to 7% in 2010. This confirms the decreasing trend of public funding for low carbon technologies in Italy with a yearly average decrease of €4.06 million since 2001. In contrast, corporate R&D initiatives intensified in Italy (from a 2% share in 2007 to 4% in 2010).
- Contrary to Italy, Germany's public funding increased in 2010 by 66% from the 2007 level. However, as a share in the European public investment, Germany's public R&D funding share decreased from 23% in 2007 to 12% in 2010. This decrease is not the result of a decrease in German public funding, but can rather be attributed to an increase in the public R&D investments in other European countries.
- France and United Kingdom maintain the same intensity of public investment as the ones displayed in 2007.

Research activities were highly concentrated in Europe: 4 countries (Germany, France, United Kingdom and Denmark) accounted for 75% of total R&D investment in 2010. In these countries intense research activities were developed both by public and corporate parties, addressing almost all the SET-Plan technologies. This spatial distribution of R&D investment tends to show that market size matters in the localisation and intensity of research activities for low-carbon technologies. As the correlation coefficient[8] between public R&D and GDP was 0.68, this indicates that larger countries tend to invest more in R&D for low-carbon technologies than smaller countries (see Figure 3). Also, corporate R&D investment was sensitive to the size of the market: the correlation coefficient between corporate R&D and GDP was 0.72. Therefore, countries with high public RD&D funds simultaneously account for the largest corporate R&D investments. In 2010 larger economies tended to invest more in SET-Plan technologies than smaller ones.

2. Methodology and data considerations

2.1 Scope of the analysis

The objective of this work is to provide for the year 2010 an estimation of the level of RD&D investment directed towards the low-carbon energy technologies addressed by the SET-Plan, called hereafter "SET-Plan technologies": wind, solar, electricity grids, bioenergy, CCS and nuclear fission[9]. In addition, fuel cells and hydrogen technologies have also been addressed. The Fuel Cells and Hydrogen Joint Undertaking (FCH JU)[10] has been one of the first Joint Technology Initiatives (JTI) of the European Union, established before the SET-Plan and its EIIs. It is a private-public partnership at European level, established in 2008 to develop and implement a targeted RD&D and demonstration program with a total budget of EUR 940 million up to 2013, of which 50% is contributed by the European Commission and 50% by the private sector. The FCH JU aims to accelerate the development and deployment of fuel cells and hydrogen technologies by executing an integrated European program of research and innovation activities. It strives towards a common programmatic and implementation frame for its Joint Technology Initiative (JTI) with that of the SET-Plan EIIs. Consequently, a Technology Roadmap to 2020 has been proposed for the hydrogen and fuel cell technologies. As such, seven technologies are studied herein.

2.2 Methodology

Information on investments in the SET-Plan technologies have been gathered by source of financing i.e., EU RD&D investments, the Member States' public RD&D investments and corporate R&D expenditure. Although a large effort was made to include information from all Member States, unfortunately, 12 Member States are missing from this analysis due to lack of data and/or procedures for data acquisition. As such, the report covers 16 EU Member States and two Associate States[11]. Table 1 gives an overview of this coverage.

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[8] The correlation coefficient gives an indication of the strength and the intensity of two variables (in this case public R&D and GDP). In general it varies between -1 and 1. A negative value shows opposite evolution , while a value of 1.0 indicates similar evolution.

[9] The nuclear energy in the SET-Plan priority technologies only concerns Generation IV reactors. Due to the difficulties in obtaining RD&D investment data allocated only on Generation IV reactors, here the total investment for nuclear fission are investigated.

[10] Fuel Cells and Hydrogen Joint Undertaking: http://www.fch-ju.eu.

[11] In the case of Hungary we have compared the data obtained from IEA Statistics with the ones from National Innovation Office Information System (NIOIS). While wind, solar and fuel cells & hydrogen are better represented by the NIOIS, the rest of the technologies are better represented by IEA.

Table 1. Geographical coverage of public RD&D investment

Member States covered	Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, the Netherlands, Poland, Portugal, Slovak Republic, Spain, Sweden, the United Kingdom Norway, Switzerland*
Member States not covered	Greece, Luxembourg, Bulgaria, Cyprus, Estonia, Latvia, Lithuania, Malta, Romania, Slovenia#

* Associate State

\# Not a member of IEA

The most recently published investment data, used in this analysis, refer to fiscal year 2010. The main database for public R&D investment at national level is the IEA RD&D statistics, which however does not include complete datasets for several countries. Consequently, a basic "gap filling" method has been used, where data from 2009 were attributed to the fiscal year 2010. This "gap-filling" method was mainly applied to Austria, France and the Netherlands. The same approach was used to fill in data gaps for other past years: whenever entries were missing, the data from the latest available year were assumed. Furthermore, questionnaires distributed by SETIS to Member States stakeholders and the EII Teams, were also used to fill in and validate the datasets.

When available, data on demonstration projects for the SET-Plan technologies were also accounted for. Data on public RD&D projects were recovered from the IEA database on Energy RD&D Budget/Expenditure Statistics. The indicators that are provided on energy RD&D take into account research, development and demonstration related to the production, storage, transport, distribution and rational use of all forms of energy; and they cover basic research when it is clearly oriented towards the development of energy-related technologies, applied research, experimental development and demonstration (IEA Guide to Reporting Energy RD&D Budget/Expenditure Statistics, OECD/IEA, 2011). It is noted that deployment projects are excluded from RD&D investments.

The present analysis is focused on the assessment of one single indicator: the RD&D investments[12] in 2010. RD&D expenditures incurred in 2010 have been taken into account, such as the cost of materials and services consumed in research and development activities, the cost of wages and other related costs of personnel engaged in research and development activities. Expenditures related to RD&D activities, which are not attributed to the period of analysis have not been considered, e.g. technology and patent licenses, amortization of intangible assets such as patents and licenses, depreciation of equipment and facilities to the extent that they are used for research and development activities, copyrights, trademarks, trade names, franchise licenses, government licenses, goodwill, and other items that lack physical substance but provide long-term benefits to a company. These types of assets are subject to amortisation, which is usually deployed over a period of 3 to 5 years (as presented in the annual reports). Subsequently, they provide a bigger picture of the medium term evolution of RD&D capacities of a company at the extent to which the firm is playing a role not only in the technology development, but also in technology diffusion. For the present analysis patent data serve only to redistribute the global RD&D over the specific sectors, considering in this case research expenditures not as a measure technological change, but rather an input to innovation activities (Oslo manual 2005).

[12] Other indicators could be used in order to provide a more complete picture of the level of RD&D efforts on a medium term basis, such as patents, copyrights, trademarks, trade names, franchise licenses, government licenses and goodwill.

2.3 Data sources

2.3.1 Data sources for EU RD&D investment

The 7th Research Framework Program (FP7) and the EURATOM Framework Program are the key sources of RD&D financing at EU level of non-nuclear and nuclear fission technologies, respectively. Other energy-related EU funding schemes, including the Competitiveness and Innovation Programme (CIP) with its Intelligent Energy Europe (IEE) program, the Structural and Cohesion Funds, the Knowledge and Innovation Community (KIC) InnoEnergy, the European Energy Program for Recovery (EEPR) and the LIFE+ Program may as well play a role in supporting the SET-Plan technologies. For example, within the Cohesion Policy budget, in the period 2007-2013 significant funding is dedicated to sustainable energy, with over EUR 10 billion planned for investments in energy efficiency and renewables across the EU as a whole, and, in addition, a strong focus has been put on research and innovation (for which the amounts cannot be separated by research field) and the EEPR, launched in 2009, dedicated EUR 1 billion to CCS and EUR 565 million to offshore wind. By the end of 2010, EUR 700 million had been distributed: EUR 361 million to gas and electricity infrastructure projects and the rest to wind and CCS projects[13].

However, not all of the mentioned programs could be assessed quantitatively at the level of detail needed for this analysis. For the purpose of the present analysis, the programs, for which data could be obtained, were considered. Primarily, the expenditure of the FP7 and the EURATOM Framework Program 2007-2011 was analysed. Most of the funded projects are planned for several years, which create difficulties for estimating annual appropriations. The method followed in this study was to evenly divide project budgets over the number of project years. Each project execution year shares an equal amount of funds, irrespective of the starting and ending month of the project.

2.3.2 Data sources for Member States' RD&D investments

The main data source for the analysis of public RD&D investment in the EU countries is the IEA RD&D Statistics[14], which has several limitations (see Box 2). Another data source is the Eurostat GBAORD (Government Budget Appropriations or Outlays on RD&D. An important difference between these two sources is that the GBAORD provides highly aggregated data on the RD&D expenditure in several defined sectors including energy, while the IEA offers disaggregated data to certain extent, especially in the category of renewable energy sources. Since GBAORD data are aggregated, they cannot be used for the objective of this study. Moreover, data for 2010 have been reported by only a few EU Member States.

Box 2 – Limitations IEA RD&D Statistics

- Since not all the IEA members provide data regularly, data gaps are present for certain technologies or countries
- Only 19 of the 27 EU Member States are IEA members. This results in a systematic lack of data from Bulgaria, Cyprus, Estonia, Lithuania, Latvia, Malta, Romania and Slovenia.
- The most recent data are from 2010, coming from only 15 European countries (Czech Republic, Denmark, Finland, Germany, Greece, Hungary, Italy, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, the UK). For the rest of the 4 countries covered in this report, a methodology called "gap-filling" was used to obtain data for 2010. Furthermore, some of the data provided are highly aggregated for the renewable sector. Greece is one example and for this reason it is not included in this study.

Even though the report mainly aims at assessing the intensity of investment in the EU, it also attempts a comparison with investments made in two other large economies, the USA and Japan. In doing so, the goal is to identify the technologies for which Europe invests less than the other developed economies.

In USA the RD&D funding in energy technology and innovation is mainly provided by the Department of Energy (DoE). The IEA RD&D Statistics was used as the primary data source as the USA is an IEA member. Another source is the "DOE Budget Authority for Energy Research, Development, & Demonstration Database" (Gallagher and Anadon, 2012), which provides slightly different values from what is reported by IEA. The latter has been used for the purpose of checking the reliability of the data reported to IEA.

The Japanese government continuously increases public investment in energy RD&D and innovation to achieve its ambitious clean energy development objectives. Japan's Council for Science and Technology Policy recently recommended the creation of a national RD&D system to centralize the management of RD&D activities. The council recommended that the government put in place a national process to evaluate RD&D activities with respect to their contribution to the technology development roadmap, as well as a process to continuously evaluate international RD&D trends and Japan's competitive position in each targeted technology (CSTP, 2009). This is carried out through a number of ministries:

- Ministry of Economy, Trade and Industry (METI)
- Ministry of Education, Culture, Sports, Science and Technology (MEXT)
- Ministry of International Affairs and Communications (MIC)
- Ministry of Land, Infrastructure, Transport and Tourism (MLIT)

Moreover, Japan's New Energy and Industrial Technology Development Organization (NEDO)[15] is tasked with enhancing Japan's industrial competitiveness through targeted RD&D and support for new technology commercialization. The IEA RD&D Statistics was used as the main data source. Other sources have been checked for the purpose of comparison.

2.3.3 Data sources for corporate R&D investment

While the EU Industrial R&D Investment Scoreboard is an important data source for basic information on annual corporate R&D investments (JRC 2009), additional important data are provided by the annual reports and facts figures provided by the individual companies. Data on corporate R&D have been herein collected from several sources (EPO, EU Industrial Scoreboards Annual report and consolidated financial statements).

The annual reports of companies provide a wealth of information on the firm's produced and shipped capacity (eventually backlog, unconditional offers, revenue and turnover), stock exchange information (earnings per share, book value per share, share price at December 31, solvency) and employees (and R&D personnel). The financial statements in the annual reports disclose specific data on R&D, such as the level of intangible assets

[15] NEDO: http://www.nedo.go.jp.

(except goodwill), research and development expenditures, capitalized research projects, software, patents and their amortization.
Validation of data and filling of data gaps (when data are not readily available) on R&D potential is based on industrial scoreboard bulletins. The sample of companies considered for the present analysis includes firms that are not among the first 1400 global investors or firms that do not disclose information about their financial activity. Consequently, the estimation of corporate R&D investments was supported by a patent analysis to which a time-lag was assumed, to account for the time between the research activity and the filing of the resulting patent application. Hence, another important data source for this analysis was the EPO (European Patent Office) and WIPO (World Intellectual Property Organization) databases. Jointly EPO and WIPO offer a more complete picture of the research intensity of the European firms and an accurate picture of the degree of R&D localization. A close look to patenting intensity reveals that even in the presence of economic crisis, patent applications continue to grow[16].

There are however some disadvantages related to a patent analysis approach. Firstly, not all firms patent their activity, as a firm could opt for industrial secrecy to prevent knowledge spillovers. Secondly, patents are not perfect indicators in capturing their commercial use: Lanjouw et al. (1998) and Popp (1999) argue that adoption of most patented inventions is not widespread, due to the fact that most patents have little commercial value. "Accordingly, the results of studies using patent data are best interpreted as the effect of an average patent, rather than any specific invention" (Popp, 2005: p. 214). Thirdly, on specific themes, such as renewable energy technologies, patenting activity is also subject to a particular caveat: as environmental policy changes, it may affect the direction of patenting activity. Market-based pollution control policies, for example, tend to induce a shift from cost-reducing to emission-reducing innovation. This may complicate the interpretation of time trends of technological innovation (Popp, 2007). Despite these drawbacks, patenting is a systematic activity; and its analysis can provide a comprehensive picture of innovative activities, since patents are usually filed in the early stages of the technology life cycle (Griliches, 1990).

Using a combination of the above data sources for each of the technological fields of interest, key EU-based industrial companies have been identified for further analysis in the context of this work. Although this is necessary for practical purposes, as it would be unrealistic to consider analysing all relevant industrial players, it also induces uncertainty, as the universe of firms that are selected for analysis is subject to some limitations:

- In this analysis, most of the technologies were approximated only by the largest investors. Small companies might have had a strong commitment to R&D, but were not considered in the analysis due to the difficulty related to data gathering. Therefore, the strategy chosen for identifying the European companies tends to underestimate the total R&D efforts dedicated to SET-Plan technologies. However, for the PV sector this limitation was overcome by including into the analysis smaller companies as well. To the extent that it was possible, the sampling error in the estimation of R&D investment in low-carbon technology for the set of the selected companies was calculated.
- Larger firms often have R&D centres in different countries or even continents. With the current fast trend of globalisation, the classification of these companies (EU or non-EU) and the accounting for the R&D investment in Europe has

[16] http://www.wipo.int/pressroom/en/articles/2011/article_0004.html.

become increasingly difficult. For the present analysis the total R&D investment of a company has been attributed to the country that hosts the headquarters.

Once the key industrial players for each energy technology have been identified based on their production capacities or innovation activities, the bottom-up approach adopted in the 2009 Capacities Map was followed to distribute specific private R&D investment: 1) collection of total R&D investment data of these companies; 2) allocation of the R&D investment to individual the SET-Plan technologies if the companies are engaged in the development of more than one technology; 3) summation of the R&D investment per technology from all identified companies.

It is noted that patent intensity differs across technologies and some SET-Plan technologies are interlinked. For example, it is difficult to distinguish the degree to which patents in wind energy related topics also describe electricity grid improvements. The same discourse is also relevant to PV inverter companies. Many of the technological improvements in inverters also improve the grid. For the present analysis a methodology that could separate the relative importance of interconnected fields was not employed.

Box 3 – Strategies employed in redistributing R&D budgets over the specific sectors

In the absence of information about a company's specific patent applications, for a particular technology, and in the absence of disclosure of its total amount of R&D expenditure, available information about the number of employees in research and their wage have been used in order to estimate their R&D budget. The approach has already been used in the 2009 Capacities Map (JRC 2009).

When the total amount of R&D expenditure of a company involved in many technologies is known, a patent analysis was used for the distribution of R&D investments in the various technology fields. It was assumed, as in the previous Capacity Map (JRC 2009) that the distribution of patents across the relevant technologies is a proxy for the distribution of its R&D expenditures, as there is significant correlation between patents and R&D spending (e.g. Griliches, 1990; Jaumotte and Pain, 2005). In order to assess the intensity of R&D expenditure per specific field, the shares of a specific SET-Plan technology patent application in the total patent applications of a company was computed. A time lag was also assumed to take into account the delay between the time that research takes place and its impact on innovation.

Furthermore, for the specific case of PV sector, a novel approach was used: the R&D investment in PV technology was estimated from the number of patent applications of companies active on solar energy and the average R&D investment per PV patent. The value of R&D investment per PV patent was assumed to be the average between the figure of 1 million euro, which is quoted as a typical R&D investment for a PV patent (see Breyer et al., 2010) and the average R&D investment per patent on any technology in the country that hosts the selected company.

As stated above, uncertainty is inherent to the adopted methodology. To increase confidence in the outcome of this analysis, the results were compared to other sources that gather and analyse data on RD&D investment, such as Bloomberg New Energy

Finance (BNEF). BNEF focuses on a portfolio of technologies including marine and small hydro, but does address CCS, nuclear fission and the power grid. As such, the comparison of the results was limited to specific technologies, such as solar, wind and biofuels.

3. Results and discussion: identifying current efforts for satisfying financing needs of SET-Plan technologies

The present assessment is focused on the RD&D investment on the SET-Plan technologies in 2010. The primary objective is to identify the extent to which public and private efforts were able to satisfy the financing needs of technology development in the SET-Plan. Achieving the EU's "20-20-20" goals and the "Roadmap 2050" vision require low-carbon energy technology innovation; and the SET-Plan has been launched as a powerful initiative towards this direction. The overall financing needs of SET Plan Technologies are presented in Box 4.

Other targets for research and development are also identified within the Europe 2020 Strategy: building on Lisbon Strategy, one essential target proposed to be reached before 2020 is the level of R&D investment that should reach 3% of Europe's GDP (see Box 4).

Box 4 – The financing needs of SET Plan Technologies
The financing needs of technology development, as described in the SET-Plan roadmaps (SEC (2009) 1295), i.e. for the implementation of the European Industrial Initiatives (EIIs), range between EUR 58.5 billion to EUR 71.5 billion over the period 2010-2020. By technology, such financing needs are as follows:

- Wind: EUR 6 billion
- Solar: EUR 16 billion (EUR 9 billion for PV and EUR 7 billion for CSP)
- Bioenergy: EUR 9 billion
- CCS: EUR 10.5-16.5 billion
- Electricity grids: EUR 2 billion
- Nuclear: EUR 5-10 billion
- The Smart Cities Initiative: EUR 10-12 billion

In addition, the cost of implementation of the Roadmap for the European Energy Research Alliance reaches EUR 5 billion over the next 10 years.

These investments should be shared between industry, the Member States and the European Commission. The partition of the cost for each EII may vary as well as for the activities within each EII (SEC (2009) 1295). This implies that Europe has to invest roughly EUR 5.4 billion per year on the six SET-Plan technologies until 2020 (this excludes investments in smart cities, fuel cell and hydrogen).

With respect to corporate R&D investment, the Lisbon Strategy[17] proposes that two thirds of total R&D expenditure should be financed by the business enterprise sector.

[17] European Union Parliament Website Lisbon European Council 23 and 24 March Presidency Conclusion

In view of the financing needs identified in Box 4, the present report assesses hereafter the current (2010) support for the development of SET-Plan technologies by source of funding. Section 3.1 and 3.2 present the public (EU and national) RD&D investment dedicated to the SET-Plan, while Section 3.3 presents the JRC-SETIS estimations for corporate RD&D investment.

Public RD&D investment
The estimated public (EU and national) RD&D investments dedicated to the SET-Plan technologies in 19 European countries, as explained in the previous section, in 2010 reached EUR 2.26 billion, out of which, EUR 2.02 billion are national funds and EUR 0.24 billion are EU funds through the 7th Research Framework Program and EURATOM. The distribution of funding over the 19 Member States is described in the following sections. This amount is comparable with the public RD&D investment in Japan (EUR 2.36 billion) and USA (EUR 1.76 billion). The results for the different countries and the seven SET-Plan technologies, the trends of investment in the past decade, and the uncertainties associated to them are presented, analysed and discussed in this section.

3.1 EU RD&D investment

The main European bodies involved in the financing of SET-Plan technologies and hence in related RD&D activities are the European Commission, EIB and EBDR. The large scale investment is assured through European banks (loans, Sustainable Energy Initiative Programme and Technical Cooperation Funds Programme) and European funding, such as the Seventh Framework Programme, the Competitiveness and Innovation Framework Programme (Entrepreneurship and Innovation Programme and Intelligent Energy Europe) and regional policy (European Regional Development Fund and Cohesion Funds).

The investments made by the major European funding in 2010 were EUR 0.86 billion, mainly focused on renewable energy technologies. The EU funding in 2010 was distributed through the various instruments as follows (Ecofys 2011):

- EUR 72 million through the SME Guarantee Facility of the Entrepreneurship and Innovation Programme
- EUR 79 million through the High Growth and Innovative SME Facility of the Entrepreneurship and Innovation Programme
- EUR 30 million from European Local Energy Assistance Program
- EUR 680 million through the European Regional Development Fund and Cohesion Fund.

In section 3.1.1 the intensity of funding through FP7 by technology in 2010 is presented (EUR 240.6 million were used to finance the SET-Plan technologies).

Another funding instrument designed to make energy supply more reliable and help reduce greenhouse gas emissions, while simultaneously boosting Europe's economic recovery is the European Energy Programme for Recovery (EEPR). The program was launched in 2009 and dedicated EUR4 billion to co-finance renewable energy projects in the fields of gas and electricity infrastructure (44 projects) and offshore wind (9 projects); and CCS (6 projects). EEPR allocated EUR 1billion to CCS and EUR 565 million to offshore wind[18]. In 2010, EUR 334 million were distributed through EEPR, of which, EUR 146 million to offshore wind projects and EUR 193 million to CCS projects.

More information on the allocation of EU funds can be found on the internet through the Cordis website, the Cohesion Policy Project, DG INFSO: ICT for Sustainable Growth, Intelligent Energy Europe –Projects, JESSICA - Joint European Support for Sustainable Investment in City Areas, JESSICA for Smart and Sustainable Cities, INTERREG projects. The data provided above was extracted from of a review of the European and national financing of renewable energy, produced by Ecofys in 2011, for the European Commission (DG ENER).

The Risk-Sharing Financing Facility (RSFF) is another innovative FP7 debt-financing instrument co-developed by the European Commission and the EIB to provide additional loan finance for research, development, demonstration and innovation in the European research area[19]. The FP7 and the EIB will each contribute with EUR 1 billion for the period 2007-2013[20]. Through a leverage effect, this contribution will underpin loans and guarantees by the EIB of approximately EUR 10 billion. RSFF loans have already been provided to R&D and innovation projects in the field of energy, which involve R&D in renewable energy technologies (low-carbon technologies). The current FP7 budget for risk-sharing (max. EUR 1 billion until 2013 with EUR 500 million already allocated by 2010) might not be sufficient if there is high demand for RSFF loans (including demand for larger demonstration projects related to SET-Plan implementation)[21]. From 2007 to 2009, 62 projects were approved for RSFF and have received EUR 6.3 billion. These projects were implemented in 18 EU Member States and 2 FP7 Associated Countries. 17% of this funding was related to energy topics (EUR 1041 million in total). Assuming that the annual intensity of RSFF in 2010 was at the 2009 level, RSFF would have potentially distributed EUR 347 million for energy related projects.

In addition, the European Commission's proposal for Horizon 2020 indicates that EUR 1.1 billion of RSFF may be used for the implementation of SET-Plan projects over the 2014–20 period[22].

3.1.1 The 7th Research Framework Programme (FP7)

The total EU contribution to the FP7 projects during the period 2007-2012 is approximately EUR 1.52 billion .This value refers only to the FP7 Energy Theme's budget lines; this is raised to EUR 1.78 billion when contributions to the FCH-JTI are taken into account, which results in EUR 0.30 billion per year on average.

Figure 4 presents an estimate of the FP7 contribution to the SET-Plan technologies in 2010. The Community funds in FP7 and EURATOM are EUR 0.24 billion. Nuclear fission receives about a third of the total funds, followed by fuel cells and hydrogen, bioenergy, electricity grids and solar energy. The total figure shows an increase compared to the one from 2007 (EUR 0.16 billion, JRC 2009). The differences include the slight decrease in CCS, wind energy, fuel cells and hydrogen; and the increase in the rest of

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18 European Energy Programme for Recovery: http://ec.europa.eu/energy/eepr/index_en.htm.

19 RSFF projects are evaluated by the EIB and validated by the European Commission (DG RTD, co-operation with other DGs) if the project contribute to FP 7 objectives

20 Sharing risk in research, development & innovation: www.eib.org/rsff.

21 Presentation by M. Koch: www.ceps.eu/files/Koch.pdf.

22 Investing where it matters: An EU budget for long-term growth. Download from: www.ceps.eu/book/investing-where-it-matters-eu-budget-long-term-growth.

technologies (solar, bioenergy, electricity grids and nuclear fission). Moreover, CCS technology has also been supported by the EU through the EEPR programme that effectively distributed EUR 193 million to CCS projects[23] in 2010.

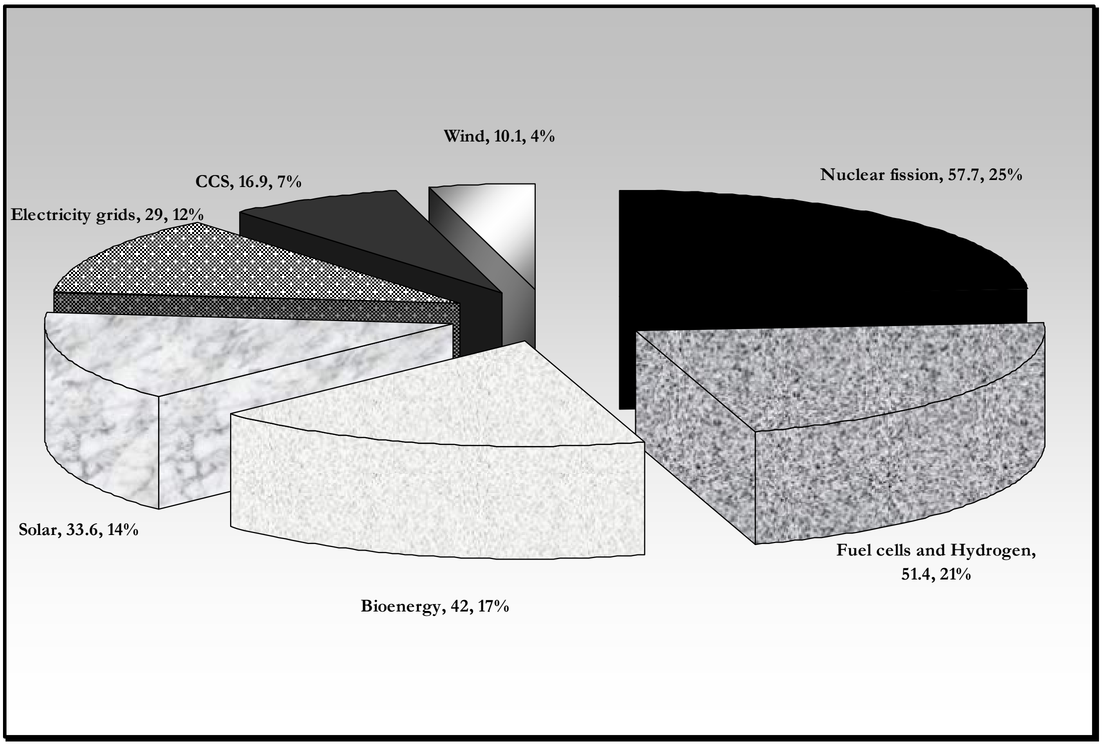

Figure 4. Estimation of EU FP7 funds (in absolute -million euro- and relative terms) in SET-Plan technologies in 2010.

However, the FP7 budget dedicated to energy-related projects includes a wider range of technologies than those addressed in the present report. By consequence, there is some uncertainty with the present assessment, resulting mainly from: 1) raw data – some projects simultaneously address two or more technologies but have been allocated to one to avoid double-counting; 2) methodology – the budgets of all projects are evenly divided by the number of execution years, irrespective of the actual starting date of a project within 2010 or the distribution of activities throughout the duration of a project. Nevertheless, the impact of this uncertainty is expected to be limited; hence the results provide a good indication of the effort and the trend of investment at the EU level.

3.1.2 The European Investment Bank-EIB

In assuring financial support to the renewable energy and energy efficiency sectors, the European Investment Bank-EIB has substantially increased its support over the last 5 years. Its annual lending increased more than tenfold since 2006 (EUR 0.5 billion) reaching EUR 6.2 billion in 2010. The majority of this lending is directed to wind and solar power generation.

The EIB has also developed other means of financing, such as equity and carbon funds, to further support renewable energy and energy-efficiency projects. The EIB also manages and participates in several other initiatives and programmes related to energy

[23] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52011DC0217:EN:HTML:NOT.

and climate change, such as the Mediterranean Solar Plan (MSP) and the GEEREF (Global Energy Efficiency and Renewable Energy Fund).

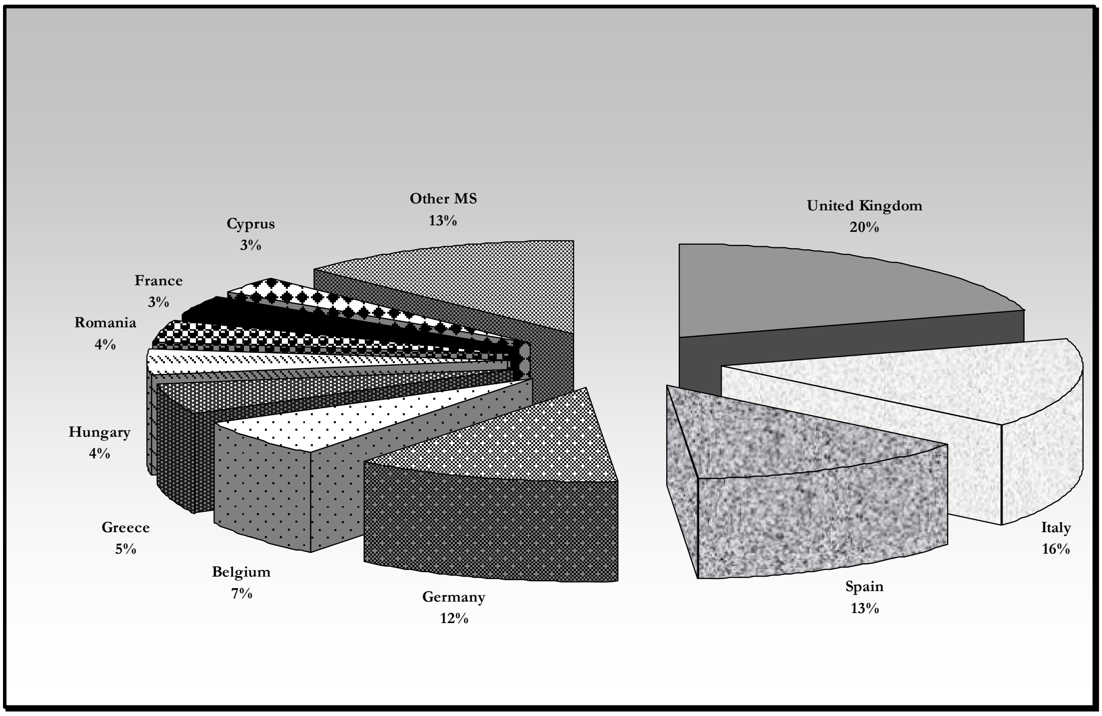

Figure 5. EIB expenditure in renewable technologies addressed by the SET-Plan in 2010, in million euro (source: EIB24). The projects taken into account are those for which the loan has been signed in 2010. The EIB loans included in 'Other Member States' refer to the ones signed with Finland, Slovenia, Czech Republic, Malta, Estonia, Poland, Portugal, Austria and Sweden.

The main EIB beneficiaries in 2010 were Italy, UK, Germany and Spain, which received almost 61% of EIB investments (see Figure 5). In the energy sector, 55% of the funds were allocated to electricity grid improvements, while 33% were directed to wind energy projects (mostly offshore) and 11% to PV projects. This snapshot is different from that of 2009, when wind was the principal sector funded by EIB, with EUR 1.28 billion representing 46% of total EIB expenditure on renewable energy that year.

3.1.3 The European Bank for Reconstruction and Development-EBRD

The strategic initiatives of EBRD are designed to pursue the challenges of increased energy security and energy efficiency, which can contribute to stronger productivity and economic growth in lesser developed countries. In order to achieve these goals, the EBRD commitments accounted for nearly one quarter of total EBRD financing in 2010: 21% of the signed projects are energy related, comprising both natural resources and the power sector.

Investment under the Sustainable Energy Initiative rose 64% between 2009 and 2010. The Bank signed 21 projects in 13 countries with a total value of more than EUR 1.2 billion, approximately one third more than in 2009 in terms of the level of investment and number of projects (EBRD annual report). The Bank shows a strong interest in financing wind projects and in particular large wind farms, such as the 120 MW

[24] For example, data about Austria can be found at: www.eib.org/projects/loans/sectors/energy.htm?start=2010&end=2010&region=european-union&country=austria

Margonin project in Poland. Table 2 provides an overview of projects for which a loan has been signed in 2010. Loans are mainly provided to wind energy (EUR 207.6 million) and electricity grid projects (EUR 581.3 million) and to a lesser extent hydro, CCGT (combined-cycle gas turbine) and natural gas. Electricity grid projects are of high priority for EBRD in 2010 (51% of projects in power and energy sector are grid related). This technology also represents a priority for EIB loans in 2010 as well (see section 3.1.2.).

Table 2 EBRD expenditure for Power and Energy in 2010, in million euro. The projects taken into account for 2010 are those for which the loan has been signed in 2010 (source: EBRD) http://www.ebrd.com/pages/research/publications/flagships/annual.shtml.

Country	Project name	Description	Portfolio class	Total project value	EBRD loan	EBRD equity	Total EBRD finance
Bulgaria	Suvorovo Windfarm	A loan to finance the construction of a 60MW wind power generation station.	Private	103	42.5	0	42.5
Hungary	Magyar Wind	Equity participation in Iberdrola Wind Farm portfolio.	Private	200	0	50	50
Lithuania	Lietuvos Elektrine	Financing of a new combined-cycle gas turbine power plant.	State	360.4	71	0	71
Poland	Polska Wind	Equity participation in Iberdrola Windfarm portfolio.	Private	300	0	75	75
Latvia	Latvenergo Riga CHP-2	The construction of a new combined cycle gas turbine unit to replace the old conventional gas-fired units.	State	394.33	84.99	0	84.99
Kazakhstan	Aktobe combined heat power rehabilitation	The loan will be used for the rehabilitation and upgrade of the equipment.	State	50	40	0	40
Georgia	Black Sea Energy Transmission System	Financing of the construction of a new 315 kilometre high voltage transmission line and a "back-to-back" substation.	State	315	80	0	80
Poland	Energa S.A.	Financing of extension/upgrade of electricity distribution network	State	567.07	67.40	0	67.40
Bulgaria	Gas Rimini	Loan to finance the development of the gas network in Trakia.	Private	62.6	20	0	20
Serbia	EPS Metering	Loan to fund acquisition/installation 200,000 advanced meters.	State	80	40	0	40
Poland	Margonin Wind Farm	Financing towards construction and operation of a 120 MW wind farm in the Margonin region.	Private	184.71	40.08	0	40.082
Serbia	Western Balkans Sustainable Energy Direct Financing Facility	Financing of small hydropower plant.	Private	2.52	1.4	0	1.4
Ukraine	South Ukraine Transmission Project	Loan to fund construction of 750 kV 190km overhead line between Zaporizhzhia NPP and Kakhovska substations.	State	449	175	0	175
Russia	RusHydro Bond Issue	Participation in RusHydro's bond issue as an anchor investor.	State	107.77	107.77	0	107.772
Russia	Federal Grid Company	Financing will contribute to the modernisation of the Pakhra substation.	State	87.65	87.65	0	87.655
Montenegro	EPCG Metering and Distribution	Loan for metering and distribution network reconstruction.	State	43.5	35	0	35
Turkey	Sedas Electricity Distribution Loan	Financing of SEDAS'capital investment programme.	Private	482.84	77.25	0	77.256
Georgia	Telasi Rehabilitation Project	Investment programme to improve electricity supply in Tbilisi.	Private	24.72	19.31	0	19.314
FYROM	Western Balkans Sustainable Energy Direct Financing facility	Loan for the construction and operation of seven small hydropower plants.	Private	11.57	6	0	6

3.2 National R&D investment

3.2.1 Competent authorities and main RD&D policies

Europe lacks of a top-down structure to coordinate and manage the RD&D activities from all Member States, which reduces the effectiveness and efficiency of the pan-European exploitation of synergies in strategic energy planning. Box 5 presents the different European Member State competent authorities for RD&D policies.

Box 5 – European Member State competent authorities for RD&D policies

	Competent authority
AT	Austrian Federal Climate and Energy Fund (Klima- und Energiefonds)
BE	Administration of Company Taxes and Income - SPF Finance. Federal Science Policy Department
BE	Energy Technology Innovation Platform (MIP)
BE	The Department of Energy and Sustainable Building (DG04) Department of Economy, Employment and Research (DG06)
DK	The Minister of Climate, Energy and Construction(The Green Labs DK Programme)
DK	The transmission grid operator Energinet.dk is in charge of the subsidies.
EE	Ministry of Economic Affairs and Communications, Ministry of Education and Research, Ministry of Agriculture. Foundations (Entreprise Estonia, Archimedes Foundation, Rural Development Foundations respectively).
FI	Ministry of Employment and the Economy, The Centre for Economic Development, Transport and the Environment
FR	French energy agency ADEME.
FR	French National Research Agency (ANR).
DE	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)
GR	Ministry of Development, Competitiveness and Shipping; Ministry of Environment, Energy and Climate Change (MEEC)
IE	The Sustainable Energy Authority of Ireland (SEAI) administers the programme.
IT	The ministry of Economic Development, ENEA(National agency for new technologies, Energy and sustainable economic development), CNR(Italian National Research Council) ar RSE(Ricerca sul Sistema Energetico),.
LU	The competent authorities are the Ministry of Economics and the Ministry of Finance.
NL	'Topconsortia voor Kennis en Innovatie' or TKI's (Top-class Consortia for Science and Innovation). Off-shore Wind
PT	Energy Agency (ADENE)
ES	The Ministry of Economics and Competitiveness
SE	Swedish Energy Agency

There is diversity in financial incentives and policy instruments in the EU Member States that encourage the development of RD&D activities in SET-Plan technologies (see Table 3). Direct support to innovation activities is manifested through public subsidies to research and demonstration (in France, Germany and UK). Indirect support for R&D is provided in Belgium (credit tax) and the Netherlands (public-private partnerships) to encourage the active participation of private parties.

Table 3. Main RD&D policies within European Member States (www.res-legal.eu)

Country	RD&D Policies	Description
AT	Neue Energien 2020 program (Smart Energy R&D , Energy Efficiency , Renewable Energy, Education, Awareness Raising, Technology Transfer)	Austrian Climate and Energy Fund allocated EUR 30 million
BE	national — Partial exemption of 75% of the business tax	An indirect fiscal mechanism collected EUR 500 million for investment in R&D.
BE	regional — Flanders: The Environment and Energy Technology Innovation Platform.	Finance specific research projects to develop sustainable technologies, products and services.
BE	regional — Wallonia: Department of Energy and Sustainable Building; Department of Economy, Employment and Research of the Public Service of Wallonia	Advance payment of up to 70 % of investment costs for projects of applied research or technological development.
DK	Green Labs DK Programme finance projects related to energy efficiency and renewable technologies.	The programme's budget is 210 million DKK (approx. EUR 28 million) for a period of two years, from 2010 to the end of 2012.
DK	Forsk-El Programme - Support for research and development of environmentally friendly power generation technologies	ForskEL is financed through a so-called Public Service Obligation (PSO), which is paid by final energy consumers.
EE	Operational Programme for the Development of Economic Environment	2007-2013
FI	Grants	R&D projects for generation of renewable energy
FR	Fonds démonstrateur. Grenelle of Environment (Ademe) SEED programme), electricity from renewable energies (PROGELEC programme), or sustainable transport (TDM programme).	A fund of EUR 325 million was granted for the period 2009 to 2012 for environmental demonstration projects.
DE	6th Energy Research Programme	For the period 2011-2014, the budget is EUR 3.5 billion
GR	Ai Stratis - the first green island: non-interconnected island in Aegean Sea	85% of the electricity consumption is met by RES technologies
IE	Renewable Energy RD&D Programme	-
IT	ENEA, CNR and RSE	Research program on electrical system
LU	No specific RD&D Policies. general support scheme within the Law of 5.6.09	The financial support covers 25% to 100% of the eligible costs
NL	R&D programme based on Funding from the parties involved	60% funding from private companies and 40% from the government
PT	Fundo de Apoio à inovação - FAI Fund to Support Innovation	-
ES	National plan of scientific research, development and technological innovation 2008 - 2011)	Energy, climate change mitigation, energy efficiency; Sustainable mobility / transport; Other climate change areas.
SE	Grants for research and development in the field of wind energy	Offshore projects and onshore projects (baring wind speed restrictions).
GB	UK Renewable Energy Strategy	GBP 50 million until 2015 (innovation activities in offshore wind, marine energy, waste and biomass)

In addition to the above mentioned national funding, since 2008, EU Member States have launched national economic recovery programmes. The fiscal stimulus envisages support to R&D activities in the field of renewable energy technologies. The green share in these recovery packages focuses mainly on the following categories: investment in energy efficiency, investment in transport infrastructure, vehicle scrappage schemes, investment in renewable energy sources and funds to support eco-innovation (Pollitt, 2011). The size of the stimulus packages and their green part are summarised in Table 4.

Table 4. Summary of the stimulus packages in several EU Member States. Due to lack of information, some Member States (Bulgaria, Greece, Hungary, Ireland, Luxembourg, Malta, Poland, Romania, and Spain) are not included.

Member States	Size of stimulus package (€ bn)	Size green part (€bn)	Share green part (%)	Implementation period
Austria	1.9	1.07	56	2009-2012
Belgium	1.7	0.17	10	2009-2011
Czech Republic	2.7	0.90	33	-
Cyprus	0.5	0.03	1	-
Denmark	-	15.60	-	-
Estonia	~1.0	0.25	~20	2009-2010
Finland	-	0.20	-	-
France	26.0	3.55	8-20	2009-2010
Germany	80.0	10.60	13	-
Italy	65.5	3.80	6	2009-2011
Lithuania	1.5	0.30	20	-
Latvia	-	0.80	-	-
Netherlands	17.3	2.90	17	-
Portugal	-	0.31	-	-
Slovak Republic	1.5	0.17	6-12	2009-2010
Slovenia	1.3	0.20	15	-
Sweden	12.0	0.70	5-6	2009-2011
UK	31.4	1.60	5	2009-2010

Most of the economic stimulus programmes presented above have a duration of a few years and include 2009 and 2010 (see Table 4). The green parts of the stimulus package from Denmark and Germany are remarkable (in absolute terms). Italy, France and the Netherlands are also countries with significant green parts.. However, only in a few Member States, part of the green share of the package focuses on R&D and innovation related to renewable energies:

- France: EUR 150 million for R&D of low-carbon vehicles (4% of the green part)
- Germany: EUR 500 million for R&D of alternative mobility concepts (5% of the green part)
- Sweden: EUR 39 million for green technologies, such as biogas and solar-cells (6% of the green part)
- Slovenia: R&D focus stated, but absolute value and field unspecified

The R&D and innovation measures offer the potential for long-term economic benefits, though it is difficult to quantify the scale of these benefits. However, as shown above, they are very limited in the stimulus packages in the EU Member States.

In assuring financial support to the renewable energy sector, national loans have been put in place to encourage related research activities (Table 5).

Table 5. Summary of the national loans in the selected EU Member States (www.res-legal.eu)

Country	Name of the support	Loan features	Amount
BG	Bulgarian Energy Efficiency and Renewable Energy Credit Line -BEERECL	Maximum loan amounts to EUR 2,500,000 in one or more loans, unless otherwise approved by the EBRD.	From 2004-2010 BEERECL, financed 152 projects, EUR 110.82 million loans were disbursed and EUR 19.15 million incentive grants have been awarded to businesses.
HR	HBOR Bank scheme (Programme for Environmental Protection)	The minimum loan amounts to HRK 100,000 (approx. EUR 13,000). The interest rate is variable from 2-4% per year.	Credit lines with EIB for the financing of SMEs, environmental projects and infrastructure projects in the public and private sector of EUR 250.0 million[25].
CZ	ECO-ENERGY Programme	The maximum loan is CZK 50 million (approx. EUR 2 million). The interest rate is fixed at 1%/year.	Co-financed by the Structural funds (ERDF, ESF,etc.) Overall budget of ECO-ENERGY - OP Enterprise and Innovation was 65.722 million for 2010 [26]
DK	Loan guarantees for local initiatives for construction of wind-energy plants	The maximum guarantee is 500,000 DKK (approx. EUR 67,209) per project	Energienet.dk has provided a budget of 10 million DKK (approx. EUR 1.3 million) for guarantees.
DE	KfW Renewable Energy Programme	Up to 100% of the investment costs eligible for financing (without VAT), however, not more than EUR 25 million per plant/project.	Loans totalling EUR 1.2 billion were granted in 2010 for investment in environmental and climate protection (KFW annual report).
ES	The Centre for The Development of Industrial Technology CDTI	Programs such as INNPRONTA	Loans were granted for Wind(30.3 million), PV (11.38 million), CSP(10.7 million), Bio-energy (3.77 million), CCS(5.28 million), Grids(6.83 million), Nuclear Energy (0.22 million)
LT	The Fund of the Special Programme for Climate Change Mitigation	The amount to be provided by the credit institution shall be no less than 20% of the loan.	No information has been found on the amount invested for 2010.
PL	National Fund for Environmental Protection and Water Management - RES	The amount of loan may be PLN 4 to 50 million (EUR 1-12 million) but must not exceed 75% of the project costs d) Priority Programme RES). The investment must exceed PLN 10 million (EUR 2.4 million)	The total budget for renewable energy and combined heat and power for 2009-2012 is around EUR 333.6 million. In 2010 financing of environmental protection by the National Fund [27]: PL 1269 million as loans and capital investment of NFEP&WP ;PL 4298 million subsidies and grants from funds of NFEP&WP and EU Funds;PL 347 million as bank loans.
SI	Eko Sklad	The minimum. interest rate for is the three-month EURIBOR rate + 1.5 percentage points	The calls currently open provide a total of EUR 25 million for municipalities, enterprises and EUR 5 million for residents.

The variety of programs that are in place makes the collection of data on national investment from all the Member States difficult. Recent initiatives such as the SETIS project mapping offer opportunities to monitor EU national funding in a centralised way to explore Europe's full potential in RD&D capacities. This initiative aims to identify

[25] HBOR Bank annual report 2010.
[26] http://erawatch.jrc.ec.europa.eu/erawatch/opencms/information/country_pages/be/country?section=ResearchFunders&subsection=ImportantResearchProgrammes.
[27] http://www.nfosigw.gov.pl/en/financing-environmental-protection/.

gaps and topics[28] for leveraging best on-going efforts with complementary joint actions as prioritised by the Implementation Plans of each EII.

3.2.2 Public RD&D investments: comparison between the EU, the USA and Japan

The total RD&D investments dedicated to the SET-Plan technologies in 2010 from the 19 European countries addressed in this report are estimated to be EUR 2.02 billion, which shows a significant increase in the past decade (EUR 929.04 million[29]). The level of European RD&D investment in 2010 is comparable with that of Japan and USA for the same year. However, these three economies display different trends from 2001 to 2010: while R&D investment clearly increases in Europe and USA, they are slightly decreasing in Japan. Moreover, the intensity of investments in these countries is very different: from 2001 to 2010, an annual average increase of EUR 82.86 million in the EU is observed, while it is significantly higher in the USA (annual increase of EUR 202.0 million). The growth rates of public subsidies in these three major economies display similar trends but are significantly different in absolute terms: the yearly average increase in the growth rate in the USA is 2.2% and while in the EU it is 0.7 %. The yearly growth rate of RD&D in the USA is rapidly changing, reflecting to some extent policy choices, since a higher priority is now given to the federal strategy for alternative energy research. For example, in 2001, R&D investment in low-carbon technologies in USA represented only 17.65% of those in Japan. Since then, RD&D spending in USA showed a significant increase, in all the SET-Plan technologies, with an even distribution of funding between them. Especially in recent years (2008-2010), among the low-carbon energy technologies, bioenergy, electricity grids, solar energy and CCS take increasingly larger shares. R&D investments show a peak in 2009 due to the economic stimulus package, the so-called "The American Recovery and Reinvestment Act" (abbreviated as ARRA). ARRA was enacted by the 111th United States Congress in 2009 to create jobs and promote investment and consumer spending during the recession. The combination of the energy related provisions in ARRA and the regular federal RD&D funds have been considered an important step in creating a sustainable energy system for the future of the USA (Anadon et al., 2009). This shows the significant position of low-carbon RD&D in the strategic planning of the energy sector in the USA.

The source for public spending data in the USA was the "DOE Budget Authority for Energy Research, Development, & Demonstration Database" (Gallagher and Anadon, 2012), which has also been used for this analysis. A comparison of data included in the IEa and DoE databases is shown in Table 6.

Table 6. Comparison of the energy RD&D data from IEA and DOE databases

Energy technology	IEA (€ million)	DOE (€ million)
Carbon storage & storage	169.88	114.56
Solar energy	197.06	185.89
Wind energy	63.42	60.33
Biofuels	593.43	165.11
Nuclear fission	354.85	383.99
Fuel cells & hydrogen	251.42	155.03
Electricity grids	134.39	128.68

[28] To facilitate this process questionnaires have been distributed by SETIS to Member States stakeholders and the EII Teams.

[29] In 2009, the JRC public investment totalled EUR 1.14 billion, including EUR 172.48 million for FCH_2 and EUR 38.48 million for CSP.

Table 6 shows that for most of the technologies, data are comparable, except for fuel cells and biofuels, where the difference between the two data sources is significant. The reason for this difference is that, the data on biofuels in the IEA database include the production of liquid biofuels (EUR 142.70 million) and other biofuels (EUR 450.74 million). Here, the RD&D activities on "other biofuels" focus on 1) assessing biofuel production potential and associated land-use effects, and, 2) genetics and biology to develop new crop varieties or modify certain characteristics of existing varieties (IEA Guide to Reporting Energy RD&D, 2011). The DOE data focus on biomass and biorefinery systems and presumably do not include the same activities as the IEA database.

The comparison of RD&D investments for 2010 reveals that Japan, Finland, France, Denmark, Norway and Sweden have higher intensity in RD&D investments (defined as the ratio of RD&D investment over GDP). Countries like Germany and Italy have a high RD&D investment in absolute terms, but a low R&D intensity: measured as the RD&D investment per GDP , the public R&D intensity in these countries reaches barely 0.01%. Table 7 and Figure 6 show the RD&D investments for the SET-Plan technologies per GDP for the important economies under study. Countries with high GDP show also a high level of investment in low-carbon technologies. Moreover, the correlation coefficient between public RD&D and GDP is 0.68, indicating that the size of the market is an important factor for the R&D intensity for low carbon technologies.

Table 7. National RD&D investments in the SET-Plan technologies

Country	RD&D investment (€ billion)	GDP (€ billion)[30]	RD&D investment/GDP
France	0.685	1937	0.035%
Germany	0.237	2496	0.010%
United Kingdom*	0.250	1710	0.015%
Italy	0.136	1553	0.009%
Poland*	0.124*	355	0.035%
Netherlands	0.102	589	0.017%
Norway	0.090	318	0.028%
Spain*	0.080*	1049	0.008%
Denmark	0.074	236	0.031%
Sweden*	0.073*	350	0.021%
Finland	0.067	179	0.037%
Switzerland	0.064	416	0.015%
Belgium	0.034	356	0.009%
United States	1.764	10937	0.016%
Japan	2.364	4150	0.057%

* The RD&D investment data for these countries are based on the content of IEA RD&D statistics database after being corrected by JRC-SETIS in consultation with the Member States.

Innovation activities in renewable energy are seen as important determinants for Europe's green growth. In order to fulfil the 20/20/20 climate and energy targets, the overall European investments from the private and public research and development sectors should reach 3% of GDP (Box 6). In the absence of synergies with other actors and considering that two thirds of total R&D investment should be made by the private sector, public RD&D investment should account for 1% of GDP. Table 7 reveals that EU countries such as Finland, France and Poland invest in SET-Plan technologies around 3.5% respectively of the above-mentioned target of 1%. For the year of 2010, the

[30] Data source: Eurostat for 2010 (online data codes nama_gdp_c and tec00001).

intensity of public R&D investments in SET-Plan technologies is low in Italy, which also has private R&D investments below the Lisbon target (48% of total R&D investment in SET-Plan technologies). On the contrary, the low intensity of public R&D investment in Spain and Germany is accompanied by high intensity of corporate R&D investment (almost 65% of total R&D investment in SET-Plan technologies in Spain, and almost 80% of total R&D investment in SET-Plan technologies in Germany).

Box 6 – Europe 2020 Strategy
The Europe 2020 Strategy has identified three priorities: Smart, sustainable and inclusive growth. Innovation is recognised as a key driver for revitalizing the European economy. Building on Lisbon Strategy, one essential target proposed to be reached before 2020 is the level of R&D investment that should reach 3% of Europe's GDP. Moreover, the 20/20/20 climate and energy targets should be met. In 2010, the Commission estimated that the level of R&D expenditure in Europe was below 2%, which is lower than level of investments in USA (2.6%) and Japan (3.4%).

The intensity of public R&D investment in each technology is shown in Figure 6. It reflects the priorities that have been given to the technological development of SET-Plan technologies. However, although electricity grids are of great importance for the future deployment of renewable sources, the R&D intensity remains small.

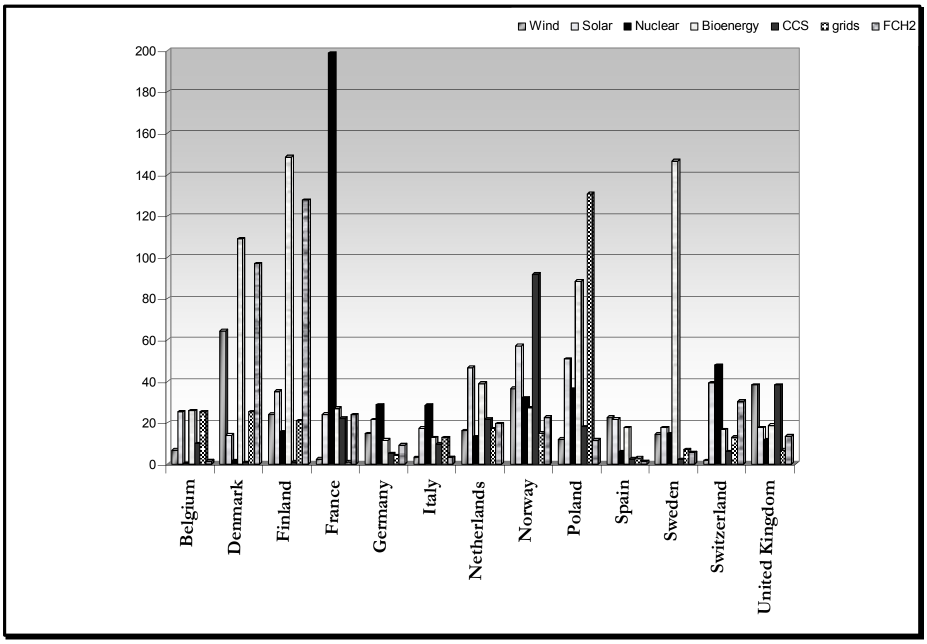

Figure 6. RD&D intensity by technology per country in 2010. RD&D intensity is defined as ratio of public R&D investment to GDP and expressed as 10-6

Moreover, the R&D priorities by technology are quite different for Europe, Japan and the USA. However all three countries display a high level of investments in nuclear fission. Even though it has a decreasing trend, R&D investments in Japan were made predominantly into nuclear fission (83%)[31]. Nuclear fission investments account for the

[31] As the year of the present assessment is 2010 does not take into account consequences of Fukushima accident which took place in 2011

largest share of the EU RD&D investments, followed by fuel cells, bioenergy, solar energy and CCS. In the USA the focus of RD&D investment in the energy sector is to a large extent on fossil fuels and energy efficiency. Hereafter a comparison of the distribution of research across SET-Plan technologies in the European Member States, Japan and the USA is presented (Figure 7).

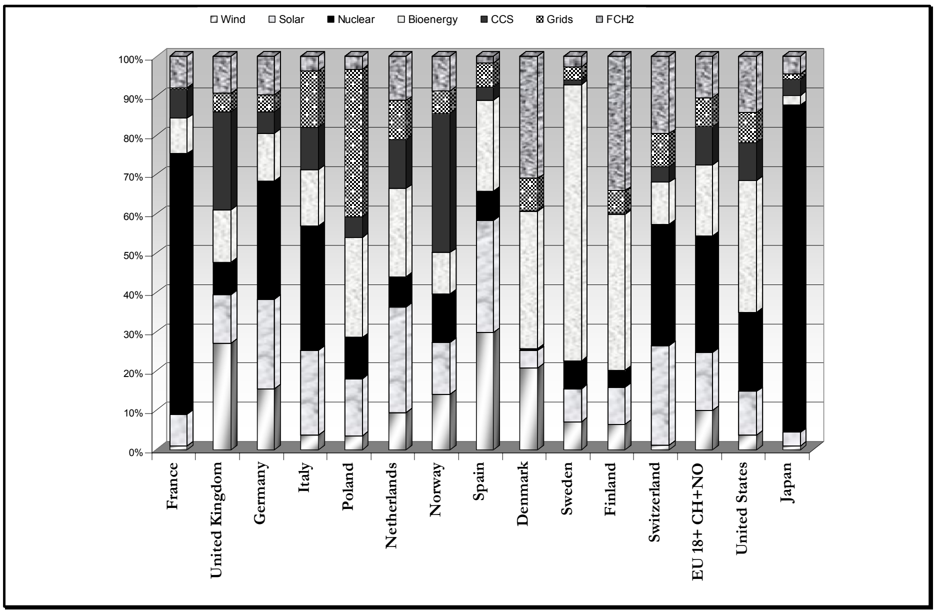

Figure 7. Technological breakdown of the total RD&D investment per country (EU Member States, Japan and the USA) in 2010

The distribution of RD&D investments across the SET-Plan technologies varies substantially between countries:

- Public RD&D investment in Japan, France and Belgium is focused to a great extent on nuclear fission technology.
- With its abundance of biomass feedstock, bioenergy shares are around 70% of the RD&D investment in Sweden, followed by Finland, Denmark and the USA for the same reason. Besides this, RD&D heavily focuses on production of ethanol from cellulose, referred to as second-generation biofuels.
- In Finland and Denmark, fuel cells and hydrogen have a significant share among all SET-Plan technologies.
- A distinction of solar technology into PV and CSP (Table 8), reveals that countries tend to invest less in CSP (almost 15% of the total investments in solar energy) than in PV technology.

Table 8. PV and CSP RD&D investments per region in 2010

	PV (€ million)	CSP (€ million)
FP7	28.93	4.63
EU Member States (incl. Norway & Switzerland)	245.46	39.45
Japan	80.47	0.00
USA	163.08	33.98

Among the European countries that invest the most in CSP technology are Germany (EUR5.84 million), Italy (EUR 13.00 million), Spain (EUR 10.80 million) and Switzerland (EUR 3.62 million.

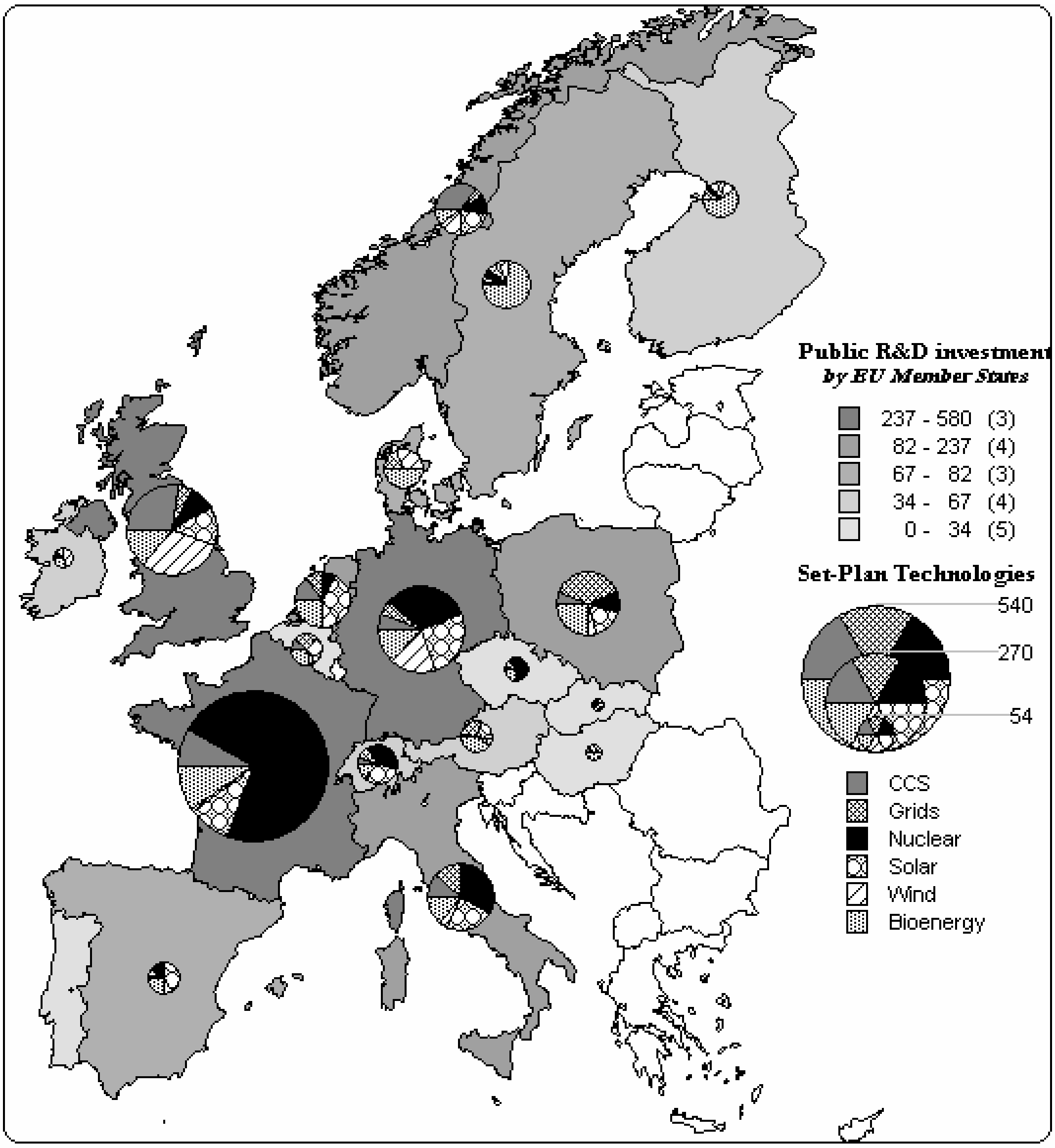

Figure 8. Regional distribution of the public RD&D investment in the SET-Plan technologies in 2010

Figure 8 shows the national RD&D investments of the leading European economies in the SET-Plan technologies in 2010. France accounts for almost one-third of the total R&D investment (EUR 0.58 billion), followed by the United Kingdom (EUR 0.26 billion), Germany (EUR 0.24 billion) and Italy (EUR 0.14 billion). These four countries combined account for two-thirds of the total European national RD&D investments in the SET-Plan technologies. These countries are also the main investors in 2010 to both fossil fuels and renewable energy technologies. On a yearly basis, these countries show a different attitude towards financing renewable energy sources, nuclear and fossil fuels (including CCS).

The case of United Kingdom is described below first, which shows the highest increase in RD&D budgets, both for fossil fuels and for renewable energy technologies. Compared to 2009, the United Kingdom in 2010 shows a significant increase (219%) in national RD&D budget for fossil fuels, mainly attributed to CCS technology: CCS represents 95% of the total RD&D budget for fossil fuels in 2010 (compared to 85% in 2009). In addition, the UK's governmental RD&D budget also increases by 78% for renewable energy sources from 2009 to 2010 and by 51% for nuclear technologies. Thus, R&D investment increases for both low-carbon technologies and fossil fuels.

There is a different approach in Germany, where RD&D investment in fossil fuels decreases by 18%, with RD&D for CCS decreasing at a slower rate (by only 1%). RD&D in nuclear energy technologies decreases by 5% while for renewable energy sources RD&D increases by only 1%. As in other countries, RD&D budgets seem affected by the global economic recession.

Also affected by the economic crisis is Italy, a country that displays an interesting pattern. In 2010, RD&D in renewable energy decreases by 9%, while it increases for nuclear by 9.8% and for fossil fuels by 4%. This finding is consistent with the support for nuclear power by the Italian government at that time. However, the Italian nuclear programme faced strong local opposition and ten Italian regions blocked a law aimed at reopening nuclear facilities. Therefore the evolution of technology development depends on the effectiveness of public policies, which in turn is affected by the level of public consensus for a specific technology (Corsatea and Dalmazzone, 2012).

In France, RD&D public funding increased for both fossil fuels and renewable energy, showing an average yearly increase of EUR 15 million for the Set-Plan technologies[32]. From 2001 to 2010 most of the Set-Plan technologies receive growing public funding, while RD&D investment for nuclear fission programs showed an average annual decrease of EUR 8.37 million. In fact, from 2009 to 2010, public RD&D decrease by EUR 105 million (almost 15%). More than 35% of this reduction is attributed to the decrease in public RD&D investment in nuclear technology.

From the analysis presented above it is concluded that beyond the economic crisis, and the specific countries' industrial specialization, the socio-political acceptance has also played an important role in shaping the intensity of RD&D public investments in low-carbon technologies in 2010. However, this outcome may reflect also the advantages and constraints with regard to the renewable energy resource potential, the current energy mix and its historical development, and regional industrial capacities (Figure 6 and 7).

[32] From 2001 to 2010

3.3. Corporate R&D investment

The European innovation activities on low-carbon technologies are not only subject to domestic policies (such as European support for research or policies promoting deployment of renewable energy sources), but also respond to policies in the non-EU countries, where these low-carbon technologies are deployed. Such sensitivity to policies of non-EU countries is reflected on an increased regionalization of the production capacities for low-carbon technologies. Scale-intensive companies are subject to globalization the most, where sources of innovation are both internal and external to the firm. On the one hand, European companies are attracted by green stimulus packages of foreign markets; and foreign companies could benefit from the environmental/climate policies of European countries. On the other hand, innovation of foreign companies could be influenced by European environmental policies. Additionally, the economic crisis has triggered dramatic changes to the organization of the productive systems of major in-house R&D energy technology companies. This has led to a leakage of assets reflected in a decreased employment and innovation activities in Europe.

3.3.1 The selection of main companies

In this analysis, most of the technologies have been approximated only by the largest companies. Although small companies can be very committed to RD&D, they are not considered in this analysis due to difficulty of data gathering. Therefore the strategy chosen in this analysis for identifying the main European companies tends to underestimate the total RD&D efforts dedicated to SET-Plan technologies.

The notion of large companies/investors considered for this analysis should be interpreted in the light of two criteria: the production capacities (measured in terms of cumulative annual power generation capacity of manufactured units) and the innovation efforts (measured in terms of patent applications). Sometimes, the two criteria (production and research) are closely linked together: large companies develop important R&D activities mostly relying on own internal effort, and called hereafter *science-based* companies. Other firms are relying on both internal and external efforts, and called hereafter *scale-intensive* companies. The last category of firms considered in this analysis comprises large firms, which do not develop important research activities, and called hereafter *supplier-dominated* companies.

The companies involved in producing wind energy technology were identified as *science-based*. The sample of firms considered in the analysis for this sector relies extensively on recruiting high quality scientists. Research activities for these companies are largely performed in-house, and are characterized by intensive patenting activities and 'technology races' that push upward the frontier of knowledge production. Solar energy technology companies are scale-intensive, relying both on in-house and external R&D. To increase their market share innovation efforts of these companies were focused on cost reduction and process optimisation. In general, scale-intensive firms invest 2.58% from sales on R&D and direct their innovation efforts into applications that renew markets. The level and the localization of research in SET-Plan technologies for scale-intensive and science-based companies are determined by the providers of these technologies. This is the case for solar, biofuels and wind technology companies.

For the supplier-dominated companies, the innovation and production activities are decoupled. The supplier-dominated companies were identified also in the previous edition of the Capacities Map (JRC 2009) in the light of Pavitt's Taxonomy (1984): the companies involved in the traditional energy sector are considered to be supplier-dominated, where the relevant R&D efforts are carried out by the original energy equipment manufacturers and suppliers (OEMs) (Jacquier-Roux and Bourgeois 2002). The identification of the companies considered as relevant for measuring the research intensity in a certain SET-Plan technology did not rely only on statistical classification of economic activities (NACE). The present analysis includes also traditional energy companies (producing energy from fossil fuels) which rely extensively on sources of innovation external to the firm.

The assessment of R&D investments of all these companies (supplier dominated or science /scale intensive) is based on an evaluation of their innovation activities, such as the number of patent applications. This is the case of companies involved in CCS and the electricity grids. The intensity of patenting in these specific technologies is considered as a proxy of their R&D efforts for that field. This approach is also subject to limitations, where the biggest shortcoming comes from the patent's nature. The patent approach should be able to identify individual technologies; however for technologies that are closely linked, this methodology produces results with a degree of uncertainty. For example, in many occasions it is difficult to disentangle the degree to which patents related to wind energy also result in electricity grid improvements. The same situation is valid for PV inverter companies. Many of the technological improvements in inverters also indirectly improve grid connectivity. Expert opinion should address the issues of the present methodology and suggest improvements for future analysis.

In summary, the main companies considered in this analysis were identified based on their production capacity and by their innovation efforts. Certain associations, such as EPIA (European Photovoltaic Industrial Association), EWEA (European Wind Energy Association), and the European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP) provided support for the identification of the main actors.

3.3.2 Sampling and errors of sampling

For each SET-Plan technology, key industrial EU-based companies have been identified. For wind and solar energy technologies, the selection of main companies was based on their innovation activities (thorough analysis of EPO and WIPO databases), analysis of markets (e.g. through the surveys from EUROBSERV'ER 2010 and 2011), and information on production capacities (through the companies' websites). For electricity grids, CCS, nuclear energy and biofuels a patent analysis was only employed, as described below.

- **Wind:** The selected European wind manufacturer companies account for more than 40 % of global supplied capacity and 15% of total WIPO wind patent applications. Based on the number of European wind technology developers (31- including non-active) and a sample size (12) the theoretical margin of error is 22% for the wind sector[33]. The complete sample includes European and non-European wind companies that account for more than **75% of global supplied capacity.**
- **Solar:** The selected European solar manufacturer companies account for 63 % of European cell production and cover 20% of WIPO patent applications for solar energy material and 10% for modules. Based on the number of solar companies (240 in 2012) and the sample size of this report (32) the theoretical margin of

[33] Plus or minus in percentage points, 95% of the time.

error is 16.16% for the solar sector[34]. The sample includes European and non-European solar technology companies that account for about **84% of global supplied capacity.**

- **Electricity grids:** The EPO classification is used, which is the only data source that distinguishes the patent applications related to grid connections. The European manufacturers represent just a small share of the applicants of patents for electricity grid technology: a search by country codes reveals that 11.5 % of the total electricity grid patent applications at EPO in 2010 was made by European companies. Based on grid patent applications filled by European companies in 2010 (116) and a sample size of electricity grids (19) the theoretical margin of error associated to this sampling is 20%. The final selected European grids technology developers account for more than **60% of all patent applications filled in at EPO by European based companies.**
- **CCS:** The major investors in CCS technology were identified based on a novel EPO classification (2010). Based on the CCS-related patent applications filled by European companies in 2010 (147[35]) and a sample size of 22 companies, the theoretical margin of error associated to this sampling is 18%.The final selected European CCS technology developers account for **50% of all patent applications filled in at EPO by European based companies.**
- **Nuclear:** Based on nuclear energy related patent applications filled by European companies in 2010 (48) and a sample size of 13 companies, the theoretical margin of error associated to this sampling is 23.46%.The final selected European nuclear technology developers account for **49% of all patent applications filled in at EPO by European based companies.**
- **Biofuels:** The WIPO classification has been used, as it provides a separation of liquid and solid fuels. Data accounts only for bioethanol, biodiesel and biogas; hence, they include all liquid biofuels except vegetable oil production and genetically engineered organisms. Such a choice is supported by the limited information on production, mostly offered by the Eurobarometers. The theoretical margin of error associated to this sampling is 16.2%. The final selected European biogas technology developers account for **12.4% of global patent applications.**

The total sample of firms included in this report includes **102 companies** identified as main R&D investors in the SET-Plan technologies. Only 22 large companies are simultaneously active in all 6 SET-Plan technologies. German and French companies have a diverse portfolio of technologies, such as Siemens (DE), Bosch (DE) and Alstom (FR). The sample also includes also companies that invest both in traditional fossil fuels and renewable energy sources (such as BP in the UK and Statoil in Norway). For some companies it was possible to recover data from the World Top 1400 R&D Investors included in the European Scoreboard. For the companies that are not listed on the stock exchange, and thus, not obliged to publish their financial report, relevant information, such as annual reports and yearly facts, was extracted from the companies' internet sites.

For companies focused on a single technology, it was assumed that their research activities remain within the main field of their business subject. However, an effort was made to disentangle their research efforts between energy generation and grid connections. The newest EPO classification allows the identification of patents that are

[34] Plus or minus in percentage points, 95% of the time.

[35] Including all subsidiaries.

used for both main energy generation technologies, such as wind or solar, and their related application to grid connectivity. Therefore, particular attention was paid herein to allocate the R&D investment to energy generation and to improvement in grid connectivity.

For companies with a diverse technological profile the share of patents for renewable energy sources with respect to the overall intensity of patenting was used to capture the level of research in specific technologies. Specific R&D funding intensity per patent by industry was also used in the absence of total R&D expenditure.

However, acknowledging that not all companies patent for obvious reasons (fear of imitations or knowledge spillovers) further calculations were also made to provide information on specific research expenditures. One approach was to estimate R&D expenditures from the number of researchers in a specific technological field (JRC, 2009). A rough estimation of the R&D investment is obtained by assuming an average R&D investment per research employee ranging between €120,000 and €150,000 (JRC 2009). The R&D-to-sales intensity ratio was also used to compare R&D investments obtained by a combination of computations described above.

3.3.3 Geographical distribution of corporate R&D investment
Using the above described methodology, it has been estimated that the selected sample of companies invested EUR 3.047 billion in 2010 in the SET-Plan technologies (wind, PV, nuclear fission, biofuels, CCS and electricity grids). This estimate is based on companies in 14 countries (13 EU Member States and Switzerland). Overall, corporate R&D funding in non-nuclear technologies increased from 2007 levels (EUR 1.24 billion[36]), reaching EUR 2.33 billion in 2010. Corporate R&D is highly concentrated in Europe: 88% of R&D investment in the SET-Plan technologies is carried out in 5 countries: Denmark, United Kingdom, Switzerland, Germany and France (see Figure 9). The last two countries account for 54% of the total R&D efforts. The results are consistent with the intensity of public support toward environmental issues, over the last years in these countries.

With respect to the previous edition of the Capacities Map (JRC 2009), Italy shows an increase in private investment, while in Sweden and Austria corporate R&D has decreased. It is recalled that public funding decreases in Italy by 22% during the same period, while corporate initiatives intensify (from 2 to 4% of the selected sample).

The industrial specialization of a country also affects the R&D intensity in specific low-carbon technologies. Countries such as Germany and France have a multi-technological investment portfolio (Figure 9): solar and wind initiatives represent more than 72% of Germany's corporate R&D expenditures. In France, bioenergy and nuclear initiatives represent 85% of corporate R&D expenditures in the country. This situation has not changed since 2007.

[36] Excluding CSP and FCH_2.

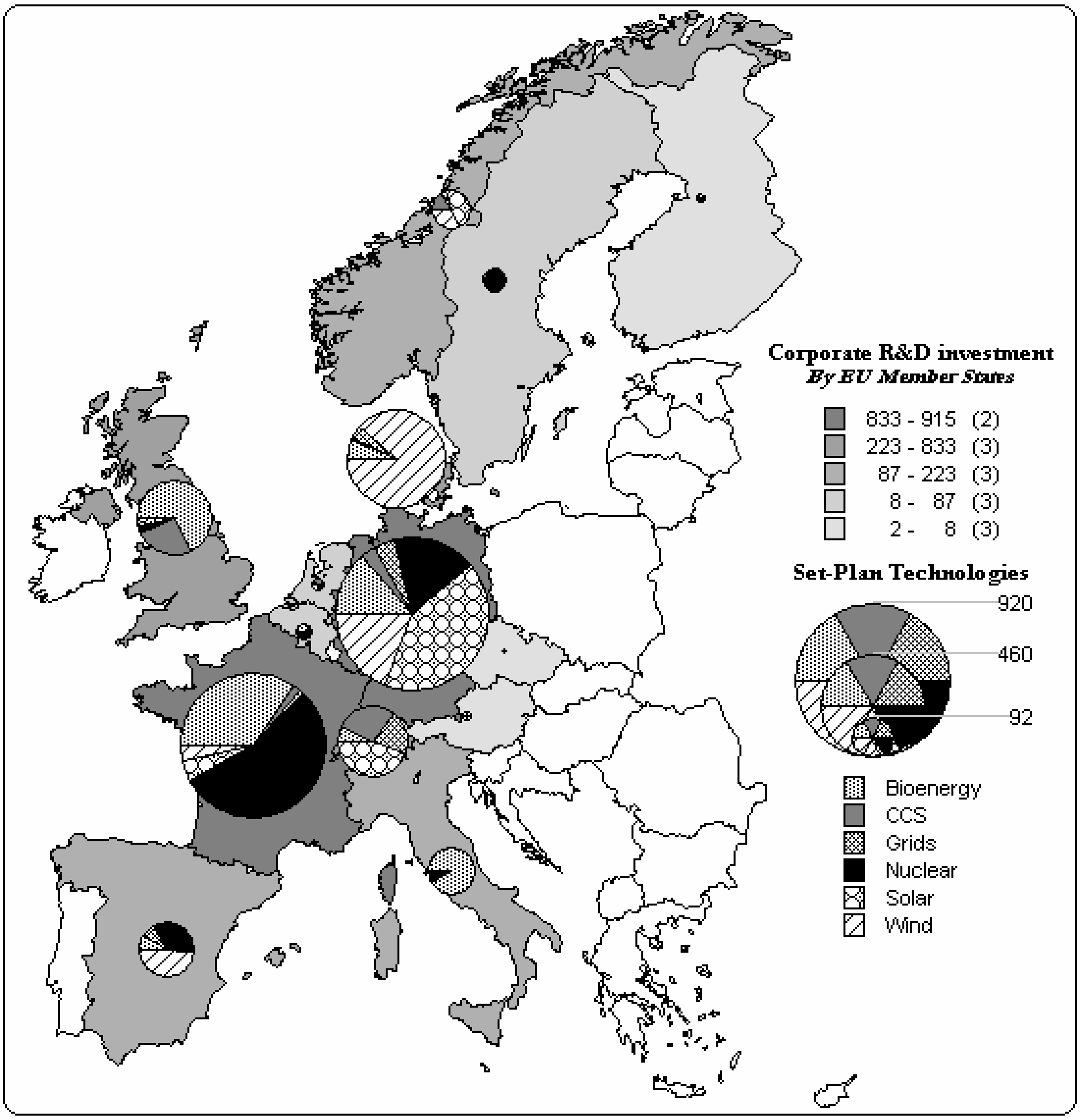

Figure 9. Indicative regional distribution of corporate R&D investment in SET-Plan technologies in 2010. The intensity of colours reflects the magnitude of corporate R&D investment. The pie charts reflect the distribution of corporate R&D investment to the SET Plan technologies.

3.3.3.1 Wind energy technology

In 2007, Europe was a global leader in wind energy technology, holding a 61% share of the globally installed wind energy capacity in 2007 and hosting 7 of the top 10 wind energy suppliers in 2006 (EUROBSERV'ER, 2008a). In 2010, Europe accounted only for 48 % of total installed wind capacity and 27% of new installed capacity; and hosted only 5 of the top 10 wind energy companies (including Repower, which was bought in 2009 by the Indian company Suzlon). China is rapidly expanding in the wind energy sector with 3 companies in the top 10 wind manufacturers in the world and accounting for 46.2% of global installed capacity in 2010.

The penetration of wind power in the energy markets of developing economies triggers technological improvements, new business solutions, new products and production reorganization of the European-based companies in order to serve these new customers. To this end, European companies redirect and resize their research efforts to adapt their technologies the needs of the new markets. The general principle in 2010 was "thinking globally, acting locally". Delocalization was seen as a way of reductions in the cost of shipments and manufacturing (JRC, 2012). Consistent with their globalization strategy, European and American companies are in this context more exposed to knowledge spillovers and research collaborations than their Chinese counterparts.

The European firms considered in the analysis[37] continue to intensify research efforts in 2010, with an average increase of 21% in R&D expenditure over 2009 levels. The aggregated R&D investment of EU-based companies (EUR 670 million in 2010) is the result of an assessment of 11 companies. Vestas, Siemens, Gamesa, Enercon, and Nordex are the largest investors in the sample. Nordex showed the largest annual increase of R&D investment in relative terms (80%), and Vestas in absolute terms (EUR 130 million). 52% of the total corporate investments is made in Denmark, followed by Germany (28%) and Spain (10%).

The estimated corporate R&D investment in wind energy has increased by an order of magnitude (130%) since 2007. This increase is not uniform across countries, as it is higher for Demark (158%) and Germany (240%) and lower for France (3.4%).

The JRC-SETIS estimates of the European corporate investments in wind energy (EUR 670.15 million) are not far from the 2012 edition of BNEF. The latter source reports that global investment in wind technology development was USD 800 million.. At a country level, not surprisingly, Germany and Denmark invested the most in Europe followed by Spain and France.

Corporate R&D represents 76% of total R&D investment in wind energy, which is a typical value for a mature technology. This value is increased in relative terms by 5 % with respect to 2007 levels. It is noted however that the share of corporate R&D investment decreases to 65 % when the EEPR contribution is included.
The estimates of public and private R&D (Figure 11) indicate that countries with high public R&D funds simultaneously account for the largest corporate R&D investments.

[37] Nordex (DE), Vergnet (FR), Siemens (DE), Vestas Wind (DK), Acciona Energy(ES), Alstom (FR), Gamesa (ES), Enercon (DE), REPower Systems (DE), Dong Energy (DK), Iberdrola (ES).

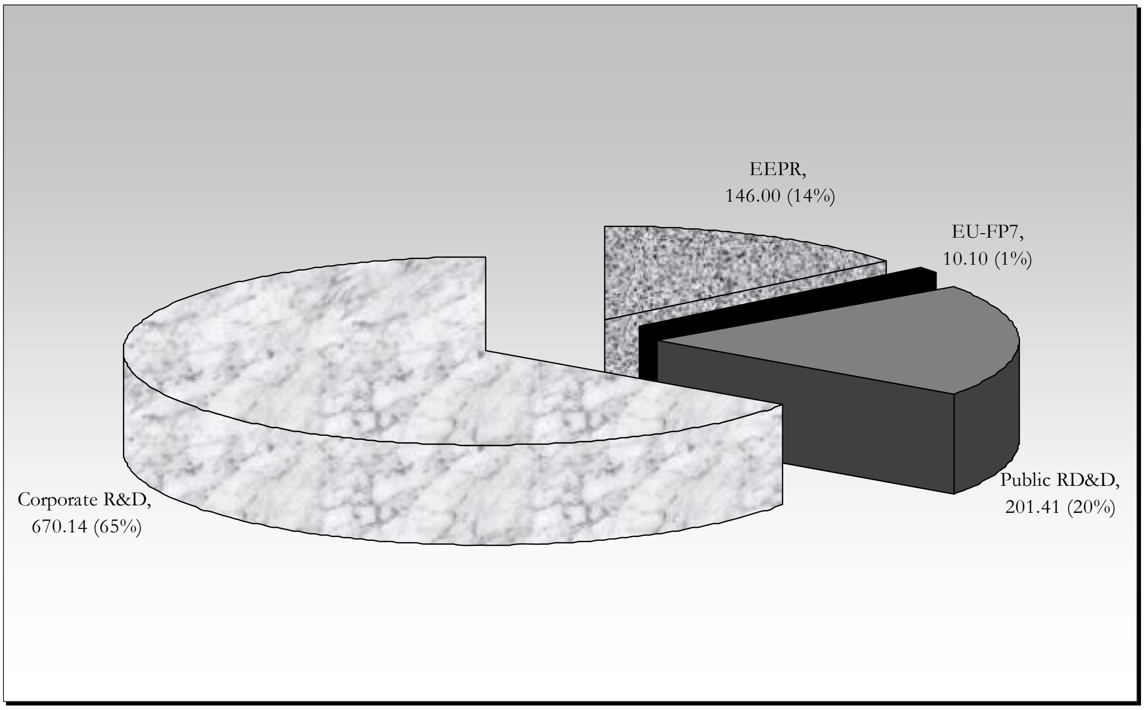

Figure 10. R&D investment in wind energy technology in 2010 (in million euros)

The total R&D investments in wind energy technology in 2010 were €881.66 million (EUR 1027.66 if the EEPR contribution is included). The EU contribution was EUR 10.10 million through FP7 and EUR 146 million from EEPR funding for offshore projects. Public national investments accounted for EUR 201.41 million, increased by 78% over 2009 levels and 143% with respect to 2007 levels. The level of public RD&D programs the highest in the United Kingdom (EUR 67.33 million), Germany (EUR 36.77 million) and Spain (EUR 23.76 million)[38] , which together they accounted for 63% of public Member State investments. The continuous increase of investments in wind energy is consistent with the stated goals of large European countries to achieve the 20-20-20 goals with an increased share of wind in their renewable mix.

The ratio of R&D investments of European companies to their turnover is on average 2.587%. As, in general, engineering firms allocate 7% of their sales for R&D expenditures, the above average value of 2.6% could be interpreted as underinvestment in research for wind energy. The R&D-to-sales ratio is higher for companies dedicated to wind energy, such as Vestas (almost 5%) and lower for multidimensional technology companies, such as Dong Energy and Iberdrola for which this ratio is below 0.5%.

To some extent, the intensity of research efforts is correlated with the firm characteristics: American General Electric and Danish Vestas are among the key investors in wind technology. Asian companies are smaller compared with the European ones, but lately successful in the wind business Nonetheless, Chinese companies' cumulative turnover represents as much as 85% of Vestas' revenues. Chinese firms are less R&D intensive[39], investing only 10% of what Vestas invested in 2010.

[38] The public R&D investment in Spain is obtain by adding up the investment made by national research centre for energy research(CIEMAT) and Energy investments made by The Centre for the Development of Industrial Technology in 2010.
[39] According to JRC-SETIS calculations.

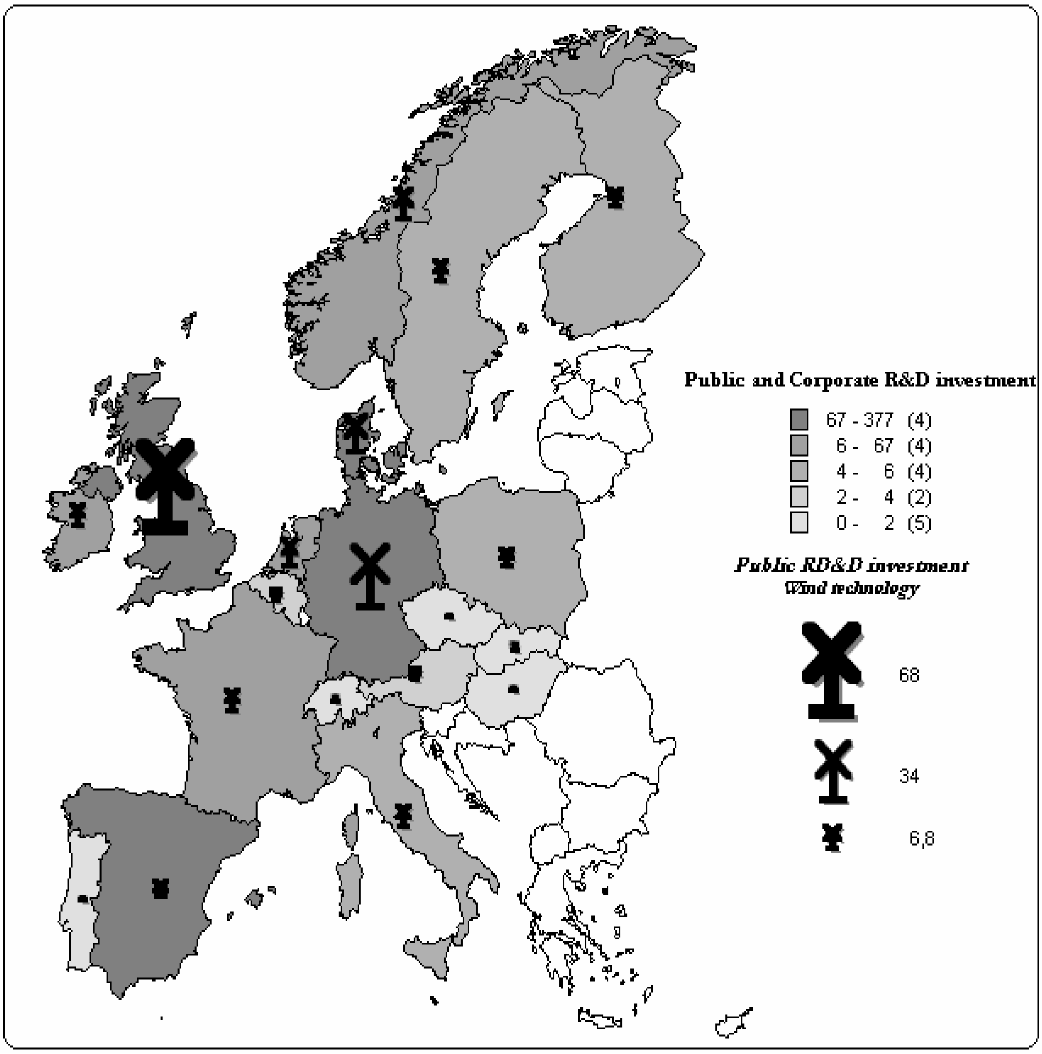

Figure 11. Indicative regional distribution of public and corporate R&D investments in wind energy technology (2010). The intensity of colours reflects an aggregate (public and corporate) R&D investments. The symbols reflect only the public RD&D.

3.3.3.2 Solar energy technology: The case of photovoltaics

The global solar market is dynamic, growing from EUR 5.415 billion (USD 7 billion) in 2004 to EUR 63.439 billion (EUR 82 billion) in 2010[40]. In 2004, Japan led the world in annual production of PV systems with about 500 megawatts (MW), followed by Europe (300 MW) and the United States (140 MW). Japan hosted at that time many of the world's largest solar companies. At that time 2 European companies were also among the world leaders (BP Solar, and RWE Schott Solar). In 2010 the situation was completely different: Chinese companies (such as Suntech, Jasolar, Trinasolar, Yingli), dominated the market. European companies with large scale production were Q-Cells, SMA Technologies and Schott Solar

[40] Becky Stuart2010 PV market growth strong, http://www.pv-magazine.com/news/details/beitrag/2010-pv-market-growth-strong_100002459/#axzz24rNTpfZ2. The same report mentions a 105% growth from year to year (in 2009 the industry generated USD 40 billion).

One of the reasons for these changes of the solar market was the high price elasticity that stimulates demand and redirects investments, also away from Europe (Germany) to emerging markets such as China or India. The strategy embraced by the European companies was delocalization with local production serving local consumption. The globalization process of the European companies justifies the delocalization of their facilities outside Europe, as a way of avoiding exchange rate disadvantages, reducing transport routes and costs and enhancing customer service. (JRC, 2011b) provides additional causes for the current situation related to research, manufacturing and market implementation of PVs.

Concerning their technological specialization, many European companies, such as Siemens, Bosch, and British Petroleum (BP), developed large-scale production facilities for crystalline silicon technology. Few European companies invested in the second generation of PV (Centrotherm PV, Q-Cells ag) and none of the European firms invested in third generation technologies.

Global corporate R&D investment in PV technologies for the sample of firms considered in this analysis, reached EUR 1,653 million (USD 2,139 million), with EU ranked second with EUR 574.57 million (USD 743 million) after Asia (USD 916 million or 42 % of global investment). The findings of this analysis are consistent with those of BNEF that state for the same period USD 2.1 billion for corporate investments in R&D. The selected sample of corporations include international competitors such as American firms that account for 19.5% share in global R&D investments, Japanese firms that account for 21% share of the global R&D, Korean firms that account for 15 % of global R&D and Chinese firms that account for 5% of R&D investment. Looking at the complete sample of companies, the average R&D-to-sales intensity varies between 1.4% (France and Spain) to 3.2% in Germany, Japan and USA. The highest R&D intensity is shown by Japan,

German firms account for a quarter of global R&D investments and 57% of European investments. The analysis has shown that European firms[41] continue to intensify research efforts with an average annual increase of EUR 58 million between 2003 and 2010. In relative terms, in 2010 the highest increase was by Centrotherm PV (83%), whereas in absolute terms the highest annual increase of R&D expenditure was by Oerlikon Solar (EUR 33 million). However, the R&D-to-sales intensity for the EU-based PV companies is around 2.16%, indicating that these companies underinvested in research.

Corporate R&D investments were focused on the improvement of production processes and cost reduction for first and second PV generation (crystalline technology and thin-film). Current efficiencies of different PV technology modules using wafer-based single-crystalline silicon range between 14-20%.., Wafer-based multi-crystalline silicon PV systems have 13-15% efficiency, The efficiency of thin films using amorphous silicon ranges between 6-9%, thin films based on cadmium telluride 9-11% and copper indium gallium (di)selenide thin films 10-12% (IEA Industry Conversion Efficiencies 2010, technology Map).

[41] Centrotherm PV(DE), Conergy (DE), Manz automation (DE), Meyer Burger (CH), Oerlikon Solar (CH), PV Crystalox Solar (DE), PVA TePla (DE), Q-Cells ag (DE), Roth&Rau (DE) , Schott ag (DE), SMA Solar Technology (DE), Solar World (DE), Solon1 (DE), Sunways (DE), von Ardenne (DE), Wacker BU Polysilicon (DE).

The distribution of total R&D expenditure in European countries is shown in Figure 12. Research is highly concentrated in two countries (Germany with a 49% share and Switzerland with a 13%share) accounting for more than 63% of total R&D expenditure. Their research intensity is correlated to public incentives for renewable energy.

In contrast to PV, most of the countries invested negligible amounts in CSP, with the exception of Germany (EUR 5.84 million), Italy (EUR 13.00 million), Spain (EUR 10.80 million) and Switzerland (EUR 3.62 million).

The total R&D investments in solar energy technology in 2010 were EUR 901.03 million[42]. Even though corporate R&D accounts for almost 64 %, public investments are not negligible (EUR 297.53 million from EU Member states and EUR 33.60 million as FP7 contribution).

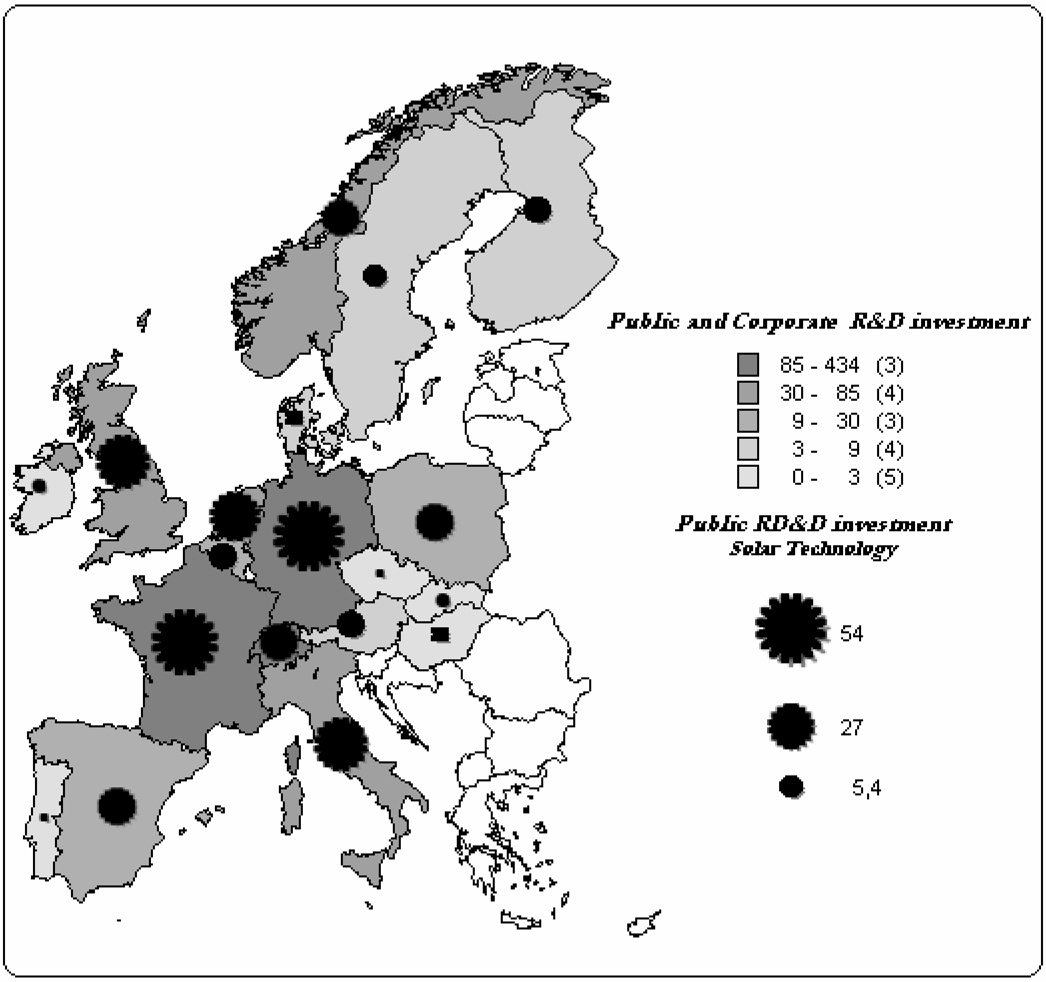

Figure 12. Indicative regional distribution of public and corporate R&D investments in PV technology (2010). The intensity of colours reflects an total (public and corporate) R&D investment. The symbols are reflecting only the public RD&D.

PV public R&D investment is the highest in Germany (EUR 53.64 million). Northern European countries with relatively small potential due to the low irradiation conditions, such as the Netherlands and Norway also make significant investments. The high level of

[42] The amounts refer to PV and CSP R&D investment. PV R&D investment amounts EUR 0.81 billion, from which EUR 210.96 million from EU Member states and EUR 28.93 million as FP7 contribution.

R&D expenditure in Norway is due to private investments from companies such as REC and Orkla Elkem solar. In contrast, the high investments in the Netherlands are due to public initiatives (almost EUR 28 million).

3.3.3.3 Electricity grids technology

Several factors incentivise R&D activities dedicated to electricity grids, such as the shift from a centralised generation towards an increasing deployment of distributed energy resources, the need for larger cross-border interconnection capacities to ensure higher security of supply and access to the most efficient energy resources and the foreseen transmission over long distances of electricity generated in locations far from the actual consumption centres.

Grid technologies can be grouped into high voltage, medium voltage, low voltage and demand-side management technologies. It should also be noted that super-high voltage (well above 400kV) is also currently being studied in an attempt to significantly decrease losses and increase reliability of power transmission.

- For high and extra-high voltage (so-called "super grids"), HVDC – high voltage direct current and FACTS – flexible AC transmission systems, seem to be the most promising technologies and therefore are the main targets of private R&D funds.
- At medium voltage, low voltage and demand side management, R&D activities are oriented towards research in smart grids, including not only the study and manufacture of specific equipment, but also the integration of ICTs into the distribution network and end-customer appliances. For further reference see the forthcoming edition of the smart grids inventory, expected in the first half of 2013.

The sample of European firms investing in grid technology was selected using as criteria the intensity of their patenting at WIPO[43]. Among the main investors in grid applications are European inverter companies and wind technology manufacturers. The involvement of these companies aims to supply a product that is able to be implemented in diverse topographical conditions and various electricity networks. Consequently, firms customize solutions for new markets, enhance product varieties and adapt technologies to different natural context and improve efficiency of existing manufacturing turbines. An example is the PMDD technology for which some companies claim that it is superior to traditional drive train machine, with respect to grid connectivity. The same is observed for the PV inverter companies: many of the technological improvements in the inverters also have an indirect impact on grid connectivity. As an example, SMA Technologies became involved early on in the area of grid management in order to make it possible to integrate more photovoltaic plants into the German electricity network.

The total R&D investment in electricity grid technology in 2010 was EUR 323.25 million. The national R&D investment reached EUR 150.63 million, and FP7 funding was EUR 29 million. Corporate R&D investment had a 44% share of the total amount. Concerning corporate R&D, countries such as Germany, Switzerland and Spain accounted for 70 % of the research in grid technology. The special case of Swiss ABB

[43] Auxilien [AT], Fronius Int Gmbh [AT], Hehenberger Gerald [AT], Eandis [BE], Vestas [DK], ABB Technologies [CH], Areva [FR], Nexans [FR], Adensis Gmbh [DE], Bosch Gmbh Robert [DE], Enercon [DE], Repower Systems AG [DE], RWE AG [DE], Siemens [DE], SMA Solar Technology [DE], Nordex [NO], Smartmotors [NO], Ingeteam Energy SA [ES], Gamesa [ES], ABB Technologies [CH].

Technologies Company is noted, which alone has a 31% share of R&D expenditure in electricity networks.

An indicative regional distribution of public and corporate R&D investments in electricity grid technology in 2010 is presented in Figure 13.

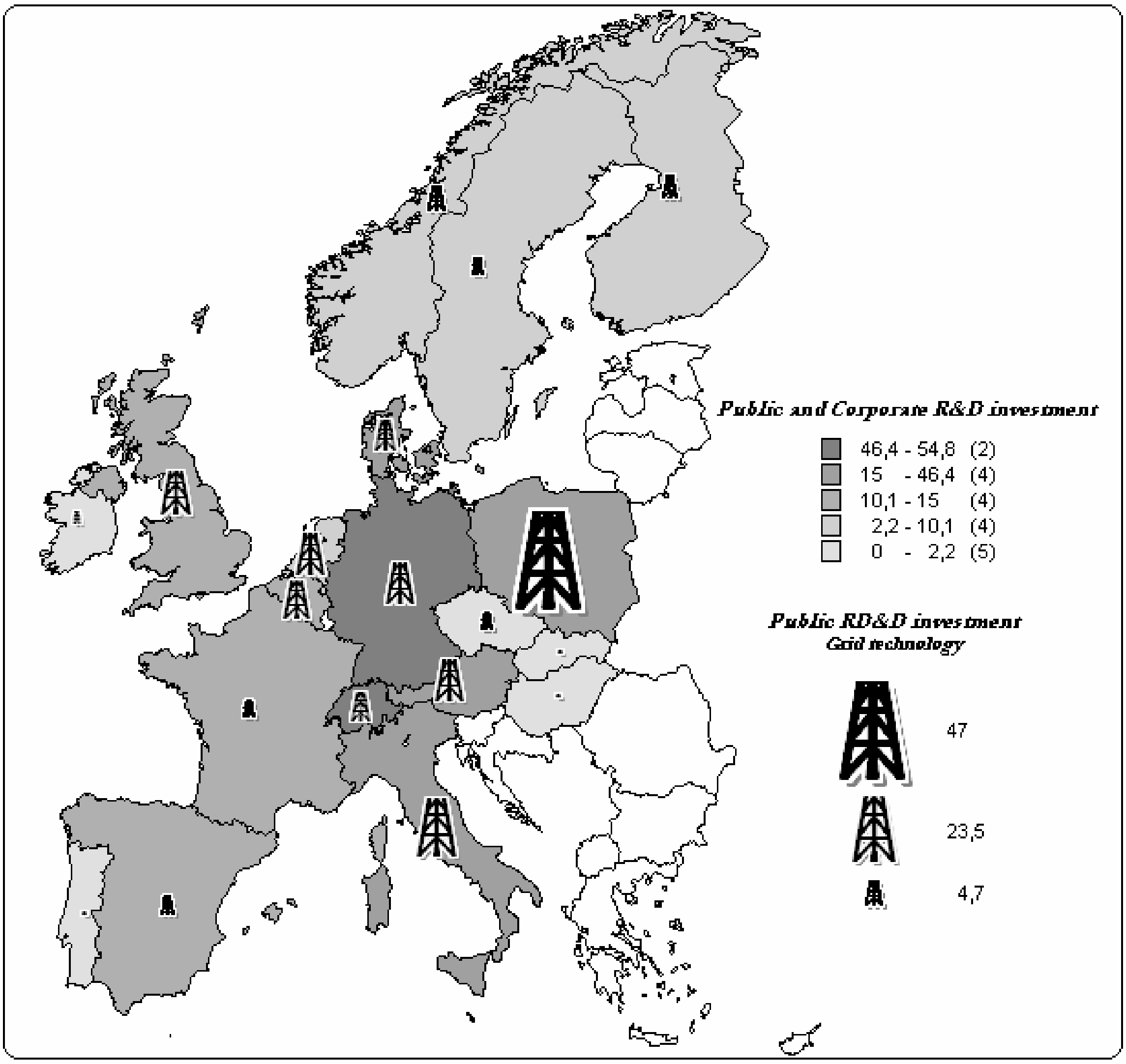

Figure 13. Indicative regional distribution of public and corporate R&D investments in electricity grid technology (2010). The intensity of colours reflects an aggregate (public plus corporate) R&D investment. The symbols reflect only public RD&D.

European RD&D investments in electricity grids have more than doubled from 2007 to 2010. The steady increase of RD&D investment in electricity grids of the Member States confirms the ever growing concern for the pressure of increasing demand on existing electricity networks.

The highest share of the public RD&D investment in electricity grids across EU Member States was in Poland (31%[44]), Italy (13%), United Kingdom (8.2%), Germany (7%) and the Netherlands (7%).

[44] Data provided by the Sherpa of the SET-Plan Steering Group.

3.3.3.4 CCS technology

The total R&D investment in CCS technology in 2010 was EUR 400.39 million (EUR 593.39 million if the EEPR contribution is included). The FP7 contribution was EUR 16.90 million. Public investment was very significant (EUR194.62 million) (Figure 14).

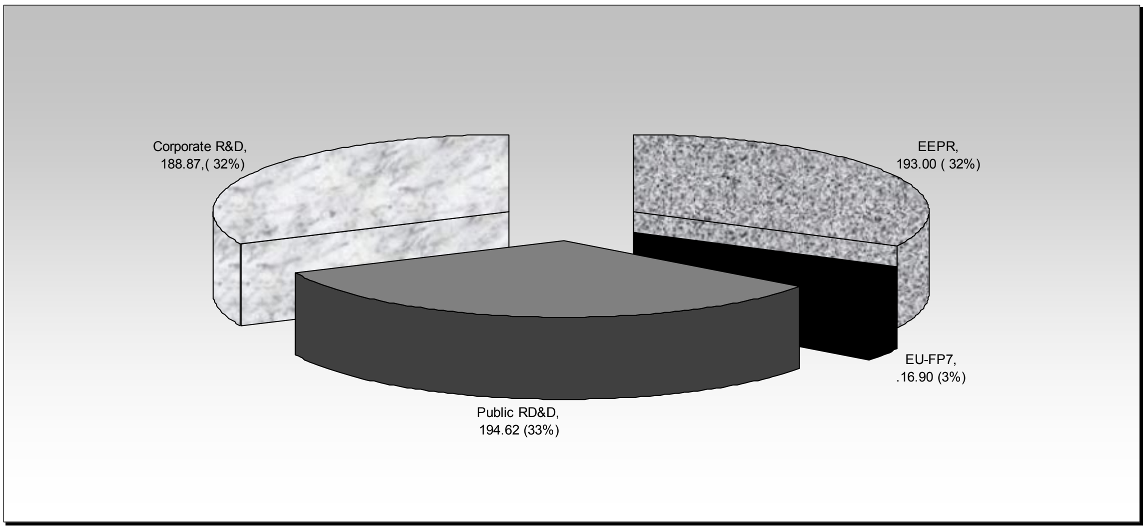

Figure 14. R&D investment by source of funding for CCS technology in 2010

An indicative regional distribution of public and corporate R&D investments in CCS in 2010 is presented in Figure 15.

Corporate R&D accounts for as much as 47.17% of total investment. A close look to the composition of corporate R&D investment in this sector (around EUR 189 million in 2010) reveals an ever growing interest for this technology of large utilities and oil companies. The identification of the main European companies investing in CCS-related applications was based on the composition of the technology platform for zero emission fossil fuel power plants (ZEP ETP) and information on the intensity of their patenting activities at WIPO[45]. In the case of R&D investment in CCS technology, a decoupling of public and private efforts was observed: in contrast to the other technologies, public and corporate R&D investments are not correlated at country level. Corporate R&D investments are higher in Germany (BASF, Siemens) and Switzerland (Alstom). Only for United Kingdom both public and corporate R&D investments (Shell, BP) are correlated. With respect to 2007 levels, the public R&D in CCS related topics has increased almost tenfold in United Kingdom, and by 50% in France.

[45] Blackcarbon [DK], Novozymes [DK], Air Liquide [FR], Basf [DE], Bosch Gmbh Robert [DE], Evonik Degussa [DE], Linde [DE], Siemens [DE], AST Engineering [IT], Stichting Energie [NL], Tno [NL], Aker Clean Carbon As [NO], Sargas AS [NO], Statoil [NO], Nordic Gas Cleaning AB [SE], Alstom Technology Ltd [CH], Shell [UK], BP [UK], Carbon Cycle Ltd [UK].

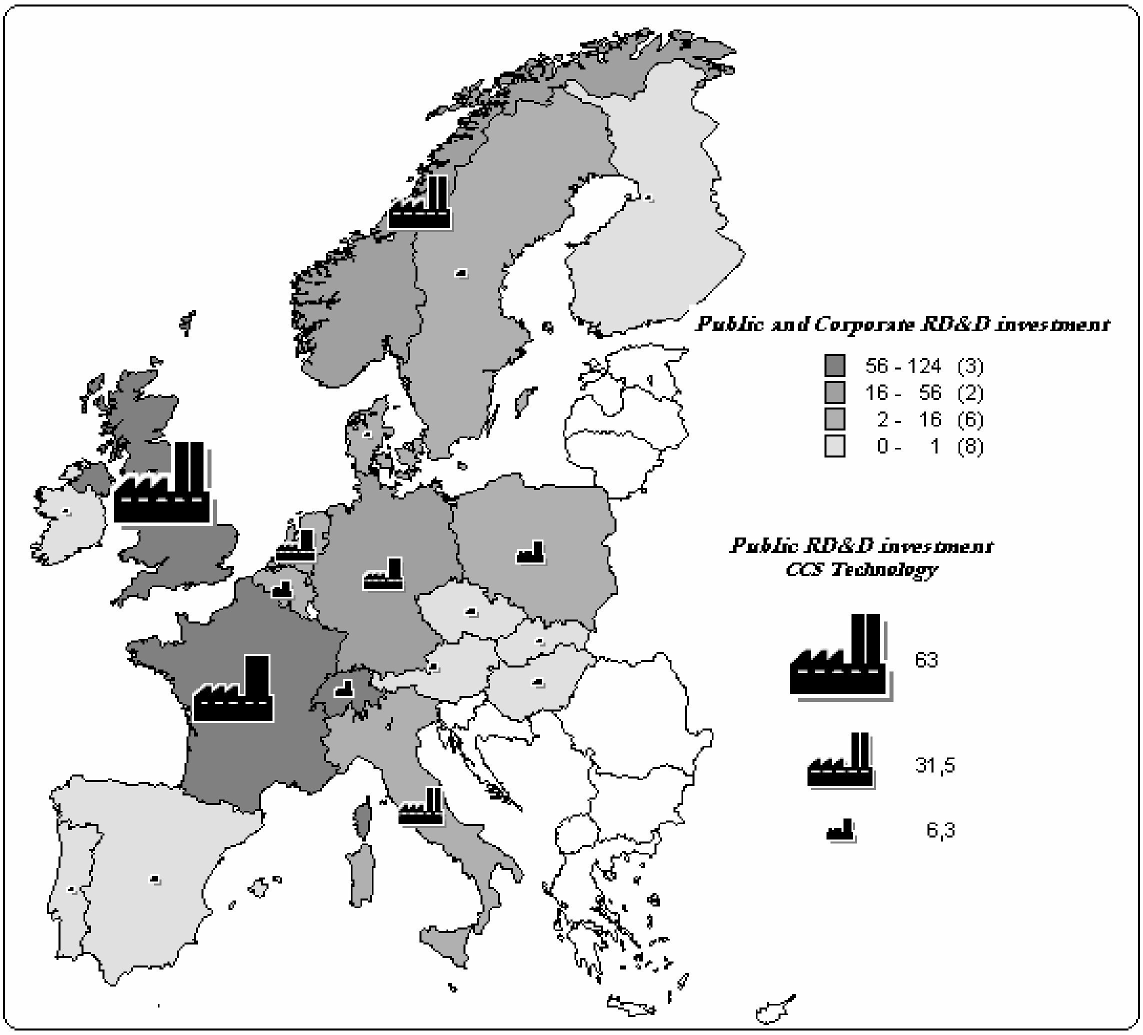

Figure 15 Indicative regional distribution of public and corporate R&D investments in CCS technology (2010). The intensity of colours reflects an aggregate (public plus corporate) R&D investment. The symbols reflect only public RD&D.

3.3.3.5 Bioenergy technology

The public R&D investment remains rather low compared to corporate investments (EUR 365.3 million from EU Member states EUR 42 million as FP7 contribution and EUR 750 million from the private sector). France is a major investor, followed by Sweden and the UK. Public R&D investments tripled in France compared to 2007, while halved in the UK (which had the most intensive R&D at country level in 2007). It is difficult to assess with a high level of accuracy the R&D investment for this technology, as Member States do not explicitly disclose data on biofuels, but rather allocate it under the category 'bioenergy-related research'. However, countries with high public biofuel-related R&D budget are home to companies with substantial research investments in biofuels (i.e. France, Germany, Italy, and the UK): the correlation coefficient between public and corporate R&D investments is 0.59 (Figure 16).

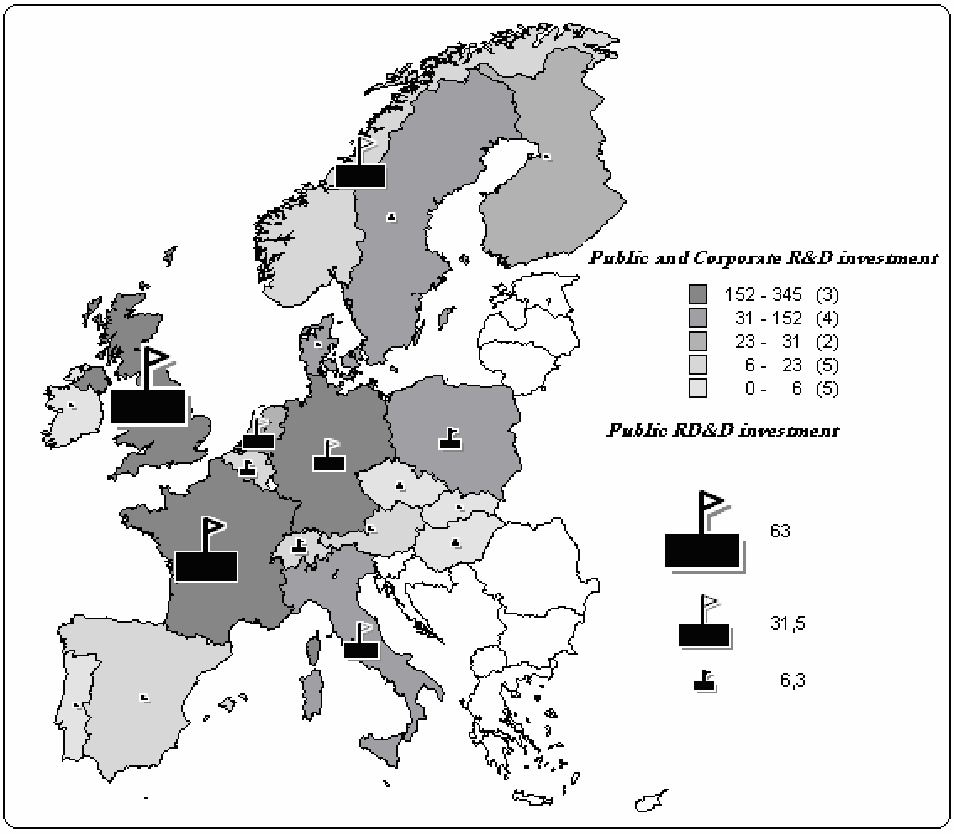

Figure 16. Indicative regional distribution of public and corporate R&D investments in bioenergy technology (2010). The intensity of colours reflects an aggregate (public and corporate) R&D investment. The symbols reflect only public RD&D.

The sample of companies was selected based on patent applications at EPO and WIPO[46]. These companies focus their R&D investments on biodiesel, bioethanol and biogas. As in the previous version of the Capacities Map (JRC, 2009), the companies included in the analysis are specialised biofuel companies, large car manufacturers and oil companies. The latter two categories of firms account for the majority of the corporate R&D investment in bioenergy. The total R&D budgets For some biodiesel and bioethanol producers were not available. In order to approximate their R&D investment in bioenergy the number patent applications of these firms was multiplied by the average R&D investment per patent of the rest of biofuels producers that their budget was known. In doing so, sample of companies captured also smaller companies, not present in the Industrial Scoreboards or not quoted on the stock market, which however made considerable research efforts that led to patent applications at EPO or WIPO.

The above-mentioned approach allowed the assessment of 33 firms involved in R&D in bioenegy technology. Their total R&D investment was around EUR 750 million. This represents a three-fold increase from the 2007 levels.

[46] Novozymes [DK], Cursor Oy [FI], Air Liquide [FR], Arkema [FR], IFP Energies Nouvelles [FR], Marliere Philipe Instituts Pasteur [FR], Saint Gobain [FR], Tereos [FR], Total S.A. [FR], Veolia [FR], Diester Industrie [FR], Anaergia Inc [DE], BASF [DE], Bayer [DE], Bosch GmbH Robert [DE], Hoermann Interstall GmbH & Co KG [DE], KSB Aktiengesellschaft [DE], KWK GBR [DE], Linde [DE], Sattler AG [DE], Siemens [DE], Voith Patent GmbH [DE], ADM Biodiesel [DE], Crop Energies [DE], Eni [IT], Abengoa [ES], Biosling Ab [SE], Novartis [CH], BP[UK], Shell [UK].

3.3.3.6 Nuclear fission technology

In 2010, the R&D budget for fast reactors, one of the SET-Plan technologies, was EUR 130 million. One third of this investment represents EURATOM funding of projects (around EUR 40 million). The development of fast reactors takes place mainly in France, where sodium-cooled fast reactor (SFR) initiatives have been nurtured since early 50's. In 2010 the development of SFR-based ASTRID prototype (500-600 MWe) has triggered annual investments of approx. EUR 80 million during the period 2009 - 2017[47]. The total cost of the ASTRID project after 2017 is estimated to be EUR 5 billion. An alternative technology to SFR, the lead-cooled fast neutron reactor (LFR) has generated an annual investment of EUR 10 million in Belgium: the MYRRHA pilot plant "is scheduled to be operational in 2020 and its cost is estimated as EUR 960 million (ESNI Concept Paper). Another project on lead cooled technology is the Genius project, which has triggered 1 million annual investments in Sweden.

In 2010, Member States R&D investment in nuclear fission was EUR 600.7 million and the EU contribution was EUR 57.70 million. The estimated overall corporate R&D investment in nuclear fission technology was EUR 720 million[48], almost 52% of overall investment in nuclear technology. Public and corporate efforts are highly correlated (the correlation coefficient is 0.97).

Both private and public funds largely concentrate in France, which accounts for 62% of corporate and 60% of public R&D investment (Figure 17). Generally, countries which invest in renewable sources tend to invest also in nuclear technology: in 2010 the correlation coefficient between total R&D investment in SET-Plan technologies and nuclear R&D investment by European country was high (0.97). Previous studies have demonstrated that countries that have already invested in nuclear or hydro power have lower energy prices and have little motivation to invest in renewable energy sources (Popp et al 2011). The present assessment cannot identify a substitution effect among the R&D investment by type of SET-Plan technologies. However, a close examination shows that there is no correlated movement in investment between nuclear and wind technologies (correlation coefficient is almost 0): countries which invest in wind energy technology have a low share in nuclear R&D investment and vice versa. The exception is Germany where nuclear and wind technology have the same intensity in R&D investment.

[47] Total budget is EUR 650 million from 2009 to 2017 to which industrial participation rises to 20%.

[48] Plansee [AT], Areva [FR], EDF [FR], Menser Carbonne Loraine [FR], Ald Vacuum [DE], Bakal Semen [DE], Nukem Technologies Gmbh [DE], RWE AG[DE], Ansaldo [ES], Del Nova Vis [ES], Iberdrola [ES], Vestingkhaus Ehlektrik [SE].

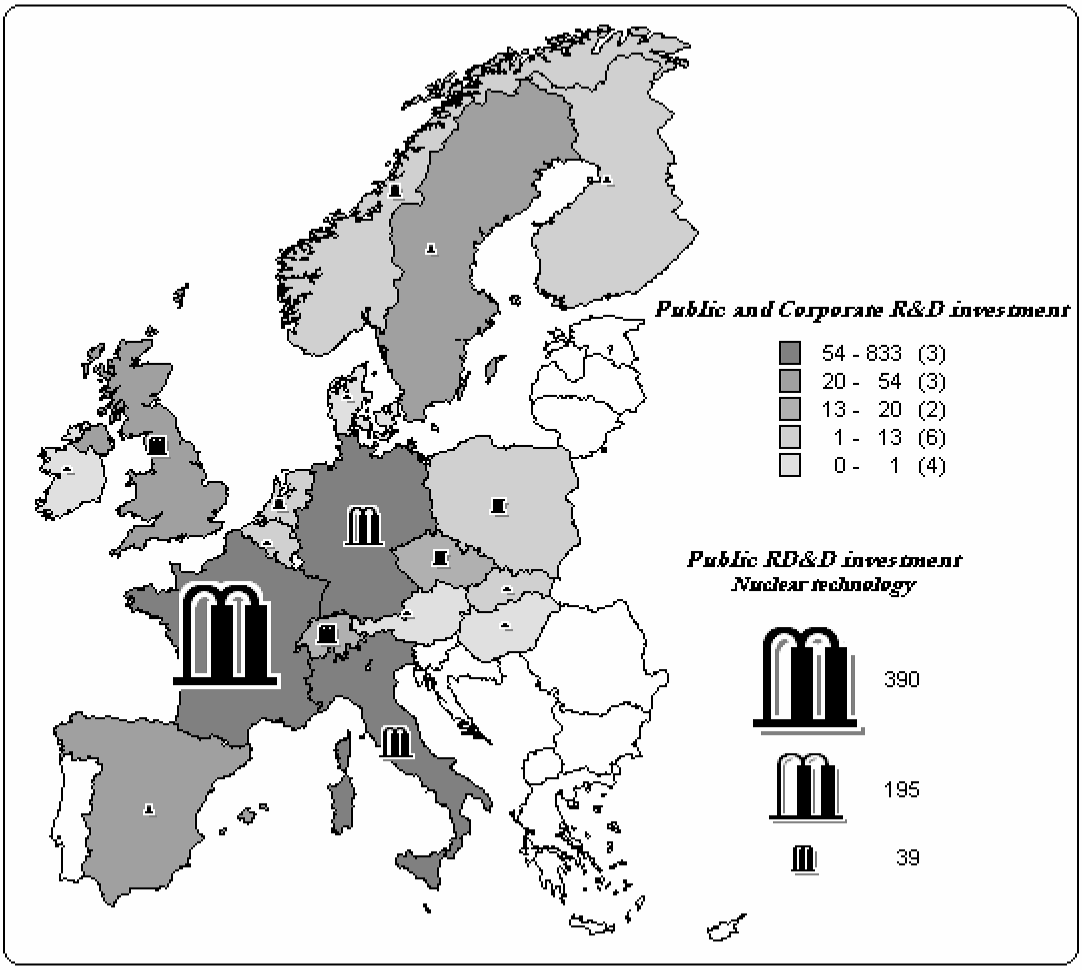

Figure 17. Indicative regional distribution of public and corporate R&D investment in nuclear fission technology (2010). The intensity of colours reflects an aggregate (public and corporate) R&D investment. The symbols reflect only the public RD&D.

3.3.4 Analysis of uncertainties

As in the previous edition of the Capacities Map (JRC, 2009), assumptions were made to compensate for missing information to reduce the overall uncertainty of theresults of this analysis.

It was assumed that no uncertainty is associated with the data from companies active in a single technology, whose R&D investment is known through annual reports or the EU Industrial R&D Investment Scoreboard. It was assumed that all their R&D investment is allocated to the respective technology.

For the rest of the companies for which the R&D investment is obtained using patent analysis uncertainty ranges of ±10% and ±50% were applied. A reduced uncertainty (between ±20 and ±30%) is attributed when cross checking methodologies (patent analysis vs. researchers' wages vs. R&D expenditure-to-sales ratio intensity) arrive to the same results. Higher uncertainty (±50%) is allocated when estimates rely on only one method of estimation of R&D investments (mainly a patent analysis). Based on these assumptions:

- The maximum uncertainty in the wind energy corporate R&D investment is ± EUR 75.64 million, roughly ±11% of the total R&D investment.

- The maximum uncertainty in the solar energy corporate R&D investment is± EUR 58.61 million, roughly ±10% of the total R&D investment.
- For CCS, electricity grids, biofuels and nuclear the higher level of uncertainty (30-50%) was assumed, as the companies are focused on many technologies and hence, cross checking is not possible in view of the limitations in data availability. The maximum uncertainty of corporate R&D investment is ± EUR 750 million for these technologies.

Overall, the maximum uncertainty in the estimates of corporate R&D investment is ± 33.21%.

4. Conclusions

The goal of the present assessment is to present the public and corporate investment in energy technology innovation in Europe, at EU, national and corporate levels in 2010. The methodology employed to estimate public and private RD&D investment in specific technologies, is associated with a great deal of missing data and hence with uncertainties[49].

This assessment finds that the total public RD&D investment in the SET-Plan portfolio of technologies in Europe in 2010 is comparable with those in Japan and the USA. The evolution of public RD&D investment seems to be affected by the economic recession, by the Member States' specific industrial capacities, as well as by the socio-political acceptance for low-carbon technologies. Both public and corporate RD&D investments are commensurate to the size of the market: large countries such as France, United Kingdom, Germany, and Italy have higher research intensity in SET-Plan technologies and account together for more than 62% of both public and corporate RD&D in Europe. Countries' industrial specialization leads also to a higher RD&D intensity in specific low-carbon technologies. Countries such as Germany and France reflect a multi technological investment environment: Germany invests mostly in solar and wind energy, while in France priority is given to bioenergy and nuclear technology. Summarizing, EU countries share one or more priorities in public RD&D spending on energy technologies which indicates that Europe has great potential in this front if more active policy coordination and synergies are exploited.

The present assessment also identifies the extent to which current efforts for technology development are able to satisfy the SET-Plan financing needs, previously identified to be in the range of EUR 5.2 billion to 5.4 billion per year (see Box 4), though it does not attempt to compare the funded priorities against those in the Technology Roadmaps (JRC, 2009a). Regarding the current financing sources for the SET-Plan technologies, public and private, the present analysis estimates that EUR 5.3 billion is the total RD&D investment (EU-FP7, national and corporate R&D). This amount would rise to EUR 5.64 billion when the effective EEPR payments in 2010 for CCS and offshore wind projects are taken into account. However, this assessment considers all investment for nuclear fission technologies (not only Generation IV reactors, which are the focus of the SET-Plan). By technology, the RD&D investment was higher for wind (EUR 0.88 billion) and PV technologies (EUR 0.9 billion) and lower for electricity grids (EUR 0.32 billion) and CCS (EUR 0.4 billion). By adding the EEPR contribution for CCS in 2010 (EEPR payments in 2010 for CCS being EUR 0.19 billion) the present assessment identifies a financing gap with respect to SET-Plan needs for CCS technology. Partly, the under-investment identified for CCS could be the result of a low corporate contribution: the private share in CCS investments was 47% (and barely 30% if EEPR funding is taken into account), which is below the Lisbon strategy that targets that two thirds of R&D expenditure should be financed by the business enterprise sector. Except for CCS, also electricity grids present a corporate R&D underinvestment (45%). Corporate investments in wind technology are in line with the Lisbon target displaying a high corporate share for RD&D investment (76%). The overall corporate RD&D funding in non-nuclear technologies was EUR 2.33 billion in 2010. Despite this high value, at a firm level, EU wind manufacturing companies are associated with an average RD&D-to-sales ratio of

[49] Applying a range of uncertainties from 20-50% for the private sector firms, for which RD&D data were not available, we finally obtain an overall uncertainty of not more than ±33% for the estimates on the corporate RD&D investment.

2.87%, and PV companies of around 2.2%. Based on JRC-SETIS estimates, major Korean PV manufacturing firms spend almost 4% of their turnover on RD&D. Compared to the average investment in engineering sectors of 7%[50] of turnover in R&D, it seems that European companies (with some exceptions) underinvest in research. The consequences could be important in the context of international competition: in 2007 Europe hosted 7 of the top 10 wind energy suppliers, while in 2010 only 5. China is rapidly expanding, with 3 wind technology developers in the first top 10 wind manufacturers and accounting for 46.2% of global installed capacity in 2010. Europe also comes second after Asia in corporate RD&D investment in PV technology.

The EU needs to plan carefully its support to energy RD&D and the appropriate allocation of investment. In this context, a lot could be gained from improving transnational collaboration in RD&D, as advocated by the SET-Plan initiative. Furthermore, in view of the important conclusions stemming from the analysis of RD&D investment, as presented in this work, the methodology of collection and processing relevant data need to be further improved. In this direction, The European Commission intends to work with the Member States and the industry in the immediate future.

[50] For engineering sectors Laleman and Albrecht, 2011 identified an average R&D to sales ratio of 7%.

Acronyms

EUR (€) Euro
CCS Carbon dioxide Capture and Storage
DoE Department of Energy (USA)
EII European Industrial Initiative
EPIA European Photovoltaic Industry Association
EIB European Investment Bank
ERBD European Bank for Reconstruction and Development
EPO European Patent Office
EU European Union
FP Framework Programme
GBAORD Government Budget Appropriations or Outlays on R&D
GDP Gross Domestic Product
IEA International Energy Agency
IEE Intelligent Energy Europe
JRC Joint Research Centre (of the European Commission)
JTI Joint Technology Initiative
MS Member State of the European Union
NACE Statistical Classification of Economic Activities
OECD Organisation for Economic Co-operation and Development
PV Photovoltaic
R&D Research and Development
RD&D Research, Development and Demonstration
SETIS Strategic Energy Technology Plan Information System
SET-Plan (European) Strategic Energy Technology Plan
WIPO World Intellectual Patent Organization
ZEP The European Technology Platform for Zero Emission Fossil Fuel Power Plants

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