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Update on the R&D Investment in Three Selected Priority Technologies within the European Strategic Energy Technology Plan: Wind, PV and CSP

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EXECUTIVE SUMMARY

Collective R&D investments in the three selected low-carbon (LC) energy sectors (wind, PV and CSP) and the share of corporate, national and EU public R&D appropriations in 2008 were assessed by a method comparable with the previous SET Plan capacities map. Collective R&D investments in the three selected priority energy sectors were approximately 40% higher than the 2007 values and amounted to €1.23 billion. The corporate sector contributed more than half of the overall R&D investments in the three priority energy technologies in 2008: 84 % in wind technology, 56 % in PV and 55 % in CSP. The overall corporate R&D expenditures in Europe accounted for close to €850 m, whereas public R&D expenditures by the EU Member States (and also CH and NO) were €303 m and public EU investments were €80.6 m (including FP6/FP7 and CIP-IEE programmes, but excluding SF/CF as well as EIB and ERDF financing). Both public and corporate R&D investments in wind, PV and CSP energy technologies are largely concentrated in a limited number of the EU Member States — wind: DE, DK and ES; PV: DE, FR and IT; CSP: IT, ES and DE. The countries with high levels of public R&D support also accounted for the largest corporate R&D investments in the revised sectors, suggesting that public and industrial research investments complement one another. European corporate R&D remains the world leader in terms of investments in the wind sector in 2008 with 76 % of the world's total corporate R&D investments. The PV sector's corporate R&D investments in 2008 were distributed equally among the Europe, the US and Asia, each holding approximately 1/3 of the R&D investments (with Europe slightly ahead). In the CSP sector, Europe is leading with close to 70 % corporate R&D investments followed by the US, while Asia and the rest of the word have negligible shares in the sector's corporate R&D funding.

1. INTRODUCTION

The European Union (EU) has committed to contribute decisively to the worldwide efforts oriented at mitigating the effects of climate change and limiting the average global temperature increase to no more than 2 ˚C above the pre-industrial levels. Moreover, the heads of governments of the EU Member States (MS) endorsed a firm commitment by individual countries to reduce greenhouse gases (GHG) by at least 20 % by 2020, in comparison with the 1990 level, with the aim to extend the target to 30 % if a comprehensive international agreement broadens global participation and obliges other developed countries to commit themselves to comparable emission reductions (European Commission, 2007a; European Council, 2007). Since energy production/consumption remains one of the largest sources of GHG emissions in Europe, these objectives require firm commitment to significantly decreasing emissions, which will entail considerable effort on the part of the energy sector (EEA, 2008). Hence, the EU adopted a strategic objective to guide Europe's energy policy (European Commission, 2007b) that includes a 20 % target for renewable energy by 2020, a 20 % increase in overall energy efficiency and the deployment of new technologies for carbon reduction. Furthermore, the European Emission Trading Scheme has provided economic incentives for the reduction of GHG emissions (IEA, 2010).

In the light of these policy developments, a broad acknowledgement was reached in the energy sector regarding the need for development and refinement of low-carbon (LC) technologies in order to substantially contribute to the required emission cuts (European Commission, 2007c) while simultaneously supporting the other two dimensions of European energy policy: supply security and competitiveness (European Commission, 2007b). The two key objectives for those technologies were:
- lowering the cost of clean energy, and
- maintaining or placing the EU industry at the forefront of the rapidly growing low-carbon technology sectors (European Commission, 2007b).

The European Strategic Energy Technology Plan (SET-Plan, European Commission, 2007 c & d) recognises the complex nature of these challenges amidst misaligned roles and interests of stakeholders (e.g. national governments of different MS, the business sector and end consumers), and linked them to the research, innovation and deployment necessary to successfully promote renewable energy technologies. The strategic approach advocated comprehensive, articulated governance based on a "variable geometry" principle relying on partnerships and a dedicated governing board with a clear mandate (Hervás-Soriano & Mulatero, 2011).

1.1. Scope of the Report

An important part of successful governance, and therefore a precondition for monitoring the progress towards demanding commitments, is a thorough analysis of overall technological and financial inputs into R&D and a demonstration of these LC energy technologies in Europe (the EU and countries associated with its R&D programmes). While the first has been effectively addressed through the launch of the SET-Plan European Industrial Initiatives, the second has been initiated with the extensive methodological study and coverage of R&D expenditures in Europe in the 2002–2007 period (Wiesenthal et al., 2009). While the report was widely recognised as an important contribution to methodology and awareness of the size and sources of financing at the time, the need for systematic updating of the capacities map and financial contributions to the most important LC energy technologies in Europe and worldwide became apparent in the following years.

Thus, the objective of this report is to list (or where this was not feasible, to estimate as accurately as possible) the R&D investments, both public (national and the EU) and industrial, in three selected renewable low-carbon priority technologies of the SET-Plan: wind energy, solar photovoltaic (PV) and concentrating solar power (CSP) in Europe. They are then compared with those of the most important competing economies: the US, Japan, China and India. The information is given for the most recent years for which data are available. Considering the importance of assessing innovation components in R&D outputs measured through innovation surveys and patent analysis (Griliches, 1990), and vigour of the selected LC SET-Plan energy technologies (Jaumotte & Pain, 2005), the efficiency of innovation process in these technologies is not reported here but will be presented in a separate JRC-IPTS study based on the acquisition of patent data commissioned to a consortium led by NIFU STEP.

This report on update of the R&D investments in the wind, PV and CSP sectors provides one of three key complementary contributions to the analysis of the selected LC technologies. It will be complemented by the analysis of technological performance in the three LC energy technology sectors based on extensive patent analysis, as well as by the report on assessment of the competitiveness of the EU based companies in these technologies based on the analysis of sector-specific factors determining industry competitiveness over the medium-long term, analysis of company dynamics from research, innovation and technological perspectives and benchmarking of EU industry against worldwide competitors in these LC technologies (Hernandez & Tübke, 2011).

As well as allowing deeper analysis, there are a number of reasons for focusing on a limited number of LC energy technologies. The previous SET-Plan Capacities Map report (Wiesenthal et al., 2009) has shown that these three LC SET-Plan priority renewable technologies were the ones with a high R&D potential that enjoy broad public support and have demonstrated vigorous growth in the period 2002–2007. The three selected technologies represent a substantial share of the current LC energy market (mainly PV and wind). Moreover, a calculation based on data in Bloomberg New Energy Finance, UNEP SEFI (2010) has shown that in 2009, wind and solar technologies accounted for about 77 % of the global financial sector's new investments in sustainable energy technologies, clearly indicating the latest global trends in sustainable energy investments. While solar energy has become renewable energy’s fastest-growing sector, with photovoltaic installations climbing 140 % in 2010, the wind industry had a tough time in 2010 with annual installations shrinking for the first time since 2004. However, the outlook for the next few years suggests recovery that will be sustained, but unequal across markets and characterised by growing competition and stringent cost pressures (Bloomberg New Energy Finance, 2010).

It is important to note also that in the three selected LC energy technologies, the roles of both corporate and public R&D investments are significant when compared, for example, to nuclear fusion research with low corporate expenditures. In addition, the scope of R&D and its (public and private) actors in these technologies is quite well-defined compared to many other LC renewable technologies (e.g. biofuels) and the mix of technologies is at the same time very diverse in terms of technological complexity (requirements for grids, etc.). Last but not least, it is important to acknowledge that the selected technologies are in line with the first Energy Industrial Initiatives (EIIs) that were officially launched in June 2010 and include elaborated implementation plans (EPIA, 2010; ESTELA, 2010; SETIS TP Wind, 2010). These can use updated information on R&D expenditure for policy planning and thereby ensure a direct impact of monitoring and public and private financing trends for related R&D activities in Europe and the rest of the world.

2. METHODOLOGY

The current assessment of strengths of the three selected low-carbon SET-Plan renewable technologies focuses on R&D expenditure, a single indicator reporting investments in research and development as well as demonstration activities (RD&D) financed through three different sources:

- **industry R&D expenditure** (based on a specific study, combining bottom-up information from interviews with leading companies in each selected technology field with top-down company data from the EU industrial R&D investment scoreboard for 2008. See section 2.2)
- **Member States' (MS) national public sector R&D investments** (IEA RD&D data updated and partly gap-filled by the MS updates and cross-checked with the EUROSTAT GBAORD databases - see section 2.3); and
- **EU public sector R&D investments** (FP6/FP7 databases of specific projects, combined with the CIP-IEE project databases for 2008 and 2009 - see section 2.4). The Structural Funds (SF)/Cohesion Funds (CF) investments in 2008 and 2009 were not considered due to their prevalent technology deployment nature involving little R&D and demonstration.

The specific investment indicator "R&D expenditure" was selected for its practical value of demonstrating the comparative strength of selected SET-Plan technologies in economic terms, as well as for comparative purposes with the 2009 EU SET-Plan Capacities Map reporting on the comparisons of SET-Plan technologies in the period 2002–2007 (Wiesenthal et al., 2009).

2.1. R&D Investment Data: Observations and Caveats

The previous edition of the SET-Plan Capacities Map provided an extensive discussion of the methodology and the potential shortcomings of the selected indicator "R&D investments" (Wiesenthal et al., 2009). However, a brief definition of research, development and demonstration activities is provided here in order to better understand the term and its coverage in this report. According to the Frascati Manual (OECD, 2002), R&D activities cover basic research, applied research and experimental development. The degree to which the financing of different R&D activities and engineering costs are included in the R&D investments figures in this report differs between industrial and national public and EU funds, between technologies as well as across individual Member States. It also depends on the type of sector/activity, and is influenced by the maturity of a particular technology and the policy support for its deployment. Nevertheless, this type of variability in the expenditure data can be neither eliminated nor controlled, and it is inevitably implicit in any investment data obtained for these renewable technologies.

EUROSTAT and OECD data on GBAORD in the category "Production, distribution and rational utilisation of energy" include R&D investments separately without demonstration activities. However, they employ different groupings of the selected three LC SET-Plan technologies. Hence, solar energy is reported as total solar, thus including solar thermal as well as photovoltaic energy; wind energy is reported together with water and wave energy. Furthermore, disaggregated data on renewable energy sources is not available for some of the major energy-R&D funding Member States such as France and Italy.

Therefore, the IEA RD&D statistics, including demonstration activities — the most complete data on MS public R&D expenditure in the selected technologies for the years 2005–2009 — is used for the comparisons while the GBAORD data were used in this study for the exclusive purpose of cross-checking the overall R&D investment data. While demonstration projects may be conducted on a large scale, they are not expected to operate on a commercial basis (IEA, 2008). Moreover, the changes and updates related to the three technologies received by the MS (AT, BE, CY, DK, ES, FR, IT & UK) and associated countries (NO) for 2008 and 2009 provide reasonable corroboration of the reliability of the IEA R&D investment statistics. Since IEA RD&D statistics include demonstration activities, it is implicit that the R&D investments reported in this report contain also demonstration activities, especially in the sectors comprising mature technologies (wind energy and some mature PV technologies such as crystalline silicon cells). Due to the fact that corporate R&D investments and public EU R&D funding in these technologies also include a certain proportion of demonstration activities, a comparison with the IEA-reported R&D investments appears not to entail appreciable methodological differences.

Whereas direct comparison between public and corporate R&D investments may give rise to some uncertainties resulting from different definitions of R&D between the actors and between the three selected LC technologies, it is likely that publicly funded research in all areas tends to focus more on basic and pre-competitive industrial research, while industry tends to finance applied research and pilot demonstration projects. According to classical innovation theory, close-to-market technologies that require expensive pilot and demonstration projects for up-scaling typically feature larger industrial contributions, while public R&D funding is the primary resource for more risky frontier technologies that are still under development and further from the market (Griliches, 1980). Additionally, there may be systematic differences even within the category "R&D" (IEA, 2008).

Although the share of demonstration activities may vary among different LC technologies, the data on aggregated national public funds of EU Member States dedicated to demonstration were found to account for some 9 % of the total energy R&D budget and approximately 8 % of the SET-Plan technologies in 2007, with wind technology in the lead (Wiesenthal et al., 2009). In practice, however, many MS either do not provide data on funds directed towards demonstration or they do not disaggregate them.

In line with these considerations, the term R&D will be used in the subsequent analysis, despite the fact that demonstration activities are included to a certain extent which varies depending on the different funding sources, countries and companies, especially in the mature wind energy field.

It has been shown that much of the R&D efforts relevant for the renewable energy sector are carried out by the suppliers of energy equipment, especially in supplier-dominated sectors such as those of solar and wind technologies (Jacquier-Roux & Bourgeois, 2002). Hence, the indicator "R&D investments" may not fully capture industrial R&D activities performed on the side of the component suppliers or the research conducted in the departments or groups not formally designated as such (Freeman & Soete, 2009), thus leading to an under-estimation of R&D and innovation efforts related to solar and wind technologies. On the other hand, however, the IEA RD&D as well as the corporate and EU public R&D expenditure figures integrate certain demonstration activities in which acquired or purchased components produced outside the reporting country or region are applied, which contribute to a certain expenditure over-estimation of such demonstration projects, especially in public investments (by the MS and by the EU).

The lack of information on the real proportion of both in the data renders challenging to provide an exact evaluation of the yields and proportions of R&D investments in the energy equipment supplied within the demonstration activities in the selected LC energy technologies.

2.2. Corporate Energy R&D Investments

It has been reported that corporate R&D expenditure data are difficult to obtain, particularly when focusing on R&D investments by technology (De Nigris et al., 2008; Van Beeck et al., 2009). This is particularly true for the large leading multinationals while in case of smaller dedicated companies, e.g., in the wind sector, expenditure data are usually more readily available.

Although there is no regulation obliging private companies to report their R&D investments, the important companies are usually listed on the stock markets and thus need to present their financial accounting and annual reports. However, the asset finance and balance sheets of companies on their R&D investments are usually not itemised by technology or organised according to the field of activity, which constitutes a major challenge when assessing the RD&D efforts of large component supplier companies that are key industrial players with many diversified activities in different RES fields. Furthermore, even when data is available, attention needs to be paid to the fact that companies may over- or under-estimate their R&D expenditure for strategic purposes (Gioria, 2007).

A well-defined approach was needed in order to tackle the combined various difficulties in obtaining a solid corporate R&D investment data and estimating the percentages of corporate R&D relevant to the particular SET-Plan energy priority technology considered in this report. The approach was in line with the previous SET-Plan capacities map (Wiesenthal et al., 2009; 2012) and is shown in **Figure 1.**

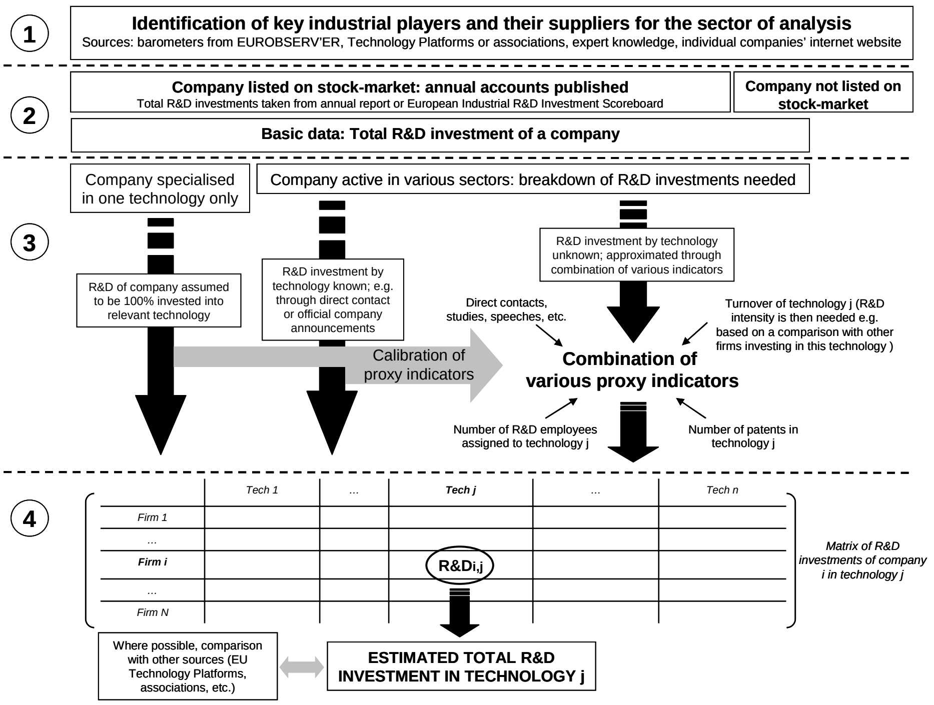


Figure 1: Overview of the methodology applied for the selection of the companies' R&D investments in the three LC renewable technologies in 2008 (Wiesenthal et al., 2012).

The selection of specific companies and reporting of their corporate R&D investments in selected LC technologies was commissioned to a subcontractor, Ecofys Netherlands BV. A focused separate study gathered corporate R&D expenditure through specially designed company interviews that meticulously covered the most important companies in each of the three technology sectors both inside and outside the EU. The data on corporate R&D investments in three technologies reported here are based on the data obtained through that study; however, supplementary R&D investment information on additional companies was added to achieve an even more representative coverage. Nevertheless, the original Ecofys data served in the preparation of a complementary JRC-IPTS report focusing on techno-economic analysis of corporate R&D investments in three LC energy technologies and the screening of the key market factors and competitiveness conditions in each of these technologies (Hernandez & Tübke, 2011). Therefore, the analysis in this report goes as far as to compare collective corporate R&D investments with the public ones in each sector. An international comparison of corporate sectors' R&D expenditures between the main world economies such as the US, Japan, China and India and Europe is given in the section 4.3 of this report.

2.3. Public Energy R&D Investments by Member States

The availability of highly detailed public IEA energy RD&D statistics on R&D investment, which mostly adhere to the requirements for the specific provision of R&D investment data by single technologies, rendered the IEA database a crucial tool for this study. We must note, however, that the breakdown of public IEA RD&D statistics for CSP technology entails a systematic over-estimation of its investment shares by the MS due to there being a joint category III.1.3,"Solar thermal-power and high-temperature applications". The IEA RD&D statistics used to ascertain public R&D investments by EU MS and the OECD countries (here, the US and JP) in three technologies follow scientific/technical nomenclature which groups CSP together with other solar-thermal applications thus leading to overestimated CSP R&D investment shares. Conversely, simple solar-thermal power systems, especially water heating systems, represent a well-established mature technology for which little R&D currently undertaken, thus limiting their share in the joint IEA category III.1.3.

Despite being the most reliable data source for reporting public R&D investments in the three selected low-carbon technologies, the IEA RD&D statistics also have certain limitations. As only 19 of the 27 EU Member States are IEA members, there is a systematic absence of data from BG, CY, EE, LT, LV, MT, RO and SI. Furthermore, quite a few IEA members do not provide the data regularly.

Therefore, the national public R&D investment data for the EU MS are generally taken from the IEA RD&D statistics and later updated with the data provided directly by some countries (AT, BE, CY, DK, ES, FR, IT, NO and UK) and partly gap-filled with the average country R&D investments in each sector for the period 2005–2007 for a few countries with appreciable expenditures in the sector during the previous years but with no data for the 2008 and/or 2009 (e.g. FI, IE, NL and IT for public R&D expenditures for the wind sector).

While the R&D contributions of MS not included in the IEA database might be appreciable for some individual technologies, a comparison of R&D investments covered by the IEA database with the GBAORD data accounts for almost 99% of the overall EU-27 energy budget, thus limiting the errors incurred by the lack of data from the missing European countries.

The report focuses on the year 2008. This is due to the absence of data on 2009 R&D expenditures for some of the important RES energy R&D funding Member States, notably Italy and the Netherlands, as well as the possibility of directly comparing funding using corporate data that was available for 2008 only, and comparing overall European investments with those in major world markets. However, for the individual comparisons of public R&D investments by MS, both years are represented in the report.

2.4. Public Energy R&D Investments at the EU Level

European funds complement the Member States' public R&D support. The 7th Research Framework Programme (FP7) is the key source of R&D financing of renewable energy technologies at the EU level. Other EU funding schemes — the Competitiveness and Innovation Programme with its pillar 'Intelligent Energy Europe' (IEE), the Structural and Cohesion funds (SF and CF) with their initiatives to support the European Economic Recovery Package and an amendment to the European Regional Development Fund allowing energy efficiency and renewable energy sources (RES) interventions in MS' residential buildings, as well as certain parts of the Trans-European Networks' funding — also play an important role in the overall funding support to the SET-Plan renewable technologies. However, not all of these programmes could be quantitatively assessed at the level of detail needed for this paper. Indeed, some of these programmes were considered less relevant to research as they focus mainly on deployment. The allocation of the EU expenditures to the three SET-Plan priority technologies was performed on a project-by-project basis instead of by following the usual approach with a more aggregated level for budget lines.

- The EU Framework Programmes for research and technological development (FP6/FP7): For the purpose of this paper, detailed databases and information on R&D expenditures on the project level of the 6th and 7th Research Framework Programme for the years 2008 and 2009 have been analysed. This provided an in-depth assessment and a reasonably accurate assessment of distribution/allocation of R&D spending among the three selected LC renewable technologies.

The assessment systematically includes separate yearly yields for all FP projects funded in 2008 and 2009 within the FP6/FP7 core budget line used for energy-R&D projects (both FP6: *Sustainable Energy Systems*; and FP7: specific work programme "*Cooperation" — Theme 5: Energy* were included in both projects supported by DG RTD as well as by DG ENER) and the data were cross-checked with official published information (European Commission, 2010).

To the extent that it was possible, this has been complemented by certain percentages of funding for energy-relevant projects that were financed through other budget lines such as "horizontal research activities involving SMEs", and "Nanotechnologies and nano-sciences". Due to various high-tech nano- and micro-electronic technologies being involved in the latest generation technologies of the complex frontier PV and CSP systems, it was difficult to estimate exactly how much of the FP projects' funds stemmed from 'non-core-energy funds' in 2008 or/and 2009. Similarly, some of the ERA-Net and ERA-Net Plus Coordination Research Activities partly contributed to the solar and wind energy research. Nevertheless, other budget lines resulted in only minor additions to the base project funding from the main energy-related FP6/FP7 programmes.

- **Competitiveness and Innovation Programme – Intelligent Energy Europe (CIP-IEE):** Only the IEE sub-programme ALTENER was of interest for this study as it aims at catalysing new market opportunities for innovation in the field of renewable energy through supporting RES initiatives in capacity building and market development in the low-carbon renewable technology fields. Part of the funding also raises awareness about the transformation of new markets. The support is given through two main instruments: grants (grant agreements and direct grants) and procurement. Of the €19 m in funding available for the programme in 2008, the share to support small-scale renewables and RES-electricity projects that includes our technologies of interest would jointly reach 56 % or €10 m of the available funding.

As with the FP data, the detailed databases and information on R&D expenditures on project level for years 2008 and 2009 of the IEE-II programme (2007-2013) have been analysed. This allowed for an in-depth assessment and a reasonable direct allocation of R&D spending to the selected three LC renewable technologies.

- Structural Funds (SF) / Cohesion Funds (CF) / European Investment Bank (EIB) and **European Bank for Regional Development (EBRD) data:** In terms of financing, the European Energy Programme for Recovery (EERP) cleared about €3.83 billion in investments by 31 December 2010 for major new energy infrastructures, and each of the existing EU financing instruments has been adapted to respond to the new challenges of climate change and securing EU energy supplies (European Commission, 2011).

Although the Community's structural and regional funds now include specific commitments to support sustainable energy initiatives, and the European Investment Bank has introduced major new instruments (such as "ELENA") to meet the growing need for sustainable energy investments, it is still rather unclear to what extent these financial mechanisms actually influence R&D activities associated with practical implementation in the three selected LC SET-Plan technologies.

As the initial screening of projects and R&D components of their funding showed that they mainly entail deployment and the RD&D components were impossible to identify, these data were not included in the comparisons of the R&D expenditures in the wind, PV and CSP sectors in this report. However, since the European Recovery Plan had an important takeoff in its implementation stage in 2010-2011 also following the ELENA model, it might be interesting for future capacity maps covering the R&D expenditure to duly check and analyse the SF/CF and EERP data bases and integrate the percentages of technology-related public EU funding that can be attributed to R&D expenditures with a degree of certainty.

Following the initial funding, of the three low-carbon technologies selected for the capacity map R&D expenditure analysis, wind energy with its offshore applications benefited from approximately 15 % of the total EERP funding (European Commission, 2011), although it remains unclear how much of the investments could be attributed to RD&D.

3. RESULTS

3.1. R&D Investments by the SET-Plan Priority Technologies in Europe

3.1.1. Wind energy

In a context in which global demand for wind energy is greater than production capacities, the trend of globalisation has further challenged Europe's share of cumulative installed capacity by continuously contracting from 50.9 % in 2006 to 48.0 % in 2009 (43.5 % in 2007; 41.2 % in 2008) and down to 44.3 % of the world's wind energy market in 2010 (EurObserv'ER Wind Energy Barometers 2008, 2009, 2010; GWEC, 2010, 2011). In 2009, Europe has managed to retain a leadership position with 48.0 % of 158.5 GW of the world's installed cumulative wind energy capacity despite the economic crisis. At the same time, it maintained a prominent position with some of the most important wind turbine and component manufacturers. Nevertheless, the margin of European installed wind power as well as the importance of its manufacturing capacities have been quickly disappearing, as other large-scale installations and rapidly growing manufacturing industries take off, especially in China and India (GWEC, 2009, 2010).

Concurrently, wind R&D investment figures in important markets such as those in the US and Asia drew increasingly closer to R&D contributions attributed to the wind sector in Europe (Bloomberg New Energy Finance, 2010) — for a comparison, see also sections 4.2.1 (Figure 6) and 4.3.1 (Table 1).

Nevertheless, compared to total R&D investments in 2007 of €383 m, the sector has expanded its research expenditure in Europe to a total of €575 m, which accounted for an overall increase of €192 m compared to the 2007 figure. However, the increase of R&D expenditure is to be attributed entirely to the business sector, which increased its investments from €292 m to €482 m, while collective public sector support in the same time period decreased from 24 % in 2007 (€91.9 m) to 16 % of total R&D investments in the sector in 2008 (€92.5 m), retaining the 3 % margin for EU funding – see **Figure 2.**

As wind energy is considered a mature technology, corporate R&D expenditures have continued to dominate, accounting for €482.1 m in 2008, which represents 84 % of the total R&D investments. It is important to note that due to the proportion of demonstration activities, the R&D figures may contain a certain margin of error (see section 1.2). Nevertheless, the data for the wind sector confirmed the previously established characteristic of a typically high proportion of demonstration activities compared to the other two selected low-carbon technologies (Wiesenthal et al., 2009). The growth of corporate R&D investment in the sector in 2008, 66 % compared to the previous year, should, to some extent, also be attributed to the larger sample of the companies interviewed, 3 more than the 13 covered in the previous capacities map study casing the year 2007 (Wiesenthal et al., 2009). Methodology for the assessment of corporate R&D expenditure is described in **Figure 1** (see 2.2). A combined top-down and bottom-up approach and assessment of companies took into consideration the global trends in sustainable energy investments (Bloomberg New Energy Finance, UNEP SEFI, 2009) and JRC-IPTS SET-Plan 2009 study (Wiesenthal et al., 2009). We selected corporate R&D expenditures by the 16 most important EU-based wind sector companies with an R&D turnover intensity of 2.6 %-3.0 %. The companies are listed here by order of R&D investment relevance as suggested by Ecofys Netherlands BV (2010): **Vesta Wind Systems** (DK), **Gamesa** (ES), **Enercon** (DE), **Alstom Power (Ecotecnia Energias Renovables)** (ES), **Dong Energy** (DK), **Siemens Wind Power** (DK), **Nordex** (DE), **LM Glasfiber Holding A/S** (DK), **BARD Engineering GmbH** (DE), **Acciona Energy** (ES), **Clipper Windpower** (UK), **AREVA** (FR), **Multibrid** (DE), **Vattenfall** (SE), **Iberdrola Renovables** (ES), **EDF Energies Nouvelles** (FR), and **Vergnet** (FR).

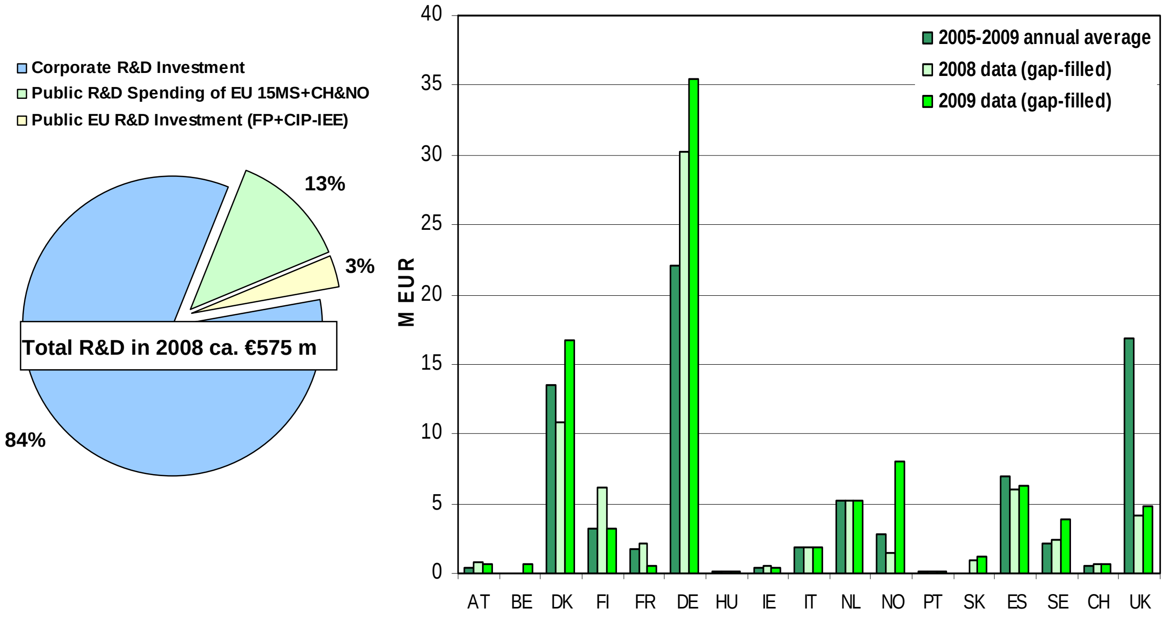


Figure 2: Comparison of R&D investments in wind energy from industry and public sectors in 2008. Annual averages for public R&D expenditures for the period 2005–2009 and for the single years 2008 and 2009 are given on the right.

Source: JRC-IPTS analysis of national public R&D spending covering 15 MS + CH & NO is based on IEA RD&D statistics and official updates for AT, BE, DK, ES, FR, UK & NO; EU funding: FP6/FP7 and CIP-IEE; corporate R&D expenditure is based on an analysis of the leading EU companies performed by a subcontractor, Ecofys Netherlands BV (2010).

Note: Public R&D expenditures for FI & IE (2009) and for IT & NL (2008 and 2009) were gap-filled with the average country R&D investments in the sector for the period 2005–2007 (see bar graph).

Public EU R&D funding based on calculated yearly yields for each of the wind-related funded projects in 2008 amounted to €19.2 m, with FP6/FP7 support in the amount of €18.6 m and CIP-IEE-II programme support at € 600 000. The public EU R&D contribution calculated for 2008 is in the range with the information on support for wind R&D at the EU level during the FP6 (EWEA Earthscan, 2009), which reports total funding at €31.59 m during FP6 as well as with the EU support for technology in the first dedicated calls in FP7 (European Commission, 2009).

Despite relatively limited FP6/FP7 public financing in 2008, the following years saw a surge in EU public support for wind sector technologies with a noticeable shift in Europe's interest towards commissioning and planning construction of new offshore wind farms. Important milestone demonstration activities such as wind intermittent generation of offshore wind developments, integration of wind energy and its flexibility for the transmission grid with particular emphasis on replicability of results within an entire pan-European system was introduced through the project Twenties, involving ten MS and one AC, which started in 2010 with a total budget of €56.8 m and the EU FP7 contribution of €31.8 m for three years, which was also to contribute to mitigating a challenging business contraction in the field in 2010.

The European Energy Programme for Recovery (EERP) with total support in the amount of €565 m for deployment of a few large-scale offshore wind farms also contributed to a noticeable increase in public financial support to the European wind energy sector in late 2009 and 2010 (European Commission, 2011).

3.1.2. Photovoltaics

The sector enjoyed a steady rise and annual global installation of PV power plants doubled in a single year, from less than 7.2 GW in 2009 to over 16.6 GW in 2010 (EPIA, 2011). This has brought the world's total installed capacity to approximately 40 GW; Germany is the world leader with 7.4 GW of installed grid-connected applications. While the photovoltaic industry generated 38.5 billion USD (approximately €27.7 billion) in 2009 alone, the globalisation trends nevertheless posed a challenge to Europe's PV potential as well as its production and installation capacities (EurObserv'ER Photovoltaic Barometer, 2011).

While Europe's 2007 R&D investments came to approximately € 384 m, the sector has expanded its R&D expenditure to a total of €513 m, which accounted for an overall increase of € 83 m compared to the 2007 figure. Public sector contributions in MS contracted 1 % in overall R&D investments to 34 % in 2008, although they expanded for €40 m from €134 m in 2007 to €174 m, while corporate R&D investments are up €62 m from close to €223 m to more than €285 m; EU public support in particular grew substantially to reach a total of €53.2 m in 2008 (10% and up 3% from the previous year) – see **Figure 3.**

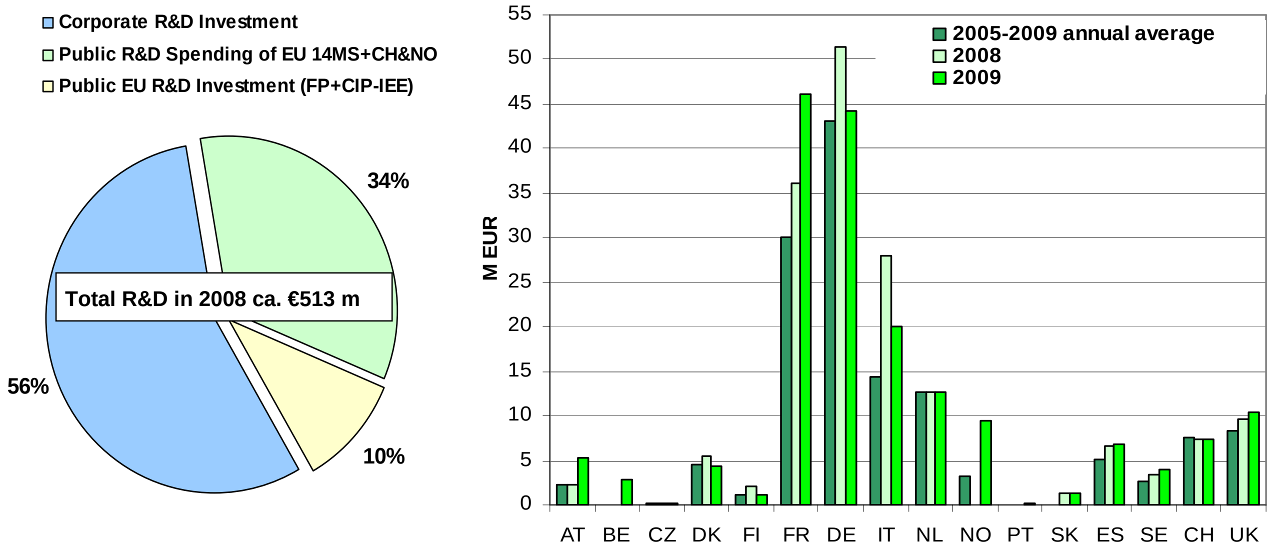


Figure 3: Comparison of R&D investments in PV energy from industry and public sectors in 2008. Annual averages for public R&D expenditures for the period 2005–2009 and for the single years 2008 and 2009 are given on the right.

Source: JRC-IPTS analysis of national public R&D spending covering 14 MS + CH & NO is based on IEA RD&D statistics and official updates for AT, BE, DK, ES, FR, IT, UK & NO; EU support: FP6/FP7 & CIP-IEE-ALTENER; corporate R&D expenditures are mainly based on analysis of the leading EU companies performed by a subcontractor, Ecofys Netherlands BV (2010); however, PV-related percentages of R&D budgets for a few additional important companies, calculated by JRC-IPTS following the methodology shown in Fig.1, have been added.

Note: Public R&D expenditure data for FI (2009) and NL (2008/2009) were gap-filled with the country average R&D investments in the sector for the period 2005–2007. PV R&D investments by CZ (€0.2 m) & PT (<€0.1 m) appear small due to the scale of the chart (see bar graph).

Though in 2009, Europe has managed to retain the world's leading position with 29.3 GW, i.e., almost 75 % of approximately 40 GW of cumulative in-grid PV energy capacity installed around the globe, fierce competition led to only one European company remaining among the top ten photovoltaic cell manufacturers in 2010 (EurObserver Photovoltaic Barometer, 2011). As in the wind sector, PV R&D investment figures in important markets such as the US and Asia are increasingly able to rival the R&D contribution attributed to the sector in Europe (see section 4.2.2).

Jäger-Waldau (2008) provides a useful comparison of PV budget shares and their position alongside EU MS 2010 targets as well as the review of important companies located inside and outside the EU and their activities. In 2008 only four (Q Cells, Isofoton, SolarWorld and BP Solar) of the top 15 manufacturers of PV modules were located in the EU and correspondingly produced 25.6 % of globally-produced PV cells that year (EPIA, 2010). Due to fierce competition, the European share further diminished to 19.4 % in 2009 (EurObserver Photovoltaic Barometer, 2010).

Corporate R&D expenditures by 17 Europe-based PV-focused companies in 2008 were calculated at €233.6 m (Breyer et al., 2010) which is well within the range of corporate R&D budget calculations in this report. The source suggests that these R&D expenditures based on publicly listed PV-focused companies in 2008 could be topped up by certain estimates of additional R&D expenditures of more generally-oriented companies concerning their PV related activities, e.g. for PV-related sales and patents. We therefore provided estimates for 22 additional Europe-based companies active in the PV sector but without disclosed specific PV R&D financial data for the year 2009 (as calculated from the list of R&D expenditures of 62 globally active companies). Although it is uncertain what percentage of their R&D budget could be correctly ascribed to PV activities alone, the calculated R&D appropriations for 2009 amounted to €186.6 m. Despite reported total growth in the sector being close to 22 %, from 2008 to 2009, the reduced topping up of the proposed 2008 total corporate R&D budget with a proportionally reduced amount for 2008 still appears rather excessive from the perspective of corporate R&D expenditures calculated in this report. Estimating shares of PV-related budgets for major generally-oriented high-tech companies and PV raw material producers is rather uncertain and may lead to considerable deviations from the actual PV R&D investment figures. Therefore, we believe that a more conservative methodology considering selection of proportions of companies' PV-related activities based on well-elaborated company selection, careful gathering of R&D budget information from the most important specialised PV companies and the evaluation procedure shown in **Figure 1** (see section 2.2) correspond better to the assessment of actual PV-related corporate R&D appropriations in Europe.

Calculated corporate PV R&D expenditures by 34 Europe-based companies specialised in the sector in 2008 reported here amount to €285.1 m, which would fall short of the approximate combined total R&D budget for 2008 reported by Breyer et al. (2010) if it were also to include estimates of R&D appropriations of the companies without disclosed PV R&D financials. Nevertheless, the estimated 2009 appropriation figure re-applied for the year 2008 shall be reduced by the reported 2008-2009 growth rate of about 22 %. Moreover, close scrutiny of the company sample, budget figures and estimates reported by Breyer et al. reveals that such a composed sample would cover five additional companies that were not included in our calculations. Therefore, the total theoretical R&D budget for 39 Europe-based companies, about €379 m (Breyer et al., 2010) including the adjusted amount of 2008 R&D budget estimates with a total R&D expenditure increased by about 30 % would still fall within the same range of magnitude of the total corporate PV R&D expenditure reported here (Ecofys and JRC-IPTS combined data).

Selecting companies and gathering their R&D investment data in the PV sector for 2008 was commissioned to a subcontractor, Ecofys Netherlands BV, in order to perform techno-economic assessment of corporate investments in the sector. A combined top-down and bottom-up approach and assessment of companies, also considering information reported by Bloomberg New Energy Finance (UNEP SEFI, 2009) and JRC-IPTS SET-Plan 2009 study (Wiesenthal et al., 2009) resulted in the sample of companies surveyed for corporate R&D investment in the sector, containing two more than the previous capacities map study covering the year 2007

(Wiesenthal et al., 2009). The methodology resulted in selection of corporate R&D expenditures by the 34 most important EU-based companies active in the PV sector with an R&D turnover intensity of 2.2 %–2.5 %. The specific amounts of R&D expenditures directly associated with PV technologies were based primarily on specific PV-related company R&D investment data from the Ecofys report and supplemented with R&D investment data from a few additional important companies in the sector calculated by JRC-IPTS, identified and calculated as shown on **Figure 1**. The selected 34 Europe-based companies are listed by decreasing order of estimated R&D investment relevance in the PV sector in 2008 (based on combined calculations by Ecofys Netherlands BV and JRC-IPTS, 2010):

SMA Solar Technology (DE), **OC Oerlikon Solar** (CH), **Q Cells** (DE), **Isofoton** (ES), **REC Group** (NO), **Saint-Gobain Solar** (FR), **Centrotherm Photovoltaics Group** (DE), **SolarWorld** (DE), **Schott Solar** (DE), **BP Solar** (UK), **Helianthos** (NL), **Meyer Burger** (CH), **PV Crystalox Solar** (UK), **Photowatt Technologies** (FR), **Wacker Chemie AG – BU Polysilicon** (DE), **Solar Watt** (DE), **Roth & Rau PV** (DE), **Photovoltech** (BE), **Solland** (NL), **Electricité de France-EN** (FR), **T-Solar** (ES), **Abengoa Solar (Solucar – New Technologies)** (ES), **Solon** (DE), **Acciona Energy** (ES), **Centrosolar Group AG** (DE), Conergy (DE), **Bosch Solar Energy AG (former ErSol Solar Energy)** (DE), **Siemens Renewables** (DE), **Linde Group** (DE), **Iberdrola Renovables** (ES), **Tenesol** (FR), **Würth Solar** (DE), **Aleo Solar** (DE), and **Solar-Fabrik** (DE).

The European Commission projected an overall Energy FP7 R&D budget of €217.3 m for 2008, of which the cost of projects selected under FP7 2008 theme "Energy" calls for PV would come to €30 m, with an EC contribution of €19.6 m (European Commission, 2009). Actual EU public R&D funding based on calculated yearly yields from each of the PV-related funded projects in 2008 accounted together for €53.2 m. In this area, FP6/FP7 have contributed €52.6 m, including about €2.6 m from eco-buildings and other budget lines such as 'horizontal research activities involving SMEs', and 'Nano-Mat'; the CIP-IEE ALTENER programme contributed approximately €0.55 m. The 2008 R&D budget contribution by EU public funding thus includes the 2008 yearly yield of FP7 projects, the yields of the last related FP6 projects still running in 2008 and the 2008 portions of the CIP-IEE ALTENER projects as well.

3.1.3. Concentrated Solar Power

As in the 2007 R&D analysis, CSP-related research spending was relatively limited compared to solar PV and wind technologies. Considering that potential locations for meaningful application are concentrated in the Mediterranean countries, national public R&D investments are dominated by Italy and Spain, while the public contributions of Germany and Switzerland may be explained by their strong positions in this field of technology. Relatively small national public investments in other listed countries (see **Figure 4**, bar graph) can likely be accounted for by some R&D investment in classic solar thermal power rather than in high-temperature applications.

While the sector enjoyed a steady but slow rise in importance and therefore in annual global installation capacities, the high-temperature systems still require a breakthrough in order to become widely used. Nevertheless, the yearly 2007-2008 increase in overall R&D investments in the sector was €57 m (approximately 39 %) with corporate sector investment growing from €48.2 m (56 %) in 2007 to €79.1 m (55 % of the total CSP R&D expenditures) in 2008. R&D investments in CSP by public sector in the MS have also increased from approximately € 33 m in 2007 to € 48.2 m (or 36 %) in 2008, although this support was not sustained in the crisis year 2009 when public support fell to one-third of 2008 levels, mainly due to a substantial reduction in public R&D expenditure for this technology in IT (see Fig.4, bar graph). Public EU funding has been kept at a constant proportion of 6 % with €5.2 m in 2007 and €8.2 m in 2008. It is important to note that the CIP-IEE programme did not support any CSP projects in the period 2008–2009. The overall R&D funding distribution for CSP is shown in **Figure 4.**

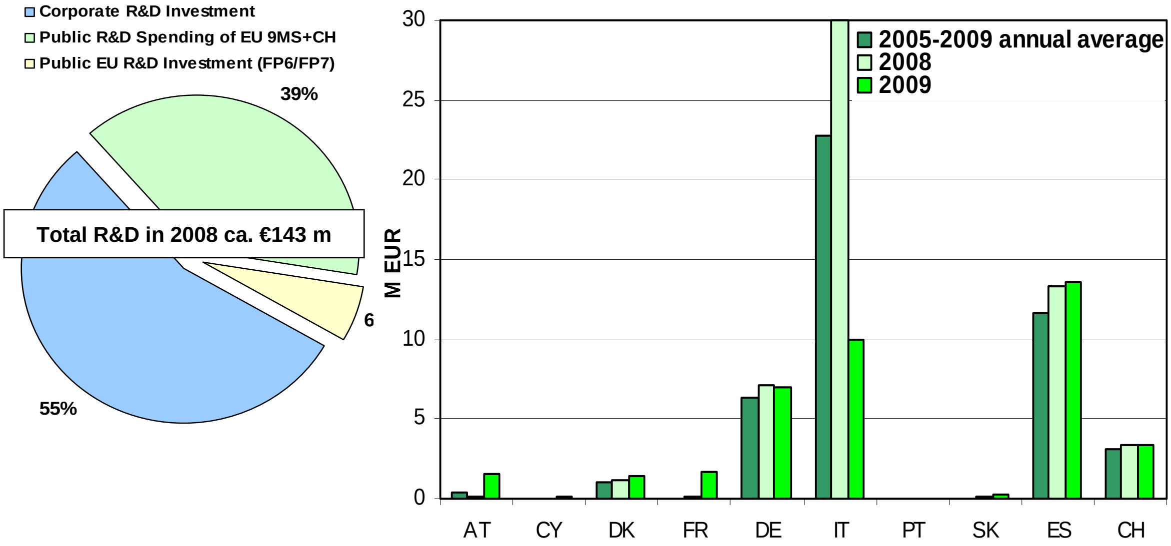


Figure 4: Comparison of R&D investments in CSP energy from industry and public sectors in 2008. Annual averages for public R&D expenditures for the period 2005–2009 and for the single years 2008 and 2009 are given on the right.

Source: JRC-IPTS analysis of national public R&D spending comprised 9 MS + CH and official updates for AT, CY, DK, ES, FR & IT; EU support: FP6/FP7 only as no CIP-IEE-ALTENER financing was attributed to this technology in 2008; corporate R&D expenditure is based on an analysis of the leading EU companies active in the CSP sector performed by a subcontractor, Ecofys Netherlands BV (2010).

Note: Public R&D expenditures below €0.1 m such as the one for PT (€ 0.02 m EUR) cannot be displayed at the current scale of the chart (see bar graph).

Companies based in Germany and Spain led in corporate R&D investments, accounting for 58 % of overall CSP R&D spending in 2008. They were followed by Italian and Swiss companies, which were also the ones involved in the ongoing demonstration projects launched in Spain, Switzerland and Italy and supported through the national feed-in-tariff legislation.

Corporate R&D expenditure reported for the CSP sector follows the methodology described in **Figure 1** (see section 2.2) and is based on a combined top-down and bottom-up approach and assessment of the companies taking into consideration the global trends in sustainable energy investments (Bloomberg New Energy Finance, UNEP SEFI, 2009) and JRC-IPTS SET-Plan 2009 study (Wiesenthal et al., 2009). The 18 most important Europe-based companies active in the CSP sector were selected and are listed below in order of relevance (Ecofys Netherlands BV, 2010):

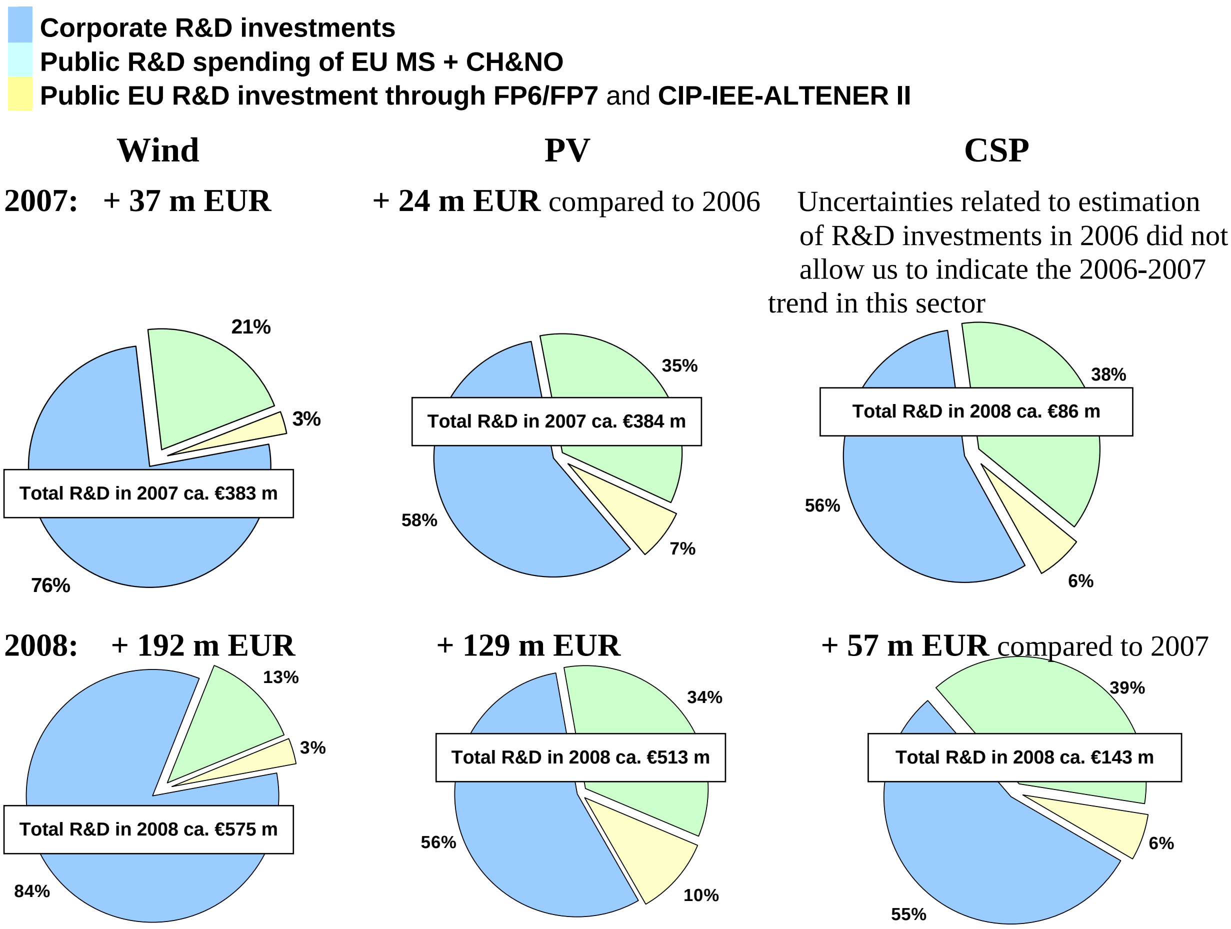
Abengoa Solar (ES), **Saint-Gobain Solar** (FR), **MAN Ferrostal AG** (DE), **Siemens CSP** (DE), **Torresol Energy** (ES), **Solar Millennium AG incl. Flagsol** (DE), **Schott Solar** (DE), **Acciona Energy** (ES), **AREVA** (FR), **Friatec AG** (DE), **Solar Power Group** (DE), **Kraftanlagen München** (DE), **Alanod** (DE), **Flabeg** (DE), **Novatec Biosol** (DE), **Nolaris** (CH), **Solar Euromed** (FR), and **Solitem Group** (DE).

4. OVERVIEW OF INVESTMENT TRENDS

4.1. Trends in R&D Investments in Low-Carbon Renewable Energy Technologies in Europe

A similar approach to data collection and analysis of uncertainties with the previous SET-Plan Capacities Map study (Wiesenthal et al., 2009) enables direct comparisons of R&D investments by the corporate and public sectors in the selected LC energy technologies between the years 2007 and 2008 (see **Figure 5** and sections 3.1.1-3.1.3). The overall R&D funding for the three LC energy sectors in Europe represented roughly 40 % of non-nuclear SET-Plan priority technologies in 2007. While total European R&D investments in the selected three LC energy technologies in 2007 amounted to €853 m, the 2008 R&D investments in these sectors in Europe were approximately 40 % higher and amounted to €1.23 bn.

Figure 5: Comparison of overall R&D investments in Wind, PV and CSP energy technologies in Europe between 2007 and 2008 with yearly increases by sector.



As the MS official energy statistic indicators always report for the period dating to approximately two years before the present, we have available most public R&D expenditure data for the EU MS as well as the EU public R&D investment data for the FP7 and CIP-IEE programmes for the year 2009. Unfortunately, corporate R&D expenditure data for 2009 collected in a similar way to that applied for the years 2007 and 2008 were not available, which prevented us from undertaking a detailed comparison of that year's overall R&D expenditure. Since the report covers the time span prior to the onset of the major economic crisis in late 2008–early 2009, it would be even more challenging to furnish a comparison with the complete set of 2009 data as well. In the absence of detailed information on corporate R&D expenditures for the year 2009, only comparisons of overall R&D investments in the three LC SET-Plan technologies for the years 2007-2008 could be elaborated.

4.1.1. Corporate Energy R&D Investments

As regards investment trends in corporate R&D financing, this report focuses on the assessment of R&D investment shares in the overall funding as well as the trends in R&D expenditure by technology type in the period 2007–2008. The market factors and the details from interviews with European and non-European companies conducted by the sub-contractor (Ecofys Netherlands BV, 2010) are reported in a separate study (Hernandez & Tübke, 2011). Comparisons of the world regions by the size of corporate R&D investments and by sectors for the year 2008 are provided in section 4.3 of this report.

A comparison of R&D investments in the three LC renewable energy technologies in Europe between 2007 and 2008 (see **Figure 5**) shows an increase in the already high percentages of corporate R&D funding for the wind sector — from 76 % (2007) to 84 % (2008). Despite the increase in corporate R&D expenditures in the solar sector from 2007 to 2008 (from €222.7 m to €285.1 m for PV and from €48 m to €79 m for CSP), the share of corporate R&D in the sector decreased somewhat (PV down from 58 % to 56 % and CSP down from 56 % to 55 %), which was largely due to higher public MS and the EU R&D financing support. Although the observed changes in percentage between 2007 and 2008 are hardly statistically significant, they probably result from an array of different factors, such as specific calls for EU public funding being opened in a certain year or introduction of a feed-in tariff for solar technologies in some MS. To a degree, the high percentage of corporate R&D funding for CSP could also be caused by IEA financing category III.1.3."Solar thermal power and high-temperature applications" in the IEA public RD&D statistics used to ascertain MS public R&D investments for CSP, and by the maturity of solar thermal power, which tends to represent an important share of the entire category in some MS (e.g. AT, DK and SK). Part of the reason may also be the specific CSP technology requirements which are slowly entering mainstream SET-Plan RES technologies, as well as its geographically-dependent large-scale testing and regular deployment. The relevance of changes in the proportions of corporate and public R&D funding in investment totals for these sectors can only be appreciated if we consider developments in these sectors in the following years.

4.1.2. Public Energy R&D Investments by Member States

When comparing R&D expenditures for the years between 2006 and 2008, we observe a steady decline in national public energy R&D funding by the EU MS for the wind sector, while in PV and CSP, percentages of public R&D support by MS and the EU remained stagnant while total levels increased.

As the proportion of MS investment in overall R&D financing in the period 2006–2008 typically represents the middle share — lower than corporate R&D investments but higher than public EU investments — the percentages for the three selected LC SET-Plan priority technologies have varied slightly. While the highest national public R&D investment share in 2007 corresponded to CSP technology at 38 %, followed by PV (35 %) and wind technology (21 %), MS public R&D investment shares in 2008 remained stable in the solar technologies, with a slight decrease in PV (34 %) and a slight increase in CSP (39 %); however a 7 % decrease was observed in national public R&D funding in the wind sector (13 % share in 2008). For 2009, despite some individual MS having invested more than in the previous year, the overall public R&D investments appear to have stagnated further, in spite of the economic crisis which progressively wore away at active companies' ability to compensate for diminished public investments in these fields of technology. Moreover, competitive pressure from Asia in each of the technology sectors in question has been growing stronger (see section 4.2).

4.1.3. Public Energy R&D Investments at the EU Level

Despite representing the smallest part of R&D investments in all three low-carbon SET-Plan technology categories, EU public R&D funding in the period was characterised by quite stable proportions. These represented approximately 3 % of the overall R&D investments in wind energy, 7-11 % of the overall investments in the PV and 6 % of these in the CSP. Considering the extent to which the assessment and analysis could identify the topics and the corresponding EU contributions from other budget lines such as 'horizontal research activities involving SMEs', 'Nanotechnologies and nanosciences' and ERA-Net activities, the addition of up to € 1 million to R&D could be appropriate through FP6/FP7 programmes other than core energy programmes; we suggest dividing this sum fifty-fifty between PV and CSP. However, such an allocation approach is associated with certain uncertainties as some projects simultaneously address various RES technologies, a share of which is not clear and therefore does not enable counting fractional contributions to each of the two categories. This means it was not possible to avoid counting funds twice because an accurate division of funds between the two solar technologies could not be obtained from the available data. As the results attributable to each type of technology presented in this report are comparable to official data on related EC web sites and publications (European Commission, 2010) and to the previous capacity map data, and as splitting EU public funding from other related FP programmes between the two solar technologies would be highly subjective, the suggested amount of € 1 million was not aggregated to the PV and CSP results presented here. However, while uncertainties are being cleared up an additional of € 0.5 million could be allocated to the EU share of public R&D funding for PV and CSP technologies.

As the Cohesion / Structural Funds and the IEB / EBRD RES energy investments have the potential to considerably change EU and MS public investments in these sectors once the European Energy Recovery Plan (EERP) in the MS enters the implementation phase (it was launched in 2010), the methodology for acknowledging the financial contributions of these programmes to R&D, demonstration and deployment in the EU shall be elaborated. The extent to which the large projects undertaken encompass RD&D components of the selected three LC technologies in each MS should be clarified, as well as the extent to which demonstration and deployment undertakings in these projects should be considered while performing the public R&D budget comparisons.

4.2. Comparison of Public Energy R&D Investments in Low-Carbon Renewable Energy Technologies in Europe vs the US, Japan, China and India

Comparable data on R&D expenditures by other countries in the selected low-carbon SET Plan technologies is readily available only for the OECD countries, e.g. the US and Japan, as both are also members of the IEA. While no breakdown is available for national public R&D investments in the US, the data for the wind expenditures as well as for overall solar technology R&D expenditures clearly show that the US remained a strong competitor in both sectors during 2006–2009, especially in the solar technology. Whereas it is also clear that Japan's public R&D expenditures in renewables as well as in the rational use of energy are rather high, the selected low-carbon RES technologies in the SET-Plan capacities map received relatively little public R&D support. The reason may owe partly to Japan's pre-2011 decision to concentrate on nuclear energy as well as specific less favourable geographical conditions for PV and CSP technologies. Thus, despite the fact that its industry is an important player in the sector of hi-tech component development, public R&D funding in the sector was rather low for such a prosperous and highly developed country.

Although there are no systematic, detailed data on public energy R&D spending in developing countries, data for the emerging economic superpowers China and India indicate that their governments invest fairly heavily in this area (Sims-Gallagher et. al, 2006). According to Bloomberg New Energy Finance (BNEF), new global investment in clean energy reached 243 billion USD (approximately €175 bn) in 2010, up from 186.5 billion USD (€134 bn) in 2009. Last year's investment figures practically doubled those from 2006. The main factors accounting for this growth were the massive market growth in China, the expansion of offshore wind, sizzling European solar markets and the global increase in R&D investments in renewables. Investment in clean energy technologies in China was up 30 % to 51.1 billion USD (€36.7 bn) in 2010, by far the largest yearly figure for any single country, although there are no indications of how the expenditures are broken down, nor it is clear which energy technologies fall under the terminology in use. Nevertheless, in 2009, Asia and Oceania overtook the Americas, and in 2010, the region narrowed the gap with Europe, the Middle East and Africa as the world's leading regions for clean energy investment (Bloomberg New Energy Finance, 2010). In light of these developments on the international energy market in the selected three LC renewable technologies, it is interesting to compare public R&D investments broken down by technology type or at least by sectors — i.e. wind and solar— due to more information being available.

4.2.1. International Comparison of Public Wind Energy R&D Investments

Data from 2009 were taken for wind energy R&D expenditure comparisons and for the immediate comparison, missing data for some of the important EU MS in the sector, such as Italy, Ireland and The Netherlands, was gap-filled with the last available data (typical average of the 2005–2007 public R&D investments in the sector).

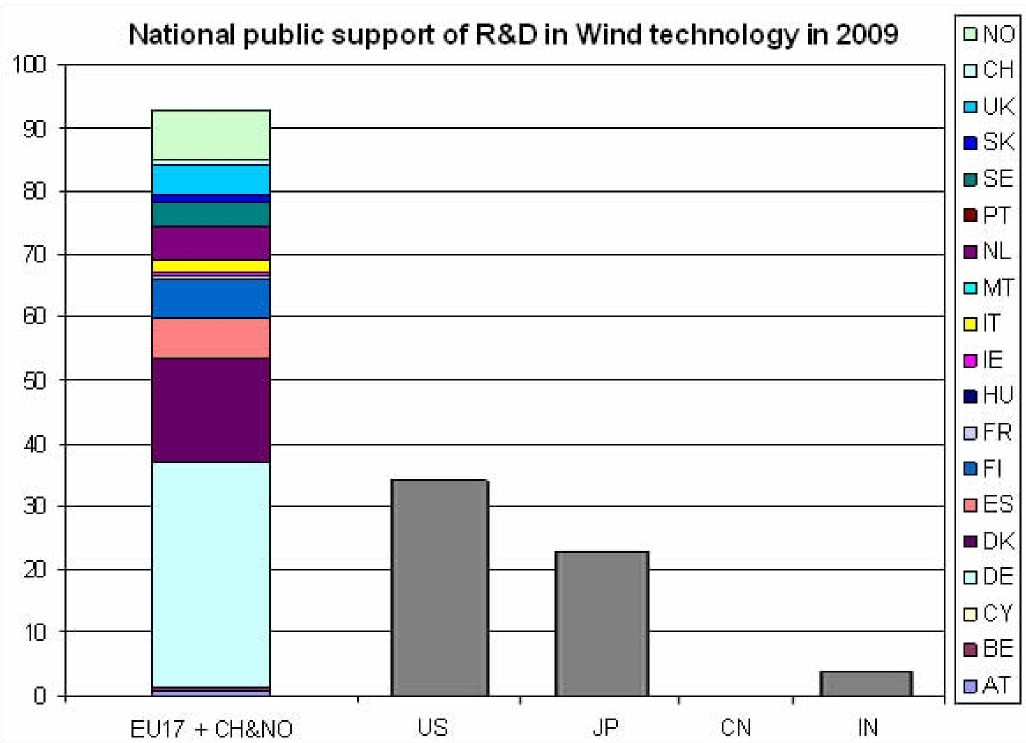
While different sources report Japan's wind R&D investments for the comparative year 2009 as 0 (IEA R&D Statistics) or 31.7 m USD (€22.8 m) (NEDO; conversion rate used from JPY to USD was 82.0: 1 (January 31, 2010); for USD to EUR, a yearly conversion rate was applied (1 USD = 0.719 EUR), this report opted for the later one. The only available data giving a projection over the wind technology R&D expenditure in India in 2009 presents the amount of 5.5 m USD (€3.95 m) (Annexe & Road, 2006). In the absence of any official data for India, this figure is taken for merely comparative purposes.

Similarly, the lack of data on Chinese national public R&D investments in the wind sector for any of the years in the last decade prevented comparative analysis. Still, despite there being no itemised data for China's public R&D investment in the wind sector, meaning that no comparison of public R&D investments can be made, researchers with the Pew Charitable Trusts calculated that in 2009 alone, China invested around 34.6 billion USD (approximately €25 billion) in clean energy, which represented almost double the US investment figure for the same year (Black, 2010). The growing wind power market in China has also provided a quick boost to its domestic production and manufacturing industry, which has, according to the Chinese Renewable Energy Industry Association (CREIA), rapidly spread through its entire supply chain. Recently, China has moved to satisfy the needs of the international wind market, especially for components and turbine manufacturers (GWEC, 2009). In 2007, China already had the largest wind manufacturing industry in the world with more than 40 wind component manufacturers, followed closely by its southern neighbour, India (Perrot & Filippov, 2010).

According to Bloomberg New Energy Finance (2010), the growth in installed capacity in China was driven by a record level of investment in wind power, which exceeded 20 billion USD (€14.4 bn) in 2009. In the third quarter of 2010, China's national investment in new wind power projects accounted for half of the global total. In addition, the Chinese government report "Development Planning of New Energy Industry" calculated that the cumulative installed capacity of China's wind power industry will reach 200 GW by 2020 and generate 440 TWh of electricity annually, creating more than 250 billion RMB (€28 bn) in revenue. Be that as it may, there is no concrete data available on China's public R&D investments in the wind sector.

A comparison of public R&D investments in the sector based on available data for the EU, US, JP and IN is given in **Figure 6.**

Figure 6: Comparison of national public R&D investments in the wind technology in the EU (+CH & NO), the US, Japan and India in 2009.
(Note: Wind technology R&D investments in all the countries shown here are shown on the same scale in m EUR.)



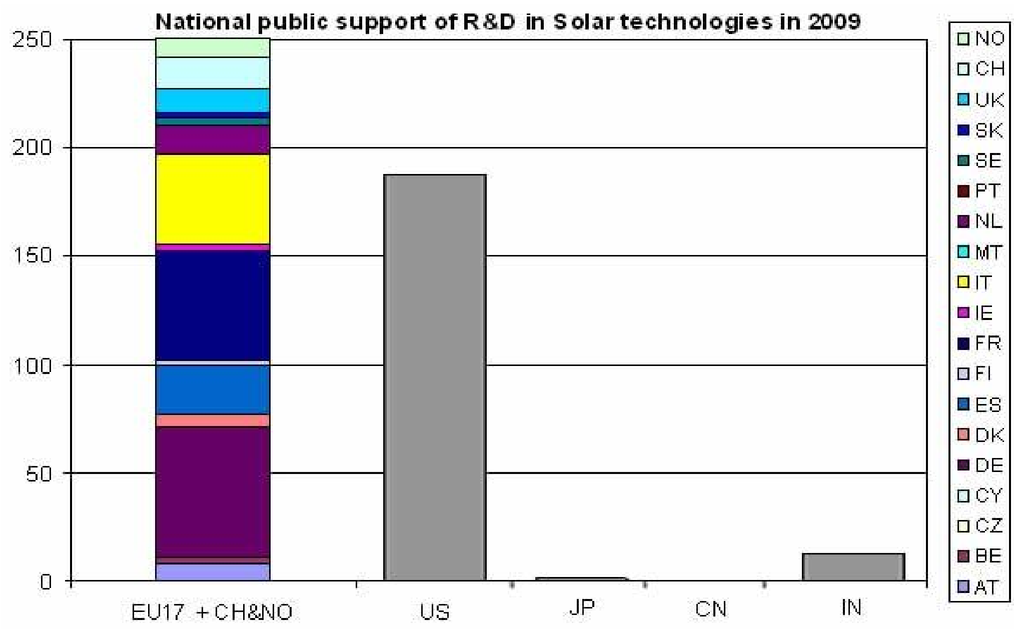
4.2.2. International Comparison of Public Solar Energy R&D Investments

The cumulative global installed capacity of solar PV systems by the end of 2008 reached 15 GW, growing by more than 50 % during the year with 90 % of the generating capacity being integrated into grid electrical systems. Europe maintained its leading position in installed power with strong growth coming from the Spanish market, which added about 2.5 GW of new capacity in 2008, while outside Europe, the US (2.5 GW), Japan (3.6 GW), South Korea and China (1 GW) sustained positive growth trends through 2010 despite the global financial crisis which began in the second half of 2008 (EPIA, 2011).

Once again, the year 2009 was used to compare solar energy R&D expenditures; data missing for some important EU MS in the sector, such as the Netherlands, was gap-filled with the latest available data (typically the average of the 2005–2007 public R&D investments by country in the sector). Retrieving the respective data for the non-IEA countries such as China and India proved to be a very cumbersome task that was only partly fruitful in the case of India, while the data on Chinese national public R&D investment in the solar sector for any of the years in the past decade could not be identified despite reviewing numerous reports, governmental statistical information, etc. An international comparison of public R&D expenditures in the sector was made based on 2009 investments calculated in EUR according to the yearly average conversion rate for 2009 (1 EUR = 0.719 USD).

While Japan's R&D investment in the solar sector reported by the IEA R&D statistics for the year 2009 were rather low — only €1.16 m — a Japanese New Energy and Industrial Technology Development Organisation (NEDO) reported a draft budget of a substantially higher R&D investment of 11 m USD (€7.9 m) for that year for the PV technology alone. Nevertheless, due to the uncertainty of this figure and its non-compatibility with the overall solar sector investment figure for Japan reported by the IEA, this report acknowledges the conservative official expenditure given by the IEA R&D statistics. Indian national public R&D investments into the solar sector were about 10-times higher than Japan's, but still represented only about 5 % of the yearly public R&D investment in the sector in the EU. Thus, the only data comparable to the EU's according to the scale was that of the US, which came to approximately 73 % of the EU's public R&D investment in the sector (see **Figure 7**).

Figure 7: Comparison of national public R&D investments in solar technologies in the EU, US, Japan and India in 2009. **(Note: All investments are shown in m EUR in the same scale.)**



4.3. Comparison of Corporate Energy R&D Investments in Low-Carbon Renewable Energy Technologies in Europe vs the US, Japan, China and India

As corporate energy R&D investment data for Europe and non-European countries for 2009 were not available, the 2008 corporate R&D expenditures were compared. The sample of companies representing the key companies in each sector was carefully elaborated in collaboration between Ecofys Netherlands BV and JRC-IPTS (2010) for balanced Europe–non-Europe comparability. As described for the European corporate R&D investments in sections 2.2 and 4.1.1, data collection for non-European companies, company interviewing and the screening of market factors were mainly carried out by a sub-contractor, Ecofys Netherlands BV, following the methodology described in **Figure 1**. However, following an extensive stakeholder consultation process, R&D expenditures by some additional important companies were added by JRC-IPTS to assure that important industry and market players in each technology field would be covered.

The process of selecting companies for inclusion in the sample of European and non-European companies took into account the companies' relevance in terms of R&D and innovation efforts in the given technology field, aiming to cover a substantial representative part of the related industry. It includes the world's most important companies involved in demonstration activities and companies dealing with relevant components in the supply chain. The data sources in addition to the company interviews were their financial accounting and annual reports as well as the data available in the EU Industrial R&D Investment Scoreboard and some commercial databases.

The companies' R&D expenditure for the three LC energy technologies shown in sub-sections 4.3.1–4.3.3 are listed based on the ultimate parent company's main headquarters for each technology (see Tables 1-3). An analysis of the companies' supply and demand factors as well as their market positions in each of the technology sectors were reported by Ecofys Netherlands BV (2010), and these are presented in more detail in a separate report (Hernandez & Tübke, 2011). A thorough analysis of the following years' investments should follow in order to catch turns in the markets of each of the technology sectors.

4.3.1. International Comparison of Corporate R&D Investment in Wind Energy

The comparison is based on a sample of the 16 most important Europe-based wind sector companies with specific R&D investments totalling €482.1 m and an R&D turnover intensity of 2.2–2.5 %, and 9 key non Europe-based wind sector companies with specific R&D investments totalling €152.8 m, selected and ranked by the order of relevance (Ecofys Netherlands BV and JRC-IPTS, 2010).

- The selected 16 Europe-based companies were: **Vesta Wind Systems** (DK), **Gamesa** (ES), **Enercon** (DE), **Alstom Power (Ecotecnia Energias Renovables)** (ES), **Dong Energy** (DK), **Siemens Wind Power** (DK), **Nordex** (DE), **LM Glasfiber Holding A/S** (DK), **BARD Engineering GmbH** (DE), **Acciona Energy** (ES), **Clipper Windpower** (UK), **AREVA** (FR), **Multibrid** (DE), **Vattenfall** (SE), **Iberdrola Renovables** (ES), **EDF Energies Nouvelles** (FR), and **Vergnet** (FR).

- The selected 9 non Europe-based companies were: **GE Energy** (US), **Suzlon** (IN), **Mitsubishi Power Systems** (JP), **Goldwind** (CN), **(Hara) XEMC Wind Power** (CN), **Sinovel Wind** (CN), **Dongfang Electric** (CN), **Shanghai Electric** (CN), and **Daewoo Shipbuilding & Marine Engineering** (KR).

The international comparison of corporate R&D expenditures of a representative sample of the most relevant companies in the wind sector broken down by world region is shown in **Table 1**.

Table 1: International comparison of corporate R&D expenditures of the representative sample of the World's most relevant companies in the wind sector.

World region	Total bottom-up R&D in 2008 (m €)	No. of companies included in comparison	Share in the sample of corporate R&D expenditures in 2008 (%)
EU	**482.1**	**16**	**75.8**
US	**57.0**	**1**	**9.0**
Asia	**96.8**	**8**	**15.2**
CN	34,4	5	5,4
IN	41,9	1	6,6
JP	19,5	1	3,1
KR	1,0	1	0,2
Total	**635.9**	**25**	**100**

Source: JRC-IPTS calculation based on the Ecofys report (Ecofys Netherlands BV, 2010).

As seen in the "pre-crisis" 2008 comparison of corporate R&D investments in the wind sector, Europe was, with almost 76 %, still the top investor in the wind sector by far. Meanwhile, China and India have started boosting their investments (>15 %), which has rendered their market achievements closer to that of their competitors in subsequent years. The US was positioned third with 9 %.

4.3.2. International Comparison of Corporate Energy R&D Investment in PV

The international comparison of corporate R&D expenditures by the representative sample of relevant companies in the PV sector broken down by world region is shown in **Table 2**. The comparison is based on a sample of the 34 most important Europe-based PV technology companies with total specific R&D investments of 285.1 m EUR and an R&D turnover intensity of 2.2-2.5 %, and 23 key non Europe-based PV sector companies with total specific R&D investments of €558.5 m, selected and ranked by the order of relevance (combined JRC-IPTS and Ecofys Netherlands BV calculation, 2010).

- The selected 34 Europe-based companies were: **SMA Solar Technology** (DE), **OC Oerlikon Solar** (CH), **Q Cells** (DE), **Isofoton** (ES), **REC Group** (NO), **Saint-Gobain Solar** (FR), **Centrotherm Photovoltaics Group** (DE), **SolarWorld** (DE), **Schott Solar** (DE), **BP Solar** (UK), **Helianthos** (NL), **Meyer Burger** (CH), **PV Crystalox Solar** (UK), **Photowatt Technologies** (FR), **Wacker Chemie AG – BU Polysilicon** (DE), **Solar Watt** (DE), **Roth & Rau PV** (DE), **Photovoltech** (BE), **Solland** (NL), **Electricité de France-EN** (FR), **T-Solar** (ES), **Abengoa Solar (Solucar – New Technologies)** (ES), **Solon** (DE), **Acciona Energy** (ES), **Centrosolar Group AG** (DE), Conergy (DE), **Bosch Solar Energy AG (former ErSol Solar Energy)** (DE), **Siemens Renewables** (DE), **Linde Group** (DE), **Iberdrola Renovables** (ES), **Tenesol** (FR), **Würth Solar** (DE), **Aleo Solar** (DE), and **Solar-Fabrik** (DE).
- The selected 23 non Europe-based companies were: **Applied Materials** (US), **Sharp Solar** (JP), **Dow Corning** (US), **ET Solar** (CN), **First Solar** (US), **Sanyo Electric** (JP), **Kyocera** (JP), **Mitsubishi Electric** (JP), **Evergreen** (US), **SunPower** (US), **Fuji Electr**ic (JP), **Suntech Power** (CN), **Tokuyama** (JP), **Yingli Green Energy** (CN), **Motech** (TW), **LDK** (CN), **Kaneka Electronics** (JP), **JingAo Solar Co.Ltd.** (CN), **United Solar Ovonic** (US), **NSG Group** (JP), **Trina Solar** (CN), **Moser Baer PV** (IN), and **Tempress** (US).

Table 2: International comparison of corporate R&D expenditures by the representative sample of the world's most relevant companies in the PV sector.

World region	Total bottom-up R&D in 2008 (m €)	No. of companies included in comparison	Share in the sample of corporate R&D expenditures in 2008 (%)
EU+CH&NO	**285.1**	**34**	**33.8**
CH	40.1	2	4.8
NO		1	
US	**283.4**	**7**	**33.6**
Asia	**275.1**	**16**	**32.0**
CN	62.5	6	7.4
TW	5.7	1	0.67
IN	2.0	1	0.24
JP	204.9	8	24.0
Total	**843.6**	**57**	**100**

Source: JRC-IPTS calculation based on the Ecofys report (Ecofys Netherlands BV, 2010) and additional company listings.

As seen in the "pre-crisis" 2008 comparison of corporate R&D investments in the PV sector, the shares pertaining to Europe (34.1 %), the US (33.9 %) and Asia (32.0 %, with Japan accounting for 24 %) were very similar. The US led with a marginal advantage over Europe, closely followed by Asia. While Japan still played the leading role in Asia, China was moving in rapidly, while the rest of the countries still held negligible shares. As reported by the EurObserv'ER Photovoltaic Barometers (2010, 2011), in the following "crisis" years, Asia and especially China abruptly took the leading world market position in PV, a move which must have been preceded by a sharp increase in corporate R&D investments.

Although some sources estimate very high overall global corporate R&D expenditures by companies active in the PV sector in 2009, between 3 and 6 bn EUR (Breyer et al. 2010), the analysis of a representative sample of the most important companies in the PV sector does not suggest a total R&D appropriation of much more than one billion EUR in 2008. Estimations suggesting three to six times the amount appear to be excessive, taking into account the closely analysed PV R&D expenditures of the Europe-based PV companies as well as the representative sample of companies having their headquarters in the rest of the world.

4.3.3. International Comparison of Corporate Energy R&D Investment in CSP

The comparison is based on the sample of the 18 most important Europe-based PV technology companies with specific R&D investments totalling €79.1 m and an R&D turnover intensity of 2.2-2.5 %, and 11 key non Europe-based PV sector companies with specific R&D investments totalling €37.4 m, selected and ranked by order of relevance (Ecofys Netherlands BV, 2010).

- The selected 18 Europe-based companies were: **Abengoa Solar** (ES), **Saint-Gobain Solar** (FR), **MAN Ferrostal AG** (DE), **Siemens CSP** (DE), **Torresol Energy** (ES), **Solar Millennium AG incl. Flagsol** (DE), **Schott Solar** (DE), **Acciona Energy** (ES), **AREVA** (FR), **Friatec AG** (DE), **Solar Power Group** (DE), **Kraftanlagen München** (DE), **Alanod** (DE), **Flabeg** (DE), **Novatec Biosol** (DE), **Nolaris** (CH), **Solar Euromed** (FR), and **Solitem Group** (DE).
- The selected 11 non Europe-based companies were: **eSolar** (US), **Alcoa** (US), **BrightSource Energy** (US), **Stirling Energy Systems & Tessera Solar** (US), **Wizard Power** (AU), **Sopogy** (US), **3M** (US), **SkyFuel / Reflec Tech Inc.** (US), **Infinia** (US), **Aora Solar** (IL), and **Southern California Edison** (US).

The international comparison of corporate R&D expenditures by a representative sample of the world's most relevant companies in the CSP sector by world region is shown in **Table 3**.

Table 3: International comparison of corporate R&D expenditures by a representative sample of the world's most relevant companies in the CSP sector.

World region	Total bottom-up R&D in 2008 (m €)	No. of companies included in comparison	Share in the sample of corporate R&D expenditures in 2008 (%)
EU	79.1	18	67.9
US	35.3	9	30.3
Asia	0	0	0
Australia	1.5	1	1.3
Israel	0.5	1	0.43
Total	116.5	29	100

Source: JRC-IPTS calculation based on the Ecofys report (Ecofys Netherlands BV, 2010).

With respect to corporate R&S expenditures in CSP, the EU maintained its leading investment role with approximately 68 %, and held the vast majority of investments with the US (about 30 %). The data shows that in 2008, Asian companies had not yet made significant headway into the sector.

5. CONCLUSIONS

1) Collective R&D investments in 2008 in the three selected priority energy sectors — wind, PV and CSP — were approximately 40 % higher compared to the 2007 values and amounted to €1.23 billion EUR.

2) Aggregated public and corporate R&D investments in the period 2007–2008 were in a similar range for all three low-carbon energy technologies.

3) The major investor in each of the three sectors in 2008 was the corporate sector, which contributed more than half of the overall R&D investments in the three priority energy technologies: 84 % in wind technology, 56 % in PV and 55 % in CSP. The overall corporate R&D expenditure accounted for nearly €850 m, whereas public R&D expenditures by the EU Member States amounted to €303 m and public EU investments came to €80.6 (including FP6/FP7 and CIP-IEE programmes, but excluding SF/CF as well as EIB and ERDF financing).

4) Both public and corporate R&D investments in wind, PV and CSP technologies are largely concentrated in a low number of specific EU Member States — wind: DE, DK and ES; PV: DE, FR and IT; CSP: IT, ES and DE. The countries with high public R&D support simultaneously accounted for the largest corporate R&D investments in the revised sectors, which suggests that public and industrial research investments complement one another.

5) While EU corporate R&D maintained the leading position in investments in the wind sector in 2008 with 76 % of the world's total corporate R&D investments, the PV sector's corporate R&D investments in 2008 were distributed equally among Europe, the US and Asia, with each providing approximately 1/3 of the investments (Europe had a slight lead). In the CSP sector, Europe plays a leading role with close to 70 % of the corporate investments followed by the US, while Asia and the rest of the world account for negligible shares of the sector's corporate R&D funding.

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Abstract

Collective R&D investments in the three selected low-carbon (LC) energy sectors (wind, PV and CSP) and the share of corporate, national and EU public R&D appropriations in 2008 were assessed by a method comparable with the previous SET Plan capacities map. Collective R&D investments in the three selected priority energy sectors were approximately 40% higher than the 2007 values and amounted to €1.23 billion. The corporate sector contributed more than half of the overall R&D investments in the three priority energy technologies in 2008: 84 % in wind technology, 56 % in PV and 55 % in CSP. The overall corporate R&D expenditures in Europe accounted for close to €850 m, whereas public R&D expenditures by the EU Member States (and also CH and NO) were €303 m and public EU investments were €80.6 m (including FP6/FP7 and CIP-IEE programmes, but excluding SF/CF as well as EIB and ERDF financing). Both public and corporate R&D investments in wind, PV and CSP energy technologies are largely concentrated in a limited number of the EU Member States — wind: DE, DK and ES; PV: DE, FR and IT; CSP: IT, ES and DE. The countries with high levels of public R&D support also accounted for the largest corporate R&D investments in the revised sectors, suggesting that public and industrial research investments complement one another. European corporate R&D remains the world leader in terms of investments in the wind sector in 2008 with 76 % of the world’s total corporate R&D investments. The PV sector's corporate R&D investments in 2008 were distributed equally among the Europe, the US and Asia, each holding approximately 1/3 of the R&D investments (with Europe slightly ahead). In the CSP sector, Europe is leading with close to 70 % corporate R&D investments followed by the US, while Asia and the rest of the word have negligible shares in the sector's corporate R&D funding.

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