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Techno-economic analysis of key renewable energy technologies (PV, CSP and wind)

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Abstract

This report shows the results of a techno-economic analysis of key renewable energy technologies: Solar Photovoltaics (PV), Concentrating Solar Power (CSP), and Wind Energy Technologies (wind). For this purpose, bottom-up company-data were collected, market supply and demand factors addressed, the regulatory framework examined, and EU industry compared against its main competitors. Personal interviews with 10 key industrialists from these sectors were undertaken to generate first-hand feedback from companies. The information generated was validated in a workshop with selected study participants, industrialists and policymakers.

The three technologies hold potential for tackling major energy issues and creating jobs and economic growth, but electricity production costs associated with them are still higher than for conventional technologies. Appropriate regulatory and framework conditions are a prerequisite for introducing PV, CSP and wind into the market and to become competitive. The time horizon for this to happen depends on whether these industries can reduce costs and how conventional energy prices evolve. The 2009 EU Renewable Energy Directive has set targets for increasing the average share of renewable energies in final energy consumption, and PV, CSP and wind will play a key-role in achieving these targets. Their application will however create multiple challenges for the existing electricity grid in terms of integrating the new capacities, energy storage and distribution. Although these challenges have been recognised and gained political momentum at the EU level, the degree to which they will be resolved within the coming decades depends on how quickly they are implemented in the Member States and the interplay of all new super- and smart-grid components.

Competition is an important driving factor for improving the three technologies' cost-effectiveness as they also have to compete with other energy technologies and against the various technology options throughout the whole supply chain. An important question here is to which degree externalities are included in the cost calculation. If externalities in conventional energy generation are taken into account, some renewable technologies (wind) already have a competitive edge. The CSP sector is the less mature industry, not yet at the stage of mass manufacturing.

In terms of R&D investment, the study shows that the EU companies lead in CSP and wind energy and the non-EU companies (USA and Asia) lead in PV. However, these results, based on 2008 figures, need careful interpretation since recent patterns of investment in renewable energy show significant changes. This is due to the effects of the economic crisis and to different investment reactions by emerging and developed economies. By spring 2011, there is evidence of stronger R&D activity in some non-EU countries, namely in China, South Korea, India, Japan and the US. Also a number of companies with significant R&D investment were not included in the study either because they had only recently been created or because they did not disclose specific R&D investments in renewable energy. A conclusion on this matter is that the EU does not currently seem to under-invest in these technologies but recent trends indicate a likely challenge on this over the medium term.

So as to stimulate R&D for PV, CSP and wind energy, policy should check if there is a balance between policy support for technological development and policy instruments promoting market penetration. Regarding the specific support and Feed-In Tariff (FIT) schemes implemented in the EU, it is necessary to understand their actual impacts, i.e. which part of the value chain obtains the most benefits.

JEL Classification: O33

Keywords: R&D, renewable energies, solar photovoltaics, concentrating solar power, wind energy, industrial competitiveness

1 Introduction

Investment in research and innovation is at the heart of the Europe 2020 strategy.[1] It has set a goal for Europe's market economy in the 21st century to emerge from the crisis stronger and turn the EU into a smart, sustainable and inclusive economy, delivering high levels of employment, productivity and social cohesion. Private sector R&D investments play a particularly important role in this strategy both as part of the EU's headline target of 3% R&D investment intensity (in terms of GDP) and in their contribution to the so-called 'Innovation Union' and 'Industrial Policy for the Globalisation Era'[2] flagship initiatives.

The Industrial Research Monitoring and Analysis (IRMA) initiative[3] supports policymakers in these initiatives and monitors progress towards the associated (Barcelona) targets. The *EU Industrial R&D Investment Scoreboard*[4] is at the heart of the IRMA project, analysing private R&D from a company perspective based on companies' audited annual accounts. The Scoreboard therefore examines ex-post trends. As part of IRMA, additional instruments have been developed around the Scoreboard to obtain a greater understanding of companies investing in R&D by establishing direct contact with them and collecting up-to-date information on trends and main factors: the *EU Surveys on R&D Investment Business Trends*[5] and techno-economic analysis of key sectors.

The role of key sector techno-economic analysis is to establish a bottom-up perspective, complementing the above information by including R&D information from the Scoreboard and entering into a personal dialogue with key R&D players in company interviews to capture their feedback directly. The focus of these interviews is a high value-added exchange of information to address the role of R&D (and innovation) for competitiveness, assess R&D capacities of EU versus non-EU companies, identify supply and demand factors in the value chain and factors determining attractiveness for locating manufacturing, pilot and R&D facilities, and assess the competitiveness position of EU industry versus main competitors like the US, Japan, or emerging Asian countries.

[1] See: European Commission: Europe 2020: A strategy for smart, sustainable and inclusive growth: http://ec.europa.eu/eu2020/index_en.htm.

[2] The Industrial Policy for the Globalisation Era flagship aims at improving the business environment, notably for SMEs, and supporting the development of a strong and sustainable industrial foundation for global competition.

[3] See: http://iri.jrc.ec.europa.eu/. The activity is undertaken jointly by the Directorate General for Research (DG RTD C, see: http://ec.europa.eu/research) and the Joint Research Centre, Institute of Prospective Technological Studies (JRC-IPTS, see: http://ipts.jrc.ec.europa.eu/activities/research-and-innovation/iri.cfm).

[4] The Scoreboard is published annually and provides data and analysis on companies from the EU and abroad investing the largest sums in R&D (see: http://iri.jrc.ec.europa.eu/research/scoreboard.htm).

[5] See: http://iri.jrc.es/research/survey_2009.htm.

For this purpose, we selected and analysed three renewable energy sub-sectors among the list proposed by the SET-Plan[6], namely Solar Photovoltaics (PV), Concentrating Solar Power (CSP), and Wind Energy Technologies (wind), using a three-step approach:

(1) Collecting bottom-up company data, analysing market supply and demand factors, addressing the regulatory and institutional frameworks, and comparing EU industry against main competitors.[7]

(2) Undertaking personal interviews with 10 key industrialists from these sub-sectors to generate first-hand feedback from companies.[8]

(3) Validating the information generated in the previous steps and proposing policy conclusions. For this purpose, a workshop was held on 28 February 2011 with a selected group of study participants, industrialists and policymakers.[9]

The objective of this study is to take full advantage of work on R&D not only from the IRMA project, but also from other sources in- and outside the European Commission. For this purpose, a wide range of sources was screened, existing information prepared and completed with additional information generated in the three steps above. The approach however had to be focused on an industry perspective and excluded detailed analyses of technological potentials for improving cost-effectiveness, public support schemes and regulatory frameworks, and other measures for innovation, e.g. patents.

The present document summarises the information collected and presents the main findings and policy implications. For data protection reasons, all information provided during the company interviews is presented in an anonymous fashion. It should be kept in mind that the findings presented here are subject to the limitations of the approach both in terms of resources and sample size and do not represent the European Commission's official position. The present report is a stocktaking exercise which may include partial or sometimes conflicting views, but this is rather typical of such bottom-up approaches and reflects the dynamic nature of renewable energy technologies and markets.

The findings are presented in the following way: Chapter 2 presents the results of the data collected and analyses the main competition factors. Chapter 3 contains a summary of the interviews with key industrialists. Chapter 4 shows the main lines of discussion and results of the validation workshop, and Chapter 5 presents general and policy conclusions.

[6] See: http://ec.europa.eu/energy/technology/set_plan/set_plan_en.htm.
[7] These activities benefited from the contribution of Ecofys (The Netherlands).
[8] These activities benefited from the preparation and support of the company interviews by Enerdata (France) and the Energy research Centre of the Netherlands (ECN, The Netherlands).
[9] See the list of participants in the Annex.

2 Results of the data collection and main competition factors' analysis

Main worldwide industry players in the selected sub-sectors were identified and their R&D and relevant economic/financial indicators collected. The sample consists of two subsets: companies based in the EU and those based in non-EU countries. For EU companies, we took advantage of previous work by the JRC-IPTS[10] and updated the information. The focus on data collection for non-EU companies was on companies from current and emerging competitor countries such as the US, Japan, China or India.

The main demand and supply factors driving the development and deployment of the three selected energy technologies were identified and analysed along the following lines:

- Demand-side factors including resources (wind speed, total irradiation for PV, direct irradiation levels for CSP), prices of existing energy technologies and ability of consumers to finance renewable energies.
- Supply-side factors comprising cost of production; workforce skills; quality culture; presence of a home market; enabling technologies; knowledge infrastructure; R&D stimulation programmes; intellectual property; tariff framework; local framework; and access to capital.

The data collection and market factor analysis were performed by Ecofys.[11]

2.1 Data collection

As a starting point, the data collection summarised the most up-to-date information from previous work. The data collection of companies followed a company-by-company bottom-up approach. Both EU and non-EU companies were included in the sample, taking into account their relevance in terms of R&D and innovation efforts within their related technological field, aiming to cover a substantial (if possible, representative) part of the related industry. It included companies involved in demonstration activities and companies dealing with relevant components in the supply chain. The main data sources were companies' annual reports and accounts, commercial databases, and direct contact with companies. EU companies are considered those whose ultimate parent company's registered office is in a Member State of the EU (EU-27). Likewise, non-EU companies are those whose ultimate parent company was located outside the EU. Main limitations were due to data availability and uncertainties involved. The following indicators for the company's financial year 2008 were covered: net sales, operating profit, number of employees, R&D investment in 2007 and 2008, and the specific R&D investment of the company in one of the selected technologies. The following sections summarise the findings of the background study according to the data collected.

[10] See Wiesenthal et al. (2009).
[11] See Molenbroek et al (2010).

Photovoltaic companies

The sample of most relevant companies for R&D spending in PV included 31 companies based in the EU and 21 companies based elsewhere. The 31 EU companies invested €239.6m in 2008 and the 21 non-EU companies invested €576.2m (Table 1).

Table 1: Total bottom-up corporate R&D numbers for the sample of PV companies (focus year 2008)

World region	Total bottom-up R&D (million €)	Typical R&D intensity (% of sales)	Companies used for estimating R&D intensity
EU	239.6	1.4-4.5%	Q-cells, REC group, Centrotherm, SolarWorld, Schott Solar, Crystalox
non-EU	576.2	0.8-2.7%	Suntech, Yingli, Motech, Sunpower, First Solar

Source: European Commission JRC-IPTS based on Molenbroek et al. (2010)

Companies working with relatively mature c-Si technologies such as Suntech, Motech and Yingli were mainly located in Asia and are cost competitive. On the other hand, companies working on thin-film technologies (CdTe, a-SI and CI(GS)) were rather young companies, often start-ups, and mostly located in Europe, the US or Japan (Sharp, Mitsubishi).

It can be noted that the variation in R&D intensity over the companies is large. Established companies focused on the relatively mature c-Si technology have an R&D intensity of ~1%. First Solar has a unique technology (CdTe) and is committed to maintain leadership in this technology (R&D intensity 2.7%). Equipment companies like Applied Materials and Oerlicon have R&D intensities in the 7%-10% range. Companies with higher technology emphasis (e.g. Evergreen) have R&D intensities in the 15%-30% range.

Wind energy companies

The sample of the most relevant companies for R&D spending in wind energy included 16 companies based in the EU and 9 companies based elsewhere. The 16 EU companies invested €482.1m in 2008 and the 9 non-EU companies invested €152.8m (Table 2).

Table 2: Total bottom-up corporate R&D numbers for the sample of wind companies (focus year 2008)

World region	Total bottom-up R&D (million €)	Typical R&D intensity (% of sales)	Companies used for estimating R&D intensity
EU	482.1	0.8-3.7%	Vestas, Gamesa, Nordex, Clipper
non-EU	152.8	1.7-2.2%	REpower[12], Goldwind, Sinovel

Source: European Commission JRC-IPTS based on Molenbroek et al. (2010)

[12] REpower is incorporated in Germany but 90% owned by Suzlon (India).

Wind energy is the most consolidated sector and a relatively small amount of companies gave a detailed picture of their R&D investments. EU companies were leading in wind energy-related R&D and is expected to maintain this leading position. Some non-EU companies (Suzlon, XEMC[13]) have R&D activities based in the EU.

R&D spending in wind energy showed a substantial 65% growth in R&D from 2007 to 2008. This is illustrated by the example of Vestas or REpower, with 87% and 64% one-year growth rates, respectively.

Wind energy R&D investment is dominated by a few large companies. Vestas R&D on wind energy is 46% of the total corporate R&D investment of EU companies in the sector. GE and Suzlon together had a 65% stake in the total corporate R&D investment of non-EU companies in the sector.

CSP companies

The sample of the most relevant companies for R&D spending in CSP included 18 companies based in the EU and 11 companies based elsewhere. The 18 EU companies invested €79.1m in 2008, whereas the 11 non-EU companies invested €37.4m (Table 3).

Table 3: Total bottom-up corporate R&D numbers for the sample of CSP (focus year 2008)

World region	Total bottom-up R&D (million €)	Method for estimating R&D intensity
EU	79.1	Share of total R&D spent on CSP
non-EU	37.4	Share of external funding spent on R&D

Source: European Commission JRC-IPTS based on Molenbroek et al. (2010)

CSP was the least mature of the three industries analysed. The market was dominated by larger conglomerates operating CSP activities, plus start-up companies and venture capital. Public data about net sales or R&D investments directly related to CSP were very scarce.

Companies from Germany, Spain and the US were strong in CSP-related R&D. Some EU-based companies (Areva and Siemens, who acquired Ausra and Solel, respectively) had R&D activities in non-EU countries.

The non-EU sample of companies was dominated by start-up companies working exclusively on CSP, with the exceptions of AlCoA and 3M.

Due to the synergy of CSP technology with glass and metal technology, large companies with glass and metal know-how have entered into the CSP industry (Saint Gobain, MAN Ferrostaal, Siemens, Schott, Alcoa).

[13] XEMC's R&D activities in Europe result from the acquisition of Dutch companies Darwind and VWEC.

2.2 Market factors

The main demand and supply factors driving the development and deployment of the three selected energy technologies were identified and analysed. Demand-side factors covered were resources (wind speed, total irradiation for PV, direct irradiation for CSP); prices of existing energy technologies; and consumers' ability to finance renewable energies. Factors considered in the supply-side included production cost; workforce skills; quality culture; home market presence; enabling technologies; knowledge infrastructure; R&D stimulation programmes; intellectual property; and access to capital.

The following sections summarise the demand and supply factors of the three technologies based on the company data for the main world regions (EU, US/Japan and other Asian countries). In addition, a broad qualitative comparison is provided.

Photovoltaic market factors

Although PV cell production is not very labour-intensive, low-wage countries have exploited labour cost advantages as production locations. Moreover the quality culture in manufacturing has increased substantially in countries like China, coming close to the European level and the USA.

For the more mature c-Si-based technology, we have observed that Chinese and Taiwanese companies are becoming very successful. For less mature technologies, like thin-film technology and wet processing based CI(G)S, we see that most Intellectual Property (IP) is generated in the R&D-favourable countries in Europe and the USA. This is also where pilot production projects take place.

The European home market showed the most developed status. The home market situation in the USA and Asia was also developing well.

PV modules, still the largest portion of the cost of a PV-system, are relatively low cost to ship. This implies that the supply region supply does not have to be in close vicinity to the demand centres. The weight of the home market factor, as a supply factor (production) is therefore not as strong as for wind and CSP. In the last few years, an increasingly large portion of the modules production is in China and other low-wage Asian countries, even though the market in these countries was originally substantially smaller than the European market.

Relevant enabling technologies, i.e. a supplier and equipment infrastructure for semiconductor products, are present in all three regions.

A good Intellectual Property (IP) position is not per se necessary for a successful PV company, because older technologies based on crystalline silicon still work quite well. It is debatable whether EU companies can withstand this price pressure for flat plate PV technology. It is possible though for a company to compete on price only, as the example of the rapid expansion of CdTe manufacturer First Solar shows. There may still be niche markets, such as low weight modules for light weight roofs, flexible PV modules or high efficiency modules in places where severe area constraints are present that give a need for IP-protected technology.

A potential market that can be much more than a niche market is CPV, where IP is important. Many successful and promising (multinational) companies have an R&D/Pilot facility in the US or Europe and volume production in Asia. The headquarters of these companies can be in either country. The presence of a home market was initially important (in 2000-2005). Now that the (relatively simple) c-Si technology matured, the advantage of a home market is much smaller, as the transport cost of the PV products is not very high. Table 4 compares PV market factors across the main world regions.

Table 4: Comparison of PV market factors for main world regions (focus year 2008)

		EU	USA/Japan	Asia
1	Production cost	--	-	++
2	Workforce skills, quality culture	++	++	++
3	Home market	++	+	+
4	Enabling technologies	o	o	o
	Supply Factor (production)	**o**	**o**	**+**
5	Knowledge infrastructure	++	++	+
6	R&D stimulation programmes	++	+	o
	Supply Factor (R&D – pilot)	**++**	**+**	**o**
7	Intellectual Property	++	++	-
8	Access to capital	+	++	+
	Supply Factor (companies)	**+**	**++**	**o**

Source: European Commission JRC-IPTS based on Molenbroek et al. (2010)

Wind energy market factors

For production of advanced wind turbine blades, knowledge and mastering of composite technology is necessary. For the design of the blades, advanced aerodynamics knowledge is needed.

Production cost was the most favourable in the Asian countries. Production skills and also production quality systems are up to standard in countries like China and India. The presence of a home market is relatively important, because it is relatively expensive to ship heavy components. Nevertheless shipping high-tech components (like blades and gears) is common practice. Foundations and towers are usually produced locally to the site.

Europe is losing ground to Asia and North America in terms of installed capacity of home market onshore wind power. However, in offshore wind power Europe has the advantage of a developing home market.

Enabling technologies and a supplier infrastructure from e.g. the aircraft industry were present in all three regions.

The offshore wind industry is becoming a significant player in its own right. And as Europe is loosing ground to Asia in onshore wind power, Europe is leading the way in the offshore wind power. This is an important driver for current R&D. Offshore wind power is the driver for larger wind turbines; increased reliability; optimising maintenance; assembly and installation of offshore wind turbines and their substructures.

Table 5 compares the wind energy market factors across the main world regions.

Table 5: Comparison of wind energy market factors for main world regions (focus year 2008)

		EU	USA/Japan	Asia
1	Production cost	--	-	++
2	Workforce skills, quality culture	++	++	++
3	Home market			
	- onshore	+	+	+
	- offshore	+	-	-
4	Enabling technologies	+	+	+
	Supply Factor (production)	**+**	**+**	**++**
5	Knowledge infrastructure	++	++	+
6	R&D stimulation programmes	++	+	o
	Supply Factor (R&D – pilot)	**++**	**+**	**o**
7	Intellectual Property	++	++	-
8	Access to capital	+	++	+
	Supply Factor (companies)	**+**	**++**	**o**

Source: European Commission JRC-IPTS based on Molenbroek et al. (2010).

CSP market factors

Most CSP companies are located in regions in the world where CSP can be applied: the hot and sunny regions in the world. There is an obvious advantage to that: it is a much easier way to test and demonstrate CSP. Nonetheless, a consistent government stimulation policy can also lead to results. It looks like there are good arguments for producing CSP components close to where the systems are made. This could be because mirror components are fragile, making them more difficult and expensive to transport. However, it could also simply be because the low-wage countries have not directed their attention to this technology yet.

Most IP is in the hands of Europe and North America. Asia is not a big production region yet. However, a first joint venture between a US firm and a Chinese partner has already been made. One could wonder to what degree new technologies will develop to once CSP component production has started in low-wage countries because this would lead to a race in cost reduction through innovation against cost reduction using low-wage countries and scale-up strategies.

Most company innovation takes place for tower technology, with smaller companies and smaller efforts going into Fresnel technology. Constructions and mirrors are relatively easy to copy. However, high temperature technology for the receiver still offers plenty of room for innovation and IP development.

CSP is less mature than PV. Therefore, the R&D- and pilot-related supply factors are more important. Besides, CSP components are heavier than PV components. Therefore, home market presence as a supply factor is more important. As mentioned before, the USA has relevant enabling technologies from other industries.

Table 6 compares CSP market factors across the main world regions.

Table 6: Comparison of CSP market factors for main world regions (focus year 2008)

		EU	USA/Japan	Asia
1	Production cost	--	-	++
2	Workforce skills, quality culture	++	++	++
3	Home market	+	++	o
4	Enabling technologies	o	+	-
	Supply Factor (production)	**o**	**+**	**+**
5	Knowledge infrastructure	++	++	+
6	R&D stimulation programmes	++	+	o
	Supply Factor (R&D – pilot)	**++**	**+**	**o**
7	Intellectual Property	++	++	-
8	Access to capital	+	++	+
	Supply Factor (companies)	**+**	**++**	**o**

Source: European Commission JRC-IPTS based on Molenbroek et al. (2010).

3 Summary of the key industrialists' interviews

The present interview approach was established in the context of the IRMA project for collecting up-to-date information on trends and main factors of corporate R&D behaviour in the three renewable energy sectors.[14] Due to resource limitations, complementarity with the IRMA project and a wide range of existing information, we decided to focus on a maximum of 10 personal interviews with key players (at least 3 in each sector).

While such small samples do not allow for statistically representative inference, the previous data collection helped to identify the main players and put individual companies into context. We would like to thank all participating companies, especially the interviewees, for their contributions summarised below. While individual statements may be biased, we have strived to highlight the most important aspects to show the main trends and serve as a base for further discussion.

This chapter describes the information validation, preparation and implementation of the interviews and the main findings.[15]

3.1 Validation of the information collected beforehand

The data on company R&D and competitiveness factors collected in the previous steps allowed us to identify key-players in the field. They include publicly-available information on company R&D and main technology and market factors from a sector perspective and serve as a good starting point for further in-depth analyses of:

- ⇨ Main company trends (overall strategy, business model, value chain, and degree of vertical integration);
- ⇨ Main corporate R&D trends (overall R&D strategy, collaboration, outsourcing);
- ⇨ Location trends and factors (overall and market or production-related R&D);
- ⇨ The role of competitors from other countries, especially the US, China or India; and
- ⇨ The role of public policies and support schemes for company strategy and R&D efforts.

Due to the important role of public support schemes for developing and using energy technologies, the company interviews had a significant potential for gathering company views on these schemes as a base for formulating recommendations for future policies.

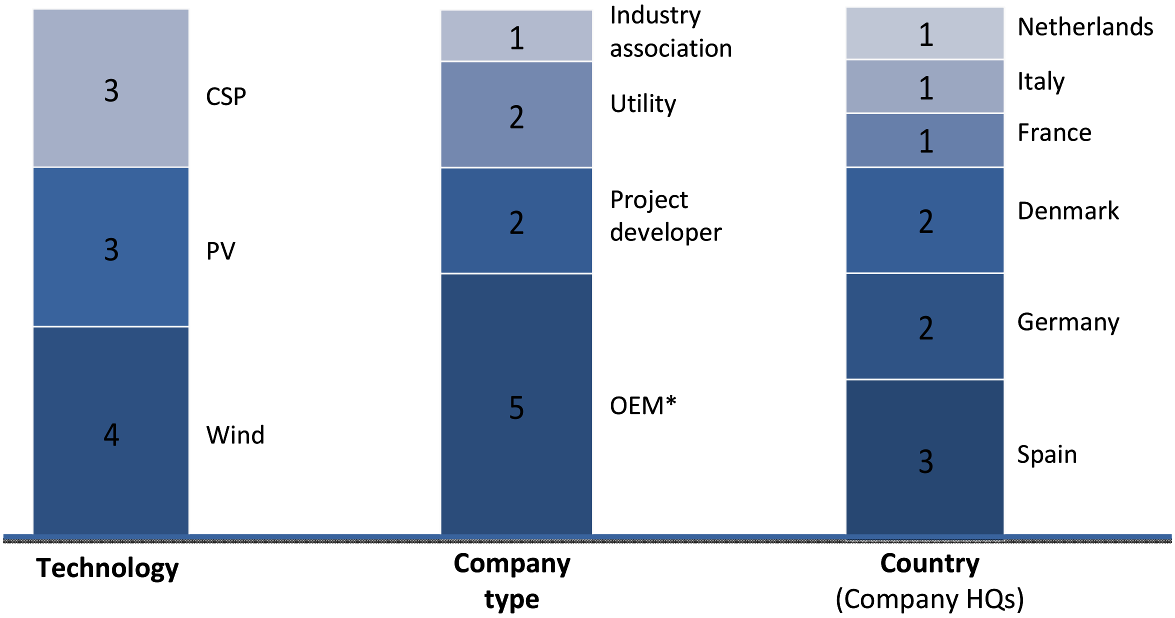
3.2 Preparation of interviews

To ensure that we obtained the most information possible from the participating companies, the interviews were prepared as an exchange of information relying on company-specific interview templates. We identified potentially knowledgeable candidates in companies and asked whether they would like to participate in an interview. We prepared a personalised interview template for each participating company prior to the interview. These templates included a case-study based on publicly-available information, showing the company's R&D, innovation and competitiveness profile. The figure below shows the sample composition for the 10 companies interviewed.

[14] See also Chapter 1 for more context of the activity.

[15] This activity was supported by Enerdata (France) and ECN (the Netherlands). The present Chapter summarises the information from the confidential reports provided (Enerdata and ECN, 2011).

Figure 1: The 10 companies interviewed by technology, company type and headquarters' country



Note: * OEM (Original Equipment Manufacturer).
Source: Enerdata and ECN (2011).

All the three renewable energy technologies were covered with at least three interviews. Most companies were OEMs (Original Equipment Manufacturers), i.e. actual producers of products for energy generation. As well as the other company types covered (utilities, project developers and one industry association), the sample provides a good representation of the actors involved in developing, manufacturing and installing energy power plants. Spanish, German and Danish companies are dominating the sample.

The 10 company interviews were face-to-face and carried-out between September 20th and November 30th 2010 at the companies' premises. All participants were company executives with a good knowledge of R&D strategy and overall competitiveness issues, e.g. CEOs or director level (R&D, product development, technology, etc). Additional research was undertaken to consolidate and validate main findings (interviews with two experts from the European Commission for the European R&D programmes for PV and wind, plus desk research).

The interviews lasted a maximum of 90 minutes. We started by introducing the project and were then loosely structured around the main issues of the templates in order to leave room for capturing the individual perspective and adapting to issues of interest for the interviewees. While specific emphasis was set on individual experiences with public policies and policy recommendations, the objective was not on a detailed assessment or comparison of policy schemes.

3.3 Main findings applying to all the three sub-sectors

Structure of the technology supply-side

Solar and wind energy generation differ with respect to the reliability of solar irradiation and wind prediction. These predictions are necessary for managing energy production and the peaks it produces when fed into the grid. Large farms use simulation software for prediction.

R&D strategy

In terms of competition with Chinese companies, the strong efforts of learning Western technologies by making and then nurturing a local industry via loans and infrastructure were mentioned. After the ‘apprenticeship’ via Joint Ventures, these companies later compete in global markets. This has already lead to establishing important Chinese players, and a few interviewees see the risk of losing the European competitive edge in the medium term at least for components or sub-technologies. The US has filed a WTO complaint on renewable energy trade barriers from China.

Policy support

Funds for policy support of the energy sector are limited, and the different technologies (conventional, nuclear, renewable) at the end compete for funding. Renewable energies are a younger technology than many others, and some lobbying institutions have been established relatively recently. It is also a question to which degree and until when citizens will be willing to pay a premium for renewable energies.

Also the three renewable energy technologies compete among them, especially the solar ones (PV farms versus CSP plants). More than a few interviewees were in favour of FIT schemes with technologically more demanding criteria than in the past, which were perceived as potentially beneficial for European companies. Also the administration of these schemes, instead of a first-come-first-served approach, should take into account the lead-times of the different technologies, value more technologically ambitious projects and provide a realistic and reliable phasing-out. For this, however, the public administration needs a certain degree of technological knowledge to be able to assess a project.

It was also pointed out that policies should take into account the companies’ vulnerability with respect to Chinese competition. This was not meant in a protective fashion, but in the sense that those sectors where China has the biggest price competition potential are the most vulnerable towards the erosion and hollowing-out of European manufacturing, which will consequently affect R&D.

3.4 Main findings from wind companies' interviews

Structure of wind technology supply-side

The wind technology supply-side contains both independent companies (some of them large, like Vestas or Enercon), and conglomerates (like Siemens or General Electric) which entered the technology via related products or acquisitions. These conglomerates have the advantage of being able to supply turnkey installations to their customers, which are mainly large utilities firms. These turnkey installations seem to be a current trend in the wind industry. This evolution is reinforced by the rapid development of offshore projects. Systems integration and optimisation of wind and standard components, as well as increasing overall reliability and cost reduction, are the keys to competitiveness in the market.

Onshore and offshore wind farms are two different areas of wind farm location with different customers and conditions for installation and maintenance. Onshore wind turbines may be installed in wind farms, but also individual units by smaller customers (e.g. farmers). Offshore installations are normally organised in large wind farms located several kilometres from the shore. They are more complex in terms of foundations, security and maintenance due to harsher weather conditions and remoteness.

Offshore wind

The role of EU policies for onshore and offshore wind was frequently mentioned in the interviews. Some interviewees felt EU support focus on offshore wind technologies, especially with respect to R&D support, and proposed to rethink the balance between onshore and offshore targets as the integration of larger shares of offshore wind energy would require large grid investments: connections from farm to shore and European grid reinforcement. Also, offshore wind is a large scale business (often several hundred MW), technologically more complicated and costlier in terms of machinery, installation, maintenance and service. Other interviewees highlighted that onshore wind should not be neglected on account of support for offshore wind, especially concerning the expansion of onshore wind energy capacities and grid access. The offshore-onshore discussion seems to have many aspects beyond individual corporate strategy, ranging from available land and sea use to actual costs of grid integration and reduction potential of generation costs. In general, R&D for offshore wind energy is much costlier than for onshore as the elements beyond the turbine (foundations, wave and wind monitoring, security, and maintenance) is much more complex. Offshore wind suppliers therefore need much more complex technical due diligence and highly specialised staff not only for R&D, but for offshore farm installation and servicing. In this regard, they also learn from oil and gas offshore business. Due to the high costs involved, a large stream of offshore wind projects would help in kick-starting the industry. While experience from onshore projects may provide economies of scale and cost reductions in the supply chain, especially for offshore, a larger stream of demonstration projects would be beneficial for companies to gain critical mass in experience and climb up the learning curve enabling further wind energy cost reduction.

R&D strategy

It should be stressed that the R&D strategies at companies are highly individual, even if companies are comparable in terms of size and market segments. The strategic focus ranges from specific technological characteristics (aspects of turbine design, capacity for generation, efficiency), vertical integration, applications (onshore-offshore), to turnkey installations and integration with the conventional energy grid. As a consequence, their needs and objectives, also in terms of what they expect from policymakers, vary considerably. This also applies to R&D location and manufacturing activities, where some companies are mainly present in the EU and others are globally-locally. It seems, however, that the more strategic R&D activities are located closer to the company's home due to Intellectual Property (IP) and other practical issues (easier testing and proximity to manufacturing). Some interviewees stressed that there is actually little incentive to relocate R&D, especially the strategic parts, outside the EU due to IP protection and the technological leadership of the region at present. Interestingly, R&D costs were not mentioned in this respect.

Collaboration and clusters

While a supportive home market was felt key for seeding and sustaining local wind technology clusters, the industry is now completely global. Companies try to take advantage of local knowledge via internationalisation. For example, local and foreign companies both participate actively in local wind clusters, also because of collaboration with local Universities (e.g. the Roskilde area, Denmark with the DTU University). In such clusters, Universities are often the bridge enabling collaboration between competing companies allowing knowledge and R&D results to be shared. Controlling Intellectual Property (IP) and privacy issues is a very important concern here, and some interviewees preferred to limit collaboration due to these issues.

These clusters are not only important for local-global and industry-University knowledge exchange, but also for knowledge transfer between sectors. For example, aerospace test facilities are used for blade optimisation and some automotive suppliers also provide components for wind technologies. Further, wind companies learn from aerospace and automobile companies for improving system integration and reliability. The R&D undertaken by companies in these clusters is mainly for the global market, and only in few cases for adapting to local markets. Company R&D strategy is mainly determined by overall market-pull and technology-push factors. Policies are important where they incentivise a market for wind generation installations, which may trigger R&D investment in local clusters in the course of developing home markets. Fiscal incentives for R&D are less important than local markets and clusters for R&D location.

Policy support

The associated paperwork and need for justification for the use of EU funds for large projects with many participants were seen as obstacles by some interviewees. This was less so for national policies with fewer participants. The involvement of industry in the design of the EU Wind Initiative was however felt to be a good example. Some interviewees stated however that the 2020 targets were relying too much on growing the EU market which is accessible to international competitors instead of directly helping EU companies become true global leaders. China is creating a local wind industry supporting national companies directly. Around 60 competitors exist there at the moment, 10 of which are expected to survive over the long-term. At a somewhat smaller scale, this also applies to India. These firms are gradually increasing their presence in the European and global markets, in some cases due to acquisitions of local suppliers.

An additional aspect raised was the stability of public support schemes, especially Feed-In Tariffs, as part of a project's viability. The scale of public support might not be as decisive as the track-record of stability of the support system. Many interviewees stressed that companies seek public funding as an additional element in R&D funding only and are generally capable of pursuing R&D with other sources of finance if it is necessary or strategic.

EU and national policies

Some interviewees saw the enforcement of EU targets via the Member States as a good example as it allows national governments to adjust policy schemes to their needs, especially Feed-In Tariffs (FIT), i.e. land availability, use and integration into national grids. For others, there was a need for harmonising FIT schemes in the EU. It was also stressed that, once the 2020 targets are confirmed,[16] we should start thinking about targets for 2030 (e.g. 30% for 2030). A special challenge for reaching the 30% targets is the expansion, integration and better management of wind energy, both on- and offshore, in the grid. Also, it was stressed that policies should focus on making wind energy competitive against conventional power thus enabling European companies to be successful in international markets. At the end of the day, wind energy will have to do without subsidies because relatively few countries have support schemes as attractive as those currently in place in Europe.

3.5 Main findings from PV companies' interviews

Structure of the PV technology supply-side and market

The industrial application of solar PV technology has been seriously developed over the past 30 years. Since then, many players have contributed to technological development. Solar PV panels are very versatile. Installations range from very small (individual homeowners) over communities (public buildings or shopping centres) to large farms with hundreds of panels. Solar PV efficiency is continuously improving and is expected to increase to around 15% without disruptive technology in the near future.

The solar PV value chain consists of two parts which constitute around 50% each of the chain:

⇨ **global market**: silicon production, cell manufacturing and module production;
⇨ **regional market (in Europe for Europe)**: marketing and sales, engineering, procurement and construction (EPC), installation, operation and maintenance, after-sales services and energy management.

The whole value chain needs many capabilities in any given firm. The competition of Chinese PV manufacturers is a problem for many European companies given that these panels cost much less. European companies have focused on lifecycle costs and reliability to withstand price competition. However, the competitors from emerging countries are learning quickly and their performance may reach European level over the medium- to long-term.

Competitiveness in silicon, cell and module production (global market) is a volume issue, where labour cost competition can partially be addressed by advanced manufacturing technologies. As solar PV technology is relatively scalable and versatile it can be used in many different applications. The retail market (roofs of houses, commercial centres, warehouses, etc.) is a large interesting market as the price of electricity they receive is equal to or higher than that of wholesale PV farms. There, regional and local requirements come in and European companies have an advantage due to market proximity and design. This also further pushes the downstream of vertical integration as PV panels are expected to become a more common construction component in the future than in the past.

[16] See the Communication on Renewable Energy of 30 January 2011: http://europa.eu/rapid/pressReleasesAction.do?reference=IP/11/113&format=HTML&aged=0&language=en&guiLanguage=en.

Some respondents mentioned that this downstream part of the value chain has important potential for solar PV R&D and employment creation. There is an emerging trend towards improving the local living space and producing electricity locally. As soon as individual PV installations come close to the retail price for electricity and reach 'grid parity', they will become self-sustainable. Smart grids are enablers for such distributed electricity generation schemes as the electricity not produced locally must be provided by the grid and the other way around.

R&D strategy

The interviewees, all from companies headquartered in the EU, stated that a large share of their R&D was centred in the EU. Emerging markets like China or India still play a minor role and are basically focused on local development or adaptations.

The link between a critical mass of manufacturing base and R&D was pointed out. There is still a manufacturing base for solar PV in the EU, but competition from emerging countries is very intense and rapidly increasing. The danger is that, as these countries climb up the learning curve and attract more and more manufacturing volume, the manufacturing base in the EU is at the end too small and R&D is moved outside. This happened e.g. in consumer electronics.

While some companies strive to stay ahead of the competition via R&D-based innovation, the price factor is still important as in the end grid parity has to be reached.

Policy support

Only in few countries (e.g. China, Canada or Japan), domestic components (silicon production, cell manufacturing and module production) are required for receiving policy support. While European PV manufacturers suffer from competition with Chinese manufacturers, protective measures were not felt to be suitable by some interviewees as European companies are both importers and exporters and their overall competitiveness would be reduced. It was stressed that the individual companies should decide how to best increase their competitiveness, and policies should focus on making the European companies competitive globally.

It was mentioned that some Chinese firms benefit from free infrastructures and that the Chinese PV sector has grown on the back of subsidies from EU countries. It was proposed to link subsidies better to technological criteria and long-term objectives, where possible with local sourcing.

EU and national policies

Some interviewees stated that they see the Feed-In Tariff (FIT) schemes in individual Member States as very different, and some of them could actually benefit from the exchange of best practices. Realistic time horizons and targets, stability of the scheme, and progressive reduction or phasing out of subsidies were seen as more important than the mere amounts subsidised. Companies also favoured schemes where projects are subject to technological and economic scrutiny over a longer-term perspective rather than generating short-term windfall profits for standard projects.

The different retail prices in the Member States have an impact on their attractiveness for solar PV companies. It was stated that by 2015 some installations could reach the retail price in those Member States where prices are higher. Consequently, these markets are more interesting for companies to engage in solar PV generation.

3.6 Main findings from CSP companies' interviews

Structure of the CSP technology supply-side

Concentrating Solar Power (CSP) technologies are usable for larger electricity generation plants. The current demonstration plants are in the range of 20 MW upwards. No matter which of the main technologies (tower, parabolic trough, Fresnel, Stirling) is used in a CSP plant, their installation requires mastering a wide range of engineering and system integration capabilities and local conditions must be adopted. CSP plants require a minimum solar irradiation of 1800 kWh/m^2 per year upwards, so CSP plants are generally located in the world's Sunbelt (latitudes 35° north to 35° south). The southern parts of Spain, France, Portugal, Italy and Greece are areas where commercial CSP plants in EU Member States are operating or in projection.

Since the 1980s, when the first demonstration plants were built, European companies have achieved leadership in developing CSP plants and associated key technologies. The biggest market potentials for CSP are located however outside the EU, especially the US, Northern Africa, some Middle East countries, and parts of China.

Specifications for individual plant development, construction and operation are directly connected to the local conditions: weather, regulation, and space and water availability.

CSP companies are not as vertically integrated as e.g. their counterparts in wind energies.

R&D strategy

CSP technology has been driven by R&D since the 1980s. As a world-leading demonstration site, the Plataforma Solar de Almería[17] has played an important role for contributing to the current leadership of European companies and the continued CSP development. Demonstrating CSP's commercial feasibility is currently regarded as the most important challenge for the sector. In this sense, R&D for cost reduction of the total plant (installation, operation and maintenance) is becoming increasingly important as there is room for standardisation.

The direct R&D investment for the construction and operation of the CSP plant itself is generally in the range of a few percent compared to the total investment of several hundreds of million euros. These plants incorporate practical applications of other R&D results, often from other sectors (aerospace, material science, mechanical engineering, plant management informatics and radiation forecasts, water management, and energy storage systems to flatten peaks). The R&D in most CSP plants constructed today is a rather incremental innovation and contains mainly development and systems integration and few research activities. However, the former is very important for the efficiency and reliability of the plant.

Due to the technological leadership of European companies, the plants in operation and planned in the EU, and the need for local know-how, it is seen as difficult for companies from emerging countries to catch up with the technological lead of the European companies over the short-term. However, some countries, especially China, are starting to exploit the technology at a small regional scale with their local companies and make market entry subject to the participation in Joint Ventures.

[17] The Plataforma Solar de Almeria belongs to the Spanish Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT). It is the largest European centre for research, development and testing of concentrating solar technologies (see: http://www.psa.es/webeng/index.php).

Policy support

At the present stage of the CSP technological development, policy support is an important element for plant feasibility because banks are risk-averse. Commercially feasible CSP plants are limited to the Sunbelt and only few EU Member States offer specific policy support for them. The interviewees stressed that an important technological incentive could come from FIT schemes designed in a way to accommodate innovative CSP demonstration plants. Also criteria for collaboration, spillovers and standardisation could lead to further innovation. This would be especially interesting for European companies in order to further advance their technological leadership. Such schemes should focus on the development and demonstration of new technologies and phase-out once the technology proves to be commercially successful. Due to the high investment costs and long timeframe, the need for reliable support schemes over time was highlighted.

EU and national policies

Support from the EU Framework Programme generally constitutes a very small share of the overall plant investment of several hundreds of millions of euros. Compared to the Member States' FIT schemes, which are critical for project feasibility, companies tend to regard EU subsidies as complementary.

4 Main lines of discussion and validation workshop results

The objective of the validation workshop was to validate the findings of the analysis among a group of selected study participants, industrialists and policymakers. The main findings were presented, discussed and validated among the workshop participants. The discussion focused on the following key questions:

1. Stocktaking of the findings of the JRC-IPTS activity and company interviews;
2. Validation of the company perspective using firm-level data and the trends detected; and
3. Discussion of potential policy implications.

The discussion took place on the basis of the present exercise as a bottom-up study with limited scope and resources. While the discussion revealed several areas of improvement, it confirmed that the general aspects addressed, the material analysed and the companies interviewed provide interesting and relevant information and a reasonably accurate picture of the actual situation. The main results of the discussions at the validation workshop are summarised below.

4.1 Stocktaking the findings of the JRC-IPTS activity and company interviews

The study on data collection and analysis of main competition factors has identified 31 companies from a range of publicly-available information sources. These companies represent most of the sector in terms of R&D investment, but not in terms of the number of companies. For example, there are over 200 PV-related companies in the EU and 40 manufacture PV cells or modules. Also, there are many companies in PV equipment and materials, which are not covered but very important for the PV value chain.

Further, it was outlined that it is very difficult to compare EU and non-EU companies in terms of R&D investment and value-chain because of the lively competition, high firm creation and mergers and acquisitions (M&A), data coverage outside the EU, and the different framework conditions. EU PV and wind may be covered overall, but EU CSP and non-EU data are incomplete. Further, the R&D of public companies (not covered in the study) is important outside the EU, e.g. China or India. In addition, much of the data is from 2008 and would benefit from an update to 2009. The years 2008-2009 have been especially critical with respect to the position of EU versus non-EU companies, because of the combined impact of the financial crisis and the revision of FIT schemes in some countries. Faced with these financial constraints, it will be interesting to see to what degree companies will keep-up their R&D investment after the financial year 2008.

4.2 Validation of the company perspective using firm-level data and the trends detected

The interviews confirm that company strategies are highly individual, even for companies in the same market segment. This is not only the result of different ways of capturing the market, but in some geographic areas it is also the question of market access and framework conditions (e.g. grid connection issues). All these factors shape the companies' R&D strategies.

The degree of vertical integration is important when analysing the competitiveness of the industry. Along the value chain, European wind companies are the most integrated, followed by PV. CSP companies are almost not vertically integrated.

It was outlined that the final costs of the three renewables are difficult to foresee and will be very different from now to the next ten years. Advancements in energy storage may change the game, e.g. PV plus low-cost batteries for electric/hybrid cars.

Wind energy

Although the EU can be considered the R&D base for wind energy, there are many larger and fast-growing companies from outside (not only from China, but also from South Korea, the US and Japan).
Offshore wind companies need a wide range of capacities for implementing projects, and these partially overlap with the offshore industry and utilities in general.

Concentrating Solar Power (CSP)

CSP is at a different stage compared to wind and PV, because it is at the edge of commercial feasibility and needs demonstration projects. CSP is at a crossroads between a niche-technology and scale up. While there is a high degree of local supplier content, the EU's first-mover advantage is eroding and market- and technology-standards will be set in the near future.

4.3 Discussion of potential policy implications

The study was driven by the following main policy questions:

1. How can the benefits of PV, CSP and wind energy technologies be maximised in terms of employment, growth and tackling energy issues throughout the value-chain?
2. How can competition between the various technology options be enhanced?

The workshop discussions are summarised below:

The workshop made it clear that the three different technologies are at different stages of development and levels of vertical integration. Policy measures should consider the degree of vertical integration and all the players in the value-chain. Many of them may be outside from these three sectors in a narrow sense, e.g. producers of electronic components or special glass tubes. In this sense, it is important to preserve the European manufacturing base and a wide range of technological capacities. In this respect, it should be regarded with concern that cost considerations are still important for manufacturing PV panels outside the EU, but cost considerations are increasingly important as countries like China climb-up the technological ladder.

Further, related materials and technologies may become an important trigger changing the game completely. Energy storage systems may make new generator-storage combinations feasible or commercially viable. New materials may open-up new applications, e.g. higher temperature ranges.

It was stressed that the option to develop local markets is open only to few countries as this needs not only a critical mass of companies, but the whole cluster (Universities, framework conditions, testing facilities, etc.). This means co-evolution of technologies, institutions, markets and firms. It was said that at the moment Denmark, Germany and Spain have real options to further develop and sustain their home market. Creating a home market may not be sensible once the industry has reached a certain maturity. After the start-up phase, however, market growth is mainly outside Europe where there is strong local energy demand.

Also, a number of non-EU countries make market access subject to conditions, e.g. via minimum local content, obligation to participate in Joint Ventures or other location requirements. This obliges companies to knowledge-transfer and benefits local employment. Some workshop participants wondered why European countries did not generally consider these policy options.

In addition, there is also an important political element to energy-related subjects, no matter the renewable or conventional technology. Renewables have benefited from increasing awareness and support by European citizens, but together with the increasing numbers of wind and solar farms, local criticism may grow. This is however not much different to the local criticism most conventional (non-nuclear) energy technologies have to face.

Finally, the results from the interviews show that the retail market has the potential to reach an interesting volume, mainly for PV. As costs of retail installations become accessible for individuals (also through FIT schemes) and design improves, the citizen gets a real opportunity to produce an important share of the energy she/he consumes. If this becomes a trend, the playing field for energy policies will change dramatically.

5 Conclusions and policy implications

The evaluated PV, CSP and wind technologies hold great potential for tackling major energy issues and creating jobs and economic growth. The main policy challenge is to maximise the benefits across the whole value chain of these industries.

At present, costs for electricity production with PV, CSP and wind technologies are higher than for conventional technologies. Appropriate regulatory and framework conditions are a prerequisite for introducing PV, CSP and wind into the market and become competitive. The time horizon for this to happen depends on whether these industries can reduce costs and how conventional energy prices evolve. For the EU, the Renewable Energy Directive18 sets targets for increasing the average share of renewable energies in final energy consumption from around 8.5% in 2005 to 20% in 2020. The targets for individual Member States vary according to their historical shares at the starting point in 2005, and Member States are also individually responsible for the way in which they reach their target. Besides increasing the share of renewables in transport energy consumption (e.g. via biofuels or electric vehicles), renewable energy generation, especially PV, CSP and wind, will play a key-role in achieving these targets. PV, CSP and wind produce variable amounts of energy based on weather conditions and thus create multiple challenges for the existing electricity grid in terms of integrating these capacities, energy storage and distribution. For example, the creation of offshore wind generation needs seaside access and power transmission capacity towards the inland ('super grids'). For an efficient integration of smaller scale renewable installations, 'smart grids' are necessary combining large- and small-scale electricity generation and storage via interconnection and optimisation of the network-consumer connection. The longer-term context is to balance the increasing disparities between renewable energy generation surplus (offshore wind in costal regions and solar farms in southern Europe) and deficit areas (southern Germany and northern Italy). Although these challenges have been recognised and have gained political momentum at the EU level,19 the degree to which they will be resolved within the coming decades depends on how quickly they are implemented in the Member States and the interplay of all new super- and smart-grid components.

A driving factor to improve cost-effectiveness of PV, CSP and wind is competition, as these technologies also have to compete with other technologies and against the various technology options throughout the whole supply chain. An important question here is to which degree externalities are included in the cost calculation. If externalities in conventional energy generation are taken into account, some renewable technologies (wind) already have a competitive edge. The three technologies are at a different stage of development and hold different potential. Wind energy is the most consolidated industry, followed by PV (conventional c-Si) technologies. The CSP sector is the less mature industry, not yet at the stage of mass manufacturing. In order to design the best policy approach, it is necessary to identify the relevant components in terms of employment and economic impact within the value chain of each technology.

The technologies should also meet different market requirements such as centralised versus decentralised applications or global versus regional/local scope. From a policy viewpoint, it is important to apply measures to avoid lock-in conditions and to encourage new entrants.

R&D plays a key role for technology development in these industries but is not considered the main source of competitive advantage. R&D intensity (R&D as percentage of turnover) of these industries is in the range of the medium tech sectors, i.e. 2%-4 % (compared with 15%-20% in biotechnology or IT hardware industries). However, equipment manufacturing companies of some components, e.g. in the PV industry, invest about 10% of their sales in R&D.

[18] See Directive 2009/28/EC
[19] See EC (2011) and EC (2010)

In terms of R&D investment, the results of the study show that the EU companies lead in CSP and wind energy and the non-EU companies (USA and Asian) lead in PV. However, these results, based on 2008 figures, need careful interpretation since recent patterns of investment in renewable energy show significant changes. This is due to the effects of the economic crisis and to different investment reactions by emerging and developed economies. In fact, there are evidences of much stronger R&D activity in some non-EU countries, namely in China, South Korea, India, Japan and the US. Also a number of companies with significant R&D investment are not included in the study either because they have recently been created or because they do not disclose specific R&D investments in renewable energy. A conclusion on this matter is that the EU does not currently seem to under-invest in these technologies but recent trends indicate that this is to be a likely challenge over the medium-term.

Policy should observe R&D stimulation for PV, CSP and wind energy by checking if there is a balance between policy support for technological development and policy instruments, promoting market penetration of these technologies. Regarding the specific support and FIT schemes implemented in the EU, it is necessary to understand their actual impacts, for example, which part of the value chain obtains the most benefits. It is also interesting to analyse why these instruments do not trigger more R&D.

Several indicators show that, despite the economic crisis, the renewable energy sector continued to grow rapidly, in particular in emerging economies such as China and India. In 2009, the World's top 15 companies in this sector reported more than €500m annual R&D investment, 28% more than the previous year.[20] Also a significant increase in investment in renewable energy power capacity is reported, including a record high of 38 GW in wind and 7 GW in PV.[21]

There are fewer differences across world regions regarding supply factors such as workforce skills that appear equal for all regions. Conditions for access to financing are more favourable in the US market than in the rest of the world, while the EU has advantages in R&D stimulation programmes (Table 4, Table 5 and Table 6).

The large number of R&D labs in Europe is due to the good knowledge infrastructure and strong R&D stimulation policy. However there is no direct relationship between the location of R&D labs and the location of manufacturing activities. On the other hand, there is evidence of relationship between a stimulated home market and a successful industry in that country.

Manufacturing PV, CSP and wind energy technological components accounts for a large share of the value added and jobs of the entire value chain. Moreover the location of manufacturing facilities depends mainly on the attractiveness of the countries and regions. Asia (excluding Japan) appears as the most attractive region for manufacturing PV and wind energy components whereas the EU is most attractive for R&D and pilot activities. The EU and the US are both attractive for R&D and demonstration activities on CSP.

The potential of these industries to generate employment in the EU is strongly affected by the requirements in non-EU countries regarding local content or location.

It is a main policy challenge to improve conditions to keep a strong manufacturing base and related technological development in PV, CSP and wind energy industries to reap the full benefits in terms of value added and jobs.

[20] Companies included in the 2010 EU industrial R&D investment Scoreboard, see: http://iri.jrc.ec.europa.eu/research/scoreboard_2010.htm.

[21] See UNEP (2009).

Specific findings by technology

Wind energy

- The wind energy market, dominated by well consolidated onshore technology and related turbines suppliers, is changing by the arrival of large suppliers offering an integrated portfolio of power generation technologies. This trend is reinforced by the current focus on offshore wind energy where turbines have a lower share of the whole facility. Cost-effectiveness of offshore facilities has to be demonstrated, i.e. against onshore and the other technology options.
- Companies identified in this study (25 main players) reported €635m invested in wind energy R&D in 2008. Companies based in the EU largely outperform their non-EU counterparts (€482.1m versus €152.8m R&D). They are expected to maintain this leading position over the medium-term. Some non-EU companies have their R&D and pilot activities in the EU.
- European firms are world leaders in the wind energy industry thanks to a large home market and sustained public support. However, their competitive position is threatened by companies that benefit from a large and dynamic home market and are starting to venture in the European market (companies from China, the US, South Korea or Japan). Europe will need to continue to have a large manufacturing base to maintain R&D leadership over the long-term.
- R&D is important for wind energy industry (the main player invested about 5% of its sales in R&D in 2009) but it is not considered as a main factor for the competitiveness of European wind companies. R&D activities are not pursued per se but are fully integrated in sales and manufacturing strategies. Currently, most of the R&D is carried out in Europe but the question if delocalisation of the manufacturing base is accompanied by delocalisation of R&D activities depends highly on the individual firm.
- The main challenge of this industry is to reduce costs at the level of conventional energy generation technologies. European wind turbine firms need to become or remain global and develop a cost competitive generation technology. An important question is to which degree externalities are included in cost calculations. If they are taken into account, wind technologies already have a competitive edge.
- The wind energy companies interviewed in the study consider that regulatory and policy frameworks at EU level can be improved. Important issues to address are the diffusion of best practices across Member States, preventing stop-and-go policies, IPR and the coordination and integration of R&D projects, e.g. increasing grid connectivity and capacity or integrating wind energy and smart grids.

Photovoltaics (PV)

- The value chain of this industry is characterised by two different parts:

  (1) The upstream part, ranging from silicon to module production, is a global cost-driven business and concentrates most R&D efforts. The global PV market is not a level playing field. Subsidies for PV in Europe are mostly indirect (via FIT schemes) and generally open to any company. Asian and Chinese firms benefit from low labour costs and additional subsidies in their home country (e.g. access to subsidised capital and infrastructure), so that European firms consider being at a disadvantage against them. PV cell and module manufacturing is dominated by Asian countries (except for thin-film PV modules led by US companies, followed by Japanese and German companies).

  (2) The downstream part, ranging from installation, operation and management of facilities is a local or regional market driven by service and quality.

  Policies to support R&D, market deployment and systems integration for PV should address the specificities of each sub-market. In terms of employment, the downstream part of the value chain may deserve more policy attention given its potential for creating jobs in the economy of proximity.

- PV R&D for conventional modules (which are predominant) is aimed at cost reduction. R&D for thin-film technology is aimed at radically lower costs as well as achieving better efficiency. The 52 companies identified in this study reported €816m invested in PV R&D in 2008 (€239.6m by EU companies and €576.2m by non-EU ones). The EU is relatively strong, especially in thin-film R&D, although losing ground to Asia in c-Si technology. These R&D figures have to be updated to take into account significant changes arisen since 2008. To evaluate the PV R&D of the whole sector it is necessary to include other companies that invest significantly in R&D but do not disclose such figures. A recent study estimated the private sector's worldwide R&D expenditure in solar technology at US$1.8bn.[22]

- Patterns of patenting in PV show a tenfold increase in Europe, Japan and the US since 1996 and a massive growth in China and South Korea since 2006. Also a decline is observed of the EU share in PV patents since 2008.

- PV is considered to have potential to be competitive against other conventional and alternative power generation technologies over the long-term. However, at present the PV industry remains highly dependent on subsidies and on the regulatory framework. Often the PV industry has to face poorly designed or rigid support schemes and a lot of bureaucracy. Programmes at the EU level are considered having sub-critical mass, e.g. not enough R&D funding to achieve the ambitious targets.

[22] See: UNEP (2010).

Concentrating solar power (CSP)

- There are two main types of CSP plants: The predominant technology is parabolic trough-based (94% of installed capacity), it is mature, cheaper, easier to deploy but less efficient. The second one is tower-based CSP plants, offering better technical potential but more complexity. Compared with the other alterative energy technologies, the CSP industry is at an earlier stage of development and, unlike wind and PV, not vertically integrated but has high local content within its supply chain. Strong competition is essential to bring costs down and make CSP competitive against other energy generation technologies. Europe, basically Spain and Germany, is currently leading in CSP but competition from the US, China and India is expected over the next few years given the favourable financing conditions for CSP in those countries.
- R&D in CSP was a main driving factor for the starting up of early CSP plants, i.e. based on synergies with glass and metal technology. However, nowadays R&D is not considered a main driver of future growth and competitiveness of this industry.
- The EU is strong in CSP related R&D. Companies identified in this study (29) invested €116.5m in R&D in 2008. The EU (18 companies) accounted for more than two thirds of the total R&D investment on CSP.
- CSP technology has the potential to become competitive against conventional generation technologies but not before 2020-2025. Therefore, appropriate regulatory frameworks are indispensable and particularly favourable financing schemes due to the high level of investment requirements of CSP plants. Also, further standardisation is needed such as that implemented for wind energy technologies. Policy support should take into account the specific techno-economic characteristics of this industry, i.e. of each sub-market, and the level of resources should match the ambitious targets, e.g. of the EU SET plan.

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Annex: Agenda and Participants of the Validation Workshop

The objective of this workshop held on 28 February 2011 in Brussels was to validate the findings of the analysis among a group of selected study participants, industrialists and policymakers. The main findings were presented, discussed and validated among the workshop participants.

The discussion focused on the following key questions:

a) Stocktaking of the findings of the JRC-IPTS activity and company interviews;
b) Validating company perspective using firm-level data and the trends detected; and
c) Discussing potential policy implications.

AGENDA

13h00-13h15 Welcome and Introduction

- Welcome, introduction and overview of the study (DG RTD-C and DG JRC-IPTS)

13h15-14h00 Main findings from company data analysis

- Collection of company data, industrial insight and analysis of supply and demand factors (DGJRC-IPTS and Wiep Folkerts (Ecofys))

- *Discussion (all participants)*

14h00-14h45 Main findings from company interview analysis

- Results from key players' interviews (DGJRC-IPTS and Nicolas Brizard (Enerdata))
- *Discussion (all participants)*

14h45-16h15 Review statements by appointed experts

Photovoltaics (PV) and Concentrating Solar Power (CSP):
Marianne Haug (University of Hohenheim)

Wind Energy:
Paul Lako (ECN)

- *Discussion (all participants)*

16h15-16h30 – Conclusions and policy implications

- Conclusions and policy implications (DGJRC-IPTS and DG-RTD)

The main recommendations of the validation workshop are reflected in the present document.

List of participants:

External experts:

Athanasia Arapogianni (EWEA - The European Wind Energy Association)
Nicolas Brizard (Enerdata)
Wiep Folkerts (Ecofys)
Daniel Fraile Montoro (EPIA)
Pepe Fresneda (Estela Solar)
Marianne Haug (University of Hohenheim)
Holger Ihssen (Helmholtz Association of German Research Centres)
Angeliki Koulouri (EWEA - The European Wind Energy Association)
Paul Lako (ECN - Energy research Centre of the Netherlands)
Mariàngels Pérez Latorre (Estela Solar)

From the European Commission :

Piero de Bonis (DG-RTD)
Norela Constantinescu (DG-ENER)
Lennart Grundberg (DG-ENTR)
Andrea Hercsuth (DG-ENER)
Thierry Langlois d'Estaintot (DG-RTD)
Héctor Hernández-Guevara (DG-JRC)
Fernando Hervás-Soriano (DG-JRC)
Lin Luo (DG-JRC)
Arnaud Mercier (DG-RTD)
Miroslava Naneva (DG-RTD)
Caroline Thevenot (DG-RTD)

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Abstract

This report shows the results of a techno-economic analysis of key renewable energy technologies: Solar Photovoltaics (PV), Concentrating Solar Power (CSP), and Wind Energy Technologies (wind). In these sectors, bottom-up company-data were collected, market supply and demand factors addressed, the regulatory framework examined, and EU industry compared against its main competitors. Personal interviews with 10 key industrialists from these sub-sectors were undertaken to generate first-hand feedback from companies. The information generated was validated in a workshop held on 28 February 2011 with selected study participants, industrialists and policymakers.

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