



PV - EC - NET

A SWOT ANALYSIS of PV RTD in Europe

Strengths, Weaknesses, Opportunities and
Threats of Photovoltaic Research, Technology
Development and Demonstration in Europe

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In memoriam Pentti Passiniemi, co-editor of this report



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Executive summary

Photovoltaic Solar Energy is one of the renewable energy sources with significant future potential. After a slow start caused by the initial high costs of PV, the world market for PV is now growing strongly with an average annual growth of approximately 25% over the last 5 years. This success is mainly derived through market stimulation and intensive RTD work during the last 10 years in Japan, the USA and Europe, causing a price reduction of a factor 3 since 1990.

The action undertaken here is part of the accompanying measure 'PV-EC-NET' (Photovoltaic European Co-ordination NETwork) which has the objective of co-ordinating organisations of the National PV RTD programmes of the Member- and Associated States of the EU in order to formulate common targets and to ensure a maximum coherence between the PV RTD programme of the EC and the independent National PV RTD programmes of the Member- and Associated States of the EU.

This report gives the results of the work carried out under work package 5 of the project: Formulation of a European PV RTD Road Map.

Based on a SWOT analysis and the benchmark activities in Work Package 4, the factors and mechanism have been identified (both on national and EU level), which could lead to a European PV RTD scheme, which strengthens the competitiveness for European industry, employment and security of energy supply. Focus has been placed on factors, which are general for several technologies, but crucial factors for a single technology will also be identified.

The SWOT analysis of the EU PV research level has been done in two steps: first the analysis of strengths and weaknesses, and subsequently of opportunities and threats. This is due to strengths and weaknesses relating to the research community itself, i.e. inward looking aspects, while opportunities and threats more relates to aspects outside the research community. Now these aspects are naturally related, and aspects of outward and inward nature have to be looked upon in parallel.

For the SWOT analysis we have identified a number of key issues which has been dealt with for each PV technology area.

The key issues regarding strengths and weaknesses are:

- R&D activities
- Industry
- Communication

The key issues regarding opportunities and threats are:

- R&D
- Industry
- Raw materials
- Policies
- Market development
- Intruding technologies



In this analysis the ecological aspects of PV did not become an issue. As one of the renewable energy sources PV has positive value, a “green image”, which has influenced on the national BIPV support programmes.

The main findings and conclusions from the SWOT analysis are presented in the table below.

Summary and overall assessment of the SWOT analysis

Strengths	Weaknesses
<ul style="list-style-type: none"> • Europe has strong and high level R&D quality in PV covering all major technologies and is geographically well spread. • The high-tech nature of PV is appealing and countries with a PV industry recommend sustained R&D efforts. • Well-developed R&D communication networks mainly due to EC funded projects that help to create teams with various competencies into PV RTD projects. • The SME structure of the PV business in Europe enables fast reactions to the market needs • European R&D strong in thin film cells, organic cells, polymers, BIPV and advanced stand-alone systems. • The existence of the roof programmes that stimulate the PV market. • European industry is strong in BOS and stand-alone systems. 	<ul style="list-style-type: none"> • Because PV RTD is evenly distributed both in technologies and geographically, effort is diluted and may not keep Europe competitive in key areas. Lack of critical mass. • Too few countries have dedicated PV programmes. • Not enough countries have fully co-ordinated programmes. • Communication between the academic and industry R&D with policymakers is not frequent. • Academic R&D and industry have different priorities. • The lack of standardisation of key PV system components. • European PV companies, which are often SME, are not making enough profit to be able to develop, on their own ground, new technologies/concepts that are not immediately commercialised.

table continues overleaf

Opportunities	Threats
<ul style="list-style-type: none"> • EC policies on security of supply, the Renewable Energies directive and the fulfilment of the Kyoto targets stimulate the PV market. • Renewable Energies including PV have by their nature long term potential. • Research co-operation between Europe, Japan and the USA speeds up PV RT • The extension/increase of current roof programmes and widening to other EU member states creates more solid base for PV industry. • A stable PV market stimulates industrial involvement and availability of financial risk capital. • Co-operation with the building sector helps them to understand what PV can Offer and PV industry understand about the building sector trends. • Cross fertilisation with other industry areas (thin film, glass coating) create possibilities for new production concepts. • Thin films (other than α-Si), polymer cells and combinations between crystalline silicon cells and thin film technologies open up potential for cheaper and new type of PV module production. • Developing countries offer remarkable market for stand-alone systems and small grids in. 	<ul style="list-style-type: none"> • The stop and go of policies and funding programmes create uncertainties to PV RTD. • Resources spent on PV R&D without substantial commercial success may result in redirection of R&D funding. • The strong Japanese PV RTD activities and PV industry weaken European industry position and national interest into PV RTD. • PV RTD is a long term investment and the current PV market relatively small so that stakeholders interest directs somewhere else. • Latest strong growth of PV is based on roof programmes. If they are reduced, that may threaten RTD programmes. • Big parent companies become impatient in poor profitability of PV and reduce efforts to it. • The PV sector, as it is now, does not respond to the tendencies of the liberalised electricity market. • Liberalised markets tend to favour low cost, off-the-shelf technologies, which is a threat PV technologies being a "new" creation.

Introduction and Background

1.1 THE PV-EC-NET PROJECT

Photovoltaic Solar Energy (hereafter called PV) is one of the renewable energy sources with significant future potential. After a slow start caused by the initial high costs of PV, the world market for PV is now growing strongly with an average annual growth of approximately 25% over the last 5 years. This success is mainly derived through market stimulation and intensive RTD work during the last 10 years in Japan, the USA and Europe, causing a price reduction of a factor 3 since 1990. However, with 'Business as usual' and thus with the present growth rate, the contribution of PV to the electricity production in Europe in 2020 is not likely to exceed 2.4%. For another price reduction by a factor 3 to 5, which is needed for PV to become competitive, an even more effective RTD activity is required during at least the coming 10 years coupled with commensurate market developments.

It is generally perceived that the budgets for PV RTD programmes in Japan and the USA are significantly greater than in the EC. Furthermore, a substantial proportion of the European budget comes from the National PV RTD programmes and relatively less from the EC PV RTD programme, with consequentially less formal co-ordination between these programmes. By comparison, in Japan and the USA it appears that there is a significant level of coherence and inter-connection across the programme activities. For Europe to retain an important role in the world PV market it is therefore important to use the funding within the EU in the most efficient way.

Within the European community, RTD activities in the field of PV are supported by European and National programmes. It has been suggested that with this multi-programme approach, the RTD work in the field of PV carried out in the different countries might include 'inefficient' and 'unnecessary' duplication. This is more a feature of Europe's RTD landscape and is not unique to PV

The action undertaken here is part of the accompanying measure 'PV-EC-NET' (Photovoltaic European Co-ordination NETwork) which has the objective of co-ordinating organisations of the National PV RTD programmes of the Member- and Associated States of the EU in order to formulate common targets and to ensure a maximum coherence between the PV RTD programme of the EC and the independent National PV RTD programmes of the Member- and Associated States of the EU.

The aims of PV-EC-NET are therefore:

- Improvement of the coherence of National and European RTD Programmes on PV Solar Energy;
- Development of a RTD Roadmap for PV through analysis of existing activities and working together with similar initiatives;
- Making an inventory of the long term possibilities for PV as one of the potentially significant energy sources for the EC.

The underlying goals, supporting these aims are:

- Establishment and dissemination of a common information base on PV RTD programmes, activities and achievements in the field of PV RTD within the EU
- Identification of strengths and weaknesses of the EC in the field of PV
- Formulation of new EU funded RTD co-ordination activities in the field of PV



- Benchmark of the National and European PV RTD programmes
- Harmonisation of activities with other organisations and networks
- Inventory of the European PV position in relation to other regions in the world

The activities required to achieve these aims underlying goals are:

- Share visions, exchange results and harmonise and divide, where possible, the PV RTD priorities amongst the member states while including national governments in these activities
- Identify and determine the most promising options for future PV RTD and formulate commonly shared targets for PV RTD activities and the approaches to reach those targets
- Investigate the possibilities and problems of large scale application of PV in the EC, assessing e.g. required surface, storage, grid connection, AC or DC nets, combination with other RE sources, etc.
- Set up information channels for PV RTD activities, including the creation of a web site on PV RTD activities and results
- Perform a SWOT analysis of the European PV position in general
- Identify new areas and fields requiring attention and co-ordination by e.g. Thematic Networks or Concerted Actions
- Compare the national and European PV RTD programmes with respect to vision, strategy, targets, budgets, approaches and results
- Compare targets of the PV-EC-NET and the PVNET with e.g. EPIA, EnR, CENELEC, EUREC, IEA and IEC
- Comparison of the European and national strategies, activities, etc. with other strong PV areas

Within the overall PV-EC-NET project, the work has been organised in the following work packages:

Work Package 1: Network Management

Work Package 2: Co-ordination with other Platforms

Work Package 3: Collection of Information

Work Package 4: Analysis of the National and EU Programmes

Work Package 5: Formulation of a European PV RTD Road Map

Work Package 6: Dissemination of Information.

Work Package 7: Proposing Recommendations for National Governments and the European Commission

1.2 THIS REPORT

Within the framework outlined above, this report gives the results of the work carried out under work package 5 of the project: Formulation of a European PV RTD Road Map.

Based on the SWOT analysis and the benchmark activities in work package 4, the factors and mechanism have been identified (both on national and EU level), which could lead to a European PV RTD scheme, which would strengthen the competitiveness for European industry, employment and security of energy supply. Focus has been placed on factors which are general for several technologies, but crucial factors for a single technology will also be identified.

The overall SWOT analysis is based on specific SWOT analyses made for different PV technologies by ADEME (crystalline silicone cells), INETI (α -Si thin film cells), FORMAS (other thin-film cells), DEA (organic cell, polymers), NOVEM (BIPV), and NAPS (Inverter/BOS and stand-alone systems).

The rest of the report is set out as follows:

A more detailed presentation of the methodology and approach used for the SWOT analysis is presented in Section 2.

Sections 3 focus on the individual SWOT analyses for the different PV technologies within the following key areas:

Strengths and Weaknesses

- R&D activities
- Industry
- Communication

Opportunities and Threats

- R&D
- Industry
- Raw materials
- Policies
- Markets
- Intruding technologies

Overall assessments with major conclusions are presented in Section 4.

2 Methodology and Approach

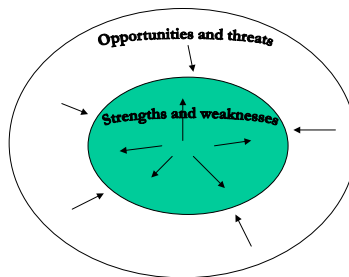
The SWOT analysis was performed using questionnaires sent in by members of the work package, compiled in a table and subsequently analysed and compared. The questionnaire and method are described in Annex 2.



3 SWOT analysis

3.1 GENERAL ASPECTS ON SWOT ANALYSIS OF PV RTD

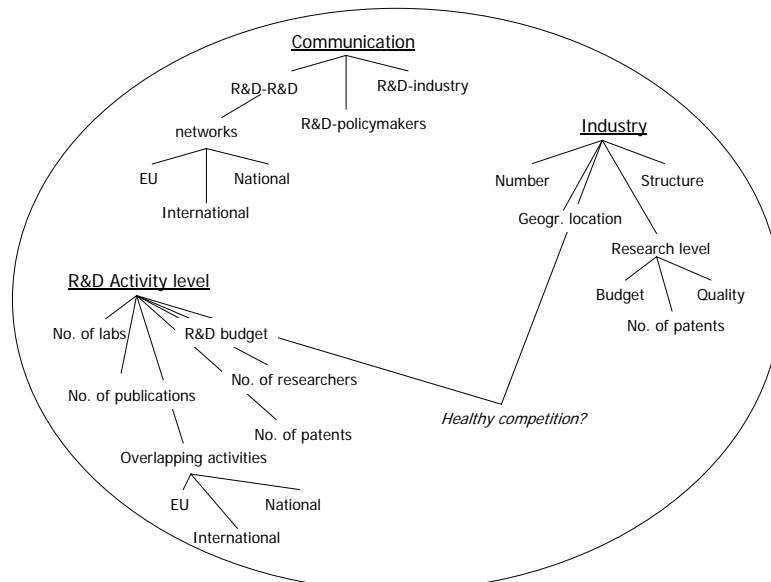
The SWOT analysis of the EU PV research level has been done in two steps: first the analysis of strengths and weaknesses, and subsequently of opportunities and threats. This is due to strengths and weaknesses relating to the research community itself, i.e. inward looking aspects, while opportunities and threats more relate to aspects outside the research community itself. Now these aspects are naturally related, and aspects of outward and inward nature have to be looked up in parallel. This can be schematically shown as follows:



Strengths and weaknesses

Strengths and weaknesses depend on several issues schematically shown in the picture below:

Strengths and weaknesses – “looking inward”

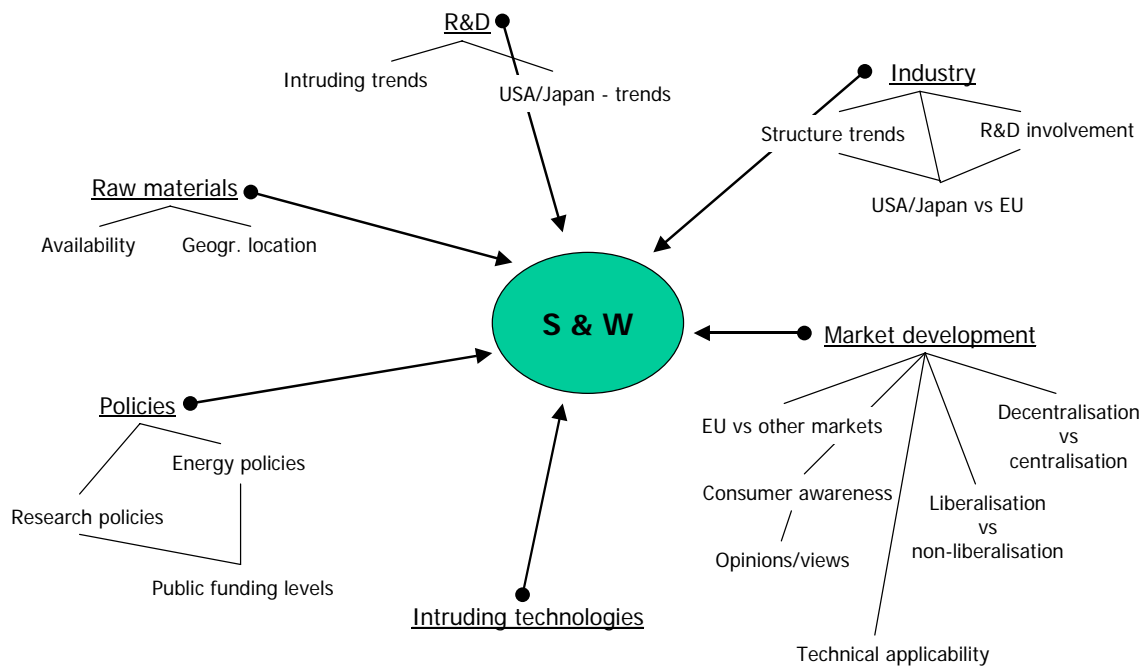


From this picture we have localised a number of key issues: Materials, industry, communication and R&D activities. These has been dealt with for each PV technology area separately (see summary tables from SWOT analyses in appendix1).

Opportunities and threats

Opportunities and threats depend on several issues schematically shown in the picture below:

Opportunities and threats – "looking outward/trends of today"



Note that all aspects dealt with in this picture should be seen as short-to-medium-term trends, and the assessment has been done from this point of view. From this picture we have localised a number of key issues: R&D, industry, raw materials, policies, market development issues and intruding technologies. These have been dealt with for each PV technology area (see summary tables from SWOT analyses in appendix1).

3.2 CRYSTALLINE SILICON CELLS

3.2.1 Strengths and weaknesses

R&D activities

There are 38 laboratories in Europe and the main actors are in Germany, Netherlands, France and Italy. The R&D budget is estimated to round 26.4 MEUR with additional budgets for other related technologies and general renewable energy R&D. There are some overlapping activities between public/university laboratories but there are a variety of approaches that make each laboratory unique in its endeavour.

Despite the fact that crystalline silicon cells (c-Si) for PV represents 25 years of investigation the potential for patents is still rich. However, the cost of patenting in the EU is ten times that of the USA (mainly due to translation), which is seen as a negative factor for competitiveness based on exploitation of technologies in general and PV technology in particular.

Most of the PV-EC-NET participating countries having a c-Si RTD activity declare that the field of crystalline silicon is strong. There are several teams working in co-operation with industry, among them research centres of high reputation. The number of publications in most of the conferences (being national or sponsored by EC) represent an average 40 % of the publications presented in the field of research and technical development on PV cells and modules. The public laboratories are also involved in medium to long term approaches e.g. material studies like crystalline silicon ribbons, or cell studies using combinations of c-Si wafers and amorphous silicon layers (see thin film silicon section).

The ‘competitiveness’ between the various public/university laboratories maintains a very good level of activity. Most of the European public R&D teams in the field of c-Si have co-operated in pre-competitive EC FP programmes involving public research and industry teams. It has to be noted that the level of exchange of information between Member State organisations co-ordinating R&D PV activity is low. The PV-EC-NET network was a successful occurrence on that respect and it is the intention of participants to continue co-operation in the future.

Concerning PV RTD, there are only two countries (FRA and CHE) having a structured programme of R&D (strategy, objectives, and projects). Other countries have activity in the PV field within generic activities on renewable sources of energy but this does not mean that the quality of work is poorer. A national RTD PV programme allows better pooling of resources particularly when there are several research teams in the same field.

A weakness of the European RTD organisation is the wish of the Commission to have too many teams in one single project. It dilutes the effort and teams are complaining of having to do more and more paperwork.

Recommendation to avoid recurrent evaluation difficulties of RTD project funded by EC and Member States. Projects must involve clear work packages with milestones against which future achievements can be measured. Regular updating of detailed objectives and work packages must also be envisaged.

Industry

There are 29 industrial R&D teams involved in c-Si field and the industry's R&D budget is estimated to round 24 MEUR with additional budgets for other related technologies and general renewable energy R&D. The companies are small to medium size businesses, most of the companies are subsidiaries of larger companies (petroleum, electronic and electric, high-tech. materials, etc.). Some among the most important belong to non-European companies.

The quality of R&D results achieved in projects granted by the national governmental agencies and the EC are rated 4 (5 is best) by the participants of PV-EC-NET. Some very fine achievements led to innovative techniques (directional solidification, cold crucible, wire sawing of thin wafers, plasma enhanced nitridation...) though no breakthrough was reported in recent years. This is due to the fact that c-Si technology progresses with step by step improvements of the various manufacturing processes.

The number of patents registered has not been worked out. The technology is gaining maturity and the industrialists develop a valuable know-how, which is often kept in-house.

Most of c-Si PV companies have a technological development activity. RTD plays an important role in maintaining competitiveness. Five to ten percent of turnover is devoted to this type of activity. The RTD activity is of international level. The industry publishes some of the achieved results in international conferences when their work receives public funds from Member States or the EC. Otherwise they keep their proprietary results for themselves (there is a lot of know-how in this industry). The JRC from Ispra played an important role in participating to the definition of standardisation procedures and qualification of c-Si PV modules. Now the industry claims a 20-year guarantee of their PV modules and accredited JRC delivers quality approval certification.

Within the EU there are manufacturers of crystalline silicon ingots, wafers, cells and PV modules. The PV modules are the commercial end products of the industry. Crystalline silicon modules represent 90 % of world-wide commercial module sales. Europe is producing 30 % of the world production of PV modules. The reliability and the quality of commercial PV modules improved over the years.

The c-Si PV European industry is still fragile. It is a capital-intensive industry asking large amount of investments (1.2 MEUR for an annual capacity of one megawatt of PV cells). The c-Si companies are not making enough profit to be able to develop on their own grounds new technologies or new concepts that are too far from industrialisation. It also takes time and money to have these new concepts introduced into the production line (2 to 4 years). Therefore, a number of public laboratories able to advance the technology and to propose (sell) the results to industry is needed.

The weaknesses of the c-Si field are its dependence on cheap feedstock of high purity. Feedstock silicon today comes from the refuse of electronic grade manufacturing. Once at 10 EUR/kg till mid 90s it increased to 25 EUR/kg today. The cost of feedstock represents roughly 10 % of the cost of a PV cell. It is said by industry that it is an upper acceptable limit. The amount of material available on market is getting scarce. In Europe there are several studies and attempts to propose solutions but they have not materialised yet and one of the reasons is the threat of cost effective thin film appearing on the market (so far thin films modules have not demonstrated this low cost capability).

A few companies are vertically integrated starting from ingot manufacturing to module fabrication. It is considered that vertical integration is a prerequisite to industrial competitiveness. Nevertheless, more recently the high demand of wafers and cells by module manufacturers allowed some companies to start business in the sector of ingot manufacturing and wafer manufacturing

Communication

There is a long tradition of shared work between the public research teams and the industry. Such co-operation was a prerequisite of public funded projects by national agencies and the EC RTD programmes. There are some private research contracts between industry and public laboratories. However, it is claimed that c-Si SMEs are not profitable enough to make such contracts a current practice.

The relationship between public research and policy makers is fine when there is a structured national RTD programme otherwise it is often noticed as loose. The researchers know the RTD programme managers and discuss with them to seek advice or when RTD contracts are negotiated.

The c-Si RTD community of PV teams is well established thanks to the EC framework programmes. Some are still active but they are dependent on EC funding.

Concerning communication between the researchers of both industry and public organisations it is acknowledged that in the field of c-Si the structured national activities and the EC FPs have contributed to several projects of high quality.

3.2.2 Opportunities and threats

R&D

Crystalline silicon based technologies are, according to various experts, the industrial technology that will be difficult to beat concerning conversion efficiency (20 % range) and production costs (less than 1 EUR per watt), and that situation might prevail for 15 to 20 years. Crystalline silicon field is no breakthrough-type technology but the strong European research base will allow new fields of investigation (low cost and high throughput process for producing feedstock silicon, thinnest and larger cells, revisited concept of multi-crystalline silicon ribbons, combinations of c-Si and a-Si, nanotechnologies, porous silicon, new concepts to make PV modules, etc.). According to experts one must push the research to 'the bone'. Moreover there are opportunities to develop new PV modules combining building materials and crystalline silicon cells. There is an opportunity for both the PV industry and the building industry to develop new components and new markets.

European c-Si research is in good position compared to Japan and the USA who also have RTD in the field. There are no threats coming from them at the university level but it is not the case in the commercial field where the actors are fierce competitors. There are opportunities to develop research co-operation's at university level between Europe, Japan and the USA. Co-operation between university laboratories is easier than that of the industry and should be reinforced. Already some bilateral co-operation operates (exchange at post-doctoral level).

It is generally commented that the Europeans study the materials, the US develops the devices and the Japanese sell the final products. PV does not escape from this statement (the case of thin film hydrogenated amorphous silicon material is striking on that respect). It does not mean that Europe must reconsider its tradition of basic research but Europe must insure that SMEs can benefit from favourable conditions to implement new technologies.

Concerning R&D the threat could be a lassitude of public policy makers not seeing in c-Si the breakthroughs they hope. The c-Si technology is improved step by step.

Industry

The Japanese c-Si industry is very strong and competitive. Sharp company the biggest c-Si producer and is the price leader in the field causing a lot problem e.g. to c-Si cell and module European producers. Kyocera company has developed high efficiency poly-c-Si cells and is going to aggressively develop technology further targeting to 18 % cells within a couple of years time. The USA is making an effort on c-Si process development. In Japan the policy is still oriented towards high efficiency c-Si cells. There is an opportunity for European researchers to 'compete' or co-operate with American and Japanese industry teams in that field. However, industry R&D co-operation is possible only within corporate contracts.

The European high-tech SMEs hold the key to employment and growth. Photovoltaics are an innovative source of new, high quality jobs. The SMEs involved in PV field (from materials to installation) contribute to this development.

A threat to c-Si technology is the constant claim of the promoters of thin film concepts that pretend that their technology is the future since thin films fit well with large area glass panels (general statement nobody opposes). Thin film are claimed to be cheaper to produce (theoretically half the production cost of c-Si if large amount is produced like 500 MW per



year), etc. thus making potential investors in c-Si field waiting for these thin films cells to demonstrate their claimed capabilities. Particularly the investors on feedstock silicon that would need an important market to justify their investment.

Financial investments in the c-Si technology are still high and greater than that of other PV technologies. Nevertheless it is questionable whether small companies with limited cell/module production capacity (say an annual capacity of the order of 10 MW) can survive against larger companies able to mass-produce (capacity of the order of 100 MW).

Raw materials

At laboratory level the best PV cell conversion efficiency attained is almost 25 %. In the industry the commercial product is 14 % to 16 % efficient. Thus there is still scope for improvement. The challenge is to reach this record efficiency at very low cost.

Policies

The public RTD money investment allowed the development of a European PV industry employing high-tech well-trained people. Photovoltaic technology is a renewable source of energy not ignored by policy makers. The high-tech nature of PV is appealing and countries where there is a PV industry recommend a sustained R&D effort.

The PV c-Si technology has a long history (25 years). It is at the same time a strength and an opportunity or threat. The technology is often regarded as old fashioned compared to more promising thin film approach.

A threat on public research is the stop and go policy (why to maintain effort on this well-known material? Why not invest more in thin film, etc.). This situation occurred in the past at the EC level. Fortunately certain Member State programmes maintained support of the c-Si field at national level. There is constant need to explain why R&D effort must be maintained on this technology.

Markets

Crystalline silicon technology is well established. Building integration of this type of material is a new opportunity for the European PV and building industry.

The European strong PV R&D base is a chance for a competitive c-Si industry. Companies announce new investments in production capacity. Nevertheless there are hesitations since European market is not fully established and the important potential export market depends upon international aid programmes. In Europe several new companies entered the field during the last three years.

PV requires policies for market development. High investment cost is a barrier. Several approaches are developed by countries (feed-in tariffs, subsidies, green electricity schemes, low interest loans, etc.). A study on the results of the various policies in connection to deregulation of electricity market might be a way to determine the most appropriate policy.

Intruding technologies

The main threats to c-Si field technologies are coming from thin film technologies. Nevertheless there are approaches such as multi-crystalline silicon ribbons, silicon microspheres, thin layers of c-Si on foreign substrate that might become a threat to silicon wafer

based technology. The c-Si industry might be able to switch from wafering to another approach without putting too much long-term investment in question.

Summary of SWOT analysis for crystalline silicon cells

Strengths	Weaknesses
<ul style="list-style-type: none"> • Most of the PV-EC-NET participating countries having a c-Si RTD activity declare that the field of crystalline silicon is strong. • The c-Si RTD community of PV teams is well established thanks to the EC framework programmes. • Several teams working in cooperation with industry, among them research centres of high reputation. • The long tradition of shared work between the public research teams and the industry. • The public laboratories are involved in medium to long term approaches e.g. material studies • RTD plays an important role in maintaining the competitiveness of the c-Si companies. • European c-Si research is in good position compared to Japan and the USA. • The high-tech nature of PV is appealing and countries where there is a PV industry recommend sustained R&D effort. • The definition of standardisation procedures and qualification of c-Si PV modules. • EU holds manufacturers of crystalline silicon ingots, wafers, cells and PV modules. • Europe is producing 30 % of the world production of PV modules. Crystalline silicon modules represent 90 % of world-wide commercial module sales. 	<ul style="list-style-type: none"> • Only two countries (FRA and CHE) have a structured national programme for RTD on PV, which allows better pooling of resources particularly when there are several research teams in the same field. • The wish of the EC to have too many teams in one single project. It dilutes the effort and teams are complaining of having to do more and more paperwork. • The evaluation difficulties of RTD project funded by EC and Member States. See report of WP4 Benchmarking regarding SMART (Specific, Measurable, Ambitious/Realistic and Time-bound). • The cost of patenting in the EU is ten times that of the USA. • The level of exchange of information between organisations co-ordinating R&D PV activity is low. • The c-Si PV European industry is still fragile. It is a capitalistic industry asking large amount of investments. • The c-Si companies are not making enough profit to be able to develop on their own grounds new technologies or new concepts that are too far to industrialisation. • A few companies are vertically integrated which is considered to be a prerequisite for industrial competitiveness. • The dependence on cheap feedstock of high purity. The cost of feedstock represents roughly 10 % of the cost of a PV cell. • The amount of material available on market is getting scarce.

Opportunities	Threats
<ul style="list-style-type: none"> • The European strong PV R&D base is a chance for a competitive c-Si industry. • To develop research co-operation's at university level between Europe, Japan and the USA. • To develop new PV modules combining building materials and crystalline silicon cells. • PV is an innovative source of new, high quality jobs. The SMEs involved in PV field contribute to this development. • Companies announce new investments in production capacity. • In Europe several new companies entered the field during the last three years. • Financial investments in the c-Si technology are still high and greater than that of other PV technologies. • Production of poly-c-Si cells with efficiency now close to 16 % and in middle term 18 % at no cost increase will open up more market opportunities for PV. • EU companies can create full chain from solar grade Si to modules enhancing competitiveness. 	<ul style="list-style-type: none"> • A threat on public research is the stop and go policy. This situation occurred in the past at the EC level. Fortunately certain Member State programmes maintained support of the c-Si field at national level. • Public policy makers not seeing in c-Si the breakthroughs they hope. The c-Si technology is improved step by step. • The Japanese c-Si industry is very strong and competitive. • Hesitations on new investments, since European market is not fully established and the important potential export market depends upon international aid programmes. • Small companies with limited cell/module production capacity can not survive against larger companies able to mass-produce (capacity of the order of 100 MW). • The constant claim of the promoters of thin film concepts that their technology is the future since thin films fit well with large area glass panels, are claimed to be cheaper to produce etc. Thus making potential investors in c-Si field waiting for these thin films cells to demonstrate their claimed capabilities.

3.3 THIN FILM SILICON CELLS

3.3.1 Strengths and weaknesses

R&D activities

There are more than 30 laboratories with many researchers spread over different research institutions and universities all over Europe. The total R&D budget is almost 25 MEUR with additional budgets for other related technologies and general renewable energy R&D. There are some overlapping activities but there is a good co-operation between the R&D institutions. There is a high quality level of R&D based on many labs spread all over Europe. In fundamental research several institutions reached excellence. This high level can be considered more a result of national efforts rather than a European strategy or policy. There is a wide fragmentation of PV RTD activities in this field.

The number of articles in reference journals is of the order of 50 in Europe in the last two years (increased in recent years). However, there are not too many patents registered found (less than 10).

Industry

The industry R&D budget is about 10.4 MEUR with additional budgets for other related technologies and general renewable energy R&D. Very small industrial activities are connected to the labs. There is a good tradition and quality of R&D in industry in this field (since early 80's). The size and structure is described as large with international ramifications but is mainly geographically placed in Germany with the concentration in just one large industrial partner. The patents are mainly concentrated in industrial companies.

There is one major industrial actor in Germany (Phototronics- RWE) and other actors not specifically related to silicon thin film technologies like Akzo Nobel-Shell in the Netherlands (roll-to-roll) Intersolar in UK, Duna Solar in Hungary, Free Energy Europe in France, VHF Technologies in Switzerland and Eurosolare in Italy (in connection with Pacific Solar, Australia).

The good co-operation though the high level R&D in Europe has not yet been translated in strong and competitive industrial partners. The cost of production equipment introduces the main barrier in limiting further silicon thin film production effort.

There is a lack of a strong and competitive European industry when compared to Japanese industry. This is probably due to the fact that European industry in this technology is spread in small companies connected to labs and the costs of production equipment are high with pay back times that can be long. The exception could be if stable silicon thin film markets could support the decision of big PV companies to invest in this technology.

Communication

Communication must be increased either between R&D and industrial partners and both with policymakers. The networks can be a way to increase this lack of communication. One important and well organised network on this technology is aSiNET and a new 6FP Network of Excellence is being proposed. Further initiatives are being proposed covering the analysis of bottlenecks to the development of thin film technologies as a whole (mainly transparent conductive oxide and development of large area new deposition equipment).

3.3.2 Opportunities and threats

R&D

It's a well known area with increased interest. The efficiency is not yet good enough calling for more R&D probably targeted to the association of silicon thin films with crystalline technologies. The collaboration between crystalline and silicon thin film technologies bringing together both technologies will represent an important opportunity.

Though Europe R&D has high level results it is still behind those of Japan and USA which constitute important threats to European R&D. A larger degree of co-ordination of national policies and support from European programmes is essential for filling this gap.

Industry

Japan's industry is an important threat with several companies (SHARP, SANYO, KANEKA, MITSUBISHI) already in the market of thin film technologies. The reputation of the thin-film Si technology has somewhat suffered from closing the US factory by BP Solar.

The lack of industrial competition in Europe will not lead to R&D involvement of industry. More SMEs based on industry collaboration with R&D institutions is an opportunity.

Raw materials

There is plenty of raw material with widespread geographical location.

Policies

This technology will lead to lower prices of electricity production and lower material consumption and in this context it is hoped that the trend will be to an increased support of R&D in this field. An increase in funding is needed both at National and European levels in order to fight the threat of the Japanese industry.

A better co-ordination between National and European policies towards the development of strong and competitive European industry is important.

Markets

The European market is not yet aware of this technology though there is a high technological level of knowledge in Europe (mostly at R&D level). The European market is threatened by the strong Japanese competition.

These technologies are well fitted for Building integration of PV giving lead to a decentralised electricity production future.

Intruding technologies

No specific intruding problems have been identified. On the contrary it is advisable to promote synergies between silicon thin film and silicon crystalline wafer technologies.

3.3.3 Summary of SWOT analysis for thin film silicone cells

Strengths	Weaknesses
<ul style="list-style-type: none"> • The high level and strong R&D spread all over Europe in many Research institutions. • The good co-operation between the R&D institutions. • Well known materials (Silicon). • Low quantity of active material required. • The possibilities of deposition over several types of substrates namely flexible and curved surfaces. • The cross fertilisation with other technologies widely diffused (Liquid Crystal Displays, X ray detectors, etc.). • Plenty of raw material with widespread geographical location. 	<ul style="list-style-type: none"> • The level of communication and networking between R&D, policymakers and industrial partners. • The lack of a strong and competitive European industry in comparison with the Japanese industry. • European industry is spread over small companies connected to labs and the costs of production equipment are high, usually with long payback times. • European industry is lacking competitiveness and the market is not yet aware of this technology. • Low efficiency of devices • The low stability of material and devices • The need for safety rules for material processing. • Pull-out of BP Solar from a-Si production lowers reputation of the a-Si concept.
Opportunities	Threats
<ul style="list-style-type: none"> • A larger degree of co-ordination of national policies and support from European programmes is essential for filling the gap to Japanese and US R&D. • A better co-ordination between National and European policies towards the development of strong and competitive European industry is important. • More R&D targeted to the association of silicon thin films with crystalline technologies for increased efficiency. • Silicon thin film technologies will be cheaper, and use less material. • Building integration of PV giving lead to a decentralised electricity production future. • A stable silicon thin film market could support the decision of big PV companies to invest in this technology. 	<ul style="list-style-type: none"> • Though Europe R&D has high level results it is still behind those of Japan and USA. • The lack of industrial competition will not lead to R&D involvement of industry. • European Market is not yet aware of this technology though there is a high level technological knowledge (mostly at R&D level) in Europe. The European market is threatened by strong Japanese competition. • Companies and financiers get tired to low speed in fulfilling the expectations the thin film technologies have given.

3.4 OTHER THIN FILM CELLS

3.4.1 Strengths and weaknesses

R&D activities

There are 25 laboratories within the EU. The total R&D budget is 10.7 MEUR with additional budgets for other related technologies and general renewable energy R&D. Thus, there are many activities in many small units except from the four large in Germany (2), Sweden and France.

The laboratories have partly overlapping activities, but with a healthy competition and collaboration and four or five labs having international status and "commercial potential". 4 competing medium size labs are preferable to one large one without competition. In addition, large budgets for small consortia give better incentives for close R&D/industry collaboration and possibilities for patent registrations.

Thin film R&D in the EU has a long and strong reputation, and several networks have been up and running for many years. Budgets are rather high and the industrial involvement is substantial. European R&D is as good as the Japanese or American R&D. Today EU holds for CIS alone approximately 400 patents and more could be expected if industrial involvement increases.

There is a medium/average production level of articles in journals. Most have been published in recent years, but otherwise they have been well spread over the years.

Industry

There are eight industrial R&D laboratories with a budget of 8.4 MEUR with additional budgets for other related technologies and general renewable energy R&D. There are two larger industrial actors and the rest small and connected to R&D labs. At present the concentration in Germany is considered a strength, but new strong non-German industrial actors would be "healthy".

One company is in the forefront of R&D quality. It is necessary to find good collaboration between research, development and industry. This is the case for the best solutions today in the EU.

One company is dominating the patent figures, and the number of patents is concentrated to industrial actors rather than R&D institutions.

The one large industrial actor is large on silicon thin film cells, but is also highly involved in other thin film cells. The rather low industrial activity and concentration to few large companies is a weakness. More strong financial involvement is needed from industry. On the other hand, the dominating industries are good in international comparison.

Communication

There has been a good and healthy collaboration and communication over the years, both between R&D institutions themselves and between industry and the R&D community. In recent years as commercial aspects are getting closer at hand, the communication tends to reduce somewhat.



There is good communication between R&D institutions in Europe and the USA, but to a lesser extent between R&D and policymakers. Details on research activities are given to R&D community rather than on decision maker level (FP6).

EU projects have been forcing the networking, and in this area of PV cells several networks were established early in the "R&D history"

If EU R&D community manages to maintain communication at a high level (networking), e.g. through traditional EU projects, this will be strength. However, formal network structures that are too large and non-specific tend to be less effective.

3.4.2 Opportunities and threats

R&D

The area continues to be of interest and no other R&D area (PV or other) is presently a threat to resource depletion. Both Japan and the USA are strong in thin film with tendencies for increased Japanese competition, and decreased American competition.

Industry

Thin film technologies in this category have large opportunities as funds are available and the industry is interested. However, tendencies of "waiting" large industrial partners and the lack of commercial feedback for R&D funding could be a threat to the thin film PV R&D. A small increase in industrial R&D involvement is foreseen in the short term.

In the USA there are fewer activities commercially exploiting R&D to industrial level which is the opposite to the situation in Japan which comprises the largest threat.

Raw materials

No immediate problem/threat is foreseen. The raw materials are globally abundant. Indium supply could be a long term problem as indium-tin oxide transparent conductors are competing with thin film PV for the raw material.

Policies

Most policies are in favour of PV in general and thin film in particular. Possible threats could be an increased focus on other technology areas for the same purpose, i.e. environmentally friendly technologies and security of supply.

The trends are pointing towards stable funding levels. National funding for thin film PV R&D is important for continuity and sustainability and tendencies from national funders to rely on EU funding could be a threat.

A threat could also be that lots of money has been spent on thin film PV R&D without a substantial commercial success. This could lead to redirection of R&D funds by the policymakers. Otherwise most things point in the direction of large opportunities.

Markets

Communication between policy and industry creates short-term programmes while the communication between R&D and policy makers is important to create long-term possibilities (new technologies).

The consumer awareness is low regarding thin film PV technologies, but good regarding PV in general. The market tends to be created in Europe and in Japan.

Liberalised markets tend to favour low cost, off-the-shelf technologies, which is a threat to thin film technologies being a "new" creation. However, the applicability of thin film technologies to many niche markets is an opportunity for thin film technologies.

Intruding technologies

The largest threat to thin film technologies (CIS, CdTe) are primarily other PV technologies. Other technologies that replace PV and compete in the same niches are e.g. wind energy.

3.4.3 Summary of SWOT analysis for other thin film cells

Strengths	Weaknesses
<ul style="list-style-type: none"> • Thin film R&D in EU has a long and strong reputation, and several networks have been up and running for many years. • The R&D competition is healthy and EU has 4-5 labs with international status and commercial potential. • Budgets are rather high and industrial involvement substantial. • There is good communication between R&D institutions in Europe and the USA, • EU R&D as good as Japanese or American R&D. • The large budgets for small consortia gives better incentives for close R&D/industry collaboration and possibilities for patent registrations. • Today EU holds for CIS alone approximately 400 patents and more could be expected if industrial involvement increases. • The dominating industries are good in international comparison. 	<ul style="list-style-type: none"> • Funding has been there for many years and few commercialisations have been seen. • Communication between R&D and policymakers can be improved. • Networks with too many nodes decrease the building of true relations between the network actors. • The rather low industrial activity and concentration in few large companies. • Difficulty in scaling-up the technologies from pilot to industrial scale leading to need for a lot “patient” money. • The low level of financial risk capital.
Opportunities	Threats
<ul style="list-style-type: none"> • The enhanced freedom in materials available and global abundance • Thin film technologies in this category have many opportunities as funds are available and industry is interested. However, tendencies of "waiting" large industrial partners and the lack of commercial feedback for R&D funding could be a threat to the thin film PV R&D. • There are opportunities in job creation through SME involvement, also being good for R&D-industry collaboration. • The applicability of thin film technologies to many niche markets. 	<ul style="list-style-type: none"> • Japanese and USA are threats to EU R&D, but Japan tends to be a bigger threat. • Tendencies from national funders to rely on EU funding. • Money spent on thin film PV R&D without substantial commercial success may result in redirection of funds by policymakers. • The weak increase in industrial involvement foreseen in the short term. • In the long term indium availability due to competing use of the material. • Liberalised markets tend to favour low cost, off-the-shelf technologies.

3.5 ORGANIC CELL, POLYMERS

3.5.1 Strengths and weaknesses

R&D activities

There are 24 laboratories in Europe and the total R&D budget is 7.3 MEUR with additional budgets for other related technologies and general renewable energy R&D. There is a high level of activity in primarily small groups with two large groups in France and Switzerland.

In early R&D phase, partly overlap is usual and expected between the European R&D centres. Overlap in the sense of synergy between the research in the polymer field and related fields, e.g. other thin film areas, also occurs (e.g. Ångström-institute in Sweden).

The area has been subject to increased interest in recent years. Polymer PV technology is believed to progress rapidly. It is far from commercial breakthrough, but the potential value of the technology is very high.

No information on patents in the data given. As larger parts of fundamental R&D is carried out in close collaboration with industry, available information on IP rights may be unclear.

The R&D quality level in this area is high. The technology is immature and in progress and the data available is scarce and presumably very conservative. As the potential value of third generation PV technology is very high to industry, it is difficult to access reliable information on industrial participation and interaction between R&D labs and industry. However, the industrial involvement is rather limited at the present stage.

Industry

There are five laboratories (three in the UK and two in Switzerland) with a total budget of 1.3 MEUR with additional budgets for other related technologies and general renewable energy R&D. Based on the data available, the industrial partners are small and highly dedicated to narrow areas. The R&D is believed to be focused on many different technologies and aspects. Assessment of quality is difficult, as information is limited.

European industry is believed to be strong in this field of technology. The industrial partners appear to be small. However, as the potential value of this technology is high, the real activity might be much higher.

Communication

The communication between R&D institutions and industry is close, in fact so close that the information given is of limited value. Networks are informal in this early phase of R&D. EU projects have been forcing the formation of networks.

Policy makers seldom include issues in this field. The policy and strategy is therefore often determined by the R&D groups.

In long term R&D such as this, continuity of funding and personnel is crucial to success. It is also judged to be important, that industrial or private investments will occur after few years of R&D based on national programmes.

3.5.2 Opportunities and threats

R&D

This area is divided in two groups: a family of technologies based on organic dye sensitising on inorganic nano-semiconductors and a family of entirely organic cells. In the past 10 years the first family attracted most of the attention, while the latter family has boomed in the past three years.

Japan, Australia and the US has running activities in DSC and polymer technologies. There is heavy commercial activity and competition from Australia and Japan, where the Australian DSC technology is based on fundamental Swiss R&D work.

Important fundamental R&D carried out in many countries world-wide. The critical argument seems to be adoption of technologies by industry. In this context both US and in particular Japanese based industries seem more willing to enter new technologies.

Industry

There is a high activity in R&D and commercialisation of these technologies in Japan. The level of activity is less in the US. A weak increase in European industrial involvement is foreseen in the short term.

Some of the PV cells of this type, such as e.g. PEC cells seem to have a great potential of flexible applications, eventually combined with shadowing solutions in vertical facades, and different architectural solutions. Even if 8 % efficiency should prove to be a provisional maximum, the perspective of a good price/performance ratio compared to other types of PV cells is an advantage. Moreover the production technology could be simpler and demand smaller investments compared to silicon technology, which could be an opportunity for smaller European manufacturers.

Raw materials

No immediate problem/threat foreseen. One of the major points in using third generation PV technology is the enhanced freedom in materials available and global abundance.

Policies

The area is given little attention compared to crystalline and traditional thin-film cells. Based on the European strength in the field of polymers in general, a more aggressive policy in this PV field seems appropriate.

Unstable funding levels and discontinued funding and start/stop effects pose a real threat. There is poor understanding or belief in technology potential. The lacking commercial success of the thin film investments stands in the way for future investments in novel technologies.

Markets

Communication between policy and industry creates short-term programmes while the communication between R&D and policy makers is important to create long-term possibilities (new technologies).

The consumer awareness is low regarding thin film PV technologies, but good regarding PV in general. The market tends to be created in Europe and in Japan. Liberalised markets tend to



favour low cost, off-the-shelf technologies, which is a threat to thin film technologies being a "new" creation. However, the applicability of thin film technologies to many niche markets is an opportunity for thin film technologies.

As these technologies are immature, they do not address specific markets yet. The development of markets is expected to follow some of the trends as for thin films. This type of PV cells will preferable be used in vertical facades, and it is foreseen that flexible applications with added value will be the future trend. A special architectural interest is therefore expected.

Intruding technologies

First of all DSC and polymer PV technologies are at an early stage and mass exploitation of these technologies is still to come. The technological potential is considered very large, though considerable work and documentation is to be done. When these technologies meet the expected reduced cost in practice and fulfil basic requirements of flexibility and stability they might be able to open considerable markets, which cannot be addressed with conventional PV or thin film PV systems.

3.5.3 Summary of SWOT analysis for organic cells, Polymers

Strengths	Weaknesses
<ul style="list-style-type: none"> • European industry is believed to be strong in this field of technology. • The many high quality level R&D labs testing different proprietary designs and technologies. • The area has been subject to increased interest in recent years. • The polymer PV technology is believed to progress rapidly. • Far from commercial breakthrough, but potential value of the technology is very high. 	<ul style="list-style-type: none"> • Apart from two major labs in France and Switzerland, the R&D groups are close to or below critical size. • For the R&D labs with partly industrial financing, the collaboration and communication is very closed. • The communication between independent labs is rather low. • Policy makers seldom include issues in this field. The policy and strategy is therefore often determined in the R&D groups. • Industrial involvement is rather limited at the present stage. • The area is given little attention compared to crystalline and traditional thin-film cells in the policy field.
Opportunities	Threats
<ul style="list-style-type: none"> • Some of the PV cells of this type, such as e.g. PEC cells seem to have a great potential of flexible applications, eventually combined with shadowing solutions in vertical facades, and different architectural solutions. • The perspective of a good price/performance ratio compared to other types of PV cells. • The production technology could be simpler and demand smaller investments compared to silicon technology, which could be an opportunity for smaller European manufacturers. • The applicability of thin film technologies to many niche markets. • The enhanced freedom in materials available and global abundance. 	<ul style="list-style-type: none"> • Unstable funding levels and discontinued funding and start/stop effects. • A lot is expected from this technology. If the speed of development is not fast enough, the financiers may get impatient and reduce financing. • The critical argument seems to be adoption of technologies by industry. In this context both US and in particular Japanese based industries seem more willing to enter new technologies. • Low commercial applicability • Liberalised markets tend to favour low cost, off-the-shelf technologies, which is a threat to thin film technologies being a "new" creation • The lacking commercial success of the thin film investments stands in the way for future investments in novel technologies.

3.6 BIPV - BUILDING INTEGRATED PHOTOVOLTAICS

3.6.1 Strengths and weaknesses

R&D activities

There are 15 laboratories in Europe and the total R&D budget is 8.8 MEUR with additional budgets for other related technologies and general renewable energy R&D. Over 300 people are involved in this applied research. About two thirds of them in small and medium size industrial laboratories, the remainder in mainly small University or R&D Center labs.

The number of articles is reducing and the increasing commercial awareness and sensitivity is resulting in less information exchange. No quantitative data regarding patents are available but the impression is that the BIPV development does not result in many patents. Patenting is often difficult, because the improvements often concern techniques that are relatively simple. Many solutions are regionally specific. The patenting process forces the applicant to publish sensitive information. This disadvantage is often seen as outweighing patenting benefits.

As most of the RTD applies to (regionally) specific building techniques, there is not much overlapping. There is a large scope however for uniform application standards, both for electronic installation as for construction techniques.

The dedicated labs with specific knowledge on the regional market are easily accessible and open to joint R&D activities with industry. More interested building parties engage in BIPV initiatives. BIPV is more integrated in building market than in USA.

There is a regional differentiation of markets (compared to Japan) and BIPV is at the end of product chain. This means that time to market must be short. Therefore the emphasis is on short-term development and relatively little attention to mid term new product development.

Industry

Around 30 laboratories are involved in product R&D research. The total industry R&D budget is 14.3 MEUR with additional budgets for other related technologies and general renewable energy R&D. Around 70 industries do project related development and engineering and there are approximately 30 industries (manufacturers system integrators) and 70 engineering installers. The geographic location is mainly in Germany (75%) and the size and structure of the industry R&D is around 50 companies with 1- 10 full-time employed (fte), 8 to 10 with 10-100 fte and 4 or 5 larger ones.

There is more overlap in development and engineering than in R&D. The R&D quality was initially poor but is getting better. Products are still often not fully adapted to building practice (tolerances, building process and marketing).

The knowledge of local requirements and flexibility to serve specific markets are a strength while the development is too diffuse and overlapping activities constitute threats.

There is a strong SME base and culture, which is particularly strong in leading economies. This SME base can respond in a very flexible way to technical and market opportunities. The industry is innovative with respect to building components. Market inspired initiatives by building companies are creating strong chain interaction in some countries.

Communication

There has been a good and healthy collaboration and communication over the years, both between R&D institutions themselves and between industry and the R&D community. In recent years as commercial aspects are getting closer at hand, the communication tends to close somewhat. This applies even stronger for BIPV. Little exchange of BIPV knowledge between Europe and USA / Japan probably because BIPV is seen as regionally specific.

The communication is even more limited between R&D and policymakers, who are more informed on Research than Development. The market does not seem to be interested to involve the governments.

The BIPV R&D organisations are generally not much involved in formal networking but some examples are the IEA task 7; EnERBUILD and EPIA (not specific for BIPV). There is a well developed informal network but no formal network and no interest in formalising network is seen. The industry prefers exhibitions and fairs, not congresses.

Researchers and electrotechnical engineers usually "do not speak the same language" as the building professionals, which is a weakness.

3.6.2 Opportunities and threats

R&D

The European building sector is searching for new building envelope materials, PV can provide that with added values. There is a strong increase in interest on energy efficiency of buildings and a trend of more demand for electricity, less for warmth. A threat is the trend to generalise R&D funding to general RE and not keep it PV specific anymore.

European BIPV markets and R&D are strongly isolated from USA/Japan. An opportunity can be to use experiences from USA and Japan as well as to use the general building industry trends.

Industry

European BIPV markets and R&D are strongly isolated from USA/Japan. An opportunity can be to use experiences from USA and Japan as well as to use the general building industry trends.

An opportunity is the possibility to work with local RDC. A threat is the little feeling at RDC for building industry problems.

Raw materials

No problem has been identified in the field of raw materials.

Policies

Other renewable energy options, especially those applicable in the build environment is competitors in the policy field. PV is just one option for realising general policy ambitions for CO₂ reduction, energy efficiency and RE implementation. There is a trend that funding object moves from PV provider to market (PV consumer). Another trend is that funding moves from PV specific to more general RE funding.

A unified European policy on RTD, norms and standardisation and market support is an opportunity. A threat is the competitive disadvantage for PV in realising short term RE policies, which may result in less funding. Another threat is the differences in funding policies within Europe and the lack of consistency over time.

Markets

The technical applicability is an opportunity; the best and most successful BIPV product is a product that can be treated (obtained, marketed, applied and serviced) as a building product.

The image of low quality products is a threat. The liberalised market provides opportunities due to the search for increased values, which BIPV can provide.

The perceived decreasing quality of electricity net and the trend to decentralise also provides opportunities for BIPV but the lack of storage capacity may be a threat.

Intruding technologies

Threats may come from other decentralised electricity generators that obtain commercial attractiveness much sooner than BIPV. Opportunities may arise from innovative combination with insulation or thermal applications.

3.6.3 Summary of SWOT analysis for building integrated PV - BIPV

Strengths	Weaknesses
<ul style="list-style-type: none"> • Dedicated labs with specific knowledge on the regional market are easily accessible and open to joint R&D- industry activities. • More interested building parties engage in BIPV initiatives. • BIPV is more integrated in the building market than in the USA. • The knowledge of local requirements and flexibility to serve specific markets. • Strong SME base and culture, which can respond in a very flexible way to technical and market opportunities. • Industry is innovative with respect to building components. • The technical applicability - the best and most successful BIPV product is a product that can be treated as a building product. 	<ul style="list-style-type: none"> • Regional differences in markets, building techniques and diversity of regulation. • Little exchange of BIPV knowledge between Europe and USA / Japan probably because BIPV is seen as regionally specific. • The increasing commercial awareness and sensitivity results in less information exchange. • Protective attitude of industry leads to more overlap in development. • Differences in experience, "language" and attitude between PV industry and building industry. • BIPV is at the end of product chain. Therefore the emphasis is on short term development and relatively little attention to mid term new product development
Opportunities	Threats
<ul style="list-style-type: none"> • Uniformed regulations and standards. • Close co-operation with, or incorporation in the building industry, making use of general trends in the building industry. • Make better use of already existing knowledge and experience, using the expertise of local RDC's, by improved networking and co-operation and interest in Japanese and American solutions • The European building sector is searching for new building envelope materials. • Optimal integration of electrotechnical and building qualities. • Innovative combination with insulation or thermal applications. • The liberalised market provides opportunities due to the search for increased values that BIPV can provide. • The perceived decreasing quality of electricity net and the trend to decentralise. 	<ul style="list-style-type: none"> • Inconsistencies of building and PV policies between countries and over time. • The trend to generalise R&D funding to general RE and not keeping it PV specific. • The BIPV business is mainly based on governmental subsidies - changes in national politics may have severe effects into the business. • Sudden closing of national BIPV (roof) programmes. • Isolated development of products that have suboptimal quality or - even more important- are not adapted to the building process. • Other decentralised electricity generators that obtain commercial attractiveness much sooner than BIPV. • The image of low quality products. • The lack of storage capacity.

3.7 INVERTERS/BOS ETC.

3.7.1 Strengths and weaknesses

R&D activities

There are 26 laboratories in Europe and the total R&D budget is 2.5 MEUR with additional budgets for other related technologies and general renewable energy R&D. The academic research groups are relatively small but have a high R&D quality especially on inverters. There is to some extent overlapping R&D both EU wide as well as inside some countries.

Industry

There are 29 industry R&D laboratories in Europe - The total industry R&D budget is 6.6 MEUR with additional budgets for other related technologies and general renewable energy R&D. The patenting activity is not that big. The companies are small and patents difficult to get/disclose too much.

There is a fairly large number of inverter and controller producers. In most of EU countries there is a BOS industry and usually the companies are smaller units of larger electronics companies. R&D has successfully created small enterprises widely in EU.

Norms direct to some extent especially inverter development. The same inverter cannot be sold as such to every EU country.

Communication

This is less academic research than industry development. Contacts are industry driven, national based R&D. Networks are nationally and between countries mostly exclusionary due to close connection to business. Mostly short term product development in the industry labs. Quite often inverters are developed for non-PV applications but can also be used with PV.

For grid-connected inverters there is good connection between R&D and national policymakers.

3.7.2 Opportunities and threats

R&D

- No intruding trends are foreseen.
- USA has more concentrated R&D than Europe where it is more spread R&D.
- USA is a threat, but not Japan.

Industry

- US products are imported much into the EU and somewhat vice versa in stand-alone systems.
- USA is stronger competitor to EU than Japan.
- In national aid programmes tendency to use domestic products.
- Higher efficiency and good stability shall require industry R&D involvement also in future.

Raw materials

Occasionally some key IC components may not be available. At most this is a logistical question.

Policies

- Policies for R&D and energy are probably not an issue for BOS.
- The funding trends are stable or reducing.
- IEC norms, if widely applied, are a threat to small companies. That is also an opportunity for larger companies selling products more widely, by improving their image and product quality.

Markets

Consumers want to have more comfort from the PV system than earlier. Therefore, one can foresee clear growth in system size and e.g. use of inverters in off-grid systems. The EU market will be similar to Japan, perhaps more than in US, if the roof programmes will continue and will be spread to many more EU countries.

Intruding technologies

Not applicable.

3.7.3 Summary of SWOT analysis for inverters/BOS

Strengths	Weaknesses
<ul style="list-style-type: none"> • In general, for BOS component producers the PV business has been profitable all the time. • European BOS technology and companies are competitive. • The inverter RTD has successfully brought into Europe several good companies, which have good reputation and are forerunners in the field. • On module inverters EU is the forerunner. • On the controller side the situation is more even, but EU is still strong • The same controllers are easily used in many countries. • For grid-connected inverters there is good connection between R&D and national policymakers. 	<ul style="list-style-type: none"> • The companies are small and patents difficult to get / disclose too much. • Strong domestic markets for inverters may prevent stronger cross-national business and technology development. • There are still many small BOS producers (esp. controllers) and their ability to obtain a leading market position is small.
Opportunities	Threats
<ul style="list-style-type: none"> • If IEC standards become common, e.g. for inverters, that may open wider geographic markets for strong companies. • IEC norms, if widely in use, are an opportunity for larger companies which sell products more widely, to improve their image and product quality. • Higher efficiency and good stability shall require industry R&D involvement also in future. • AC power is more and more demanded from PV, which widens the market. • Better efficiency makes the products more interesting. • Consumers want to have more comfort from the PV system than earlier. Therefore, one can foresee clear growth in system size and e.g. use of inverters in off-grid systems. 	<ul style="list-style-type: none"> • In national aid programmes tendency to use domestic products. • IEC norms, if widely in use, are threat to small companies. • Cheap Asian products: when production moves to Asia, cheap copies come to EU. • European companies, if they remain small, cannot compete against bigger US companies.

3.8 STAND-ALONE SYSTEMS

3.8.1 Strengths and weaknesses

R&D activities

There are R&D activities in 21 laboratories and the total R&D budget is 580.000 EUR with additional budgets for other related technologies and general renewable energy R&D. The researchers are organised in small R&D teams and there is not too much overlapping activities in hydrogen storage, FC and PV.

The EU research is well-positioned in PV/FC/H2 fields. Lead-acid batteries are a mature technology where cost reduction and longer service life are the main issues, which is not academic work.

Industry

There are 17 industry R&D laboratories and the total industry R&D budget is 7.3 MEUR with additional budgets for other related technologies and general renewable energy R&D. In traditional systems there are many companies involved, in more advanced systems only very few.

The size of the companies varies a lot. There is stand-alone system business in some big PV companies, and there are more small companies dedicated to only systems. In the majority of EU countries there are stand-alone system companies.

The R&D quality level is comparable to the competitors (Japan and the US). In advanced systems EU is probably leading in quality. In advanced systems (PV/FC/H2) there are some EU patents.

Conventional stand-alone is purely industry's daily work (system design with batteries). More advanced hydrogen based systems are still pilot products.

Communication

There is a good and healthy collaboration and communication between the academia and R&D in industry. The policymakers like to have big visions especially on PV/FC/ hydrogen systems, and see that R&D brings fast results.

PV system houses have energy storage producers as suppliers. In advanced stand-alone systems the industry is operating in close network with the R&D institutes. R&D on traditional stand-alone happens in industry. More advanced systems are still risky and work is done more in academic institutions.

3.8.2 Opportunities and threats

R&D

On conventional batteries USA and Japan lead EU, in advanced systems EU is equal and the RTD focus are in future systems.

Industry

In conventional stand-alone there is very little R&D involvement but the advanced stand-alone are driven by R&D where US and EU are quite equal and Japan somewhat behind. The conventional stand-alone is cost driven business.

Raw materials

Not applicable. Occasionally some batteries may not be available or have long delivery time.

Policies

Stand-alone is done on commercial basis for private people independent of policy making. However, there is stronger influence on communities and corporations which can get subsidy for stand-alone. Liberalised markets create an opportunity for stand-alone systems.

Advanced stand-alone will be one of the areas to get more funding. Advanced stand-alone is a long-term project which needs a lot governmental funding.

Markets

Advanced stand-alone is an area where EU can be a leading actor in the world. If decentralisation is favoured, then stand-alone market will grow more substantially than now. Otherwise, stand-alone remains as a minor share in EU and major market will be in developing countries. The US is in a more favourable situation, because there are more sunny areas where seasonal storage is not needed as in major part of EU.

Intruding technologies

Cheap Chinese diesel aggregates are the main competitor.

3.8.3 Summary of SWOT analysis for stand-alone systems

Strengths	Weaknesses
<ul style="list-style-type: none"> • The EU research is well positioned in PV/FC/H2 fields. • R&D and system know-how on advanced stand-alone systems. • There is a good and healthy collaboration and communication between the R&D and R&D industry. • The policymakers like to have big visions especially on PV/FC/ hydrogen systems, and see that R&D brings fast results. • In the majority of EU countries there are stand-alone system companies. 	<ul style="list-style-type: none"> • R&D on advanced concepts is probably in too small networks. • Batteries form quite a big share of the system costs. They need periodic replacement, which is expensive. However, solar batteries are not yet interesting enough business for battery manufacturers to develop a cheap, long lasting battery, which will withstand both cold and hot environments.
Opportunities	Threats
<ul style="list-style-type: none"> • Business grows quite moderately. No big technological leaps to be expected, the major challenge is to get cheap reliable batteries. • In long-term, hydrogen / fuel cell combined with PV will bring something new to the business and open new applications even if there is need for seasonal energy storage. • Liberalised markets create an opportunity for stand-alone systems. • To develop a cheap, long lasting battery, which withstands both cold and hot environments. 	<ul style="list-style-type: none"> • If expectations are raised too high, decision makers come impatient towards advanced stand-alone, and R&D is reduced too soon. • Competing stand-alone power systems (e.g. small diesel generators). • Cheap Chinese diesel aggregates are the main competitor.

4 Overall assessment

Strengths	Weaknesses
<ul style="list-style-type: none"> • Europe has strong and high level R&D quality in PV covering all major technologies and is geographically well spread. • The high-tech nature of PV is appealing and countries with a PV industry recommend sustained R&D efforts. • Well-developed R&D communication networks mainly due to EC funded projects that help to create teams with various competencies into PV RTD projects. • The SME structure of the PV business in Europe enables fast reactions to the market needs • European R&D strong in thin film cells, organic cells, polymers, BIPV and advanced stand-alone systems. • The existence of the roof programmes that stimulate the PV market. • European industry is strong in BOS and stand-alone systems. 	<ul style="list-style-type: none"> • Because PV RTD is evenly distributed both in technologies and geographically, effort is diluted and may not keep Europe competitive in key areas. Lack of critical mass. • Too few countries have dedicated PV programmes. • Not enough countries have fully co-ordinated programmes. • Communication between the academic and industry R&D with policymakers is not frequent. • Academic R&D and industry have different priorities. • The lack of standardisation of key PV system components. • European PV companies, which are often SME, are not making enough profit to be able to develop, on their own ground, new technologies/concepts that are not immediately commercialised.

table continues overleaf

Opportunities	Threats
<ul style="list-style-type: none"> • EC policies on security of supply, the Renewable Energies directive and the fulfilment of the Kyoto targets stimulate the PV market. • Renewable Energies including PV have by their nature long term potential. • Research co-operation between Europe, Japan and the USA speeds up PV RT • The extension/increase of current roof programmes and widening to other EU member states creates more solid base for PV industry. • A stable PV market stimulates industrial involvement and availability of financial risk capital. • Co-operation with the building sector helps them to understand what PV can Offer and PV industry understand about the building sector trends. • Cross fertilisation with other industry areas (thin film, glass coating) create possibilities for new production concepts. • Thin films (other than α-Si), polymer cells and combinations between crystalline silicon cells and thin film technologies open up potential for cheaper and new type of PV module production. • Developing countries offer remarkable market for stand-alone systems and small grids in. 	<ul style="list-style-type: none"> • The stop and go of policies and funding programmes create uncertainties to PV RTD. • Resources spent on PV R&D without substantial commercial success may result in redirection of R&D funding. • The strong Japanese PV RTD activities and PV industry weaken European industry position and national interest into PV RTD. • PV RTD is a long-term investment and the current PV market relatively small so that stakeholders interest directs somewhere else. • Latest strong growth of PV is based on roof programmes. If they are reduced, that may threaten RTD programmes. • Big parent companies become impatient in poor profitability of PV and reduce efforts to it. • The PV sector, as it is now, does not respond to the tendencies of the liberalised electricity market. • Liberalised markets tend to favour low cost, off-the-shelf technologies, which is a threat PV technologies being a "new" creation.

Appendix 1 – Summary tables from SWOT analyses

Strengths and Weaknesses

R&D activities							
	No of labs	No of researchers	No of articles in ref. journals	No of patents	Overlapping activities	R&D Budget	Overall remark
Crystalline silicon cells (ADEME)	38	Main country actors are DEU, NLD, FRA, and ITA.	– The number of articles in refereed scientific journals was not worked out at this stage of the project.	– Patents: it is considered that the field is potentially rich despite the fact that c Si for PV represents 25 years of investigations. It was decided that at this stage of study the trend in numbers of patents would be studied on another occasion. It is noticed that the cost of patenting in the European Union is ten times that of the USA (mainly due to costs of translation) and it is seen as a negative factor for competitiveness based on exploitation of technologies in general and PV technology in particular.	– There are some overlapping activities between public/university laboratories but there are a variety of approaches that make each laboratory unique in its endeavour.	26 416 500	The ‘competitiveness’ between the various public/university laboratories maintains a very good level of activity. Most of the European public R&D teams in the field of c-Si have co-operated in pre-competitive EC FP programmes involving public research and industry teams. It has to be noticed that the level of exchange of information between Member State organisations co-ordinating R&D PV activity is low. The PV-EC-NET network was a successful occurrence on that respect and it is the intention of participants to continue cooperation in the future.



R&D activities							
	No of labs	No of researchers	No of articles in ref. journals	No of patents	Overlapping activities	R&D Budget	Overall remark
Thin-film silicon cells (INETI)	Difficult to evaluate (surely >30) well spread number of labs all over Europe (ex: B, D, CH, F, GR, H, I, NL, Pt, P, S, UK), including Research institutions and Universities.	many researchers spread over different Labs and University institutions	Typical of the order of 50 in Europe in the last two years (increased in recent years)	Not too many found (less than 10)	Some overlapping activities. Good co-operation between R&D institutions	24 910 000	High level of R&D based on many labs spread all over Europe. In fundamental research several institutions reached excellence This high level can be considered more a result of national efforts rather than a European strategy or policy. There is a wide fragmentation of PV RTD activities in this field.
Other thin-film cells (FORMAS)	25	Many activities in many small units. Four large: Germany (2), Sweden (1), France (1)	Medium/average level production. Many in recent years, but otherwise well spread over the years.	For CIS alone approx 400 patents. More could be expected if industrial involvement increases.	Partly overlapping activities, but a healthy competition and collaboration. 4-5 labs having "commercial potential"	10 720 000	The competition is healthy and EU has 4-5 labs with international status and commercial potential. It is better with 4 medium size labs competing than one large without competition. In addition, large budgets for small consortia gives better incentives for close R&D/industry collaboration and possibilities for patent registrations.

R&D activities							
	No of labs	No of researchers	No of articles in ref. journals	No of patents	Overlapping activities	R&D Budget	Overall remark
'Organic cell, Polymers (DEA)	24	High level of activity in primarily small groups. Two large groups France (1), Switzerland (1)	The area has been subject too increased interest in recent years. Polymer PV tech. Is believed to progress rapidly. Expectedly long to commercial breakthrough, but potential value of the technology is very high.	No information on patents in the data given. As larger parts of fundamental R&D are carried out in close collaboration with industry, available information on IP rights might be cloudy.	In early R&D phase, partly overlap is usual and expected between the European R&D centres. Overlap in the sense of synergy between the research in the polymer field and related fields, e.g. other thin film areas, also occur (e.g. Ångström-institute in Sweden)	7 310 000	The R&D level in this area is high. The technology is immature and in progress. The data available is scarce and presumably very conservative. As the potential value of 3. Gen. PV tech. is very high to industry, it is difficult to access reliable information on industrial participation and interaction between R&D labs and industry.
BIPV (NOVEM)	15	Over 300 people are involved in this applied research. About two third of them in small and medium size industrial laboratoria, the remainder in mainly small University or R+D Centre labs	The number of articles is reducing. Increasing commercial awareness and sensitivity is resulting in less information exchange	No quantitative data available. The impression is that the BIPV development does not result in many patents. Patenting is often difficult, because the improvements often concern techniques that are relatively simple. Many solutions are regionally specific. The patenting process forces the applicant to publish sensitive information. This disadvantage is often seen as outweighing patenting benefits.	As most of the RTD applies to (regionally) specific building techniques, there is not much overlapping. There is a large scope however for uniform application standards, both for electronic installation as for construction techniques;	8 755 000	Strength: Dedicated labs with specific knowledge on the regional market are easily accessible and open to joint R+D activities with industry. More interested building parties engage in BIPV initiatives. BIPV is more integrated in building market than in USA. Weaknesses: Regional differentiation of market (compared to Japan); BIPV is at the end of product chain; time to market must be short. Therefore the emphasis is on short term development and relatively little attention to mid term new product development.

R&D activities							
	No of labs	No of researchers	No of articles in ref. journals	No of patents	Overlapping activities	R&D Budget	Overall remark
Inverter/BOS etc (NAPS)	26	Academic research groups are relatively small.	?	?	There is to some extent overlapping R&D both EU wide as well as inside some countries.	2 547 500	Academic R&D is high quality esp. on inverters.
Stand-alone system (NAPS)	21	Activity in small R&D teams.	?	?	In hydrogen storage, FC and PV not too much overlapping.	580 000	EU research well positioned in PV/FC/H2. Major technology: Pb-batteries are a mature technology; cost reduction and longer service life are the main issues, which is not academic work.
<p>Other technologies: Social & Environm. Aspects 2 labs, Grid connections 1 lab, Hybrid systems 1 lab, Storage batteries and management 1 lab, Socio economic aspects 1 lab.</p> <p>Germany has put together BIPV, Inverter/BOS and stand alone systems in their report - the numbers of labs are 3 all together. Germany has put together BIPV and inverter/BOS in the budget report, the amount is € 3 770 000.</p> <p>Austria has 650 000 € as a total R&D budget - not separated between different technologies.</p> <p>Belgium has a yearly budget of € 500 000 for process technology.</p> <p>Denmark has a budget for other of € 700 000.</p> <p>France has a budget for storage batteries and management of € 1 500 000 and a budget of € 1 000 000 for accompanying studies.</p> <p>The Netherlands has a budget for grid connections of € 30 000, a budget for Environmental aspects of € 200 000 and a budget of 50 000 for Hybrid systems.</p> <p>Poland has a budget of € 125 000 for demonstration and for development € 175 000.</p> <p>Portugal has a budget of € 12 000 for process technology.</p> <p>Sweden has a budget for Information activities of € 20 000 and for IEA PVPS cooperation a budget of € 20 000.</p> <p>Switzerland has a budget of € 710 000 for Management/Studies/IEA.</p> <p>UK has a total budget of € 4 000 000 for all research, this is not reported for separate categories.</p>							

Industry								
	No of labs	No of Industries	Size & structures	Geographic location	R&D Budget	R&D quality	R&D Patents	Overall remark
Crystalline silicon cells (ADEME)	29	– There are 29 (?) industry R&D teams involved in c-Si field.	The companies are small to medium size businesses; most of the companies are subsidiaries of larger companies (petroleum, electronic and electric, high-tech materials, etc.). Some among the most important belong to non-European companies.	– The main companies active in c-Si R&D are situated in Germany, Holland, France, Norway, Spain and Italy.	23 950 000	– The quality of R&D results achieved in projects granted by the national governmental agencies and the EC are rated 4 over 5 by the participants of PV-EC-NET. Some very fine achievements led to innovative techniques (directional solidification, cold crucible, wire sawing of thin wafers, plasma enhanced nitridation...) though no breakthrough was reported in recent years. This is due to the fact that c-Si technology progresses with step by step improvements of the various manufacturing processes.	– The number of patents registered has not been worked out. The technology is gaining maturity. The industrialists develop a valuable know-how which is often kept in-house.	Most of c-Si PV companies have a technological development activity. RTD plays an important role in maintaining competitiveness. Five to ten percent of turnover is devoted to this type of activity. The RTD activity is of international level. The industry publishes some of the achieved results in international conferences when their work receives public funds from Member States or the EC. Otherwise they keep their proprietary results for themselves (there is a lot of know-how in this industry). The JRC from Ispra played an important role in participating to the definition of standardization procedures and qualification of c-Si PV modules. Now the industry claims a 20-year guarantee of their PV modules and accredited JRC delivers quality approval certification.

Industry								
	No of labs	No of Industries	Size & structures	Geographic location	R&D Budget	R&D quality	R&D Patents	Overall remark
Thin-film silicon cells (INETI)	Difficult to evaluate.	One major industrial actor in Germany (Photronics- RWE); other actors not specifically related to Silicon Thin Film technologies like Akzo Nobel-Shell in the Netherlands(roll-to-roll) Intersolar in UK, Duna Solar in Hungary, Free Energy Europe in France, VHF Technologies in Switzerland and Eurosolare in Italy (in connection with Pacific Solar,Australia). Very small industrial activities connected to Labs.	Large with international ramifications	Mainly Germany	10 420 000	Good tradition and quality of R&D in Industry in this field (since early 80's)	Patents mainly concentrated in industrial companies.	Concentration in just one large industrial partner

Industry								
	No of labs	No of Industries	Size & structures	Geographic location	R&D Budget	R&D quality	R&D Patents	Overall remark
Other thin-film cells (FORMAS)	8	Two (2) larger industrial actors, and the rest small and connected to R&D labs	One large and strong actor. Good R&D - industry collaboration needed.	Mainly Germany. At present a concentration to Germany considered strength, but new strong non-German industrial actor would be "healthy".	8 375 000	One company in the forefront. It is necessary to find good collaboration between research, development and industry. This is the case for the best solutions today in EU.	One company dominating the patent figures, and the number of patents concentrated to industrial actors rather than R&D institutions.	The one large industrial actor is large on Si, but is also highly involved in other thin film cells. Rather low industrial activity and concentration to few large companies a weakness. More strong financial involvement needed from industry. On the other hand, the dominating industries are good in international comparison.
Organic cell, Polymers (DEA)	5	No information available.	Based on the data available, the industrial partners are small and highly dedicated too narrow areas.	UK (3), Switzerland (2)	1 320 000	The R&D is believed to be focused on many different technologies and aspects. Assessment of quality is difficult as information is scarce.	No information in the data given.	The industrial partners appear to be small. However, as the potential value of this tech. Is high, the real activity might be much higher.

Industry								
	No of labs	No of Industries	Size & structures	Geographic location	R&D Budget	R&D quality	R&D Patents	Overall remark
BIPV (NOVEM)	Around 30 involved in product R+D research; More industries (around 70) do project related development and engineering.	around 30 (manufacturers system integraters); around 70 engineering installers	around 50 with 1- 10 fte, 8 to 10 with 10-100fte and 4 or 5 big ones	Mainly in Germany (75%)	14 295 000	More overlap in development and engineering then in R&D; Quality initially poor but is getting better. Products often not yet fully adapted to building practise (tolerances, building process and marketing)	See the remark under R+D	Strength: knowledge of local requirements and flexibility to serve specific markets. Weakness: Development is too diffuse; much overlap. See also under R+D at R+D Centres
Inverter/BOS etc (NAPS)	29	There are a fairly large number of inverter and controller producers.	Usually PV BOS companies are smaller units of larger electronics companies.	In most of EU countries is BOS industry.	6 620 000	R&D has successfully created small enterprises widely in EU.	Patenting activity is not that big: companies are small and patents difficult to get / disclose too much.	Norms direct to some extent esp. inverter development: same inverter cannot be sold as such to every EU country.
Stand-alone system (NAPS)	17	In traditional systems there are many companies. In more advanced systems only very few.	Size varies a lot. There is system business in some big PV companies, and there are more small companies dedicated to only systems.	In majority of EU countries there are system companies.	7 285 000	Level is comparable to competitors (J & US). In advanced systems EU is probably leading in quality.	In advanced systems (PV/FC/H2) there are some EU patents.	Conventional stand-alone is purely industry's daily work (system design with batteries). More advanced hydrogen based systems are still pilot products.

Other technologies: Encapsulation 1 lab, Space research 1 lab, Adv. en. storage 1 lab, Storage batteries and management 1 lab, Accompanying studies 1 lab, Hybrid systems 1 lab, Management/Studies/IEA 7 labs, PV installations 33 labs.

Germany has put together BIPV, Inverter/BOS and stand alone systems in their report - the numbers of labs are 13 all together.

Germany has put together BIPV and inverter/BOS in the budget report, the amount is € 400 000.

Austria has € 812 125 as a total R&D budget - not separated between different technologies.

Denmark has a budget for other of € 300 000.

Finland has a budget for Adv. en storage of € 200 000.

France has a budget for storage batteries and management of € 1 300 000 and a budget of € 1 800 000 for accompanying studies.

The Netherlands has a budget for grid connections of € 70 000 and a budget of 50 000 for Hybrid systems.

Sweden has a budget for Information activities of € 20 000 and for IEA PVPS cooperation a budget of € 20 000.

Switzerland has a budget of € 200 000 for Management/Studies/IEA and € 2 000 000 for PV Installations.

Communication				
	R&D-R&D/industry	R&D-Policymakers	No of Networks	Overall remark
Crystalline silicon cells (ADEME)	– Public – industry: there is a long tradition of shared work between the public research teams and the industry. Such cooperation was a prerequisite of public funded projects by national agencies and the EC RTD programmes. There are some private research contracts between industry and public laboratories; it is claimed that c-Si SMEs are not profitable enough to make such contracts a current practice.	– Public research – policy makers. The relationship is fine when there is a structured national RTD programme otherwise it is often noticed as loose. The researchers know the RTD programme managers and discuss with them to seek advice or when RTD contracts are negotiated.	– Networks: The c-Si RTD community of PV teams is well established. Thanks to the EC framework programmes. Some are still active but they are dependent of EC funding.	– Concerning communication between the researchers of both industry and public organizations it is acknowledged that in the field of c-Si the structured national activities and the EC FPs have contributed to several projects of high quality.
Thin-film silicon cells (INETI)	Good cooperation though the high level R&D in Europe hasn't yet been translated in strong and competitive industrial partners. The cost of production equipments introduces the main barrier in limiting further Silicon thin film production effort.	Not a great extent of communication. Need to be increased. The networks can be a way to increase this lack of communication.	One important and well organised network on this technology (aSiNET). New 6 FP NoE being proposed. Further initiatives are being proposed covering the analysis of bottlenecks to the development of thin film technologies as a whole (mainly transparent conductive oxide and development of large area new deposition equipments).	Communication must be increased either between R&D and Industrial Partners and both with policymakers.

Communication				
	R&D-R&D/industry	R&D-Policymakers	No of Networks	Overall remark
Other thin-film cells (FORMAS)	Good and healthy collaboration and communication over the years, both between R&D institutions themselves and between industry and the R&D community. Recent years as commercial aspects are getting closer at hand, the communication tends to close somewhat. Good communication between R&D institutions in Europe and USA	Communication to a lesser extent. Details on research activities given to R&D community rather than on decision maker level (FP6)	EU projects have been forcing the networking, and in this area of PV cells several networks were established early in the "R&D history"	If EU R&D community manage to maintain communication at a high level (networking), e.g. Through traditional EU projects, it will be a strength for EC PV R&D. However, networks with too many nodes decreases the building of true relations between the network actors. The relations to commercial activities give other structures regarding networking and smaller such is preferred.
Organic cell, Polymers (DEA)	Communication between R&D institutions and industry is close, in fact so close that the information given is of limited value.	Policy makers seldom encircle issues in this field. The policy and strategy is therefore often determined in the R&D groups	Networks are informal in this early phase of R&D. No specific information given. EU projects have been forcing the formation of networks.	In long term R&D such as this, continuity of funding and personnel is crucial to success. It is also judged to be important, that industrial or private investments will occur after few years of R&D based on national programmes
BIPV (NOVEM)	As for techniques described above such as thin films: Good and healthy collaboration and communication over the years, both between R&D institutions themselves and between industry and the R&D community. Recent years as commercial aspects are getting closer at hand, the communication tends to close somewhat. This applies even stronger for BIPV. Little exchange of BIPV knowledge between Europe and USA / Japan probably because BIPV is seen as regionally specific	Communication to a lesser extent. Policy makers more informed on Research than Development Market not interested to involve government.	IEA task 7; ERERBUILD; EPIA (not specific for BIPV) Generally not much involved in formal networking.	Well developed informal network; no formal network; no interest in formalising network; Industry prefer exhibitions and fairs; not congresses. Weakness: Researchers and electro technical engineers usually "do not speak the same language" as the building professionals

Communication				
	R&D-R&D/industry	R&D-Policymakers	No of Networks	Overall remark
Inverter/BOS etc (NAPS)	This is less academic R than industry D. Contacts are industry driven, national based R&D.	In the grid-connected inverters there is good connection between R&D and national policymakers.	Networks are nationally and between countries mostly exclusionary due to close connection to business.	Mostly short term product development in the industry labs. Quite often inverters are developed for non-PV applications but can be used with PV, too.
Stand-alone system (NAPS)	Good and healthy collaboration and communication.	Policymakers like to have big visions esp. on PV/FC/hydrogen systems, and see that R&D brings fast results.	PV system houses have energy storage producers as suppliers. In advanced stand-alone systems industry is close network with R&D institutes.	R&D on traditional stand-alone happens in industry. More advanced systems are still risky and work is done more in academic institutions.

Overall assessment of Strengths & Weaknesses

Crystalline silicon cells (ADEME)	<p>Strength - Firstly within the EU there are manufacturers of crystalline silicon ingots, wafers, cells and PV modules. The PV modules are the commercial end products of the industry. Crystalline silicon modules represent 90 % of worldwide commercial module sales. Europe is producing 30 % of the world production of PV modules. The reliability and the quality of commercial PV modules improved over the years. The modules are guaranteed 20 years, which is considered an important achievement for sustainable development. The contribution to testing laboratories like the European Joint research centre at ISPRA allowed getting international certification of c-Si PV modules. A few companies are vertically integrated starting from ingot manufacturing to module fabrication. It is considered that vertical integration is a prerequisite to industrial competitiveness. Nevertheless, more recently the high demand of wafers and cells by module manufacturers allowed some companies to start business in the sector of ingot manufacturing and wafer manufacturing. Secondly, most of the PV-EC-NET participants having a c-Si RTD activity declare that the field of crystalline silicon is strong. There are XX teams working in cooperation with industry, among them research centres of high reputation. The number of publication in most of the conferences (being national or sponsored by EC) represent an average 40 % of the publications presented in the field of research and technical development on PV cells and modules. The public laboratories are also involved in medium to long term approaches. There are material studies like crystalline silicon ribbons, or cell studies using combinations of c-Si wafers and amorphous silicon layers (see Thin film silicon section). Concerning PV RTD, there are only two countries (FRA and CHE) having a structured programme of R&D (strategy, objectives, projects). Other countries have activity in the PV field depending upon general activity on renewable sources of energy but it does not mean that the quality of work is poorer. A national RTD PV programme allows better pooling of resources particularly when there are several research teams in the same field.</p> <p>Weakness - The c-Si PV European industry is still fragile. It is a capitalistic industry asking large amount of investments (1,2 MEUR for an annual capacity of one megawatt of PV cells). The c-Si companies are not making enough profit to be able to develop on their own grounds new technologies or new concepts that are too far to industrialization. It also takes time and money to have these new concepts introduced into the production line (2 to 4 years). So the need to have in Europe a few public laboratories able to advance the technology and to propose (sell) the results to industry. The weaknesses of the c-Si field are its dependence on cheap feedstock of high purity. Feedstock silicon today comes from the refuse of electronic grade manufacturing. Once at 10 EUR/kg till mid 90s it increased to 25 EUR/kg today. The cost of feedstock represents roughly 10 % of the cost of a PV cell. It is said by industry that it is an upper acceptable limit. The amount of material available on market is getting scarce. In Europe there are several studies and attempts to propose solutions but they have not materialized yet and one of the reasons is the threat of cost effective thin film appearing on the market (so far thin films cells/modules have not demonstrated this low cost capability). Some of the weaknesses of the c-Si field are shared by other RTD topics. – Weakness of the European RTD organization: the wish of the Commission to have too many teams in one single project. It dilutes the effort and teams are complaining of having to do more and more paperwork. – Recommendation to avoid recurrent evaluation difficulties of RTD project funded by EC and Member States. Projects must involve clear work packages with milestones against which future achievements can be measured. Regular updating of detailed objectives and work packages must also be envisaged.</p>
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Overall assessment of Strengths & Weaknesses	
Thin-film silicon cells (INETI)	<p>Strengths: High level and strong R&D spread all over Europe in many Research institutions. Well known materials (Silicon). Low quantity of active material required. Possibility of deposition over several types of substrates namely flexible and curved surfaces. Cross fertilization with other technologies widely diffused (Liquid Crystal Displays, X ray detectors, etc.).</p> <p>Weaknesses: Lack of a strong and competitive European industry when compared to Japan industry. This is probably due to the fact that European industry in this technology is spread in small companies connected to labs and the costs of production equipment are high with pay back times that can be long. The exception could be if stable Silicon Thin Film markets could support the decision of big PV companies to invest in this technology. Need to intensify the level of communication and networking between R&D and industrial partners. Further limiting Technical barriers are the low efficiency of devices, the low stability of material and devices and the need for safety rules for material processing.</p>
Other thin-film cells (FORMAS)	<p>Strengths: Thin film R&D in EU has a long and strong reputation, and several networks have been up and running over many years. Budgets are rather high, and industrial involvement substantial. EU R&D as good as Japanese or American R&D.</p> <p>Weaknesses: There are few (1) large industrial partners and thus low level of financial risk capital. Funding has been there for many years and few commercialisations have been seen.</p>
Organic cell, Polymers (DEA)	<p>Strengths: Many high level R&D labs testing different proprietary designs and technologies. European industry is believed to be strong in this field of technology.</p> <p>Weaknesses: Apart from two major labs in France and Switzerland, the R&D groups are close to or below critical size. Industrial involvement is rather limited at the present stage. For the R&D labs with partly industrial financing, the collaboration and communication is very closed. Communication between independent labs must be improved.</p>

Overall assessment of Strengths & Weaknesses	
BIPV (NOVEM)	<p>WEAKNESSES: Regional differences in building techniques and diversity of regulation (electrotechnical but mainly building regulation). Protective attitude of industry leads to more overlap in development. Differences in experience, "language" and attitude between pv industry and building industry.</p> <p>STRENGTHS: Strong SME base and culture, which is particularly strong in leading economies. This SME base can respond in a very flexible way to technical and market opportunities. Industry is innovative with respect to building components. Market inspired initiatives by building companies, creating strong chain interaction in some countries.</p>
Inverter/BOS etc (NAPS)	<p>Strengths: In the inverters RTD has successfully brought into Europe several good companies, which have good reputation and are forerunners in the field; that is really a European strength. On module inverters EU is the forerunner. On the controller side the situation is more even, but EU is still strong: same controllers are easily used in many countries.</p> <p>Weaknesses: Strong domestic markets for inverters may prevent stronger cross-national business and technology development. There are still very many small BOS producers (esp. controllers) so that there ability to be leaders is reduced.</p>
Stand-alone system (NAPS)	<p>Strengths: R&D and system know-how on advanced stand-alone systems.</p> <p>Weaknesses: R&D on advanced concepts should be probably in larger networks. Batteries form quite a big share of the system costs. They need time to time replacement, which is expensive. However, solar batteries are not yet interesting enough business for battery manufacturers to develop a cheap, long lasting battery which is withstanding both cold and hot environment.</p>

Opportunities and Threats

R&D			
	Intruding Trends	USA/Japan	Overall remark
Crystalline silicon cells (ADEME)	Crystalline silicon based technologies are, according to various experts, the industrial technology that will be difficult to beat concerning conversion efficiency (20 % range) and production costs (less than 1 EUR per watt) and that situation might prevail for 15 to 20 years according to experts. Crystalline silicon field is no breakthrough-type technology but the strong European research base will allow new fields of investigation (low cost and high throughput process for producing feedstock silicon, thinnest and larger cells, revisited concept of multicrystalline silicon ribbons, combinations of c-Si and a-Si, nanotechnologies, porous silicon, new concepts to make PV modules, etc.). According to experts one must push the research to 'the bone'. Moreover there are opportunities to develop new PV modules combining building materials and crystalline silicon cells. An opportunity for both the PV industry and the building industry to develop new components and new markets.	European c-Si research is in good position compared to Japan and the USA who also have RTD in the field. There is no threats coming from them at the university level but it is not the case in the commercial field where the actors are fierce competitors. There are opportunities to develop research cooperation's at university level between Europe, Japan and the USA. Cooperation between university laboratories is easier than that of the industry and should be reinforced. Already some bilateral cooperation operates (exchange at post-doctoral level).	It is generally commented that the Europeans study the materials, the US develops the devices and the Japanese sell the final products. PV does not escape to this statement (the case of thin film hydrogenated amorphous silicon material is striking on that respect). It does not mean that Europe must reconsider its tradition of basic research but Europe must insure that SMEs can benefit from favourable conditions to implement new technologies.
Thin-film silicon cells (INETI)	It's a well known area with increased interest. The collaboration between Crystalline and Silicon Thin film technologies bringing together both technologies will represent an important Opportunity.	Though Europe R&D is high level results are still behind those of Japan and USA. A larger degree of co-ordination of national policies and support from European programmes is essential for filling this gap.	Japan and USA are important threats to Europe in this field

R&D			
	Intruding Trends	USA/Japan	Overall remark
Other thin-film cells (FORMAS)	The area continues to be of interest and no other R&D area (PV or other) is presently a threat to resource depletion.	Both Japan and USA are strong in thin film. Tendencies for increased Japanese competition, and decreased American competition.	Japanese and USA are threats to EU R&D, even though Japan tends to be a bigger threat. No other R&D areas of any particular threat.
Organic cell, Polymers (DEA)	This area divided in two groups: a family of technologies based on organic dye sensitizing on inorganic nanosemiconductors and a family of entirely organic cells. In the past 10 years the first family attracted most of the attention, while the latter family has boomed in the past three years.	Japan, Australia and the US have running activities in DSC and polymer technologies. Heavy commercial activity and competition from Australia and Japan in DSC technology. Australian DSC technology based on fundamental Swiss R&D work.	Important fundamental R&D carried out in many countries worldwide. The critical argument seems to be adoption of technologies by industry. In this context both US and in particular Japanese based industries seems more willing to enter new technologies.
BIPV (NOVEM)	Opportunities: European building sector is searching for new building envelop material PV can provide that with added values; Strong increase in interest on energy efficiency of buildings; There is a trend of more demand for electricity, less for warmth. Threat: Trend to generalise R&D funding to general RE and not longer pv specific.	European BIPV markets and R+D are strongly isolated from USA/Japan. Opportunity: use experiences from USA and Japan;	Opportunity: use these general building industry trends
Inverter/BOS etc (NAPS)	No	USA has more concentrated R&D.	Due to more spread R&D in Europe, USA is a threat, but not Japan.
Stand-alone system (NAPS)	Cheap Chinese aggregates.	On conventional batteries USA and J lead EU, in advanced systems EU is equal.	Europe is quite well positioned here. RTD focus in future systems.

Industry			
	USA/Japan	R&D Involvement	Overall remark
Crystalline silicon cells (ADEME)	The USA is making an effort on c-Si process development. In Japan the policy is still oriented towards high efficiency c-Si cells.	There is an opportunity for European researchers to 'compete' or cooperate with American and Japanese industry teams in that field	Industry R&D cooperation is possible only within corporate contracts.
Thin-film silicon cells (INETI)	Japan industry is an important threat with several companies (SHARP, SANYO, KANEKA, MITSUBISHI) already in the market of thin film technologies.	Threat: The lack of Industrial competition will not lead to R&D involvement of industry.	Opportunity: More SMEs based on Industry collaboration with R&D institutions. Threats: Lack of competition at industrial level. Japanese industry.
Other thin-film cells (FORMAS)	USA: fewer activities commercially exploiting R&D to industrial level making US a lesser threat. For Japan it is the opposite.	Weak increase in industrial involvement foreseen in the short term.	Japan the largest threat and larger companies being less involved a weakness that could be a threat taking the first into account. The opportunities in job creation through SME involvement, also being good for R&D-industry collaboration.
Organic cell, Polymers (DEA)	High activity in R&D and commercialisation of these technologies in Japan. Level of activity is lesser in the US.	Same as above.	Same as above.
BIPV (NOVEM)	European BIPV markets and R+D are strongly isolated from USA/Japan. Opportunity: use experiences from USA and Japan;	Opportunity: possibility to work with local RDC Threat: too little feeling at RDC for building industry problems	Opportunity: use these general building industry trends
Inverter/BOS etc (NAPS)	US products are imported much to EU and somewhat vice versa in stand-alone.	Higher efficiency and good stability shall require R&D also in future.	USA is stronger competitor to EU than Japan. In national aid programmes tendency to use domestic products.
Stand-alone system (NAPS)	US and EU quite equal. Japan somewhat behind.	In conventional stand-alone very little R&D. Advanced stand-alone driven by R&D.	Conventional stand-alone is cost driven business.

Raw materials			
	Availability	Geographic Location	Overall remark
Crystalline silicon cells (ADEME)	At laboratory level the best PV cell conversion efficiency attained is 25 %. In the industry the commercial product is 14 % to 16 % efficient. Thus there is still scope for improvement. The challenge is to reach this record efficiency at very low cost.	Japan and Europe	The USA is making an effort on c-Si process development. In Japan the policy is still oriented towards high efficiency c-Si cells. There is an opportunity for European researchers to ‘compete’ or cooperate with American and Japanese industry teams in that field. Industry R&D cooperation is possible only within corporate contracts.
Thin-film silicon cells (INETI)	Plenty of raw material. No threats in this field.	Widespread.	No problems in this technology.
Other thin-film cells (FORMAS)	No immediate problem/threat foreseen. Indium supply could be a long term problem as indium-tin oxide transparent conductors are competing with thin film PV for the raw material.	Globally widespread. No threat.	No immediate threats, and so far only opportunities. However, in the long term indium availability could be a threat due to competing use of the material.
Organic cell, Polymers (DEA)	No immediate problem/treat foreseen. One of the major points in using 3. Generation PV technology is the enhanced freedom in materials available.	Globally widespread. No threat.	No threats identified.
BIPV (NOVEM)	no problem	na	none
Inverter/BOS etc (NAPS)	Occasionally some key IC components may not be available.	No threats identified.	At most this is a logistical question.
Stand-alone system (NAPS)	Occasionally some batteries may not be available or have long delivery time.	Globally widespread. No threat.	No threats identified.

Policies			
	R&D / Energy	Funding level trends	Overall remark
Crystalline silicon cells (ADEME)	The public RTD money investment allowed the development of a European PV industry employing high-tech well-trained people. Photovoltaic technology is a renewable source of energy not ignored by policy makers. The high-tech nature of PV is appealing and countries where there is a PV industry recommend sustained R&D effort.	The PV c-Si technology has a long history (25 years). It is at the same time strength and a weakness. The technology is often regarded as old fashioned compared to more promising thin film approach.	It is observed some damageable stop and go policies particularly in the field of crystalline silicon technology. There is constant need to explain why R&D effort must be maintained on that technology.
Thin-film silicon cells (INETI)	This technology will lead to lower prices of electricity production and lower material consumption and in this context it is hoped that the trend will be to an increase support of R&D in this field.	An increase in fundings is needed both at National and European level in order to fight the threat of Japan industry in this field.	A better coordination between National and European policies towards the development of strong and competitive European industry in this field.
Other thin-film cells (FORMAS)	Most policies in favour of PV in general and thin film in particular. Possible threats could be an increased focus on other technology areas for the same purpose, i.e. Environmentally friendly technologies and security of supply.	Stable. National funding for thin film PV R&D important for its continuity and sustainability. Tendencies from national funders to rely on EU fundings could be a threat.	A threat could be that lots of money has been spent on thin film PV R&D without and substantial commercial success. This could give political incentives for using R&D funding for something else. Otherwise most things point in the direction of large opportunities.
Organic cell, Polymers (DEA)	The area is given little attention compared to crystalline and traditional thin-film cells. Based on the European strength in the field of polymers in general, a more aggressive policy in this PV field seems appropriate	Unstable. Poor understanding or belief in technology potential. The lacking commercial success of the thin film investments stands in the way for future investments in novel technologies.	Discontinued funding and start/stop effects pose a real threat.
BIPV (NOVEM)	Threat: Other RE options, especially those applicable in the build environment; PV is just one option for realising general policy ambitions for CO2 reduction, energy efficiency and RE implementation. Opportunity: Unified European policy on RTD, norms and standardisation, market support.	There is a trend that funding object moves from pv provider to market (pv consumer). Another trend is that funding moves from pv specific to more general RE funding Threat: comparative disadvantage for PV in realising short term RE policies which may result in less funding; Differences in funding policies within Europe, lack of consistency over time	Opportunity: Unified European policy on RTD, norms and standardisation, market support

Policies			
	R&D / Energy	Funding level trends	Overall remark
Inverter/BOS etc (NAPS)	Probably not an issue for BOS.	Stable or reducing.	IEC norms, if widely in use, are threat to small companies. That is also an opportunity for strong companies sell products more widely, to raise their imago and product quality.
Stand-alone system (NAPS)	Stand-alone is done on commercial basis for private people independent on policy making. However, there is stronger influence on communities and corporations which can get subsidy for stand-alone.	Advanced stand-alone will be one of the areas to get more funding.	Advanced stand-alone is a long-term project which needs a lot governmental funding.

Markets						
	EU vs Others	Consumer awareness	Technical applicability	Liberalisation vs non-liberalisation	Decentralisation vs Centralisation	Overall remark
Crystalline silicon cells (ADEME)	Crystalline silicon technology is well established. Building integration of this type of material is a new opportunity for European industry: both PV and building industry. PV requires policies for market development. High investment cost is a barrier. Several approaches are developed by countries (feed-in tariffs, subsidies, green electricity schemes, low interest loans, etc.). Note - A study on the results of the various policies in connection to deregulation of electricity market might be a way to determine the most appropriate policy.					
Thin-film silicon cells (INETI)	European Market isn't yet aware of this technology though there is a high level technical (mostly at R&D level) European knowledge of the technology. European market is threatened by strong Japanese competition.					
Other thin-film cells (FORMAS)	Communication between policy and industry creates short-term programmes and communication between R&D and policy makers important to create long-term possibilities (new technologies). The consumer awareness is low regarding thin film PV technologies, but good regarding PV in general. The markets tend to be created in Europe and in Japan. Liberalised markets tend to favour low cost, off-the-shelf technologies, which is a threat to thin film technologies being a "new" creation. However, the applicability of thin film technologies to a many market niches is an opportunity for thin film technologies.					
Organic cell, Polymers (DEA)	Same as above. As these technologies are immature, they do not address specific markets yet. The development of markets is expected to follow some of the trends as for thin films. This type of PV cells will preferable be used in vertical facades, and it is foreseen that flexible applications with added values will be future trend. A special architectural interest is therefore expected.					
BIPV (NOVEM)	EU versus USA: The ratification of the Kyoto protocol provides opportunities; Consumer awareness opportunity: BIPV is sexy. Technical Applicability opportunity: the best and most successful BIPV product is a product that can be treated (obtained, marketed, applied and serviced) as a building product Threat: (the image of) low quality products The liberalised market provides opportunities: it searches for increased values. BIPV can provide that. The perceived decreasing quality of electricity net and the trend to decentralise also provide opportunities for BIPV but here the lack of storage capacity may be a threat.					
Inverter/BOS etc (NAPS)	Consumers want to have more comfort from the PV system than earlier. Therefore, one can foresee clear grow of system size and e.g. use of inverters in off-grid systems, too. EU market will be similar to Japan, perhaps more than in US, if the roof programmes will continue and spread to many more EU countries.					
Stand-alone system (NAPS)	Advanced stand-alone is an area where EU can be a leading actor in the world. If decentralisation is favoured, then stand-alone market will grow more substantially than now. Otherwise, stand-alone remains as a minor share in EU and major market will be in developing countries. US are in a more favourable situation, because there are more sunny areas where seasonal storage is not needed as in major part of EU.					

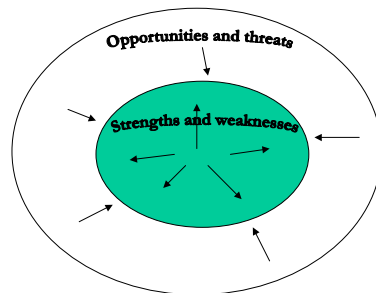
Intruding technologies (if applicable)	
Crystalline silicon cells(ADEME)	The main threats to c-Si field technologies are coming from thin film technologies. Nevertheless there are approaches such as multicrystalline silicon ribbons, silicon micro-spheres, thin layers of c-Si on foreign substrate that might become a threat to silicon wafer based technology. The c-Si industry might be able to switch from wafering to another approach without putting too much long-term investment in question.
Thin-film silicon cells (INETI)	No specific intruding problems. On the contrary it is advisable to promote synergies between Silicon thin film and Silicon crystalline wafer technologies.
Other thin-film cells (FORMAS)	The largest threat to thin film technologies (CIS, CdTe) are other PV technologies in the first place. Other technologies that replaces PV and competes in the same niches are e.g. wind energy.
Organic cell, Polymers (DEA)	First of all DSC and polymer PV technologies are in the very beginning and mass exploitation of these technologies is still to come. The technological potential is considered very large, though considerable work and documentation is to be done. When these technologies meet the expected reduced cost in practice and fulfil basic requirements of flexibility and stability they might be able to open considerable markets which cannot be addressed with conventional PV or thin film PV systems.
BIPV (NOVEM)	Threats may come from other decentral electricity generators that obtain commercial attractiveness much sooner than BIPV. Opportunities may arise from innovative combination with insulation or thermal applications.
Inverter/BOS etc (NAPS)	Not applicable.
Stand-alone system (NAPS)	Cheap Chinese diesel aggregates.

Overall assessment of Opportunities and Threats (include your comments referred to short-medium and medium-long term aspects)	
Crystalline silicon cells (ADEME)	<p>Opportunities The European high-tech SMEs hold the key to employment and growth. Photovoltaics are an innovative source of new, high quality jobs. The SMEs involved in PV field (from materials to installation) contribute to this development. The European strong PV R&D base is a chance for a competitive c-Si industry. New investments in production capacity are announced by companies. Nevertheless there are hesitations since European market is not fully established and the important potential export market depends upon international aid programmes. In Europe several new companies entered the field during the last three years. Financial investments in the c-Si technology are still high and greater than that of other PV technologies. Nevertheless it is wondered if small companies with limited cell/module production capacity (say an annual capacity of the order of 10 MW) can survive against larger companies able to mass-produce (capacity of the order of 100 MW).</p> <p>Threats The US and particularly the Japanese c-Si industry are very strong and competitive. Concerning R&D the threat could be a lassitude of public policy makers not seeing in c-Si the breakthroughs they hope. The c-Si technology is improved step by step. A threat on public research is the stop and go policy (why to maintain effort on this well-known material? Why not invest more in thin film, etc.). This situation occurred in the past at the EC level. Fortunately certain Member State programmes maintained support of the c-Si field at national level. The threat to c-Si technology is the constant claim of the promoters of thin film concepts that pretend that their technology is the future since thin films fit well with large area glass panels (general statement nobody opposes). Thin film are claimed to be cheaper to produce (theoretically half the production cost of c-Si if large amount is produced like 500 MW per year), etc. Thus making potential investors in c-Si field waiting for these thin films cells to demonstrate their claimed capabilities. Particularly the investors on feedstock silicon that would need an important market to justify their investment (XXX MEUR per ton of Si. Note: 10 to 20 tons of silicon is needed to produce 1 MW of PV cells).</p>
Thin-film silicon cells (INETI)	<p>Silicon thin film technologies can be cheaper, and use less material. These technologies are well specified for Building integration of PV giving lead to a decentralised electricity production future. The efficiency isn't yet good enough calling for more R&D probably targeted to the association of Silicon thin films with crystalline technologies. The market is already functioning and Japan is now taking the lead. European Industry is lacking competitiveness and the market isn't yet aware of this technology.</p>
Other thin-film cells (FORMAS)	<p>Thin film technologies in this category have large opportunities as funds are available and industry interested. However, tendencies of "waiting" large industrial partners and the lack of commercial feedback for R&D funding could be a threat to the thin film PV R&D. In addition, Japanese R&D and especially industrial involvement a large threat (USA to a lesser extent, but still..). Another threat in the longer term is alternative use of the raw material (indium).</p>

<p>Organic cell, Polymers (DEA)</p>	<p>Some of the PV cells of this type, such as e.g. PEC cells seem to have a great potential of flexible applications, eventually combined with shadowing solutions in vertical facades, and different architectural solutions. Even if 8 % efficiency should prove to be a provisional maximum, the perspective of a good price/performance ratio compared to other types of PV cells is at hand. Moreover the production technology could be more simple and demand lesser investments compared to silicon technology, which could be an opportunity for smaller European manufacturers.</p>
<p>BIPV (NOVEM)</p>	<p>Short term: Opportunities are found in: 1) the optimal integration of electrotechnical and building qualities. This can be enhanced by uniform regulations and standards; 2) Close cooperation with, or incorporation in the building industry, making the best use of general trends in the building industry that provide good opportunities (new building envelope with added value; interest in energy efficiency; higher demand for electricity); 3) Make better use of already existing knowledge and experience, using the expertise of local RDC's, by improved networking and co-operation and interest in Japanese and American solutions; Threats: 1) Isolated development of products that have suboptimal quality or - even more important- are not adapted to the building process may set a negative image and seriously disturb the market. 2) Inconsistencies of building and PV policies between countries and over time.</p> <p>Long term: Threats may come from other decentral electricity generators that obtain commercial attractiveness much sooner than BIPV. Opportunities may arise from innovative combination with insulation or thermal applications.</p>
<p>Inverter/BOS et (NAPS)</p>	<p>In general, for BOS component producers PV business has been profitable all the time.</p> <p>Opportunities: European BOS technology and companies are competitive. If IEC standards become common, e.g. for inverters, that may open wider geographic markets for strong companies. Also, AC power is more and more demanded from PV, which widens the market. Better efficiency makes the products more interesting.</p> <p>Threats: Cheap Asian products: when production moves to Asia, cheap copies come to EU. European companies, if they remain small, cannot compete against bigger US companies.</p>
<p>Stand-alone system (NAPS)</p>	<p>In short to medium term: business grows quite moderately. No big technological leaps to be expected: major challenge is to get cheap reliable batteries.</p> <p>Opportunities: In long-term, hydrogen / fuel cell combined with PV will bring something new to the business and open new applications even if there is need for seasonal energy storage.</p> <p>Threats: If expectations are raised too high, decision makers come impatient towards advanced stand-alone, and R&D is reduced too early. Competing stand-alone power systems develop also (e.g. small diesel generators).</p>

Appendix 2 – Description of the method for SWOT

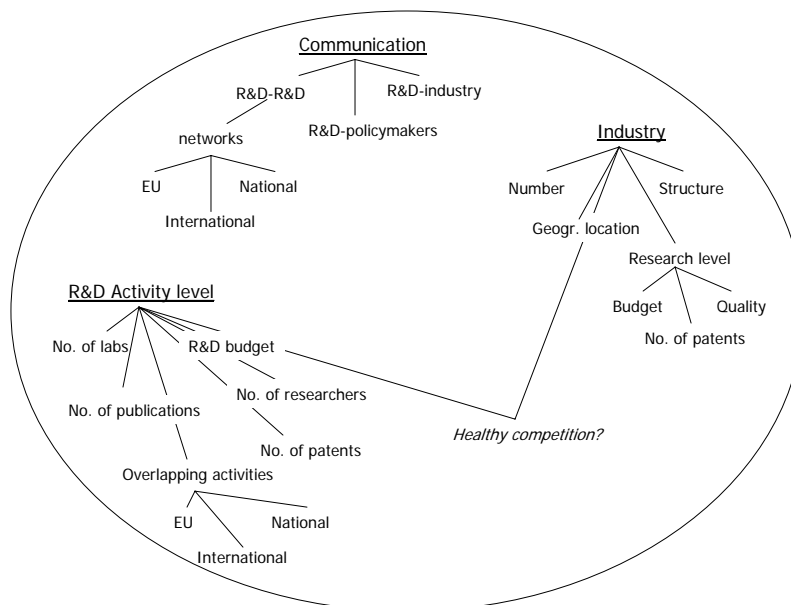
The SWOT analysis of the EU PV research level will be done in two steps: first the analysis of strengths and weaknesses, and later of opportunities and threats. This is due to strengths and weaknesses relating to the research community itself, i.e. inward looking aspects, while opportunities and threats more relates to aspects outside the research community itself. Now these aspects are naturally related, and aspects of outward and inward aspects have to be looked upon in parallel. This can schematically be shown as below:



Strengths and weaknesses

Strengths and weaknesses (from now on called S & W) depends on several issues schematically shown in the picture below:

Strengths and weaknesses – “looking inward”



From this picture we have localised a number of key issues: Materials, industry, communication and R&D activities. These will be dealt with for each PV technology area respectively in the attached Excel tables. For clarification the different key issues to be assessed for each PV technology area are described in more detail below.

R&D activity level

In order to be able to assess the present R&D status, and thereby its strengths and weaknesses we need to assess a number of aspects, such as:

No. of labs: how many labs are there in EU? This has been indicated in the previous Excel sheets made for each country. In addition to the figure mentioned, please add indications on sizes and geographical locations.

No. of researchers: if possible indicate the number of researchers in quantitative terms. If this is not possible, please indicate a qualitative assessment of how these researchers appear in the above-mentioned labs.

No of articles in reference journals: The number of articles gives an indication of activity level, as well as R&D quality. If possible, indicate if these have been well spread over the years, or if they are published recently or several years ago. If not available, please indicate, in your opinion, if key words like low, medium or high plus timely appearance could be given.

No. of patents: Just as the number of articles give an indication of the R&D activity level, so does the number of patents registered from R&D institutions. If not available, please indicate, in your opinion, if key words like low, medium or high plus timely appearance could be given.

Overlapping activities: the status of overlapping research will also have to be assessed in qualitative terms, as well as whether a competition occurs that could be healthy for the EU research community or not.

R&D budget: in addition to the above-mentioned indicators, please give in figures or as an assessment the level of R&D budgets available. Note that the figures already available have been taken from previous country-wise assessment sheets.

Finally, try to give some **overall remarks** on strengths and weaknesses regarding R&D activity level.

Industry

As the present industrial involvement in the research has an implication on the S & W of the EU research, this will have to be assessed in qualitative terms. Parameters of interest are:

- Number of industrial R&D labs
- Number of manufacturing industries available in Europe (quantitative numbers if possible)
- The size and structure of these industries (SMEs, large, multinational etc)
- The geographical location in Europe of these industries could be of interest in the S & W assessment
- The R&D activity in industry is of importance, and we have divided this into:



- Budget set aside for R&D
- An assessment of the quality of the R&D in industry
- The number of patents registered (When did they appear in time? Recently?)

Finally, try to give some *overall remarks* on strengths and weaknesses regarding Industry and industrial activities.

Communication

Communication is in this context defined as both "communication" in the meaning of the word, as well as actual work collaboration.

The level of communication between the research community and the surroundings are interesting parameters for the S & W assessment, here divided into

- **R&D-R&D/industry**: what level of communication would you consider the present R&D community to do amongst themselves? What level of communication and collaboration is there between the R&D community and industry?
- **R&D-policy/decision makers**: what level of communication is there between the policy and decision makers and the R&D community, and in what way does this manifest itself?
- **Networks**: as a manifestation of the communication networks will be established, and under this heading we want you to make a quantitative estimate of the number of "stable" networks, i.e. that has been used for more than 2-3 years.

Finally, try to give some *overall remarks* on strengths and weaknesses regarding Communication.

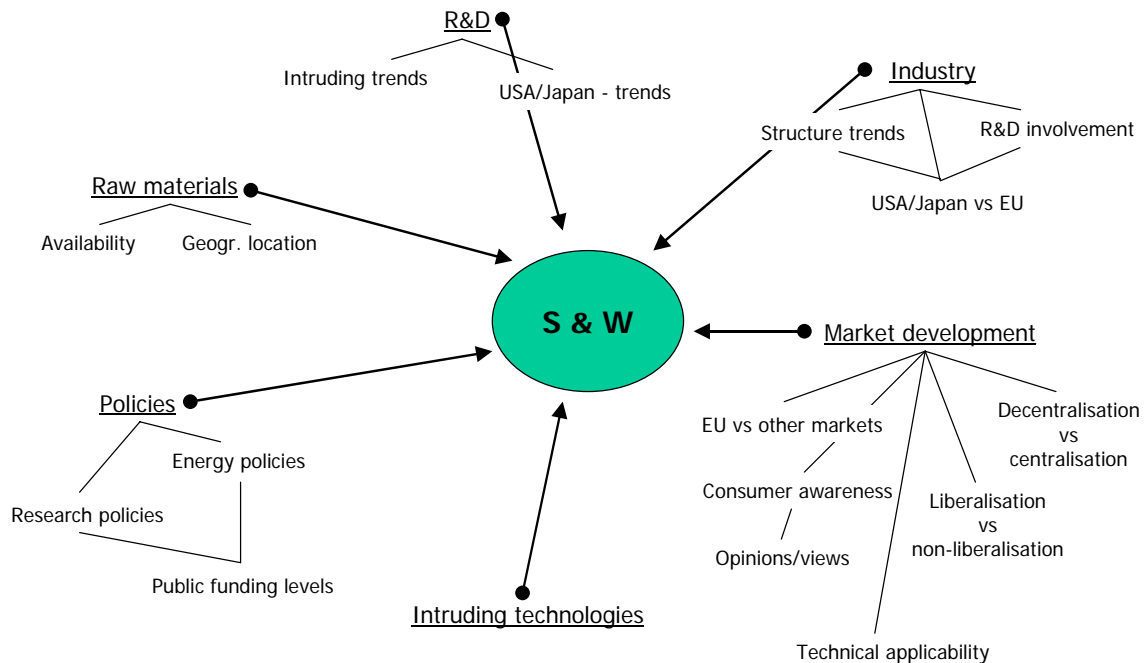
Overall assessment

Finally we want you to use the collected data and make your overall assessment of strengths and weaknesses of the particular PV sector. In addition, the assessment needs to be done on the technology area on short- and long-term aspects.

Opportunities and threats

Opportunities and threats (from now on called O&T) depends on several issues schematically shown in the picture below:

Opportunities and threats – “looking outward/trends of today”



Note that all aspects dealt with in this picture should be seen upon as short-to-medium-term trends, and the assessments should be done from this point of view. From this picture we have localised a number of key issues: R&D, industry, raw materials, policies, market development issues and intruding technologies. These will be dealt with for each PV technology area respectively in the attached Excel tables. For clarification the different key issues to be assessed for each PV technology area are described in more detail below.

R&D

In order to assess the opportunities and threats in EU PV research, we need to assess trends within the research community towards possible other areas of research (many times governed by policies, but also from other means). Will there be areas to which PV researcher or even students will prefer rather than using their skills in the PV research?

In addition, the trends in research in other areas of the world are of great interest, in particular USA and Japan.

Industry

Taking the assessment and evaluation from the S&W sheets, what are the trends in short-to-medium term regarding:

- Structures – trends speak for SMEs rather than multinational or vice versa? New establishments foreseen?
- R&D involvement – trends on increasing budgets or consolidation around key issues in the companies?
- The involvement of industries from outside Europe, especially Japan and USA – are they focusing on EU market or other markets for their increasing or decreasing involvement in PV activities (commercial and/or R&D)?

Raw materials

The raw material around which PV research in Europe is focused is of interest, and especially the availability and geographical location of these materials. This should be seen upon in the context of possible threats and opportunities in case of war or other conflicts in the world. Are there any trends on the raw materials used for PV being used in other “competing” sectors?

Policies

What are the political trends regarding research policies and energy policies? In what way will these trends possibly have an implication of the funding level available? This should be assessed on national, EU and/or international level.

Market developments

Market developments will have implication on the industry in the first place, being on the commercial side of the PV technology sector, but also on the long term on the research activities. Trends in the market also inflicts on the policies discussed mainly on national levels, but also in some cases on the EU level. From this point of view, we like you to make an assessment on

- EU vs other markets – where do they appear and what are the trends?
- Consumer – what are the consumers awareness on PV, and what are their opinion on using R&D funding for PV?
- Technical applicability – are the R&D at present compatible with technical application they are used for, seen in short-to-medium as well as medium-to-long term? Relations to industry?
- Lib/non-lib – will liberalisation of electricity markets have an implication on PV activities, and will other relevant markets have trends that could be related to the issue of liberalisation of electricity markets?
- Decentr/centralisation – what are the trends in your particular PV technology area regarding the issue of decentralisation or centralisation of electricity production?

Intruding technologies

In addition to all sorts of competition in the present and future markets, there might be niches in which PV technology could come to a situation of competing with new technologies, e.g fuel cells, wind energy etc. This will be a fair competition, but if particular market niches could be foreseen as a too large disadvantage in favour for PV technologies, maybe putting large R&D efforts could be useless and should be avoided. Maybe this is not the case, but we cannot be too sure, and the issue is therefore raised as a precaution measure.

Make an assessment on this issue taking your knowledge of the PV technology and its applications into account. Think medium-to-long term as well as short-to-medium term.



This report (and others) can be obtained from the projects' web-site:

www.pv-ec.net