



PV - EC - NET

WP4 BENCHMARK ANALYSIS

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Executive Summary

As part of the initiatives of the European Commission to develop a European Research Area for photovoltaics, a project has been developed and undertaken drawing together a team of national PV RTD programme management bodies within Europe to look at ways in which the effectiveness and coherence of these PV RTD programmes might be improved. For PV, this particularly recognises the desire to improve Europe's competitive position compared to the activities in the USA and Japan.

The approach taken by the project team was to divide the project up into the following discrete work packages:

1. An examination of existing organisations and networks within Europe with a view to identifying opportunities for more effective cooperation.
2. The definition and collection of data on PV RTD programme activities within Europe.
3. Undertaking a benchmarking of European PV RTD programmes compared to the competition.
4. Undertaking an analysis of strengths, weaknesses, opportunities and threats for European PV RTD programmes.
5. Formulating a European PV RTD Road Map.
6. Dissemination of Information.

This report describes the work undertaken in work package 3 above. The main approach was to collect a range of data on the national PV RTD programmes via a structured questionnaire and to use the collective experience of the programme managers and experts in the project team to interpret these data. This analysis was broken down into five areas looking at:

- Programme Organisation
- Aims and Achievements
- Incentives and Barriers
- Programme Spend and Effectiveness
- Areas of Activity Focus

The more detailed conclusions are spelled out at the end of this report, but in summary, there appear to be two broad areas for improvement of PV RTD programming in Europe.

The first area can be labelled as "**focussing**". It addresses the following points of weakness as compared to Japan and the USA:

- uncoordinated diversity of activities
- lack of continuity
- diffuse aims, objectives and targets
- imbalance between RTD and market incentives
- incomplete 'visibility' of a diverse field of activities
- many small and dispersed research teams

The second area can be labelled "**more involvement with the industry**". It deals with the following points of weakness as compared to the USA and Japan:

- activities do not generally have a strong industrial focus
- too little research is focused on production issues
- links between universities / research centres and industry are too weak



- industry and public RTD programmes have not yet achieved the same level of integration in programme definition as compared to the USA and Japan

This leads to a simple overall conclusion, which confirms the initial rationale for this project: European national PV RTD activities should prepare a roadmap collaboratively with the European industry.

From the foregoing analyses some factors were identified, which are seen to be helpful to the development of effective European RTD programmes. The project team has identified what they believe to be some of the key issues under the five headings of:

- Policy;
- Strategy;
- Objectives;
- Organisation;
- Resources.

Further details are given at the end of the report. Adequate implementation of these principles could help to provide a basis for 'good practice' for PV RTD programmes.

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1 Introduction and Background

This report is one of a number produced under project ENK6-CT2001-80578 ‘Network for Co-ordination of European and National RTD Programmes for Photovoltaic Solar Energy’, PV-EC-NET, supported by the European Commission. It describes the results from one of the work packages of the project. This chapter briefly sets out the general background to this project and the context of the European research area and sets out the potential for Photovoltaics before describing in more detail the contents of the report.

1.1 BACKGROUND

The Lisbon European Council in March 2000 called for the enhancement of innovation in the Union as a response to globalisation and the challenges of the knowledge-driven economy. At Lisbon the Union set itself the combined goal of strengthening social cohesion and becoming the most competitive and dynamic knowledge-based economy in the world within the next decade.

The overall strategy to achieve this was also mapped out at Lisbon. Establishing a European area of research and innovation to better combine the efforts of the Union and the Member States in these two areas was one of the key messages. Building on the economic convergence already achieved, an “open method of co-ordination” was devised in order to help Member States develop more effective policies for creating new skills and capacities. In this context, the European Council explicitly requested the introduction of a European Innovation Scoreboard¹.

The 2001 scoreboard analyses the current data in depth, depicts achievements and trends, highlights strengths and weaknesses in Member State performances, examines the level of European convergence, and leads to proposals for action. The scoreboard shows that the world’s leading countries for many innovation policy areas are to be found among EU Member States. This demonstrates the enormous potential for the exchange of good practice and learning within the EU.

The scoreboard is one of the benchmarking exercises of the European Commission launched subsequent to the Lisbon European Council. In its Communication “Realising the potential of the European Union – Consolidating and extending the Lisbon strategy”² the Commission provided a series of “structural” or “flagship” indicators, on which the more specialised scoreboards such as the European Innovation Scoreboard, the Enterprise Scoreboard³, and the ongoing benchmarking of national research policies⁴ should draw.

The activities of this project looking at one very specific segment of technological development – photovoltaics – should be seen within the broader context outlined above. Some of the results of the European Innovation scoreboard also provide useful background to the findings of this project.

¹ <http://www.cordis.lu/innovation-smes/src/policy.htm>

² COM(2001) 79.

³ Benchmarking Enterprise Policy. First results from the scoreboard, SEC(2000) 1841.

⁴ Progress report on benchmarking national research policies, SEC(2001) 1002.



1.2 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 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.

Within the European community, RTD activities in the field of PV are supported by European and National programmes. There is a suggestion 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. PV-EC-NET is designed to help facilitate better co-ordination of the national and European PV RTD programmes in order to create a stronger and more coherent set of PV RTD activities within the EU.

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.

The action undertaken here is part of a Thematic Network '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:

- To propose ways to improve 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 analyses 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 EC 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 and other stakeholders.



1.3 THIS REPORT

Within the framework outlined above, this report gives the results of the work carried out under work package 4 of the project: - an analysis of the National and EU PV RTD Programmes. The analysis is based on the data collected in work package 3.

In the original work plan the activity for work package 4 was summarised as:

'The main activity within this work package is a benchmark of the European programme and the national programmes of the EU member and –associated states. In order to get an objective view of the effectiveness and efficiency of these programmes an international survey will be part of this work package.'

'Part of the international survey, will be the analysis of the programmes of the 3 most important non-European countries in the PV market, being Japan, the USA and Australia.'

'The result of this work will be a report, giving an overview of the programmes, describing for each of them the advantages and disadvantages and the effectiveness in relation to the targets.'

In the context of the overall work plan, it can be seen that this 'benchmarking' provides an input to the SWOT analysis leading to a suggested European RTD 'Road Map'.

The rest of the report is set out as follows:

A more detailed discussion of the data, methodology and approach used for the analysis is presented in Section 2.

Sections 3 to 7 then focus on the analysis of data grouped under five key areas:

- Review of Programme Organisation
- Review of Aims and Achievements
- Incentives and Barriers
- Programme Expenditure and Effectiveness
- Areas of Activity Focus

Some overall conclusions are presented in Section 8.

2 Methodology and Approach

There was considerable constructive debate among the partners during the formative stages of the project as to how to approach the related activities of data collection and benchmarking of PV RTD Programmes.

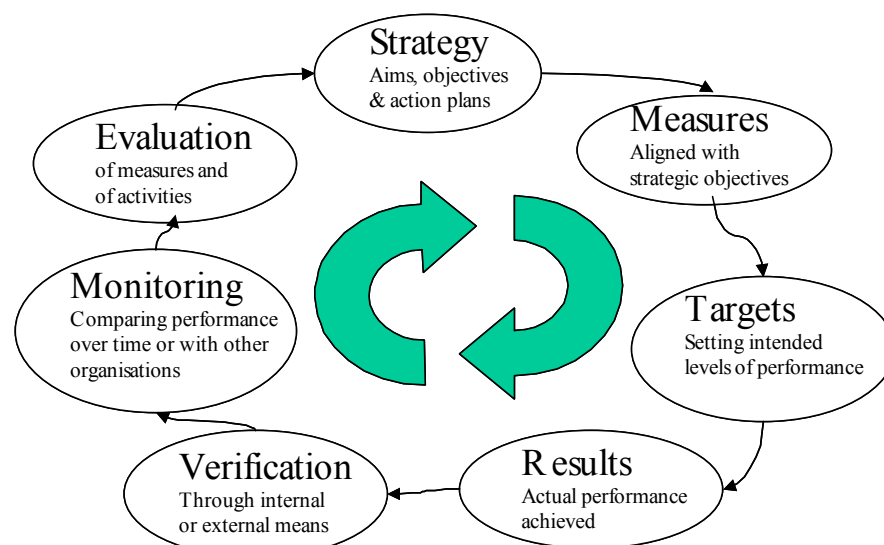
The first ideas focused more on highly quantitative and objective data, but during the discussions, this was developed into a rather more open and qualitative approach. There were a number of reasons for this:

- Firstly, more quantitative data has already been collected and is available for example through the IEA PVPS programme and the EC is also developing a set of quantitative and specific technology indicators for PV. There appeared to be no added value in duplicating this;
- Secondly, it was felt that the qualitative assessments of the experts and programme managers involved could be more valuable and effective by this means. (The individuals involved in the project represent a unique resource of experience related to RTD programmes with first hand examples and insights of the causes of success and failure.)

A typical general performance measurement model might have the following steps:

1. Set aims, objectives and action plans
2. Decide measures (aligned with strategic objectives)
3. Develop targets identifying intended levels of performance
4. Identify (measure) actual performance achieved
5. Undertake verification of results
6. Monitor – comparing performance over time or with other organisations
7. Evaluation – of measures and activities
8. Back to step 1.

This model is also illustrated schematically below:



This shows the inter-related nature of the process from the initial setting of aims and measures to the final evaluation. One of the issues for this project has been the fact that not all programmes have followed the same approach to the evaluation process and so measures and targets are often not comparable.

When trying to assess the effectiveness of a programme, it is also recognised that the programme aims are only likely to be realised over a relatively long time scale, and there may be considerable difficulties in linking cause and effect. The approach adopted here is therefore to try and capture the key activities, priorities and drivers for the national programmes (and measured outcomes where possible). This will at least enable the scale and focus of activities to be benchmarked, common or divergent themes and issues to be identified and from this some views about outcomes and effectiveness may be inferred.

The view was also taken that the scope of this exercise should focus strongly on the RTD (Research, Technological Development & Demonstration) programmes whilst recognising that they are carried out within the broader context of a range of other national and international activities driven by both the public and private sectors. An attempt to clarify the differences between 'programme' and 'context' was made as indicated below.

To be included as 'programme' organisation:

- (national) PV RTD programmes
- (national) RE RTD programmes in which PV projects may participate (with or without fixed budgets or budget-percentages for PV)
- (national) energy RTD programmes in which PV projects may participate (with or without fixed budgets or budget-percentages for PV)
- (national) general RTD programmes in which PV projects may participate (with or without fixed budgets or budget-percentages for PV)

To be included as 'context' (other incentives):

- base funding
- ad hoc projects
- legislative obligations
- tax measures
- budget allocations by R&D institutes and universities

The data collection template (questionnaire) as developed in discussion with the project partners is shown in Appendix 1. The template divides the data into a number of main sections:

- General information which sets out how PV RTD activities are organised
- The aims, scope and methodology of the RTD activity
- The assessment approach for the RTD activity
- Other PV support mechanisms

Data were collected for each of the national programmes of the project participants as well as other significant programmes. The countries covered were:

<i>Australia</i>	Greece	Portugal
Austria	Italy	Spain
Belgium	Japan	Sweden
Denmark	The Netherlands	Switzerland
Finland	<i>Norway</i>	United Kingdom
France	Poland	USA
<i>Germany</i>		

For those countries indicated in *italics* above, the country was not a participant in this project and the data were collected by one of the project partners (working in collaboration with appropriate country contacts where possible). The countries marked in **bold** are those against which European activities are compared.

The analysis of the data was broken up into five principal blocks:

- Review of Programme Organisation
- Review of Aims and Achievements
- Incentives and Barriers (the Wider Context)
- Programme Spend and Effectiveness
- Areas of Activity Focus

During the course of the initial analyses, a number of gaps and issues of clarity were identified with the data (for example, respondents had interpreted questions in different ways). This prompted a second, supplementary data gathering exercise to try and address these issues. The results of the data analyses are described in more detail in the following sections.

3 Review of RTD Programme Organisation

The aim of this section is to look at the way in which PV RTD programmes are organised and note any issues for European competitiveness. This has been undertaken through a review of the data bearing in mind the following questions:

- How do countries organise PV RTD?
- How many have a dedicated PV RTD programme?
- Which Ministries take a lead? Is there any commonality of approach?
- (For European countries) How do they interact within Europe?
- How does European organisation compare with Japan/ Australia/ USA?

3.1 ORGANISATION OF NATIONAL PROGRAMMES

In Europe, dedicated national PV RTD programmes exist only in two countries:

- France with the PV RTD governmental programme managed by ADEME (French Agency for Environment and Energy Management).
- Switzerland, where the Swiss PV Programme results from RTD energy research concepts cooperatively developed at a coordinated national level by the Federal Commission for Energy Research (CORE) and the Swiss Federal Office of Energy (SFOE).

In the past, programmes specially dedicated to photovoltaics were implemented in a number of other countries (for example UK, Finland, Italy and the Netherlands), but later they moved towards more general sustainable energy programmes, where PV is part of a wider renewable energy programme.

Photovoltaics RTD is usually placed in general RTD programmes covering a broad spectrum of research priorities in most of the European countries. PV RTD activities can also be a part or subprogram of bigger energy programme (like in Germany, Sweden, Belgium, Denmark), or can be placed in Renewable Energy Sources programmes. The priority which photovoltaics has in RES programmes depends on each country. In some of them (e.g. Austria, Denmark) PV is only a small part of RES programmes. PV-related funds are small because PV-projects have to compete with other RE options. In others, like in Switzerland, PV is one of the areas that are prioritised within the energy policy programme. In the German programme, substantial funds are made available for PV RTD together with underlying support for research organisations acting as centres of excellence and providing focus and coherence for regional and national activities.

PV Rooftop market incentive programmes can provide a stimulus for PV RTD by raising real life issues requiring solutions. Programmes like 100 000 Roof Programmes in Germany, or Roof Programmes in Italy raise environmental awareness, and can indirectly influence PV RTD. However, they have been implemented in only six countries in Europe.

In Europe the main institutions co-ordinating PV RTD on a national level are ministries or governmental agencies. Usually ministries of technology, science, economy, or energy take the lead. The ministries responsible for research and environmental matters are not involved (except France, Italy and since 2002, Germany).



In some countries specialised governmental agencies (e.g. the Danish Energy Authority, the French Agency for Environment and Energy Management, the Italian Agency for New Technology, Energy and Environment, the Swedish Energy Agency and Novem in the Netherlands) distribute funds obtained directly from Parliaments, or from Ministries.

These features of PV programme organisation are summarised in Table 3.1 below. This tabular presentation is inevitably a simplification of the situation in some countries, but tries to give a reasonable overview of the situation.

Table 3.1 Review of PV Programme Organisation

<i>Country</i>	Main Location of PV activities					Organisation level		
	Dedicated PV prog.	PV in general RTD prog.	PV in energy prog.	PV in RES prog	Rooftop Programme	Ministry	Government agency	Others
Austria		X			x	x		x
Belgium			x				x	
Denmark			x	x	x		x	
Finland		X					x	
France	X				x		x	
Germany			x		x	x		
Greece		X		x		x		
Italy				x	x	x	x	
Netherlands		X		x	x	x	x	
Norway		X					x	
Poland		X				x		
Portugal		X				x		
Spain		X				x		
Sweden			x				x	x
Switzerland	x					x		
UK				x		x		x
USA	x				x	x		
Japan	x				x	x		x
Australia					x		x	

3.2 EXTERNAL INTERACTIONS

Table 3.2 summarises interactions of PV RTD programmes with different sectors in national PV activities.

Universities play an important role in PV research. In most of the countries, there are also public, semi-public and private R&D centres concentrating on RES research, education, dissemination, promotion or information. Usually PV is one part of their activities (for example the Joint Research Center - ISPRA, the Fraunhofer Institute, the ZSW Centre for Solar Energy and Hydrogen Research (Baden-Wurttemberg) and ISFH in Germany, ENEA

Portici Research Centre, Italy, the Austrian Research Centre Arsenal Research, Institute for Energy Technology in Oslo, Institute for the Diversification and Saving of Energy in Spain, ECN in the Netherlands), but some centres concentrate only on photovoltaics (for example the Ångström Solar Center in Sweden and the PV Centre in Poland).

The national programmes demonstrate a wide range of co-operation with industry with some programmes having a low level of linkage. However, in Germany, the UK and France great attention is given to involvement of industry in PV research and similarly, in Switzerland, industrial partners are often project leaders or one of the key players in the projects.

Table 3.2 Interactions of PV RTD Programmes with different sectors in National PV activities

Country	Involvement of:			
	Universities	Industry	Utilities	EC
Austria	M	W	W	S
Belgium	S	M	W	W
Denmark	W	W	S	W
Finland	M	W	-	W
France	S	S	S	M
Germany	S	S	S	S
Greece	S	W	M	S
Italy	M	M	S	M
Netherlands	S	S	S	M
Norway	M	M	W	W
Poland	M	W	-	W
Portugal	S	W	M	S
Spain	M	M	M	S
Sweden	S	M	M	M
Switzerland	S	S	S	S
UK	M	S	S	W
USA	S	S	S	-
Japan	S	S	S?	-
Australia	S	M	?	-
Summary of strength of involvement by sector for European countries above (number per category)				
S	8	5	7	6
M	7	5	4	4
W or -	1	6	5	6

S = strong, M = medium, W = weak, - = no involvement, ? = no data

Utilities are involved in PV demonstration or research programmes, particularly in countries with significant installed PV capacity (for example Germany, Switzerland, France and the Netherlands) but also in more emerging markets such as the UK. Utilities can be helpful in different ways: in France, EDF carries out PV research projects; in Italy, utilities realised several PV plants, in Switzerland, the majority of the market implementation of PV systems

continues to be driven by the campaign for “solar electricity from the utility” and some Swiss utilities are playing a role in the PV RTD sector too. The Dutch utility NUON acts as a PV system retailer and contributes strongly to big European projects. In the past, Austrian utilities have had an active involvement in understanding the prospects for PV, but they currently have little or no active involvement in PV work.

3.3 INTERACTION WITHIN EUROPE

European Commission funding plays a vital role in some of the involved countries. EC activities in PV RTD are dispersed in more general programmes like the Fifth Framework Programme, Thermie, or Joule. The EC Framework Programmes in particular play an important role in working towards the creation of the European Photovoltaic Research Area. Moreover, the support of the EC often happens to be the main driver for PV development, like in Greece, where most national RTD funding is directly linked to EC funds, or Spain, where most of the funds for RTD were provided by the European Commission and by the “Comisión Interministerial de Ciencia y Tecnología”. Participation in RTD Programmes of the EC is also an explicit part of the national PV RTD strategy and actively promoted in Switzerland – one of the leading European countries in PV development. Support from the Commission is also crucial for PV development in Poland.

There are also countries where European projects are not so important – for example in Denmark practically none of the activities is linked to the EC, although some demonstration projects have received EU support. There are formal and informal networks providing fora for specific topics, but outside these and EC-supported projects, there has not been much formal coordination or coherence of national PV programmes.

3.4 INTERNATIONAL COMPARISON

3.4.1 USA

There is a National Photovoltaics Program in the United States. The structure of PV R&D appears clearer than in Europe. On a national level there is the U.S. Department of Energy (DOE), which directs federal PV activities. Funds from DOE are distributed through the National Renewable Energy Laboratory (NREL) and Sandia National Laboratories (Sandia). The policy of RTD funding is created by the National Centre for Photovoltaics (NCPV), which relies on the core expertise of NREL and Sandia to create, develop, and deploy PV and related technologies. The NCPV awards most of its federal funds by competitive procurements to industry, universities, and other research centres (like BNL, centres in Florida, Delaware and Georgia). There is a wide range of institutions – from education, through research centres to industry - involved in collaborative PV RTD. In addition, more than 180 universities, industry and utility research partnerships across the country are linked together to function in a unified way. The DOE program follows a well-established national paradigm – the forming of partnerships among national laboratories, industry and universities. The Program has helped to build a national effort, supporting partnerships that span the range from basic and applied research, to manufacturing technology, to product development, to commercialisation.



In the USA, industry plays a big role in supporting photovoltaics. The private sector outspends the government PV R&D by more than a factor of two – by typically paying for at least 50% of the costs of shared R&D projects, by pursuing their own R&D, and by developing manufacturing facilities. Industry generally provides a supporting role for basic and applied research and development (RTD); but when the technologies approach manufacturing and commercialisation, industry assumes a lead.

In June 1999 experts from the industry met to put together a PV Industry Roadmap, identifying research needs for the industry. The Roadmap created a blueprint of research, technology, and market priorities needed to accomplish long-term PV industry goals. The strength of American photovoltaics is supported by establishing a big national PV-related program, and involving the key actors co-operating in realising the project.

3.4.2 Japan

In 2001 Japan established a PV-dedicated national programme – a 5-year plan of Technical Research and Development for Photovoltaic Power System (Advanced PV Generation). Prior to this, the basis for the significant expansion in PV activities in Japan had been laid through the New Sunshine Programme.

In Japan, PV RTD is organised mainly on the ministerial level (The Ministry of Economy, Trade and Industry - METI), but a lot of different organisations are also involved with PV (for example, the New Energy and Industrial Technology Development Organisation - NEDO – an independent governmental entity, the Photovoltaic Power Generation Technology Research Association, and the Japan Photovoltaic Energy Association). The biggest proportion of funds goes to RTD, but it does not mean that dissemination and promotion programmes are neglected. There is also a variety of undertakings related to marketing issues of photovoltaics. In addition to METI, other ministries and local governments and municipalities promote the introduction of PV systems. Also many local governments and municipalities have implemented their own subsidy system that can be added to the Government's subsidy.

In Japan clear rules of funding are established. National budgets for PV systems are focused on R&D, demonstration programs and market incentives. The budgets of local governments are complementarily appropriated for market incentives. The budget for R&D is allocated for PV System Technology R&D and Technology Development and for the Promotion of PV Systems. The budget for demonstration is allocated mainly for a PV Field Test Project for Industrial Use and a PV Field Test Project for Public Facilities. Moreover, PV systems can be installed using the budgets of the New Energy Introduction Project and the Subsidy Program for New Energy Industrialists.

A clearly defined programme of PV developments involving the industrial sector and allocating a lot of financial resources on RTD is what differentiates the Japanese approach and makes Japan photovoltaics strong.

3.4.3 Australia

The situation in Australia is similar to Europe - there is no dedicated PV programme, but a variety of different PV RTD programmes exist. General R&D funding is available through the Australian Research Council. Governmental funding for renewable energy technology commercialisation and industry development is provided by the Renewable Energy Commercialisation Program (RECP) of the Australian Greenhouse Office (AGO).

In Australia there are two incentive programmes, which encourage PV development, but they are not directly PV-related RTD activities: the Australian Government Renewable Remote Power Generation Program and Mandatory Renewable Energy.

PV RTD activities are usually carried out by universities. The Centre for PV Engineering at University of NSW; Centre for Sustainable Energy Systems at the Australian National University; Murdoch University are continuously investigating PV materials. On national level, there is the Australian Cooperative Research Centre for Renewable Energy (ACRE), jointly funded by government and industry.

3.5 CONCLUSIONS

- In Europe national dedicated PV RTD programmes exist only in two countries: France and Switzerland. PV RTD can be a part or subprogram of general energy programmes, or Renewable Energy Sources programme, or it can fit into more general technology development programmes. There is no commonality of approach in European countries.
- The existence of a PV-dedicated RTD programme can be a better driver than location in RES programmes, as the example of the Netherlands shows, where programmes specially dedicated to photovoltaics existed in the past, but were terminated and shifted to more general RES programmes, which resulted in reduced activity and funds. (At this stage of development of PV, it is difficult for PV to compete with the other RES options.)
- Demonstration activities in the form of rooftop programmes are very important for creating market and dissemination strategy and can indirectly influence PV RTD through market feedback. Almost in each country with well-developed PV, big-scale rooftop programmes have been implemented. In USA, Australia and Japan demonstration and implementation activities are crucial part of strategy of PV development.
- While there are some good examples of cooperation between research organisations, there is little evidence of a more general trend of proactively engineered coherence between organisations responsible for PV, neither at a state level, nor in Europe as a whole. Usually, specialised governmental agencies or ministries related to technology and science, economy or energy take lead. Ministries of environment or departments of environmental protection usually are not involved in PV.
- In the USA and Japan, a clearer structure of PV organisation than in Europe exists: Although there is a variety of different organisations responsible for PV in USA, on a national level one institution – the Department of Energy directs federal PV activities and distributes funds.
In Japan PV RTD is organised mainly on ministerial level. Clear rules of funding are established - national budgets for PV systems are focused on R&D, demonstration programmes and market incentives; the budgets by local governments are complementarily appropriated for market incentives.

- Countries with significant levels of PV industry and applications often have strong interactions with universities, industry and utilities. However, in general, in Europe there is much less weight put on co-operation with industry, in contrast to the USA and Japan, where universities and research entities are much better linked to the industrial sector.
- Utilities can play important role in developing PV; especially in Switzerland, Germany and France central public utilities are taking part in financing PV, or even make research (France) and in the Netherlands private utilities play an important role in supporting demonstrations.
- In many of the European countries, the European Commission's support is important, or can even be the main driver for PV development.

4 Review of Programme Aims and Achievements

This section assesses the aims and achievements of the PV RTD programmes carried out by the European countries and the European Union and compares these with 3 reference countries the USA, Australia and Japan. The following paragraphs give an overview of the aims and objectives referring them to national policies, then achievements are briefly discussed. Finally both are compared to the reference countries.

4.1 AIMS AND OBJECTIVES

4.1.1 Policies

The national PV RTD and related programmes are generally linked to national policies. In some countries like The Netherlands, Portugal, Sweden, France, Italy and the UK this link is direct and strong. Here programmes refer to policies with environmental (Kyoto protocol) and strategic aims (diversity of energy supply). In Switzerland the link is also strong with long-term aims which are well defined and middle term aims which are regularly reviewed and defined in the 4 year energy RTD concepts which are the basis for the operational plans. Such a concept is based on strategic targets of politics (energy, ecological, social), science and industry. A similar set-up but with a longer timeframe of 10 years is practised in Germany.

4.1.2 Typology of programmes

A wide variety of aims and objectives are put forward in the national programmes concerning PV RTD. Partly, this reflects the variety in types of programmes. A dedicated PV RTD programme may have more specific objectives than a RE or even more general RTD programme. Likewise, a research programme requires other objectives than a market introduction scheme like the German 100 000 Rooftop programme. These different types of programmes were discussed in the previous chapter.

Another important characteristic that influences the way objectives are defined is the *timeframe or time horizon* of the programme. Most programmes have a limited horizon of 4 to 6 years. Some of these programmes have been renewed and thus have established a longer-term commitment. A few programmes have a longer time horizon. The German programme has a duration of 10 years. The programme in France has been characterised by its long-term commitment of more than 15 years. Switzerland operates with a longer time horizon for the orientation of the programme but concentrates on actions with a time-scale of 2-6 years in terms of their impact.

4.1.3 Target areas

The vast majority of the programmes are targeted towards *scientific and technological objectives*. For all countries the focus is not a pure scientific one but directed towards technology development. Typical aims are the improvement of performance of PV cells, modules and systems, building integration, the reduction of production and system costs and the dissemination of knowledge and awareness through demonstration projects.

Closely linked to the previous are *industrial objectives* like the improvement of industrial competitiveness, an increase in exports and the creation of jobs.

Strategic aims, like the diversification of energy resources, may be found sometimes at national policy level, (see above) but these are not elaborated on programme level.

The same applies generally for *environmental aims*. Only in the Dutch DEN and the Spanish PROFIT programme refer to environmental targets like an aimed percentage RE in total energy production; a certain CO₂ reduction following the Kyoto protocol. This also is reflected in an approach of improved environmental sustainability. In Italy, the framework of Legislative decree number 79 (1999) contains an environmental target to increase the percentage of renewable energy. The UK programme also works within the context of a broader set of policies to tackle climate change and additionally aims specifically to quantify environmental improvements and disbenefits associated with PV.

Networking and international co-operation is also part of the objectives, for example with the IEA and IEC. Denmark, Finland and Sweden refer explicitly to regional, Scandinavian co-operation through the PV-Nord programme.

Most RTD programmes aim at improving *production of PV*. The *installation* (or the use of PV systems) can be stimulated in a variety of ways. In some countries this stimulation is absent, in others it is part of the RTD programme, (like in the old NOZ-PV in Netherlands) or taken care of in a dedicated RTD (sub)programme, like the SOLAR programmes in Denmark and SOLEI in Sweden, but in most countries the use of PV is stimulated through other measures. A different approach is taken in Spain and The Netherlands. There the programmes aim mainly (Spain) or exclusively (The Netherlands) at augmenting the use of PV. RTD on PV production can still be supported under these programmes as long as a positive effect on PV installation is clearly demonstrated. The stimulation of PV installation is a direct consequence of the use of environmental aims in these programmes.

As for the programmes of the European Commission, there has been a set of successive programmes aiming at the contribution to sustainable development by focusing on key activities crucial for social well being and economic competitiveness in Europe. The objectives of the earlier programmes under the Fourth Framework are very general and of strategic and environmental nature, much like objectives at policy level:

- The main objectives of *JOULE programme* were improving security of energy supply, protecting the environment and encouraging the rational use of energy
- The objectives of the *Thermie programme* were ensuring lasting and reliable energy services at affordable costs and conditions, reducing energy consumption, reducing the environmental impact of the production and use of energy, in particular CO₂ emissions and strengthening the technological basis of the energy industry.

The objectives of the *Fifth Framework Programme* are more explicit technology specific and scientific in nature. For PV the programme's objectives are cost reduction and improvement of reliability with focus on PV cells and in the second place balance of system components.

4.1.4 Quality of objectives

The quality of objectives can be assessed using criteria that are defined in the acronym SMART. The definition varies but here SMART stands for Specific, Measurable, Ambitious/Realistic and Time-bound. These criteria are defined in a bit more detail in the chart below together with a summary assessment of how the European PV RTD programme objectives compare to these criteria.

‘SMART’ assessment of PV RTD programme objectives	
Criteria	Assessment
<i>Specific</i> here means two things: first of all, objectives should be specifically related to the programme; preferably unique to the programme. In this way results can be seen as attributable to the programme and to the programme only. Secondly, “specific” means that results are defined in terms of targets, a certain goal to be reached (i.e. a certain kWp price level or so many kWh generated) and are not defined in actions only (i.e. stimulate the use of PV.)	Most programmes have objectives that are <i>specifically related</i> to the programme. But not all the results will be attributable to the programme only. In some countries and for the EC, these results are also depending on other related programmes, market support actions and fiscal support schemes. The impression is that this complexity is growing. Few national programmes have objectives that mention <i>specific targets</i> . Most objectives are described in terms of actions or fields of action. This also applies to the EU programmes.
<i>Measurable</i> here means that objectives are defined in measurable units. This is done to facilitate the monitoring that is envisaged.	As few programmes have specific targets, as mentioned above, even less have defined them in measurable units. The programmes that do have these measurable targets generally focus on the realisation of demonstration projects. Monitoring of programme progress and results is generally envisaged, but this has to be restricted to the use of qualitative data. Otherwise assessors may use criteria that they compose in the evaluation process.
<i>Ambitious</i> and <i>Realistic</i> can be seen as the two extremes on the scale of challenge. Programmes should be ambitious so as to pose enough of a challenge. On the other hand they should be realistic and their targets should not be too far fetched	Challenge levels vary with country and programme and are generally difficult to assess due to the lack of specific targets. Overall the level is a conservative one: more realistic than ambitious.
Finally programme objectives should be <i>Time-bound</i> . They should be made clear as to when an objective should be realised. On the road to the objective intermediate milestones may be defined.	Again only some of the programmes dedicated to demonstration projects have time-bound targets although at a project level, timescales are better defined.

It is apparent that programme objectives do not typically align with the ‘SMART’ criteria. Programme developers have generally made the objectives broad and non-explicit either through choice or because of the difficulty in being precise when covering a wide range of topics. In this way the programme can cover a variety of projects and activities and is thus more flexible to react to changes in the programme environment. But it makes them difficult

to assess. Results can generally not be expressed in terms of objectives and it is, for instance, not possible to express the success or failure of a programme in terms of a simple measure of success.

This also applies to the long-term programmes, like in France and Switzerland. They seem to take a different approach which is more like a process: a long term programme, with no medium term targets, but with clearly defined areas of interest and short term targets depending on the expected results of the underlying projects. The objectives of these underlying projects are generally negotiated with a team of experts. These experts must have certain objectives in mind, but these have not been formalised and are flexible. Such a process-programme is hard to assess in general, but this does not prevent these types of programmes from being seen as successful.

In some programmes, a distinction is made between programme objectives and project objectives. Programme objectives generally indicate overall indicators to be achieved (e.g. cost/Wp, efficiency of component categories, lifetime of component categories, etc.) and they are by definition more generic than on a singular project level. On the other hand, quantitative targets on the project level are those which can really be measured and where the level of success can be more precisely assessed. Furthermore, a distinction can be made between quantitative targets on the component level and that on the system level. Ambitious targets on the component level only make sense if they contribute positively to the system target as well (e.g. the success of a high efficiency of PV cells may lead to higher costs and hence not be a real progress on the system level).

4.2 ACHIEVEMENTS

4.2.1 Programme performance

As shown above, assessment of programme performance is difficult, as indicators are generally not defined beforehand. However, using more general administrative indicators such as meeting budgets and keeping to time schedules, one finds that most programmes appear to be well managed and run. This conclusion is affirmed by the results of an opinion poll undertaken by PV-EC-NET among country programme experts. Their rating of their own countries programme or programmes in countries with well-established programmes was generally good. As for results, it has become clear from the previous section that it is generally difficult to express results in terms of programme objectives.

In the absence of clear-cut pre-defined measures of success, programme evaluators often use industrial sales and installation figures and a list of scientific successes as proxy measures. Although these data may provide valuable indicators of the RTD and industry performance, they do depend on other factors and generally cannot be related simply and solely to the performance of the RTD programme. Therefore, as has been explained in the chapter 2, this report follows a different approach, using the expert contributions from the PV-EC-NET partners. For an overview of the successes of their countries' programmes and recommendations on how to improve them as contributed by the PV-EC-NET partners, see tables 4.3 and 4.4 at the end of this chapter.

4.2.2 Critical factors



To assess the factors that have determined the rate of success of the programmes, the PV-EC-NET members have been asked to pick from a list of possible factors, up to five of the most important factors that have contributed to the success of the country programme and to comment on them. Responses are shown for 14 out of the 16 European countries under review. As noted previously, Germany and Norway were not direct participants in this project and it was not therefore practicable to get such direct responses from them. In a similar exercise the five most important problem factors have been determined. The results are presented in table 4.5 and table 4.6 at the end of the chapter. It should also be noted when reading these tables that more factors may be relevant than those indicated but that respondents were asked to select the five key factors.

The results show a diverse response, but some patterns can be distinguished. The six highest scoring success and problem factors are listed in tables 4.1 and 4.2 below, together with their scores and some examples of the comments which participants contributed in support of their choice of these factors.

Table 4.1 – Most frequently cited factors contributing to RTD Programme Success

Key Success Factor	Score	Example Comments
Policy Background	7	“Sustainable development concepts, European Commission Directives on energy helped deployment of more ambitious projects”
Other Networking	7	“For having the connection to all PV relevant activities” “Strengthens limited resources for RTD”
People & Equipment	7	“Stakeholders have good quality and are very committed”
Image (Public interest)	6	“Solar thermal industry has triggered the public interest for PV”
Interactions with PV industry	5	“Decisive for a sustainable industrial development”
Interactions with utilities	5	“Decisive for credibility” “of major importance in the beginning” “took the lead” “co-ordinated R&D activities with the building industry” “owns many of the PV systems”

Table 4.2 – Most frequently cited factors contributing to RTD Programme Problems

Key Problem Factor	Score	Example Comments
Policy Background	8	“In 2002 the new government cancelled the previous PV programmes, leaving the development solely to the industry”
Clear Strategic Plan	8	“Absent” “not yet a fully coherent overview shared by all the actors”
Long term commitment	6	“Sometimes when the project was giving the first results the budget was over and the overall effort is lost” “Changes in administrative arrangements inevitably introduce stop/start inefficiencies and delays.”
Interactions with PV industry	5	“Little or no specific industry to use the results” “progress and relevance could be improved through better interaction” “uptake of RTD results by the industry is difficult”
Continuity of budgets	5	“continuity of budget was seen as a success factor only for the past and for a few RTD institutions, but usually is seen as a problem factor”
Critical mass for activity area	4	“Several projects were closed having no critical mass” “There are small teams working separately”
Linkage / relevance to market	4	“The more problematic features are not so much related to the PV RTD Programme itself than much more to the market framework, the industry structure as well as the awareness and perception in different professional areas. This can be described in the form of barriers along the value chain. Proper information of opportunities offered by PV are lacking in the professional sector (architects, engineers, utilities, local

		authorities)” ” Difficult to reach installation branch” “Knowledge among key stakeholders, such as property owners and installation companies, needs to be strengthened.”
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Seven countries list *policy background* among their most critical success factors and eight countries list it among the most critical problem factors. For Belgium, Denmark, Italy Greece and the UK the policy background figures on both shortlists. For Denmark, Italy and the Netherlands this has to do with recent changes in policies that are perceived as negative or less assuring for PV RTD. In Belgium the policy background was perceived as unbalanced: favourable for RTD development but poor in market generation support.

The high score for *Other networking* illustrates that there are already effective communication links and networks within some parts of the national and European PV community and this offers the prospect of building on these already successful arrangements.

Availability of the appropriate quality of people and equipment to deliver the work also achieves a high score and this is testimony to the high quality and dedication of many of those working in the field. Under this category, France and the UK mentioned that the quantity of researchers available can pose problems. The respondent from Italy gives one reason: “Usually academic researchers are interested to increase their academics activity (papers, courses, etc). PV usually gives less opportunity compared to other science fields because it is a long term research and the innovative results can only be obtained after years of actions.” Also, some RTD centres are small and lack a direct global impact and this is reflected in the selection by four countries of *lack of critical mass* being a problem factor.

Interactions with the PV industry appears as both a success and a problem factor. This in part reflects the inconsistent distribution of the PV industry within Europe, but is also a pointer for possible improvements in the way PV RTD programmes are organised and run. *Linkage and relevance to market* is a linked issue which was also cited as a problem factor. These two points reinforce the need for effective two way dialogue between key stakeholders.

The positive engagement of and *interaction with utilities* was seen to be a very positive factor for five of the national programmes, while lack of such positive support was seen as a significant problem for two of the national programmes. A diversity of attitudes from utilities towards PV is not surprising given the differing national frameworks for electricity and the range of possible commercial responses to these.

Continuity of budgets, programme structure and programme personnel as well as *long term commitment* to plans is also an important critical factor. But again the picture is very diverse. Continuity of budgets is seen as a success factor in countries like France, Greece, Italy and Sweden and continuity of programme personnel and/or programme structure is regarded a success factor in Switzerland, Finland and the Netherlands. But all these and other countries except France, Switzerland, Greece an Sweden mention a lack of continuity in either budgets, personnel or structure and/or a lack of long term commitment as an important problem factor.

The *public image of PV* also has positive and negative aspects. It is generally perceived as a technology that is environmentally friendly but costly. This image can contribute to success in countries where the first aspect dominates. Austria, Denmark Greece, Portugal and the UK rank it as an important success factor, while Italy, Spain and again Greece mention it as important problem factor.



Thus in summary we can say that within the European National Programmes, the three most significant critical success factors identified by the project team were: a supportive policy background; effective national and international networking; and the availability of the appropriate quality of people and equipment. In the same exercise, the two most significant problem factors by far were: an unsupportive policy background and the lack of a clear strategic plan. The fact that linkage to policy figured so prominently as an influence on success illustrates the importance of policy in setting the context for PV RTD programmes.

4.3 INTERNATIONAL COMPARISON

This has been undertaken for the USA and Japan. As Australia does not have a national PV RTD programme it has been omitted from this comparison.

4.3.1 USA

As has been indicated in the chapter regarding organisational factors, there is a substantial difference between American and European PV RTD organisation. In United States there is National Photovoltaics Program under responsibility of the Department of Energy (DoE). In early 2000 the five-year programme 2000-2004 was presented. It states: *“The purpose of the U.S. Department of Energy PV Program is twofold: to accelerate the development of PV as a national and global energy option, and to ensure U.S. technology and global market leadership.”* It sets out objectives for 10 working areas divided over three sectors:

- Research and development:
 - Thin films
 - High performance and concentrator research
 - Crystalline silicon
 - Measurements and characterisation
 - Basic and University research
- Technology Development:
 - Manufacturing research and development
 - Module performance and reliability
- System engineering and applications:
 - System engineering and reliability
 - Partnerships for technology introduction
 - Program integration and Industry

The programme shows annual milestones to be achieved for each of the above areas. For instance: For the thin-film subprogram the milestones for 2002 are: to demonstrate a 17% efficient CdTe Cell and to support the successful transition of the CdTe cell to multi-megawatt production.

Like in most European countries the US programme is targeted at research and technological objectives, but in the US the emphasis on industrial objectives seems to be heavier. More than in Europe, the programme strives at “global market leadership”. Co-operation with the national PV industry is very strong. Or as the program puts it: “The PV program works with the nation’s PV community to build technology leadership that is paying off”. The program also relates to the PV Industry Roadmap 2000-2020, a strategic document prepared by the PV Industry. This roadmap defines goals to be achieved by 2020. The headline goals are: 25 %



annual production growth rate; 7GWp annual shipment world-wide (of which 3.2GWp for use in the US) and cost price reduction to \$1.50 per Watt AC.

The five-year programme also refers to other policy objectives that are laid down in the national energy strategy. These are not elaborated directly into programme objectives or milestones but serve as contextual background of the document. Among these are strategic objectives (Energy security for the nation), industrial objectives (energy system efficiency and increased economic productivity) and environmental objectives (promote environmental quality and health; solutions to international global issues).

When assessing the *quality of objectives* using the SMART criteria illustrated above, one finds that the US program objectives appear quite specific, reasonably well measurable and fairly ambitious. All of them are time bound using the annual milestones. These milestones are used and referred to in the annual progress report to assess achievements and programme progress. The programme appears much more focused compared to the European programme as a whole and even the national programmes. In FY2000 the programme progress was satisfactory and all milestones for that year have been achieved.

But the basis for comparison of these achievements to the achievements of the European programmes is too thin to draw definitive conclusions.

An attempt to compare the “Status of PV research, Solar Cell production and Market Implementation in Japan, USA and the European Union” has been made recently by A. Jäger Waldau and has been presented by him in a report with the same title, September 2002⁵.

Concerning the US he finds that when one compares PV production figures one finds that in Europe production growth is faster than in the US, to such an extent that European production may well have surpassed the US in 2002. Jäger Waldau does not hand a clear-cut explanation for that, but he points to a study by the Solar Electricity Power Association (SEPA) on the status of PV in the US and focussing on the critical success factors. This study indicates that while PV is already a competitive alternative in many off-grid applications the main growth potentials lie in grid connected PV. Here two major problems are encountered. The first one is the lack of infrastructure in the areas of sales, marketing as well as installation and maintenance of PV systems. The other is the lack of standardisation of PV systems to IEEE standards, posing technical problems and preventing further cost reduction by the use of cheap standard installation components. Considering the fact that state and local RE initiatives have surpassed federal support SEPA is of the opinion that federal funding should be better leveraged to support and link together the manifold state and local activities. SEPA also perceives a need for more demonstration projects and more information to the public.

4.3.2 Japan

In the report by Jäger Waldau⁵, the writer points out that the reasons and necessities for introducing new energy resources in Japan differ from those in Europe. The first topic in the “basic guidelines for new energy introduction”, in force since 1994, stipulate that Japan should decrease the almost 100% dependency on petroleum imports, which account for

⁵ Status of PV Research, Solar Cell production and Market Implementation in Japan, USA and the European Union, by Arnulf Jäger-Waldau, European Commission, DG JRC, Institute for Environment and Sustainability, Renewable Energies Unit, Via Enrico Fermi 1, TP450 I- 21020 Ispra, Italia. EUR 20425 EN European Communities, September 2002.

approximately 53% of the primary energy consumption. After the first oil crises, this was a primary issue in Europe as well, but now with the exploitation of the North Sea oil and gas fields, it has currently not the same importance.

Second, the commitment of Japan under the Kyoto Protocol to reduce its heat-trapping gas emissions is another argument for the accelerated introduction of new energies. Initially it was intended to reach this aim with a combination of new energies, energy saving and increase of nuclear power. Recently, however opposition to nuclear power is rising and the new “policy mix” approach, combining voluntary efforts by industry with mandatory restrictions and market based approaches puts more emphasis on the promotion of renewable energy, such as wind and solar.

A third reason for the introduction of new energies is stipulated in the “Basic Guidelines” chapter on photovoltaics: The international market. Jäger-Waldau finds that *“This is a fundamental difference in the attitude of implementing renewables between Japan and Europe. The Japanese policy has not only the advantage to be much more market oriented, but also has a major aim in the policy guidelines: ‘The establishment of a prospering market’. These expectations are also expressed by the long-term goals, which already in 1994 made a commitment for the next fifteen years until the year 2010. This long-term policy and commitments are a huge advantage as can already been seen, as industry can rely on such a long-term programme and plan their individual industry policy as well. Hitherto, in Europe the national as well as the European Community programmes are clearly lacking these long-term policy commitments!”*

He argues that such an approach can lead to success: *“At the beginning of the programme, the critics said that the set goals are just mere visions and will not be fulfilled due to the very high targets set in the plans. However, currently the target for 2000 to install 400 MWp in Japan was met with only one year’s delay and the present developments of production capacities and market growth indicate that the target of 4.8 GWp in 2010 can be met as well. This shows that the attempt to promote new technologies with visions of future developments is creative, competitive and successful.”* Due to these successes, the Japanese general government identifies PV-manufacturing as a high potential new market. Similarly Japanese industry now rates it as a key industry, not to be outsourced, but to be undertaken in Japan. These attitudes constitute a leading edge towards European and American competition.

Up to 2001 these result have been accomplished with the so-called “New Sunshine project”(PV RTD) in combination with national and local introduction programmes providing subsidies on the installation (50 % in 1994 diminishing to about 15 % in 2001). Installation was also promoted through “net metering” incentives and, recently the introduction of a Renewable Portfolio Standard, obliging power retailers to sell increasing amounts of RE.

The current PV RTD programme resorts under the “Projects for New Energies” and is handled by NEDO, an independent government entity. Again quoting Jäger-Waldau: *“Taking effect in FY 2001, NEDO replaced the New Sunshine Project by a programme named “Advanced PV Generation”. (APVG). As result of the New Sunshine Project (NSP or NSS) evaluation, several important priorities were selected:*

- *Technology Development for Future Mass Deployment*
- *Advanced Manufacturing Technology*
- *Advanced Solar Cell technology*
- *Innovative PV Technology*

One of the dominant priorities, besides the future increase in PV production, is obviously the cost reduction of solar cells and PV systems. The two main funding tools for R&D issues are:

First:

***Seed identification** with respect to production technologies, industrialisation and commercialisation. These measures receive funding up to 50% by NEDO with matching funds by the participating companies.*

Second:

APVG, this is a 100% NEDO sponsored R&D activity** carried out by selected research institutions and companies. **This activity includes the 100% NEDO sponsoring of pilot plant developments for new PV technologies. (An action which is completely missing in Europe!)

In addition to these activities, there are programmes on future technologies (in and outside NEDO), where participation is for Japanese institutes or companies on invitation only. For the participation of non-Japanese partners there are “future development projects” and the NEDO Joint Research Programme, mainly dealing with non-applied research topics.

Feedstock problem: METI supported a programme concerning the melt purification process of metallurgical silicon. According to the information given, Kawasaki Steel will start solar-grade manufacturing with approximately 500 to 1000 t/year in FY 2002. In addition there will be a one-year project for FY 2002 to investigate the possibilities to start solar grade silicon production with a simplified Siemens process. However, NEDO has made a survey amongst the Japanese manufacturers, which do not see the problem critical until 2004/5. In addition it is believed that industry itself will take responsibility for this problem if the current growth rates continue.

Mass Deployment of PV: A focus of this activity is the system development. NIAIST (former ETL; now an independent governmental entity) is responsible for this. The following topics are dealt with:

- Performance of systems*
- Recycling issues (**very important**)*
- Electromagnetic compatibility (focused on central inverters; only little activity on AC modules)”*

Under the current NEDO PV programme only seven PV companies were awarded research contracts. For the advanced solar cell and module research, targets for efficiency and production price have been defined for the near future: 2003 and 2005.

It must be said that the home market situation is favourable for PV, probably more favourable than in Europe or in the US: high electricity prices, high public awareness on CO2 reduction and high consumers' interest for products with low environmental impact. Also, the short average lifetime of a residential home (25 years) that corresponds well with the lifetime of a PV system favours the use of PV on residential houses.

But it is due to the development of adequate government programmes and their realisation by the joint forces of programmers, developers and industry that this market potential has been well nourished and developed. The introduction of the subsidy system “Programme for the Development of infrastructure of Residential PV Systems” in 1997 has been very instrumental in this. The assurance that the subsidy system would be in place at least until 2002 has encouraged housing manufacturers to promote the integration of PV systems in new houses. This has encouraged the PV and building industry to develop standard building components

with integrated PV, thus reducing the cost and creating very attractive products that could be marketed and applied easily, more so than in most European and American market situations.

Finally, the strong and well-developed relation between government, research and industry is illustrated by the joint development of a PV R&D and market implementation roadmap in 2001.

4.3.3 Conclusions of the international comparison

Japan and the US, in contrast to most European nations, have dedicated PV RTD programmes on national and federal level. These programmes are clearly embedded in national policies that not only have strategic and environmental objectives, but also strive, more so than in Europe, towards the development of a flourishing PV industry.

Therefore these programmes provide for closer links with the PV industry. Strategic priorities are set together and have in both countries resulted in the drafting of PV development roadmaps. In the US, this roadmap has been drafted by the industry (and referred to by the government). In Japan it has been a joint effort of government, research and industry.

The intention to develop a flourishing home market and the position of the customer is also more developed in the Japanese and US programme.

These programmes are, much more than in Europe, defined in a SMART way: Specific, Measurable, Ambitious/Realistic and Time-bound. Clearly stated targets and milestones and long-term commitment provide a challenging environment to realise ambitious goals, as Japan in particular has demonstrated.

In Japan the PV RTD programme was and is supported by a clear and long-term PV implementation subsidy programme and incentive measures. The link between the RTD and the subsidy programme is stronger and the medium term subsidy is more assured than in most European and US programmes.

The Japanese government programme is not afraid to take the lead in long-term projects that may be too risky for the industry to participate in. It is, for instance the only programme to provide 100% sponsoring of pilot plant developments for new PV technologies.

Table 4.3 - Overview of the successes of their countries' programmes as contributed by the PV-EC-NET partners (1/2)

	Successes
AUT	The success lies in international co-operation which helps the very small Austrian market to be amongst the world market leaders in some specific aspects like inverters (Fronius) and encapsulation.(Isovolta).
BEL	The biggest success is that the industrial basic research at the research centre IMEC on an highly efficient industrial screen printing method for photovoltaic cells shall be implemented at the industrial plant Photovoltech in 2003, with a production capacity of 6 to 9 MW per year
CHE	The development of the micromorph solar cell by the Institute of Microtechnics at University Neuchâtel (IMT) The development of flexible solar cells by the Institute of Microtechnics at University Neuchâtel (a-Si) and the Institute of Technology in Zurich (CIS) The development of nanocrystalline dye-sensitised solar cells ("Grätzel-cells") by the Institute of Technology in Lausanne The development and market introduction of some of the best PV inverters in Europe Manifold solutions for building integrated PV (support structures, mounting systems, BIPV modules, roofing and facade systems, etc.)
DNK	The biggest achievement in the last 5 years was the involvement of several utilities and building industries in the PV development and deployment. The utilities took over the participation on the IEA work, co-ordinated a lot of R&D projects with the building industry and succeeded in relative low end-user costs in two big demonstrations programmes, creating high public interest.
FRA	A PV industry among world leaders and competitive innovative products (Photowatt, Total Energy). A public research of international level (CNRS, CEA, Universities). A strong involvement in crystalline silicon cells/modules still major commercial technology (and still for 10 to 15 years may be more). Stronger implication of CEA in 2000 (Atomic energy commissariat, a public research organisation) in cell research and system components and involvement of electricity utility EDF in 1993, occurred thanks to a national PV activity supported by ADEME since 1982.
ESP	The most important success was the development of the 1 MW grid-connected plant at Toledo and the exploitation of the results by the electrical utilities who gained experience of integrating PV systems as a source of electricity.
FIN	During last 5 years several new products have been developed (system components, like electronics) and brought to the market under the earlier PV programme. In advanced solar energy storage back-up systems very advanced system concepts have been developed. Some good BIPV in building demonstrations done.
DEU	Development of high performance machines for the wafer slicing process. Increasing of the cell's performance, optimisation of the production process for Si PV cells, all with regard to minimise the production costs. Increasing of the performance of CIS solar Cells and Development of adequate production processes.
GRE	No dedicated PV RTD programme. However, budget for PV RTD is generally available through other more general programmes. Public awareness is high due to the very successful and well-developed solar thermal industry.
ITA	Development of one of the more relevant areas devoted to PV in Europe (ENEA Portici). Development of a full process (deposition/ module internal connection/housing) for large area integrated a-Si modules. Transfer of some developed technology to aSi-cSi HJ. Definition of a process compatible with industrial application high efficiency on planar cSi cells High level of several basic researches on PV material science, and devices technology developed in several academies. Stable CdTe solar cells and innovative contacts in CIS/CdTe devices Biggest European PV Plant. Experience with centralised power generation. Building integration by the development of specific components (façade and tile module). Hybrid PV thermal module and multi mode Power Conditioning Unit)

Table 4.3 - Overview of the successes of their countries' programmes as contributed by the PV-EC-NET partners (2/2)

	Successes
NLD	The DEN programme is too young to have established remarkable successes. The NOZ-PV-II programme (1997-2001) realised and surpassed 11 out of the 12 objectives. In the year 2000: Three clusters of technology (mcSi, aSi, organic) established. Fundamental research on new technologies. Annual Production capacity in NL of 3MW cells and 10 MW modules. Profitable sales: 5 MWp. Total installed: 4MWp stand alone and 11 MWp grid connected. Production of BOS systems. Many small, large and a very large BIPV demonstration project. System cost: €4.73 /Wp Development of guidelines for BIPV, Standards under development.
POL	Establishing a PV Centre Project entitled "Development of Photovoltaics for Energy Needs in Poland" financed by the Polish State Committee for Scientific Research (KBN), covering basic topics of photovoltaics, ranging from materials research through manufacturing of solar cells and modules to PV system testing.
PRT	The main success was the rising interest of promoters in PV systems related to good feed in tariffs. Interest in thin film technologies is starting to rise.
SWE	For the Ångström Solar Center (ASC): Finalisation of a consortium agreement with industry, investment funds and government concerning further commercialisation steps of CIGS technology are on the way. World efficiency record for CIGS modules at 16,6 %. Continuous production of flexible Nano structured cell. For the SolEl 00-02 programme: A national network representing several stakeholders in PV has been established. The programme does provide a basis for international exchange. A good coverage of the rapid international development concerning PV systems has been achieved and reported to key stakeholders. A selected number of industrial and university environments have been provided opportunity to gain in dept knowledge in fields of interest for the stakeholders. Lessons learned from procurement, installation, start-ups and operation of Swedish PV installations has been assessed and implemented through new PV projects in co-operation with Swedish building industry.
GBR	Working with the utilities and the PV industry over an extended period, the RTD programme led the development of a new simplified network connection protocol for small-scale PV systems (Engineering Recommendation G77). By commissioning and supporting a number of design studies for building integrated PV, the RTD programme was instrumental in raising awareness and developing understanding about PV among architectural and building services professionals. Establishment of a series of BIPV field trials – around 800 kWp of PV installed on 540 houses on 30 sites and around 1 MWp on 18 other buildings. These projects will be intensely monitored throughout the design, construction and operational phases. The RTD programme has produced definitive guidance and information on building integrated PV covering: design, case study examples, testing, commissioning & monitoring, health & safety and installation.

Table 4.4 - Overview of the recommendations on how to improve their countries' programmes as contributed by the PV-EC-NET partners.

	How to improve?
AUT	Establishing a national PV goal which should be reached by research and marketing programmes. One of the main aspects could be building integration covering all aspects from technical to legislation and construction guidelines. Further work on network integration would also be useful.
BEL	The weakness of the programme is the bottom up approach: now it involves only single projects and not a complete technological chain approach.
CHE	A closer co-operation with the industry on the product development sector could result in better practicable solutions. Develop a better understanding of product / market combinations to focus efforts and develop competitive products. A closer controlling of the projects should lead to better time reliability increasing the robustness and the size of the industry. Move from engineering to entrepreneurial companies Emphasise manufacturing aspects.
DNK	A new clear national plan of action involving the industry, utilities and other stakeholders and political support with the necessary means would continue and improve the development
FRA	Concerning research on new types of crystalline silicon cells, there is a need for a laboratory able to implement innovations on cells of large area up to 20 cm x 20 cm. This laboratory will be operational by end 2003 (decision taken and ADEME's budget voted 28 November 2002).
ESP	PV RTD activities will be improved with a significant increase in funds and with the participation of Universities and RTD centres.
FIN	To have a clear national plan on the subject.
GRE	Regular budget for dedicated PV RTD activities, with specific qualitative and quantitative aims for PV technology and timeframe. PV market incentives for private investors would enhance the interest in PV RTD.
ITA	The PV RTD in Italy is under reorganisation. The best solution to improve national RTD could be to try and find a co-operative organisation in the European environment. Each national programme would match in best and complementary way all other European PV RTD, without double efforts. The Italian PV industry is under reorganisation. Further operators, like Pirelli Labs, would join Eurosolare and Helios tech. On other hand closer co-operation with the industry on the product development sector could result in better practicable solutions
NLD	For the DEN (RE) programme: Include programme specific targets; For the subsidy programme: Include criteria that favour technologies with a large energy potential in the long run, (far beyond 2020). This will enable PV technology to receive appropriate support. Include criteria that will favour applied research and demonstration projects. For the action programme: propose specific actions that are favourable to RE options that are not yet fully developed (like PV): These specific actions can focus on quality standards, knowledge transfer, networking and inciting the formation of trade organisations.
POL	Concentrating RTD funds and efforts on one or two selected technologies General governmental support would create favourable conditions for implementing PV and in this indirect way support research
PRT	Market development will call for a bigger industry and more and more effective RTD (this is the market pulled vision).
SWE	Encourage better availability of industrial / financial risk capital for the development of next generation PV technology, PV-building components, system integration concepts and niche applications. Encourage broader engagement from key stakeholders, such as property owners and installation companies. Expanded resources for information dissemination.
GBR	Although there are communication channels between the main actors in PV, these could be improved and made more pro-active. This could result in more effective and co-ordinated activity.

Table 4.5 - Overview of critical success factors for PV RTD programmes as contributed by the PV-EC-NET partners.

Critical success factor	AUT	BEL	CHE	DNK	ESP	FRA	FIN	GRE	ITA	NLD	POL	PRT	SWE	GBR	Category
															Score score
Organisational set up															16
Organisational structure of programmes			x	x		x									3
Policy background		x	x	x					x	x		x		x	7
Clear strategic plan					x										1
Clear aims / objectives					x								x		2
RTD planning process					x										1
Continuous evaluation of programme and adaptability to changes							x			x					2
Continuity															7
Continuity of budgets						x		x	x*				x		4
Continuity of programme personnel / structure			x				x			x					3
Linkage to key players / factors															21
Linkage / relevance to market						x									1
Interactions with PV industry				x	x	x	x							x	5
Interactions with utilities	x					x		x					x	x	5
Interactions with other stakeholders						x		x							2
Other networking (national/international)	x	x	x				x		x			x	x		7
Other															18
Critical mass for activity area									x			x			2
Availability of appropriate quality of people & equipment (and other infrastructure) to deliver work				x	x			x		x	x	x		x	7
RTD results dissemination													x		1
'Image' of PV (public interest)	x			x				x	x			x		x	6
System oriented approach			x						x						2

Note: More factors may be relevant to each country than those indicated but respondents were asked to select the most significant factors

*historically



Table 4.6 - Overview of critical problem factors for PV RTD programmes as contributed by the PV-EC-NET partners.

Critical problem factor	AUT	BEL	CHE	DNK	ESP	FRA	FIN	GRE	ITA	NLD	POL	PRT	SWE	GBR	Score	Category score
	Organisational set up															
Organisational structure of programmes					x			x		x					3	
Policy background		x		x	x		x	x	x		x			x	8	
Clear strategic plan	x			x			x	x		x		x	x	x	8	
Clear aims / objectives											x				1	
RTD planning process		x									x	x			3	
Continuity																14
Continuity of budgets	x			x	x				x			x			5	
Continuity of programme personnel / structure				x					x					x	3	
Long term commitment to plans				x	x	x				x	x	x			6	
Linkage to key players / factors																15
Linkage / relevance to market			x						x	x			x		4	
Interactions with PV industry		x	x						x			x	x		5	
Interactions with utilities		x					x								2	
Interactions with other stakeholders	x					x				x			x		4	
Other networking (national/international)															0	
Other:																15
Critical mass for activity area						x	x		x					x	4	
Lack of international influence			x					x							2	
Availability of appropriate quality of people & equipment (and other infrastructure) to deliver work						x								x	2	
'Image' of PV (public interest)					x			x							2	
National focus on other RE							x								1	
Information of the professional sector			x												1	
Consolidation of the industry structure			x												1	
Limited budgets									x			x			2	

Note: More factors may be relevant to each country than those indicated but respondents were asked to select the most significant factors



5 Incentives and Barriers

This chapter describes market incentives, legislative supports and other related issues which have been used to promote PV in Europe, Japan, USA and Australia. Furthermore, a short review of barriers which prevent wider use of PV in these countries is cited. The analysis is based on the data collected in the questionnaire. A short summary of lessons learned concludes this chapter. As noted previously RTD programmes do not operate in isolation, and the wider context as reviewed in this chapter can have an important bearing on the level of success achieved.

5.1 NATIONAL CONTEXT

A snapshot of the information is summarized in Table 5.1 and is then presented in more detail country by country.

Table 5.1. Summary of types of incentive actions by country

Country	Investment subsidy	Feed-in tariff	Local support	Other support
AUSTRIA	x	x	x	x
BELGIUM	x (2000)			
DENMARK	x			
FINLAND	x			
FRANCE	x	x		x
GERMANY	x	x	x	x
GREECE	x			x
ITALY	x	x	x	x
NETHERLANDS	x	x	x	x
NORWAY				
POLAND				x
PORTUGAL	x	x		x
SPAIN	x	x	x	x
SWEDEN				
SWITZERLAND	x		x	x
UK	x			x
AUSTRALIA	x		x	x
JAPAN	x		x	x
USA	x		x	

Austria

- Investment subsidies up to 4 € per Wp; varies by the federal state.
- Eco-electricity law starting 2003 with feed in tariffs of 0,60 €/kWh for installations up to 20 kWp and 0,41 €/kWh for larger systems. A limit of 15 MW total installed capacity is stated in this law, which is expected to be reached within the first months of 2003.
- The Energy Law, EIWOG 2, started 2001 targeting 4 % Green Electricity by 2007.
- Incentive programme size: 200 kWp rooftop.

Belgium

- There has been an investment subsidy up to 75 % (2000).
- There is no feed-in-tariff, however, there is net metering in use.
- Incentive programme size: 1 M€.
- Other incentives: Surplus electricity from systems smaller than 2 kWp can be supplied to grid. No urban authorisation needed for systems smaller than 2 kWp. Belgian electric power suppliers support the educational institutes financially in order to enable the purchase of educational stand-alone and grid-connected photovoltaic installations. ODE -Vlaanderen vzw (organisation of sustainable energies, an information office) started in 1996 as an organisation for the promotion of renewable energies in Flanders.

Denmark

- There is an investment subsidies up to 40% of the turn-key-costs in the SOL-1000 project (1000 roofs) which was launched 2001, however delayed due to the government change.
- No feed-in-tariff but a net metering.
- Incentive programme size: 1000 roofs.
- Other incentives: Active use of seminars, conferences and mass media to promote PV. A PV installation certification scheme is established.

Finland

- Investment subsidies for enterprises 40 % and for private owners 30 %, started 2002.
- There is no feed-in-tariff, however, there is net metering in use.
- Incentive programme size: 7 M€/y.
- Other incentives: Green electricity in use.

France

- FACE fund for off grid application covers up to 70 % of the total installation cost.
- ADEME and funding partners give investment subsidies of 4.6 €/Wp for basic grid-connected systems and 6.1 €/Wp when the previous ones have safety storage;
- Feed-in-tariff for grid-connected systems 0.15 €/kWh (0.30 €/kWh for Corsica and overseas). Guaranteed for 20 years.
- Tax Exemption Law for the overseas departments.
- Incentive programme size: 1.5 MWp per year for off-grid application and also grid-connected BIPV incentive programme of 25 MWp by 2006.
- Other incentives: Complementary support can be added from several sources.

Germany

- Investment subsidies vary by federal states. A public bank loan with reduced interest rate.
- Renewable energy law (valid for 20 years): Feed-in-tariff for grid-connected systems 0.50 €/kWh with yearly 5 % lowering starting 2002.
- 100 000 Roofs Programme ending by 12/2003.
- Incentive programme size: 1000 MWp and 2 – 6 B€ loan.
- Other incentives: Churches are active. Active use of norms to help the industry to sell standardised products.

Greece

- 40-50% initial investment subsidy depending on geographic region.
- Feed-in tariff – no subsidy.

Italy

- There are national investment subsidies as well as local ones up to 75 % from the total investment costs.
- Feed-in tariff is in use.
- Provisions in supporting electricity from renewable sources. The producer and importer of fossil fuel are obliged to produce a minimum quota (2%) of electricity from renewables
- 'green certificates' for renewable electricity.
- Market incentive: roof programme
- Special programmes for architectural integration, use of PV system on the islands and for the introduction of solar energy in municipalities

The Netherlands

- Investment subsidies 3.5 €/Wp which can be increased by 25 % when an Energy Performance Assessment of the house is done. In addition, some utilities and communities may support extra 1 €/Wp.
- Feed-in-tariffs offered voluntarily by some utilities
- Net metering is practiced by some utilities
- Green energy certificates; one utility assuring 2% PV
- PV is exempted from regular energy tax.
- Other incentives: Renewable Energy Portfolio. Green investments: profit from shares free of taxes for projects > 22500. Return of Ecotax (up to end 2003). No building permit required for PV. Utilities offer PV directly to their clients.

Norway

- On-going general introduction schemes on renewable energy.

Poland

- Utilities obliged to buy renewable energy 2.4 %/2001 and 7.5 %/2010.
- No market incentive programme.
- Quick development of stand – alone systems
- Other factors: PV Center: stimulates PV RTD, education

Portugal

- Grants ranging from 20 % to 40 % of the total eligible costs of an investment (MAPE programme).
- Feed-in-tariff is in use: 0.28 €/kWh (> 5 kWp) and 0.50 €/kWh (< 5 kWp).
- Other incentives: Tax incentives.

Spain

- Investment subsidies vary by autonomous regions between 30 and 35 %.
- Feed-in-tariff is in use: 0.20 €/kWh (> 5 kWp) and 0.40 €/kWh (< 5 kWp).
- Incentive programme size: 6 M€ / 2.3 MWp (2001).

Sweden



- System for tradable electricity certificates from 2003 including all renewable energy sources. The short-term prices for the certificates are however probably too low to have an impact on the PV market in Sweden at current PV system prices.
- Other incentives: No building permit is needed as long as the PV electric power is for the owner's use.

Switzerland

- Investment subsidies vary by autonomous region between 0 and 6 €/Wp.
- Minimum feed-in-tariff for renewables of around 0.1 €/kWh is given by federal law; utilities with solar stock exchange models offer high feed-in-tariffs on a contractual basis.
- Green tariffs vary from utility to utility.
- Labels of green electricity (Naturemade®) include solar PV.
- Indirect incentive programme through the marketing action "solar electricity from the utility": 5 MWp installed capacity.

United Kingdom

- Investment subsidies (50 %) granted in the demonstration programme started in 2002 and reduced rate of VAT on professionally installed PV.
- Incentive programme size: 30 M€.
- Other incentives: The Renewable Obligation on electricity suppliers requires them to source 10% of their supplies from qualifying renewable energy sources (including PV) by 2010. This has the effect of putting a market set premium on supply which generators can negotiate with utilities.

Australia

- Investment subsidy up to 2.7 – 4 €/Wp for residential and 5.5 €/Wp for community buildings.
- Renewable energies are supported in off-grid areas to reduce the use of diesel oil -> investment support less than 50 %.
- Incentive programme size: 17 M€ / 3 MWp / 3000 systems.
- Other incentives: RE Action Agenda: market development, building community commitment, building industry capability, setting policy framework, encouraging culture of innovation, 125 % R&D tax credit for industry; NSW Solar Research Center.

Japan

- Investment subsidy up to 40 % of total costs.
- Net metering.
- There are running several national programmes as well as strong R&D programme.
- Coherent approach. Thus PV systems are accepted as standard components in buildings. (Projected building and PV system life spans are also compatible.)
- Incentive programme size: 400 M€ overall (1999 – 2001)
- Other incentives: 1) LT Energy Supply and Demand Outlook, 2) Green Power Fund by Electric Power Companies.

USA

- State and local initiatives are major part (85 %) of the support money.
- Investment rebates in 37 states, loan programmes and grants (24 states; 7 utilities).
- In 33 states there is net metering.
- Several different kind of tax exemptions: personal tax exemp. (15 states), corporate tax exemp. (17 states), sales tax exemp. (14 states), property tax exemp. (23 states).
- Federal tax credit corresponds to 0.017 USD/kWh.
- Incentive programme size: 470 M€ / 2001.

The complementary aspect to the incentives which are in place to support PV are the perceived barriers which prevent wider use of PV. The project partners were asked to identify the key barriers as they perceived them and the responses are summarised in Table 5.2. The two issues which are cited by far the most frequently are high costs and the difficulty of competing with other energy technologies. Low levels of awareness and electrical network issues are also mentioned but apparently as secondary.

Table 5.2. Barriers that prevent wider use of PV

Country	Barriers
AUSTRIA	Non-standard utility interface; Costs, lack of financing
BELGIUM	Financial break-even over 20 years
DENMARK	Interest in solar thermal and wind, no PV industry
FINLAND	Strong interest in bioenergy; prejudice (PV not for north), subsidy started only in 2002
FRANCE	High investment cost for BIPV systems Low feed-in tariffs
GERMANY	What after 100 000 Roof Programme?
GREECE	Non-existence of real feed-in-tariff
ITALY	No privileged financial resource for PV compared to other RE sources
NETHERLANDS	Conservatism of building officials, permission requirements, codes regarding appearance
NORWAY	Cost of PV; Norway has so much hydro-power
POLAND	Biomass in focus, low awareness, high prices, levels of tax (22%)
PORTUGAL	Costs, low awareness from the general public regarding the technology, energy storage in stand alone systems, need for standards and system certification, visual impact
SPAIN	Lack of funds, solar thermal more in focus
SWEDEN	Bioenergy in focus; low energy prices, availability of risk/ind. capital
SWITZERLAND	Costs, low awareness of all interested parties Missing national PV supportive measures following the RTD programme
UK	High first costs, electrical network integration issues
AUSTRALIA	Little community participation in decision making, Support and infrastructure for fossil fuel
JAPAN	None noted
USA	Focus on oil, conservatism

5.2 LESSONS LEARNED

In general the support mechanisms are very much varying from country to country in Europe and other parts of the world. Japan has the most versatile selection of support programmes which appear to be both well-integrated and based on a long-term commitment to PV. Because grid-connected PV grows fastest, it is by far the most important for the industry, and therefore the way the national RTD programmes address this topic is a significant factor in successful development.

In Europe and Japan the PV subsidy is much more based on national level programmes than in the USA where there is also emphasis on local activities. National programmes on their own may not be effective enough. A good combination of local support and national programmes seem to work best in Europe as exemplified by the activities in Germany and Switzerland.

Japan differs in one important way from the other countries: there PV systems are one of the standard building components. There are many reasons for that (PV industry has acquired building companies and there is straightforward legislation). Furthermore, in Japan electricity is relatively expensive. Thus, there the government can reduce support programmes without fear of collapse of the industry. Japanese companies have also built more production capacity than anywhere else so that they can gain more benefit from economy of scale.

If it is deemed desirable to promote PV, previous experience suggest that an effective combination of measures is the use of investment subsidy together with a feed-in tariff. Depending on the levels of subsidy provided, the amortisation time of the PV investment could be set at a more or less attractive level. The benefit of using a feed-in tariff is that it draws attention to the performance (i.e. quality) of the PV systems. That is now true at least in Japan, Germany and Switzerland where there is most installed PV per capita.

The list of barriers reflects the fact that the introduction of PV electricity to consumers, decision makers and related industry (e.g. builders) is a long-term project. Programmes should be at least 10 years long and independent of governmental coalitions. There have been examples cited of theoretically supportive actions (such as feed-in tariffs) which may actually have little or no impact due to limited or uncertain time scales. Another point is that there often need to be several parallel running programmes which support each other.

A major barrier cited for grid-connected markets is the high costs of PV systems. That is likely to remain true for years ahead except perhaps in Japan where the electricity price is so much higher (ca. 0.20 €/kWh) that even milder support programmes will be enough. Furthermore, if PV systems become a standard building integrated component, then one can count only the extra costs a PV system brings with compared to the “old” standard building component.

Another frequently cited barrier is lack of awareness of PV or prejudice against it. In some countries this problem has been addressed by giving more information, by participating actively in events and arranging educating and training courses often through a PV industry association.

6 Programme Spend & Effectiveness

This section look at the budgets allocated to PV RTD programmes and project activities and where possible the resulting outputs, including:

- What has been achieved in terms of outputs compared to how much has been spent on the programmes? (quality of objectives evaluated separately in previous section).
- How do European PV RTD activities compare to international competitors?

It starts with a more general background section looking at the wider context of R&D funding for technical innovation.

6.1 R&D SPEND ON GENERAL TECHNICAL INNOVATION

As noted earlier, the European Innovation Scoreboard has already benchmarked some of the broad indicators relating to technical innovation. We have looked at just two of the most relevant indicators as background for this study⁶ with the definitions and interpretations as indicated in Table 6.1 below.

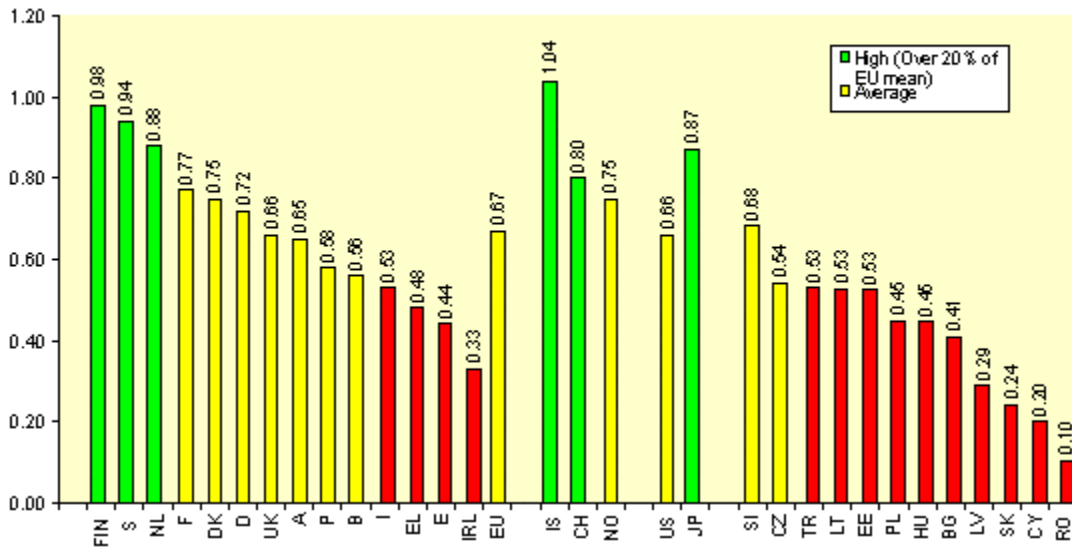
Table 6.1 - Indicators for Technical Innovation, Definitions and Interpretation

Indicator	'2.1 Public R&D expenditures' (as a % of GDP)	'2.2 Business expenditure on R&D' (as a % of GDP).
Definition	This indicator is defined as the percentage of GDP due to public R&D spending. The latter is defined as the difference between total R&D expenditures (GERD) and business enterprise expenditures (BERD). It thus includes higher education expenditure in R&D (HERD), government expenditure in R&D (GORD) and private non-profit expenditure in R&D (PNRD).	This indicator measures the R&D expenditure (from all sources of funding) of the business sector (manufacturing and services) as a percentage of GDP.
Interpretation	In addition to the production of basic and applied knowledge in universities and higher-education institutions, publicly funded research offers several other outputs of direct importance to private innovation: trained research staff and new instrumentation and prototypes.	The indicator captures the formal creation of new knowledge within firms. It is particularly important in the science-based sectors (pharmaceuticals, chemicals and some areas of electronics) where most new knowledge is created in or near R&D laboratories.

Further data and background relating to these indicators can be found on the EU website⁶. The graphical results for these two indicators are reproduced in Figures 6.1 and 6.2 below:

⁶ <http://trendchart.cordis.lu/Scoreboard2002/html/indicators>

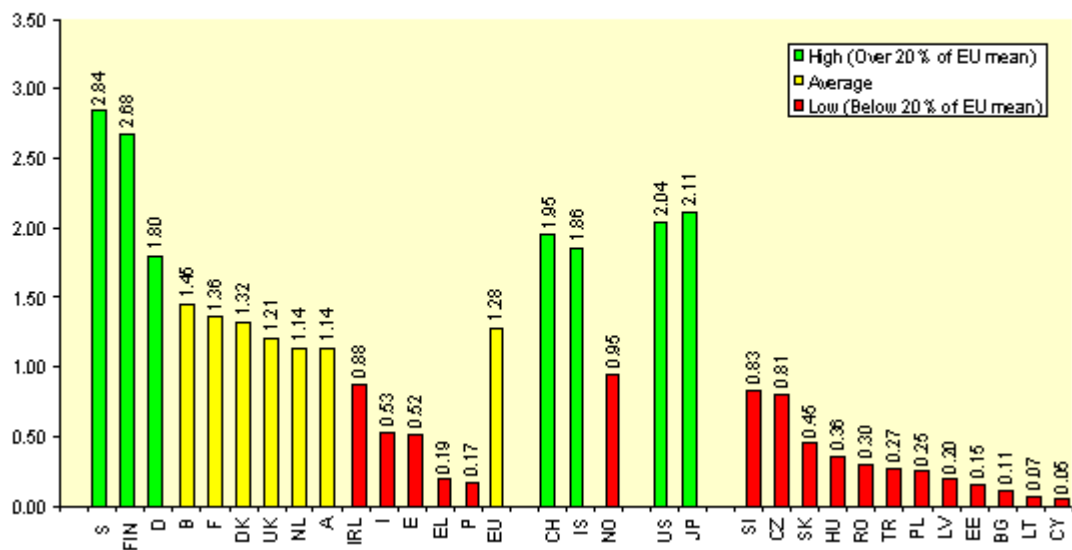
2.1 Public R&D expenditures (GERD - BERD) (% of GDP)



Source: European Innovation Scoreboard

Figure 6.1 Public expenditure on R&D (see Table 6.1 for definitions)

2.2 Business expenditures on R&D (BERD) (% of GDP)



Source: European Innovation Scoreboard

Figure 6.2 Business expenditure on R&D (see Table 6.1 for definitions)

Looking at the results of the two R&D indicators above shows that the EU as a whole compares reasonably with the US and less so with Japan in terms of public R&D but much less so with either the US or Japan in terms of business R&D. There is also quite a wide range of expenditure within Europe, particularly for business R&D. The EU average public R&D expenditure as a percentage of GDP is comparable with the USA and significantly less than Japan, whereas the EU average business expenditure on R&D as a percentage of GDP is only about half that indicated for Japan and the USA. Thus the general R&D funding context

within which an innovative, high technology sector such as PV operates indicates that public funding (ie 'programmes') on average is similar to key competitors but with a range of a factor of three across the members states. By contrast, business funding on average is about half that of key competitors but with a range of a factor of fifteen across the members states.

6.2 PV PROGRAMMES SPEND

In terms of PV R&D budgets in Europe and in the main Europe competitors (Japan and USA) the situation follows more or less the same trends as the general inovative processes budgets i.e. there is a wide variation of budgets within Europe and is not so easy to disaggregate the public and so-called business investments. These data are available from a number of sources including the IEA⁷.

The following chart (Figure 6.3) compares European funds for PV RTD with the USA, Australia and Japan. Note that the data used in the charts are not necessarily strictly comparable, coming from different sources and referred to different time period (the average value of the last 3-4 years obtained from PV-EC-Net members has been used for Europe compared with data from 2001 from the IEA for the rest). However, it is believed that the data are sufficiently representative to draw broad conclusions. The distribution of PV RTD funds depicts a favourable situation for Europe with 46% of the total.

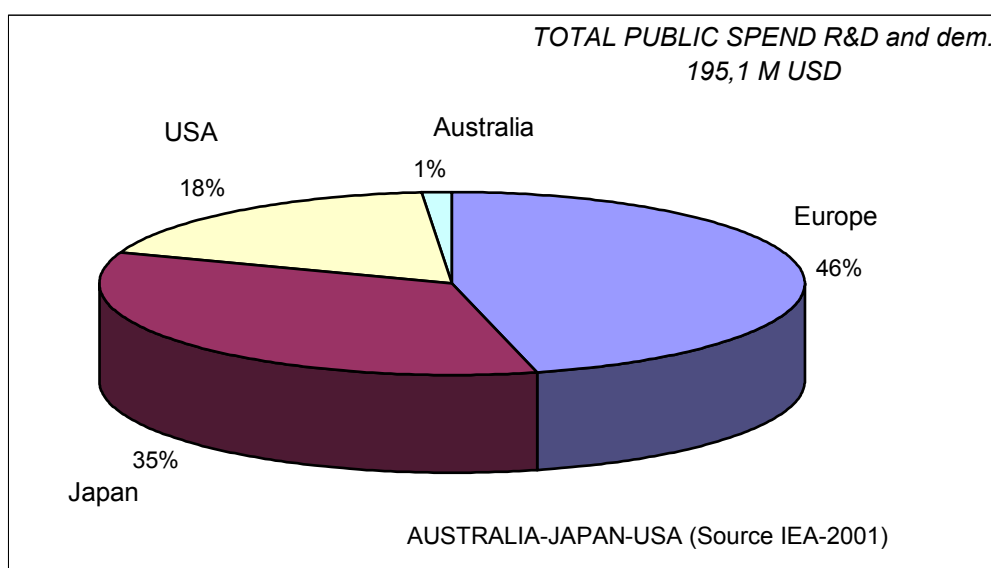


Figure 6.3 PV RTD spend in Europe, USA, Japan, Australia

Looking at market incentives shown in figure 6.4 below, the situation is reversed. Japan has a share of 53% alone, and USA and Europe have a similar share (21-24%).

⁷ For example: 'Trends in Photovoltaic Applications in Selected IEA countries between 1992 and 2001' Report IEA – PVPST1-11:2002.

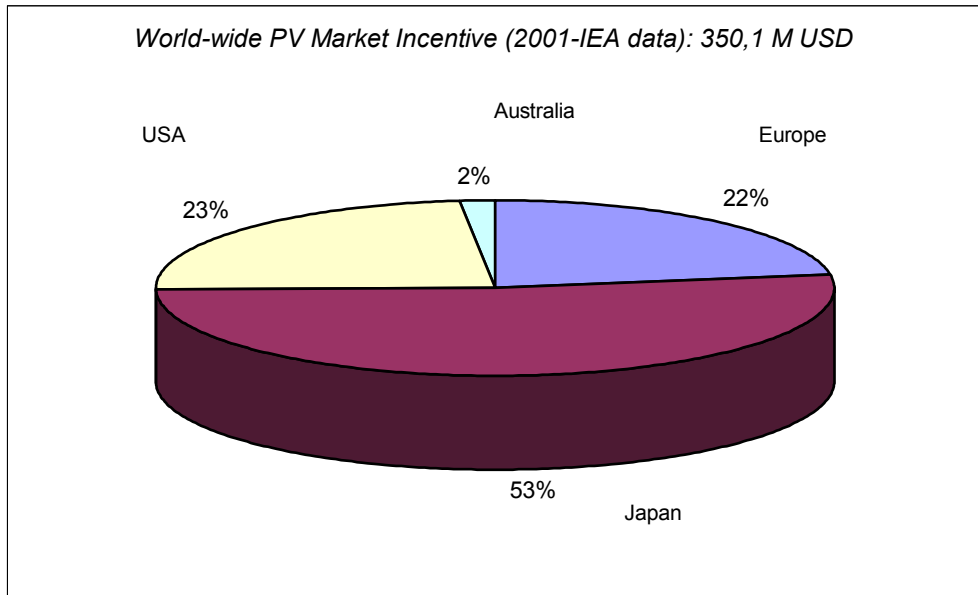
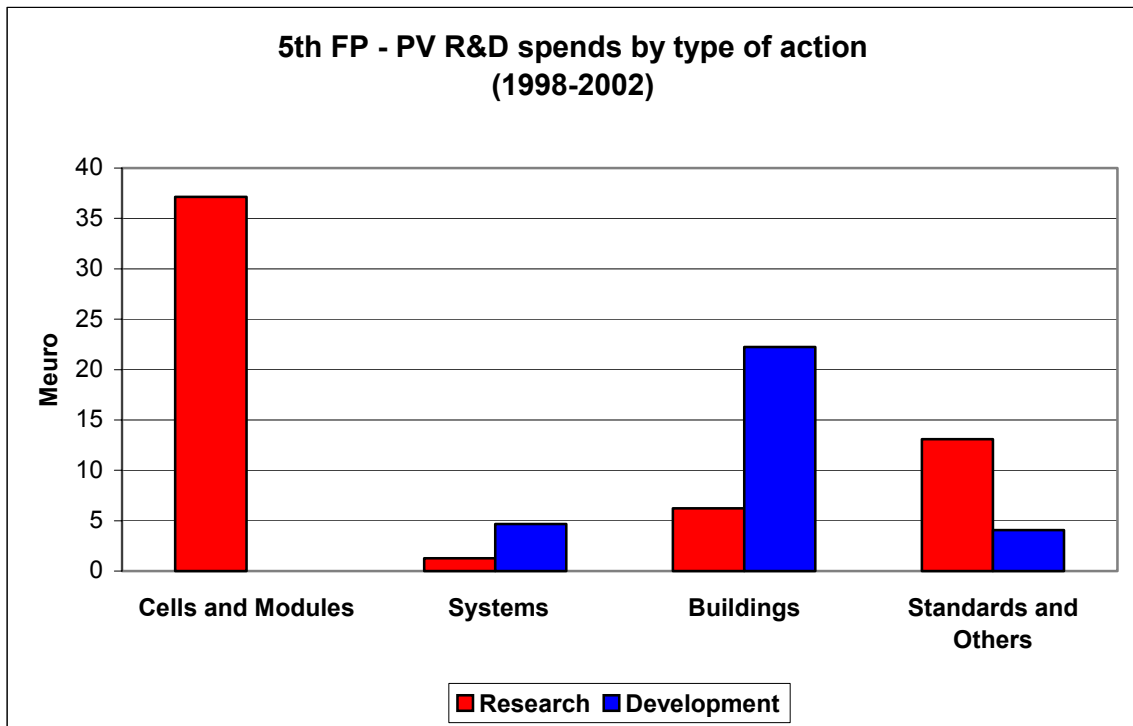


Figure 6.4 Spend on market stimulation in Europe, USA, Japan, and Australia

In terms of R&D budget by type of action data from European Commission 5th framework programme approved projects can be analysed. The results are presented in figure 6.5 below.



Source: 5th Framework Programme of the EU

Figure 6.5 Spend in the EC FP5 programme

It can be seen that Europe spends R&D money mainly on the subject of cells and modules and here the money goes mainly to research projects rather than development. In terms of development it is interesting to see that Building Integration is attracting a greater proportion of the funds.

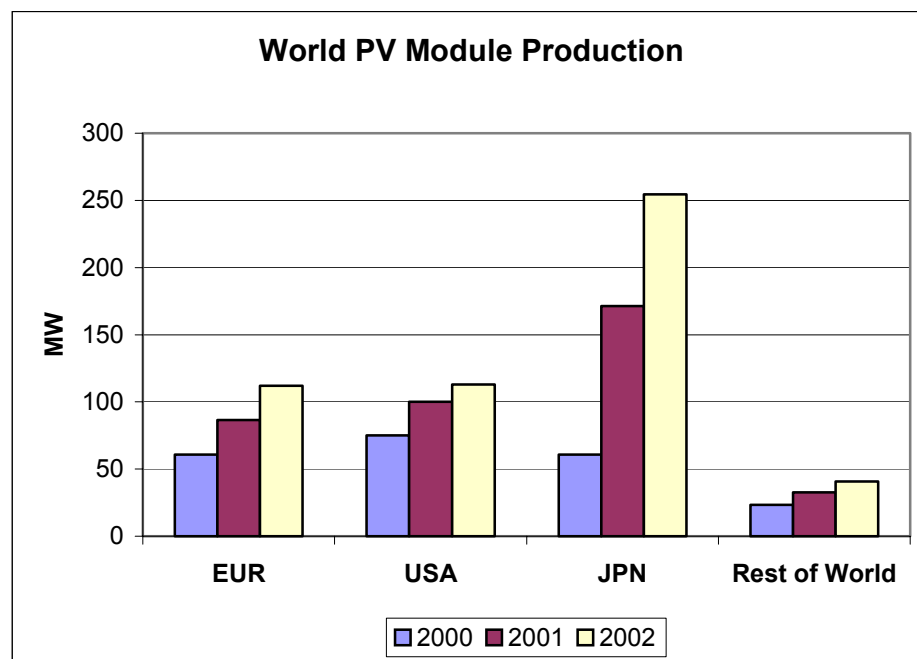
As an overall conclusions it can be said that:

- The level of R&D budget in Europe is in absolute values similar to that of Japan and bigger than USA.
- The budget in Europe has a wide distribution among countries with different policies towards PV.
- Europe spends more R&D money on pure Research than on Demonstration actions with the Research on the issue of new cells and modules receiving the greatest funding.

6.3 PROGRAMME EFFECTIVENESS

As discussed in Chapter 4, most of the PV RTD programme aims are qualitative in nature with little consistency in those which are quantitative. We have therefore had to use proxy indicators for quantitative measures of programme effectiveness. The main indicators used were PV module production which is related to industry capacity and in some sense to R&D programmes and cumulative installed power and module prices which are indicators more related to market. We would not suggest that the production and deployment of PV is directly the result of RTD programme activity and spend, but intuitively, RTD programmes are an essential part of the ingredients for the successful development of PV. In another part of this project (the SWOT analysis, reported separately), there are some other more detailed indicators of programme strengths which can also intuitively be linked to programme effectiveness.

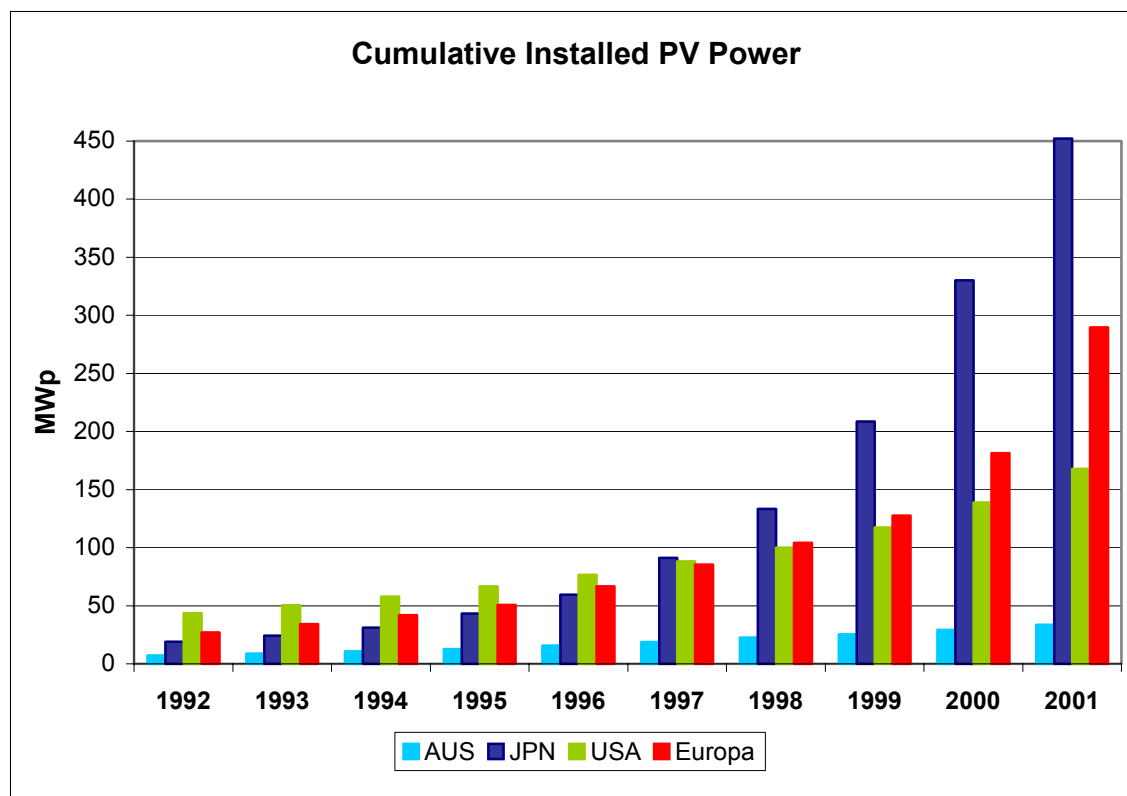
The following chart (figure 6.6) shows the evolution of PV module production in several regions of the world. Europe and USA are at a comparable level whereas Japan shows a remarkable increase in the last years (note that in 2000 the level of production in Japan was more or less the same as in Europe and in 2002 this level is more than the double of the value of Europe). This despite the value of R&D budgets being more or less the same.



Source IEA PVPS 2001 report

Figure 6.6 World PV module production

The cumulative installed power and the module price may be a better indication of market development. Here Japan also shows a rapid evolution in the last years with Europe lying in between Japan and USA. Figure 6.7 below shows this evolution using data from the IEA⁷.



Source IEA PVPS 2001 report

Figure 6.7 Cumulative installed PV capacity

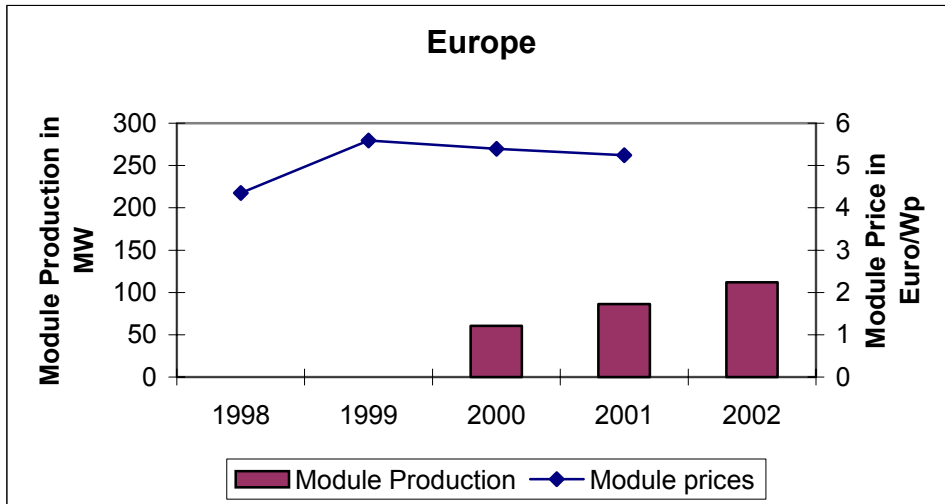
The following three charts (figure 6.8) show the evolution of module price and production over recent years in Europe, Japan and the USA. (Note that price data for only 1998-2001 and production data for only 2000-2002 were available at the point of analysis.)

In terms of module price it can be seen that in Europe the price is being more or less constant in the last years with values around 5 €/Wp whereas in Japan with a higher values in 1998 there has been a constant trend for decreasing prices with values in 2002 below 4 €/Wp. This can be a result not only specific R&D budgets (the production increased substantially) but of important market incentives measures.

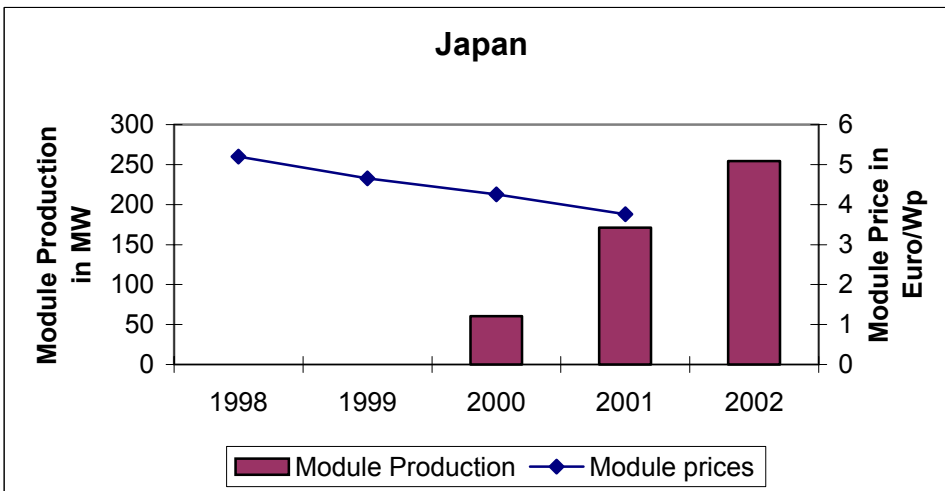
It is interesting to analyse also the values of USA. The price of modules are the lowest ones and this since 1998 were the price was already below 4 €/Wp. This price didn't change very much since that time, probably showing that some market incentives were introduced in the early and middle 90s and that some stationary state was reached.

We cannot conclude very much about the direct linkage between RTD programme activities and broader market effectiveness of PV. However, it is probably a truism to say that public RTD programmes make an important contribution to the enabling conditions for PV

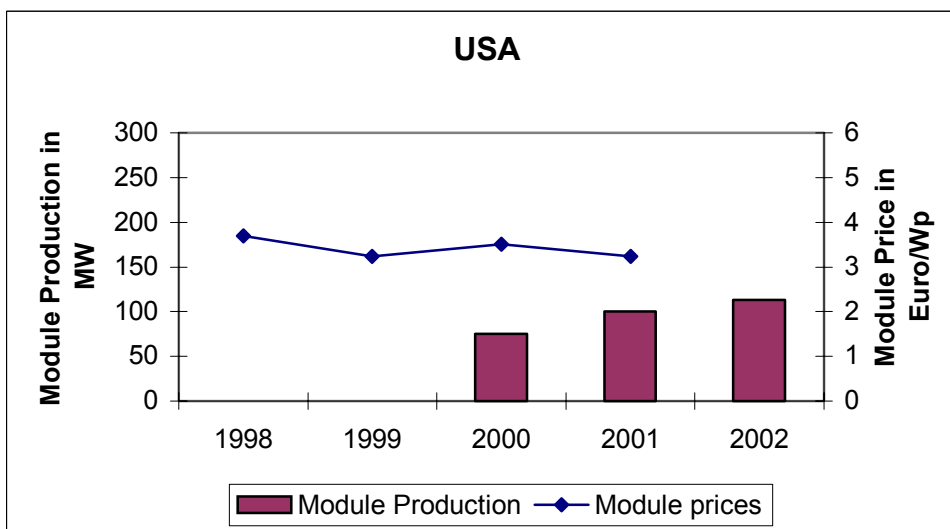
development at this stage in its product cycle through for example improving efficiency and lifetimes, and supporting the development of certification and standards.



Source IEA PVPS 2001 report



Source IEA PVPS 2001 report



Source IEA PVPS 2001 report

Figure 6.8 Price and market development in USA, Japan & Europe

7 Areas of Activity Focus

PV RTD requires a multidisciplinary approach. The creation of a European Photovoltaic Research Area (PV ERA) within the EU 6th Framework program could produce the collaborative implementation strategy for reaching commonly agreed objectives on materials, new architectures and process schemes, on manufacturing, reliability and longer life, increase of efficiency, etc. An overview of the current state of PV RTD in Europe provides a foundation block for the definition of a road map for the immediate, mid and long-term objectives and research priorities for the investment. This chapter provides such an overview.

7.1 TECHNICAL ISSUES

In 2002, around 560 MWp of PV was produced worldwide. Crystalline silicon technology represents about the 80% of the world photovoltaic market, of which around 50% are based on cast multi-crystalline silicon modules (mc-Si). Efforts are required to assure the continuous growth able to give the required positive conditions that are needed to attract investors and mobilise the financial investment, but to make the target affordable, the R&D community must be able to develop technologies that allow low-cost PV modules and systems and give the prospect for further cost reduction. Without the prospect of reducing the cost of both modules and systems level below 1 €/Wp, large-scale implementation of PV would not be likely.

European PV RTD is focused on: the closure of the gap between the existing performance of manufactured components and the predicted performance at laboratory scale; the general decrease of costs; and the solution of stability problems concerning thin film technologies.

The present state of European PV RTD efforts on material and devices can be summarized in the following sections looking at seven broad activity areas:

- Crystalline silicon
- Common features for RTD on all thin film technologies:
- Thin silicon technologies
- Thin polycrystalline film technologies- $\text{Cu}(\text{Ga},\text{In})(\text{S},\text{Se})_2$ and CdTe/CdS
- III-V Solar cells (mid-long term options?)
- Novel devices (mid-long term options)
- Systems - PV modules, inverters, storage and applications

The issues are grouped in two broad sections looking at materials and devices and modules & balance of system issues.

7.1.1 Materials and Devices

Photovoltaic conversion of solar energy is based on semiconductor electronics. Although materials such as GaAs, CuInSe_2 and CdTe may be without any doubt valid alternatives, still today the photovoltaic market is by far dominated by silicon. As noted above, about 80% of the world PV cell production for terrestrial applications has its origin in mono-crystalline and multi-crystalline silicon wafer technology. Most of the remaining 20% market is supplied by thin- silicon (amorphous, microcrystalline, nano-crystalline, etc.) and by hybrid amorphous-crystalline PV cells.



Crystalline silicon

Experience indicates that silicon technology will continue to dominate the PV market for the next 10 to 15 years. The cause of this predominant position is the combination of a number of factors, such as the maturity of silicon PV technologies, the good and well-known opto-electronic properties of the material, its availability, lack of toxicity, cost, chemical stability, etc.

During 2001 a total supply of 26 000 tons of silicon reached the electronic industry, of which around 15% were used to supply the PV market. The necessity to decrease the cost of feedstock and to sustain the growing PV market imposes a different approach to feedstock supply.

The position of Europe on the wafer production is very strong. Europe is a leader in the production of crystalline ingots and wafers for PV applications, through companies like Scanwafer, Deutsche Solar GmbH, PV Crystalox Solar AG, Solar World, etc. On other hand the European leadership does not appear so sustained on the production of cells/modules.

A large amount of R&D issues in Europe concern the attempt to solve the problems associated with c-Si wafer based technology. The main issues are summarized in Table 7.1

Table 7.1 R&D activities on Crystalline silicon

R&D activities on Crystalline silicon:
- reduction of thickness of wafers (EPIA Road map: 10 t Si/MWp in 2010 compared to 17 in 2000)
- more efficient and reliable mc-Si modules
- New processing technology for production of PV-grade-silicon feedstock
- Improvement throughout the manufacturing line, by reduction of process steps without detrimental effect on modules efficiency
- Efficient/low cost bulk and surface passivation schemes
- development of thin silicon approach (growth of thin material on insulator or cheaper substrates): EFG, Ribbon, Thin-Si on insulator, Lift-off techniques
- New modules design: alternative packages, encapsulants
- Energy saving process, environmental friendly approach (reduced toxic/harmful process)
- High efficiency applications of the devices in low/middle concentration applications ($10 < X < 300$), and space applications.

Thin PV films

In the last few years, however, new possibilities have arisen on the basis of a number of technological approaches for the fabrication of inexpensive thin film for PV applications.

Among them amorphous silicon was the first candidate. The PV application of this material was initially developed mainly in the UK, USA and Japan. More recently, the unsolved poor stability of material has introduced the need for a new approach in the growth of material by low-temperature CVD by RF, VHF plasma- enhanced and Hot-Wire CVD, the development of new alloys to enhance the light absorption spectra in stacked structures (tandem/triple

junctions). Particularly in Europe the development of Copper Indium diselenide-Gallium (CIGS) received an increased interest as an alternative candidate to thin silicon.

Irrespective of the particular technology, thin film RTD is based in the premise that with the cost and performance targets envisaged, a market share of 15-20% might be possible by 2010. Bearing in mind the growth in cells/module shipments to date, the market share of 15-20% for thin silicon technologies can be considered very ambitious. In fact considering a hypothesis of a growth of less than 25% for crystalline Si it means the growth of the market for thin film would need to be more than 9-12 times the present market. In fact the present trend is in the opposite direction. The common issues for all thin film R&D are summarised in Table 7.2.

Table 7.2 Common features for R&D on all thin film technologies

Common features for RTD on all thin film technologies:	
-	Development of new pilot lines for more stable material and higher deposition rate, including vacuum process in continuous lines.
-	Technical implementation to reduce cost of production lines
-	Best knowledge of material's physics-chemistry
-	Large area – low cost transparent conductive oxides as front contact
-	Flexible substrates
-	Packaging (humidity, diffusion of contaminant, aggressive moisture)
-	Safety requirement of material and process

In contrast to the Japanese PV programme, the situation in Europe on thin film for PV is characterised by a strong diversity in national programmes, some of which are individually strong, but with a high degree of fragmentation. In 5th Framework Programme (FP), positive actions have been launched to increase collaboration and co-ordination via RTD projects, or Thematic Networks like PV-NET (Network for the development of a road map for PV R&D-<http://www.pv-net.net>), and, of particular relevance for thin silicon, aSiNet, (European Network on amorphous-silicon device technology-<http://www.asi-net.net>). These initiatives have the chance to become much more ambitious in FP6, via Networks of Excellence (NoE) and Integrated projects (IP). In combination with similar actions in complementary research areas on materials and devices, there is an opportunity to make a significant contribution to the creation of the European Research Area (ERA. In this context, further efforts are in progress to join CIGS and thin silicon community to focus PV RTD groups on common objectives (architecture of the devices, transparent conductive oxide, characterization techniques, training and mobility of researchers, etc).

Particular issues for RTD on thin film Silicon and the thin film family of cells based around CIGS and cadmium are noted in Table 7.3 below.

Table 7.3 Specific R&D activities on thin film Silicon technologies and thin polycrystalline film technologies- Cu(Ga,In)(S,Se)₂ and CdTe/CdS

Specific R&D activities on Thin Silicon technologies:
- scale up of multi-junction and new architectures
- more stable material (micro morph concept and similar approach)
- development of alloys (SiC, SiGe, etc) to enhance the response to the light of multi-layer structures
- graded doping profiles and improvement of interface quality
- light trapping and textured transparent conductive oxide
- Improvement in pattern technology and module interconnection
Specific R&D activities on Thin polycrystalline film technologies- Cu(Ga,In)(S,Se)₂ and CdTe/CdS:
- simplification of the manufacturing process and large area deposition techniques for binary ternary compounds
- improved front and back contact
- Health and safety aspects
- Inline process control
- Strategy for re-cycling (CdTe/CdS)

III-V materials and novel devices

European R&D activity on III-V Solar cells and Novel devices is focused on mid- and long-term activities. The first one is particularly linked to space applications and PV concentrators, the second is concerned particularly with dye sensitised photo-electro-chemical cells, and polymer and organic molecular cells. The position of Europe is quite strong. Key areas of R&D are shown in Table 7.4.

Table 7.4 R&D effort on III-V PV cells and novel devices

R&D effort on III-V PV cells (mid-long term options)
- Low cost substrates and low-cost high deposition rate
- New architectures (multi junction) for high throughput and low cost of higher efficiency solar cells >35-40%
- Applications in PV concentrators (400 X-1000X)
Novel devices (mid-long term options)
- (Dye-sensitised photo-electrochemical cells, Conducting polymer cells, Quantum dot solar cells, Molecular organic solar cells)
- Collection of generated carriers Lifetime, charge separation, improved mobility to use thicker films,
- Low-cost materials and processing by simplified process (ink-jet)
- Devices and interface engineering
- Stability

7.1.2 PV Modules and Systems

During last years, the issue of storage of energy due to discontinuity of the PV source increased the interest for grid-connected applications of PV system. Further decreases in the cost of installation are introduced by using the existing infrastructures for the installation of PV system.

The key PV RTD issues to decrease the costs of material and devices are indicated in the previous paragraphs. In this paragraph we look at issues applied to PV modules and systems having the aim to decrease the cost without detrimental effects on the performance.

Particularly building integrated applications of PV (BIPV) is recognized worldwide as a good opportunity for the diffusion of grid connected PV, and several issues concern the development of BIPV oriented components, including the demand for small size inverters.

Further applications concern the storage of energy, using not only conventional batteries, but also different energy vectors (hydrogen, water pumping, etc)

The relevant issue of European PV RTD on modules and system are summarized in Table 7.5.

Table 7.5 R&D on PV Modules and Systems

R&D efforts on PV modules (not considering the particular technology)
- Development of PV technology for Building Integration, having enhanced characteristic for installation during building-construction and for the retrofit installation.
- Increased architectural appeal.
- Photovoltaic/thermal hybrid panels
- Simplified and efficient housing. Higher lifetime (>25-30 years).
- New polymers, encapsulants, resins, electrical connections. Degradation during lifetime <3%.
- Integrated electronics (see following table)

R&D efforts on PV Inverters, storage
- Development of the design and grid interconnection of building integrated and other dispersed photovoltaic systems
- Integrated electronics (e.g. AC modules), charge controllers and energy storage (feedback batteries) for small PV-system
- Higher efficiency Inverter (>97% with 100% of load and >92.5% with 10% of load) price less than 0.6 €/Wp; <500W; 0.3-0.4 €/Wp; 1kW...5kW; 0.3 €/Wp; >1 kW
- Development of dual inverters in grid-connect systems to back up in times of grid failure
- Low cost/high efficiency battery (reduced toxic/harmful process and material used). Innovative storage
- Use of PV in hydrogen production, water pumping, drinkable water production,
- Life Cycle assessment aiming to decrease the environmental impacts associated to whole PV-system life-cycle

Further PV applications will come from the use of photovoltaic power systems in stand-alone and island applications, and very large scale photovoltaic power generation systems in remote areas. Feedback from applications has an impact on PV RTD too, for example concerning the control and monitoring of plants, development of high efficiency systems for water treatment and energy storage.

7.2 DISTRIBUTION OF EXPENDITURE AND EFFORT

7.2.1 Expenditure

Indicative data were collected as part of this project and these give a picture of how public spend on PV RTD is distributed in Europe. The data are a snapshot of indicative spend of public funds on PV RTD representative of the last 3-4 years of activity. The data are not exact and are not necessarily coherent for example:

- information on private spend for RTD is often confidential information,
- fragmentation of academic research activities can make it difficult to split spend between categories.
- the boundaries of what constitutes ‘research’, ‘development’, ‘demonstration’ and ‘market stimulation measures’ often vary from country to country and are thus not always comparable.

Bearing in mind these and other limitations of the data, we can nonetheless identify some of the major features of how spend is distributed.

For example, Figure 7.1 below indicates how spend is divided between the categories of Research, Technical Development and Demonstration.

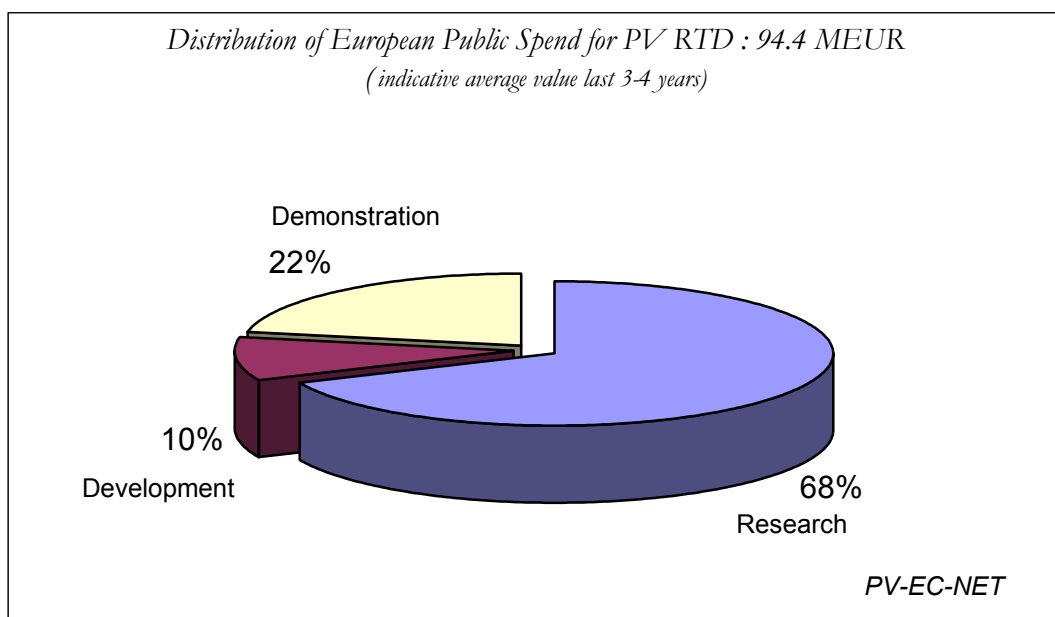


Figure 7.1 Indicative annual European spend on PV RTD distributed for research, development and demonstration

We can also see the distribution of funds among the broad topics of RTD as shown in the two charts below (Figures 7.2 and 7.3). For example, it is clear from the data that in Europe, the budget for the development of different technologies (materials, devices and modules) remains the larger proportion of the total public spent in this area (68%).

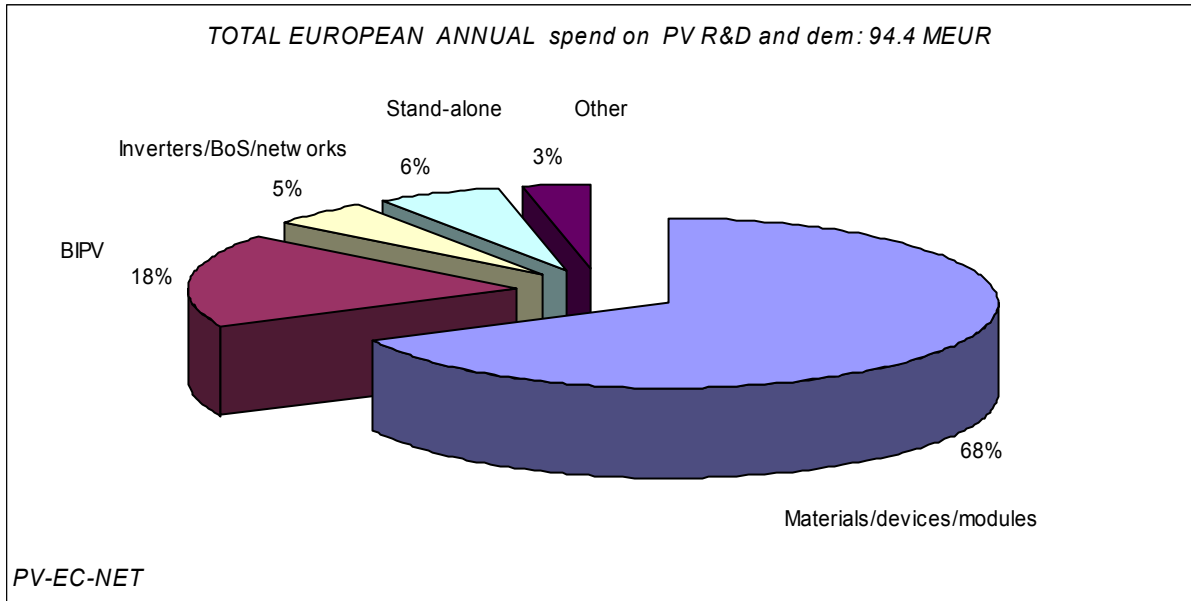


Figure 7.2 Indicative annual European spend on PV RTD distributed by category

This spend on materials/devices/modules is further broken down as shown in Figure 7.3 below:

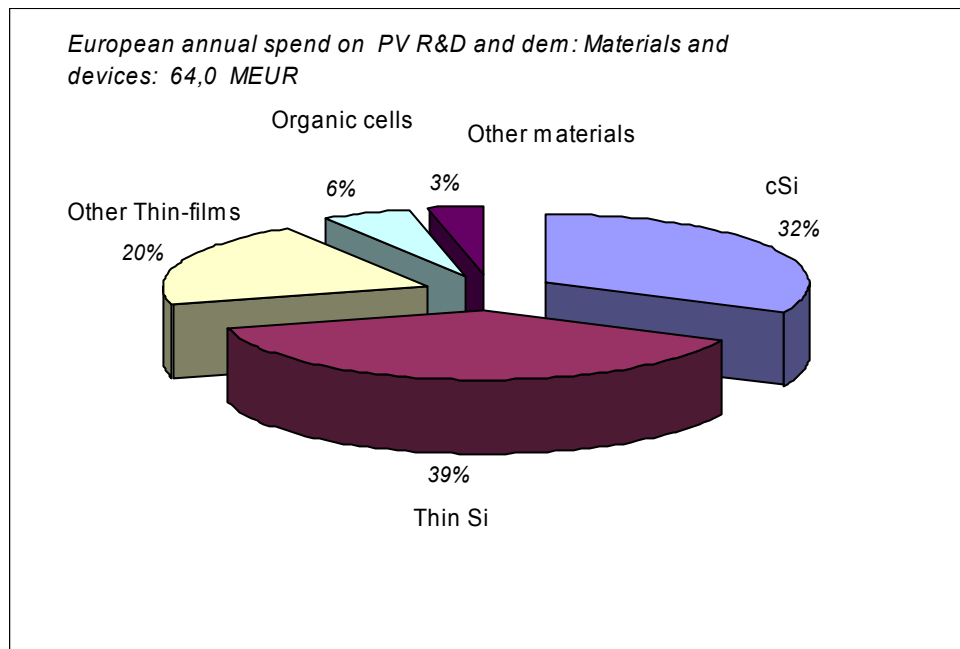


Figure 7.3 Distribution of PV R&D funds across different technologies

Of the resources spent on materials and devices, the larger amount of funds cover c-Si/mc-Si technology (32%); thin silicon (39%) and other thin films (20%). The thin film technologies alone (thin-Si+ CdTe+CIGS) cover around 59% of funds. This shows the priority given

within Europe to solve issues typical of all thin film technologies like: stability of material and devices, scale-up, high deposition rates etc, as indicated in the previous paragraph.

There is also a significant spend on BIPV (18%) in the national R&D programmes mostly relating to demonstration of building integration applications.

7.2.2 Effort and Activities

Data were collected on where the main areas of activity lay within each of the European national programmes. The data are the best estimates provided by the project partners and do not purport to be exact. However, as for the spend data in the previous section, they are thought to be sufficiently representative to be indicative of major trends and issues. Here we look at the quantitative evidence of people employed in the various sectors of PV RTD and then a more qualitative judgement from the national programme managers looking at the main areas of activity within their programmes.

Table 7.6 following shows the European distribution of PV RTD institutions (as at 2002), in terms of number of groups having Full Time Equivalent (FTE) resources operative on specific PV RTD issues in the size ranges from 1 to 5 FTE, from 6 to 20 FTE and from 21 to 70 FTE. No PV RTD institutions are reported with greater than 70 FTE staff.

Table 7.6 Indicative distribution of Staff in European PV RTD

Size of the institution expressed in Full Time Equivalent- FTE-(2002)	1 <FTE<5		6<FTE<20		21<FTE<70	
	U/R	Ind	U/R	Ind	U/R	Ind
Materials/devices:						
Crystalline silicon cells	13	10	29	18	-	1
Thin-film silicon cells	10	6	26	11	2	1
Other thin-film cells	9	2	16	6	-	-
Organic cells	14	4	13	2	-	-
Other materials	7	1	5	1	-	-
PV Systems & other applications:						
Building integrated PV	10	23	5	13	1	-
Inverters/BOS/ el. Networks	20	16	11	16	-	-
Stand alone systems	12	11	11	8	-	2
Energy Storage	2	2	1	2	-	-
Management/Studies/IEA	8	18	-	2	-	-
PV Installations	3	36	1	9	-	-
Others PV applications	-	-	2	2	-	-

Legend : U/R=Universities/Public Research centres, Ind : Industry&private labs

The information indicated in the table was prepared on the basis of data collected by the PVECNET partners through questionnaires. The data are not expected to be consistent or complete but we can draw some conclusions from it:

- There are a large number of relatively small groups spread over a wide range of topics.
- There is an apparent tendency for industrial R&D towards nearer term issues and markets such as crystalline silicon and BIPV and connection issues.
- The increased scientific interest on organic cells is showed from the wide number of public PV RTD groups focused on this specific issue.

- The PV RTD activities of companies is well distributed on all PV system issues, and particularly on BIPV there is a wider interest.
- Pioneering R&D work is often performed by small PV RTD groups (<5 FTE). Short-term PV RTD options (c-Si/thin film silicon/CIGS) require higher critical mass and a similar distribution is depicted for both academic/PRC and Industry/private labs.
- Energy storage is not an issue exclusive to PV and the limited number of groups indicated could be a result of definitions.
- Industrial research is focused on several aspects of PV systems, but there is a peak of interest on Inverters, BoS and electricity network issues.

The distribution of activities within the European national PV RTD programmes is indicated in Table 7.7. This shows where the effort is currently concentrated in terms of topic areas and in terms of research, technology development, demonstration, or actions to address non-technical barriers (four separate tables). The table is not a definitive picture but provides a graphical snapshot of European programme activities. At a top level, this enables clusters of activity to be identified with a view to either improving the coherence of work, avoiding inappropriate duplication of effort, and possibly diverting effort to other areas of work which are less well supported.

7.3 CONCLUSIONS

In contrast to the Japanese PV programme, the situation in Europe is characterised by higher public spend, and the strong diversity in national programmes, some of which are individually strong. The high degree of fragmentation suggests that there is an opportunity to enhance the collaboration of a large number of public and private institutions and thus improve the effectiveness of projects and programmes.

The high level of achievement reached by the European PV community in academic fields doesn't appear to follow through in an equivalent manner to production. Efforts are necessary to focus these achievements in scientific results towards a more production-oriented approach, particularly for short-term options (c-Si/thin silicon/CIGS). A European strategy is required to provide a credible alternative to Japan.

Particularly for thin film PV, the investment cost of production equipment, the safety requirements for processes and materials, the low efficiency of the devices, the low stability of material and devices raise real barriers in mobilising further effort on thin film PV RTD. A more collaborative environment is necessary between academies, research centres and industry.

The response of Europe on new frontier RTD is already of a high calibre, but the pooling of researchers on mid to long term options for material/devices R&D (organic cells, 3rd PV generation and Novel devices) could be beneficial to have higher critical mass and more efficient and productive methods of working.

For applications such as Building Integrated Photovoltaics, the architectural appeal of PV can be useful to help sustain the market, but at present actions are generally limited to market

incentives and further effort is required to reduce the cost and improve the availability of components and systems.

Table 7.7 National PV RTD Programme areas of activity (1/4)**RESEARCH ACTIVITIES**

RTD area	TOT	AUT	BEL	CHE	DEU	DNK	ESP	FRA	FIN	GBR	GRE	ITA	NDL	NOR	POL	PRT	SWE
Sc-Si	10		X		X	X	X	X		X		X	X	X	X		
mc-Si	9		X		X			X		X		X	X	X	X	X	
Thin film-Si	11		X	X	X		X	X		X	X	X	X	X		X	
CIS	8			X	X		X	X				X	X		X		X
CdTe	3			X	X							X					
Other thin film	8		X	X			X				X	X	X		X	X	
Nanocrystalline	6			X					X	X		X	X				X
Organic cells	10	X			X	X	X	X		X	X	X	X	X			
Fundamental materials	6			X	X		X	X					X	X			
Si Feedstock	3							X					X	X			
Inverters	5	X					X				X	X	X				
Other BoS	4						X				X	X	X				
Concentrating Systems	3						X					X					X
Building integration	5			X			X					X	X	X			
Architecture and planning tools	1											X					
Network integration	5	X		X						X		X	X				
System design / integration	1															X	
(Inter)National Standards	5	X								X		X	X			X	
Installation quality	2											X	X				
Hybrid Systems	5							X			X	X	X			X	
Remote, stand-alone systems	2											X				X	
Manufacturing	4							X				X	X		X		
Monitoring	4										X	X			X	X	
Performance standards / guarantees	4						X	X				X				X	

Table 7.7 National PV RTD Programme areas of activity (2/4)**TECHNOLOGY DEVELOPMENT ACTIVITIES**

RTD area	TOT	AUT	BEL	CHE	DEU	DNK	ESP	FRA	FIN	GBR	GRE	ITA	NDL	NOR	POL	PRT	SWE
Sc-Si	6				X	X	X			X		X	X				
mc-Si	7				X			X		X		X	X	X		X	
Thin film-Si	8			X	X			X		X	X	X	X			X	
CIS	3				X			X									X
CdTe	1				X												
Other thin film	0																
Nanocrystalline	1																X
Organic cells	3	X				X				X							
Fundamental materials	2											X	X				
Si Feedstock	2				X									X			
Inverters	11	X	X	X	X	X	X	X			X	X	X				X
Other BoS	5			X		X	X	X				X	X				
Concentrating Systems	4						X	X				X					X
Building integration	11	X	X	X		X	X	X				X	X	X		X	X
Architecture and planning tools	8			X	X	X	X	X				X	X				X
Network integration	8	X		X	X	X	X	X				X	X				
System design / integration	6			X	X	X		X				X	X				
(Inter)National Standards	6	X		X		X		X				X	X				
Installation quality	8		X	X	X	X	X	X				X	X				
Hybrid Systems	8	X			X	X	X	X				X	X				X
Remote, stand-alone systems	9	X	X		X	X	X	X	X							X	X
Manufacturing	7				X	X	X	X		X		X	X				
Monitoring	8			X	X	X	X	X				X	X			X	X
Performance standards / guarantees	3	X		X			X										

Table 7.7 National PV RTD Programme areas of activity (3/4)**DEMONSTRATION ACTIVITIES**

RTD area	TOT	AUT	BEL	CHE	DEU	DNK	ESP	FRA	FIN	GBR	GRE	ITA	NDL	NOR	POL	PRT	SWE
Sc-Si	3				X							X	X				
mc-Si	2				X								X				
Thin film-Si	2			X								X					
CIS	0																
CdTe	0																
Other thin film	0																
Nanocrystalline	0																
Organic cells	1	X															
Fundamental materials	1												X				
Si Feedstock	0																
Inverters	6	X		X		X	X					X	X				
Other BoS	3			X		X	X						X				
Concentrating Systems	2						X										X
Building integration	12	X	X	X		X	X	X	X	X		X	X	X		X	
Architecture and planning tools	5			X		X	X					X	X				
Network integration	8	X	X	X		X	X			X		X	X				
System design / integration	5			X		X	X					X				X	
(Inter)National Standards	1			X													
Installation quality	3			X		X							X				
Hybrid Systems	6			X		X	X	X				X					X
Remote, stand-alone systems	5	X		X			X						X				X
Manufacturing	2		X		X												
Monitoring	6	X		X		X				X		X	X			X	
Performance standards / guarantees	3			X			X					X					
Consumer surveys	1					X											

Table 7.7 National PV RTD Programme areas of activity (4/4)**ACTIVITIES ADDRESSING NON-TECHNICAL BARRIERS**

RTD area	TOT	AUT	BEL	CHE	DEU	DNK	ESP	FRA	FIN	GBR	GRE	ITA	NDL	NOR	POL	PRT	SWE
Sc-Si	0																
mc-Si	0																
Thin film-Si	0																
CIS	0																
CdTe	1				X												
Other thin film	0																
Nanocrystalline	0																
Organic cells	0																
Fundamental materials	0																
Si Feedstock	0																
Inverters	1						X										
Other BoS	1						X										
Concentrating Systems	0																
Building integration	6	X		X	X	X	X			X							
Architecture and planning tools	2					X	X										
Network integration	6	X	X			X	X	X		X							
System design / integration	3					X	X	X									
(Inter)National Standards	2				X		X										
Installation quality	0																
Hybrid Systems																	
Remote, stand-alone systems	2							X									
Manufacturing	0																
Monitoring	0																
Performance Standards / guarantees	1						X										
Consumer surveys	1																
Dissemination of data	0																



8 Overall Conclusions

This section draws together the main themes from the preceding sections and attempts to synthesise the lessons learnt into a checklist of ‘good practices’ for PV RTD programming.

8.1 CONCLUSIONS

Organisational Factors

There is a wide variety of national approaches to the management and organisation of PV RTD within Europe. A significant number of countries do not have a managed RTD programme dedicated to PV. For these countries in particular, the programmes of the European Commission can provide a useful focus for activities. Most national programmes are also designed to develop the particular national strengths in industry and / or research institutes. Thus within Europe there appears to be a more fragmented approach to the organisation of PV RTD compared to the USA and to a certain extent, Japan. This can be both a weakness (in terms of coherent planning of programmes) and a strength (in terms of robustness through replication and creative competitiveness).

From this exercise, it can be concluded that some features of the way that PV RTD is organised can have a significant effect on the outcomes. Key organisational features, which have a powerful enabling effect, are:

- Single point of leadership (at the national level)
- Integration of PV RTD programmes with key sectors (industry, universities & research centres, utilities)
- Co-ownership of a jointly agreed plan and vision among these sectors
- Complementary pace and direction between PV RTD programmes and market development actions.
- Pooling of resources to achieve ‘critical mass’

Conversely, if these features are not present within the organisational framework, one might expect to see some difficulties arising in the implementation of the programme.

Setting & Achieving Aims

European national programmes are generally well-managed in terms of the mechanics of their operation (for example meeting spend targets and project development targets) but programme aims are often quite general and broad and therefore results are harder to measure. Within the programmes, individual project aims are usually much better articulated and measured.

The aims and objectives of the American and Japanese PV RTD programmes appear to be **SMARTer** than those of the national European programmes. That is to say that they are more **Specifically** stated, with **Measurable** success criteria, they are **Ambitious** but **Realistic** and linked to a clear **Timeframe**. Without such SMART aims, programme planning, development and management is likely to be less effective.

Within the European National Programmes reviewed in this project, the three most significant critical success factors identified by the project team were: a supportive policy background;

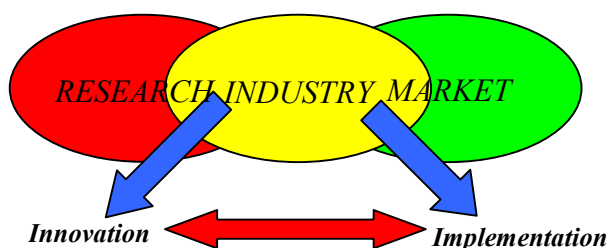


effective national and international networking; and the availability of the appropriate quality of people and equipment. In the same exercise, the two most significant problem factors by far were: an unsupportive policy background and the lack of a clear strategic plan. The fact that linkage to policy figured so prominently as an influence on success illustrates the importance of policy in setting the context for PV RTD programmes.

Japan and the US, in contrast to most European nations, have dedicated PV RTD programmes on a national and federal level. These programmes are clearly embedded in national policies that not only have strategic and environmental objectives, but also, apparently more so than in Europe, have industrial objectives aimed at the development of a flourishing PV industry. Therefore these programmes require close links with the PV industry. Strategic priorities are set together and have in both countries resulted in the drafting of PV development roadmaps. In the US, this roadmap has been drafted by the industry (and referred to by the government). In Japan it has been a joint effort of government, research and industry.

The Influence of other incentives and barriers

The most frequently cited barriers to the more widespread implementation of PV are high costs and the difficulty in competing with other energy technologies. This is of course what provides a key focus for R&D and incentive programmes to try and drive down costs and improve performance.



There is great potential for PV development in Europe, in terms of both research and the market. Both sectors are mutually dependant and they are linked by the industry. If this link is strong, development in one sector will influence the other: new products can be fed into the

market and field experience provides focus for RTD. In this way innovation is implemented through actual applications (shown schematically in the figure above). Market stimulation activities working in concert with underpinning R&D can provide a powerful driver for development (as shown by the integrated development programmes in Japan). However, industry can only contribute to and support RTD if it has a sufficiently strong market base from which to operate in order to generate the revenues to feed back into RTD. Thus successful industry-focused RTD and successful market development are mutually dependent.

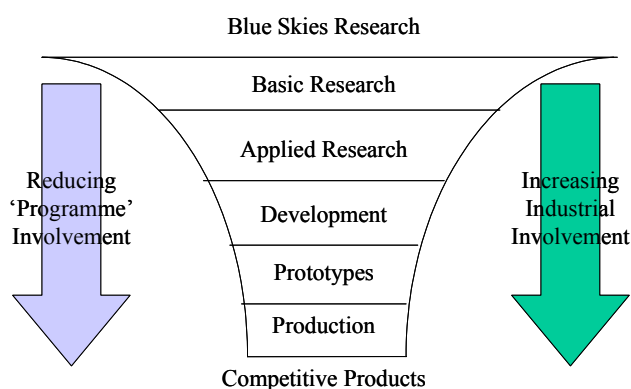
Following on from this it is clear that the market context can also have a significant impact on the scope and emphasis of the related RTD programme. For example, the market drivers for PV in Japan are different from those in the USA and these are different again from Europe. In Japan the cost of energy is higher and they have fewer indigenous energy supplies than Europe and these both provide powerful drivers for PV development and implementation.

Previous experience suggests that in terms of implementing systems ‘on the ground’ an effective combination of support measures is the use of investment subsidy together with a feed-in tariff. In order to be fully effective, the investment subsidy should provide long-term budget commitment. The benefit of using a feed-in tariff is that it draws attention to the performance of the PV systems and so provides an incentive for good quality, effective systems.

Spend and Effectiveness

In broad terms, the combined RTD budgets of all the European programmes are similar to the RTD programme budgets in the USA and Japan. However the distribution of spend between European countries is very uneven, with a few countries accounting for the majority of the spend. Within this exercise, we have found it hard to identify direct links between absolute programme spend and results achieved. Clearly there will be a general likelihood of improved results with increased spend, but within the information we have reviewed, it appears equally important how budgets are spent: how well-focused, how well-sustained, how well-integrated with industry and academia etc.

One of the crucial factors for achieving effective RTD is to have a clear development route, as ideas move through the innovation funnel (see right) from ‘blue skies’ research at the top, right through to competitive products at the conclusion. This requires programmes and projects to pay particular attention to the exploitation route for RTD. Without this there is a danger that valuable RTD results can get ‘stuck’ at some point along the innovation chain without the necessary impetus to move to the next stage. The active involvement of industry in PV RTD programmes can be a very effective way of ensuring that there is a strong interest in pulling ideas through the funnel to a commercial conclusion and so ensuring that in so far as possible, there is a smooth transition of value from RTD Programmes.



Areas of activity focus

There is a wide range of topic areas being researched within Europe. Within PV RTD programmes, there seems to be a particular emphasis on cells and modules with around $\frac{3}{4}$ of programme funding being spent in this area. Within this, about $\frac{1}{3}$ of the effort is spent on crystalline silicon, $\frac{1}{3}$ on thin silicon, around $\frac{1}{4}$ on other thin films with the remainder on organic cells and other materials. Particular strengths within Europe are crystalline silicon development and production, organic cell research and the development of power electronics equipment.

Most aspects of the PV supply chain appear to be covered by activities within Europe. However the balance and linkage between related activities in different national programmes is almost certainly not optimised. There is therefore scope to improve effectiveness and coherence in this area. This is also likely to be impacted as the industry matures and the likelihood is that PV technology manufacturers will get shaken down into relatively fewer global players.

In contrast to the Japanese PV programme, the situation in Europe is characterised by higher public spend and the strong diversity in national programmes, some of which are individually strong. The high degree of fragmentation suggests that there is an opportunity to enhance the collaboration of a large number of public and private institutions and thus improve the effectiveness of projects and programmes.

The high level of achievement reached by the European PV community in academic fields doesn't appear to follow through in an equivalent manner to production. Efforts are necessary to focus these achievements in scientific results towards issues relating to manufacturing, particularly for short-term options (c-Si/thin silicon/CIGS). A European strategy is required to provide a credible alternative to Japan.

The response of Europe on new frontier RTD is already of a high calibre, but the pooling of researchers on mid to long term options for material/devices R&D (organic cells, 3rd PV generation and novel devices) could be beneficial to have higher critical mass and more efficient and productive methods of working.

General

The very diversity we enjoy and celebrate within Europe at a cultural level poses unique challenges in pulling together trans-national RTD activities in a coherent programme. The programmes of the EC and the many formal and informal networks are very helpful in this respect. Nonetheless, one should not necessarily expect that one can replicate the approach of our successful competitors, rather that we should try and adapt the most relevant parts of this approach to our European cultural context.

The reaction of the general public and the consumer to PV is also important. The positive contribution which PV can make to society can be an important factor in mobilising political support.

Summary

In summary, there appear to be two broad areas for improvement of PV RTD programming in Europe.

The first area can be labelled as "**focussing**". It addresses the following points of weakness as compared to Japan and the USA:

- uncoordinated diversity of activities
- lack of continuity
- diffuse aims, objectives and targets
- imbalance between RTD and market incentives
- incomplete 'visibility' of a diverse field of activities
- many small and dispersed research teams

The second area can be labelled "**more involvement with the industry**". It deals with the following points of weakness as compared to the USA and Japan:

- activities do not generally have a strong industrial focus
- too little research is focused on production issues
- links between universities / research centres and industry are too weak
- industry and public RTD programmes have not yet achieved the same level of integration in programme definition as compared to the USA and Japan

This leads to a simple overall conclusion, which confirms the initial rationale for this project: European national PV RTD activities should prepare a roadmap collaboratively with the European industry.



8.2 RECOMMENDATIONS / 'GOOD PRACTICES'

From the foregoing it can be seen that there are some factors, which are seen to be necessary (but not sufficient) to the development of effective European RTD activities. We have grouped what we believe to be some of the key issues under the five broad headings of Policy, Strategy, Objectives, Organisation and Resources and we expand on these below. Adequate implementation of these principles could help to provide a basis for 'good practice' for PV RTD programmes.

Policy

- It is intuitively the case that policy, which is often a key driver for action, is very important in setting the framework for PV RTD and this is reinforced by the findings of this study. National RTD programme managers have seen and experienced at first hand the benefits of working within a supportive policy framework and the constraints on action which can arise without such support. Thus a supportive policy framework is a prerequisite for the successful implementation of a PV RTD programme.
- It has also been the experience of national programme managers that the most effective results are obtained if there is genuine long-term commitment to the policy. Sudden changes in policy are very difficult to accommodate in the real world of programme and project management, can often lead to inefficient use of funds and can send out very unhelpful signals to those considering making private investments in technology development. For a technology such as PV, commitment is required over a time horizon of the order of 10 years.
- Policy aims need to be clearly stated so that actions and plans can be developed to generate the desired results. Quantitative targets may help in achieving this clarity. Qualitative aims need to be expressed unambiguously.
- Policy needs to be inclusive & coherent, that is it needs to cover the context and relevant issues in achieving desired goals and in so far as possible to ensure that actions arising will be complementary. An example might be to ensure that the policies towards R&D and market incentives recognise the linkage between the two and have consistent aims and timescales.

Strategy

- At the agency / operational level, there needs to be the translation of policy into a strategy or plan which fills in the main details and principles of how the programme will be delivered. In so far as possible, this process of translation and the resulting strategy itself need to be transparent and lead on to objectives, organisation & resources as discussed further below. The development of a strategy also provides the opportunity to establish a framework for collaboration within Europe.
- Such a strategy should be subject to periodic review to confirm that it is still based on a sound and relevant rationale and to provide the opportunity for changes in direction and emphasis.

Objectives



- Following on from appropriate policy & strategy, programme objectives can then be set. These should ideally follow the SMART formulation (or similar) discussed earlier.
- Objectives should be clearly stated in such a way to provide a clear focus for actions.
- Objectives need to be agreed and owned by whoever is to be responsible for carrying them out.
- If suitably informed by the broader context, objectives can be set which help to avoid unwanted duplication and which could encourage and facilitate appropriate European collaboration.
- Achievements should be formally monitored and evaluated against objectives and corrective action taken as required.

Organisation

- In order to maximise effectiveness, the organisation of PV RTD programmes needs to take a coordinated, coherent approach, in particular, this means that appropriate links are made to key players, stakeholder groups and other relevant actions. In order to achieve this, good channels of communication are required to enable consultation to be undertaken and an accepted approach to be developed. For PV RTD, key groups to involve include:
 - the PV Industry
 - Utilities
 - Research Institutes
 - Other enabling industries and professions (building, architects)
 - Regulatory bodies (standards & permits)
 - Specialist PV networks
- Another crucial aspect having once involved the stakeholder groups as above is to ensure that they have co-ownership of objectives & plans arising and have a commitment to co-operation in their implementation. The organisational structure and approach needs to facilitate and reinforce this involvement. It is not usually sufficient to simply agree and launch activities – there needs to be an ongoing interaction and proactive review of progress.
- The effective implementation of PV RTD Programmes requires good quality planning & management and efficient administrative procedures. This requires the right skills and an appropriate budget and allowance of time.
- It has already been noted that a dedicated programme for PV RTD can act as a useful badge to increase ‘visibility’ and to indicate priority and weight of support. While it is not essential that PV RTD programmes are completely separate (rather than say a part of a Renewable Energy RTD Programme) it could help presentationally and organisationally if they can be given some individual focus.

Resources

- High quality, effective R&D requires that the appropriate supporting infrastructure is available in terms of the human resources, equipment and facilities. If these are being provided through industrial partners, there is often a pressure on such infrastructure from short term operational issues. In contrast, public laboratories often have the human resources available, but may not have the same quality of equipment and facilities as found in industry. Effective mobilisation of resources may involve integrating what is available from a range of sources.
- The above basic infrastructure and specific individual projects require that sufficient funding is available to undertake the work envisaged. It is prudent to allow a reasonable contingency in the financial planning of a project, which does not invite unnecessary spending but is available to respond to the inevitable changes required in a typical R&D programme. It is furthermore important that the resources are committed for an appropriate timescale.

We have seen examples of resources being diffused by being spread (too) thinly across a number of initiatives. It is important to recognise the need for 'critical mass' within a project or programme and to establish a prioritised and effective focus in order to help achieve this. With limited resources, there will always be a balance to be struck between focussing on fewer, higher priority issues and perhaps losing the overall breadth of a programme.

Appendix 1 – Data Collection Questionnaires

There follows copies of the two questionnaires used to collect data about national PV RTD activities:

1. The original questionnaire (pages 69-80)
2. The supplementary questionnaire (pages 69-80)

PV-EC-NET
**“Network for Co-ordination of European and National Programmes
for Photovoltaic Solar Energy”**

8.2.1 *A project funded by the EC under the 5th Framework Programme*
8.2.2 *Contract No: ENK6-CT2001-80578*

**Questionnaire on National RTD Activities
in the Field of
Photovoltaic Solar Energy**



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May 2002

Introduction

PV-EC-NET brings together the co-ordinating institutions of the national PV RTD activities of the member- and associated states of the European Union. The main goal is to increase the efficiency and coherence of the PV RTD activities at a National and EU level by collecting, analysing and disseminating information about these activities. To achieve this goal, a consortium of 15 partners from 14 European countries has been formed.

The purpose of this questionnaire is to collect in a simple and concise form all the information concerning recent and current PV RTD activities in Europe, e.g. from 1995 to date, as well as in other countries with major roles in the field of PV like the US, Japan, Australia etc. Answers should be clear, informative and as brief as possible. Please notice that the focus is mainly on funding schemes and support for PV Research and Technology Development and Demonstration in both basic and applied research activities. Additionally, market incentives are of interest and can be mentioned.

This questionnaire consists of 5 parts and an Annex. The first part requests contact information of the people and the organisations completing the questionnaire. The second part seeks general information on the country in question and the way PV RTD is organised and funded. The third part concerns individual RTD activities, their nature, how they are implemented, their targets, funding details etc. This part should be filled in multiple times in case there are more than one PV RTD activities per country. The fourth part attempts an assessment of each of the PV RTD activities described in the previous part. Finally, information on other PV support and promotion mechanisms is collected in the fifth part. Annex A consists of a table, where the specific fields of the PV activities and the nature of the work done should be indicated. Some financial information is also requested. Feel free to add your own comments at the end of each part. You can only start typing on shaded areas but you can extend your answers as much as you like. Please use units and symbols according to International Standards and quote prices only in Euros at the rate of the day.

Completed questionnaires should be sent in electronic form to info@pv-ec.net AND azachar@cres.gr. Additional information, if required, can also be sent by e-mail to azachar@cres.gr as well as by fax (+30-(0)10-6603301) or post (c/o Alexander Zachariou, 19th km Marathonos Ave., 19009 Pikermi, GREECE).

1.0 CONTACT INFORMATION

Please give details on the organisation providing the information and a contact person, who could provide additional information if required.

1.1 Responding organisation in this questionnaire

Name:
Address:
Tel. No:
FAX No:
Web Site:

1.2 Contact person

Name:
Department / Division:
Address:
Tel. No:
FAX No:
eMail:

Comments:

2.0 GENERAL INFORMATION

Please fill in the country name and describe how PV RTD activities operate. How programmes are managed, through which governmental or other bodies etc.

2.1 Country

2.2 Organisations funding/coordinating PV RTD activities (e.g. ministries, authorities, other governmental bodies etc.) Describe the way PV RTD is organised and funded in your country. Please give contact persons, role of authority etc.

Comments:

3. RTD ACTIVITY AIMS, SCOPE AND METHODOLOGY

This part concerns individual PV RTD activities. National Programmes, public funded RTD and other means of funding research in photovoltaics. Please provide information for each such activity on a separate copy of this part, including dates, funding, aims, target sectors etc. Also, information on the implementation mechanisms, project assessment and subsequent RTD activities are of interest.

3.1 Name/brief description of the PV RTD activity

--

3.2 This activity is:

RTD Programme <input type="checkbox"/>	Project <input type="checkbox"/>	National <input type="checkbox"/>	Public Funded <input type="checkbox"/>
--	----------------------------------	-----------------------------------	--

3.3 Is this activity linked to EC funding?

YES <input type="checkbox"/>	NO <input type="checkbox"/>	If YES, how?

3.4 RTD activity implementation date and duration

Starting date:	Duration:	[Years]
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3.5 Web addresses for additional information (if available)

http://

3.6 Activity aims

Indicate quantitative and qualitative targets set in the announcement of the activity (e.g. cell/module efficiency, cost per W_p , technology type, materials, installed power etc.).

--

3.7 Target sectors for performing RTD

E.g.: Universities, R&D institutions, industry, SMEs, individuals etc.

--

3.8 Public funding provided

Amount of money available for the programme throughout its duration.

--

3.9 Estimated other contributions

Percentage of funding from EC, private resources or others (please specify funding body).

--

3.10 Action type

In which way is the activity implemented? (E.g., basic research, applied research, development, demonstration actions etc.) – Please tick the appropriate box and comment if necessary.

Basic Research	<input type="checkbox"/>	
Applied Research	<input type="checkbox"/>	
Development	<input type="checkbox"/>	
Demonstration	<input type="checkbox"/>	
Other	<input type="checkbox"/>	Please specify:
Other	<input type="checkbox"/>	Please specify:

3.11 Project assessment method

Means of assessing and checking technical and/or financial progress on the project level, fund allocation, reporting etc. – please tick the appropriate box and comment if necessary.

Cost Statements	<input type="checkbox"/>	
Technical Reports	<input type="checkbox"/>	
Progress Reports	<input type="checkbox"/>	
Technical committee	<input type="checkbox"/>	
Experts	<input type="checkbox"/>	
Other	<input type="checkbox"/>	Please specify:
Other	<input type="checkbox"/>	Please specify:
Additional comments:		

3.12 Project follow-up strategy

What happens when a project within the described activity is completed? Subsequent funding, dissemination of results, Technology Implementation Plan (TIP) etc.

--

Comments:

4. PV RTD ACTIVITY ASSESSMENT

This part examines the success (or failure) of each PV RTD activity, national programme, public funded RTD etc. described in the previous part. Multiple copies should be submitted, each with direct links to the corresponding part 3.

4.1 Implementation assessment mechanism

How is the RTD programme/activity implementation controlled/checked? Is there an evaluation procedure and how does it work?

--

4.2 Actual/expected achievements for completed/running activities

Indicate quantitative and qualitative achievements resulting from the programme (e.g. cell/module efficiency, cost per W_p , technology type, materials, resulting installed power etc.). Please make direct links to Q. 2.4.

--

4.3 Number of projects funded under this activity and total amount of public money awarded (completed activities only)

No of projects:	Total awarded:	% of initial budget
Remarks:		

4.5 PV Programme performance

How would you evaluate the Programme? (Check the appropriate box - 1: poor...5: excellent). Give your personal opinion or feeling on the success of the RTD activity, without necessarily basing your reply on quantitative data.

1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>	4 <input type="checkbox"/>	5 <input type="checkbox"/>
Remarks:				

4.6 Improvements/suggestions

What would you suggest in order to improve the existing/completed PV RTD activity?

--

Comments:

5. OTHER PV SUPPORT MECHANISMS

In this part other mechanisms that are not related directly to PV RTD and are not covered in the previous parts, such as market incentives, laws, promotional activities etc. should be listed and briefly described. Also, existing conditions that may pose as obstacles to the promotion of PV RTD or other activities should be mentioned. In general, the context in which the PV RTD activities described above is sought.

5.1 PV Market Incentives

Indicate National Programmes that provide incentives for PV market development.

5.2 Legislative Support

Indicate briefly existing laws that promote renewable energies and particularly PVs in your country and incentives such as net metering, green electricity tariffs, tax regulations etc.

5.3 Other incentives, promotional activities

Indicate other National/regional public policies promoting scientific and industrial development, including PV.

5.4 Obstructions/barriers for the implementation of PV RTD activities

Describe technical and non-technical issues that impede the promotion and implementation of PV related activities.

Comments:

ANNEX A

Form for collection / presentation of benchmark data

RTD area	Res ¹	Dev ¹	Dem ¹	NTB ¹	Area Spend [euro] ²	Comments / Highlights
sc-Si	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
mc-Si	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Thin film-Si	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
CIS	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
CdTe	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Other thin film	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Nanocrystalline	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Organic cells	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Fundamental materials	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Si Feedstock	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Inverters	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Other BoS	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Concentrating Systems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Building integration	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Architecture and planning tools	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Network integration	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
System design / integration	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
(Inter)national Standards	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Installation quality	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Hybrid systems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Remote, stand-alone systems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Manufacturing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Monitoring	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Performance standards & guarantees	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		

¹ Click box to indicate in which of the following areas the work is being done: Res = Research, Dev = Development, Dem = Demonstration, NTB = 'Non-technical' barriers

² Typical (average) annual programme spend in sector in euros of the day.

PV-EC-NET
Supplementary Data Collection for WP4 (Version 2)

As agreed at Brussels, please will you respond to the attached questions. There are seven questions requiring brief descriptive responses and then three tables asking for budget data and success / problem factors. Please make your responses as descriptive and specific as possible while keeping it concise and brief.

1. How does your national RTD activity interact with industry?
2. How does your national RTD activity interact with the EC?
3. How does your national RTD activity interact with universities?
4. What are the national RTD activity aims?
5. Is there a policy which led to these aims (describe, reference)?
6. What are the biggest success(es) of your PV RTD activitie(s)? (Select and describe a few (maximum of 5) key advances which have occurred as a direct result of the PV RTD activity)
7. Please indicate ways in which (your) RTD activity (effectiveness) could be improved.

Please complete the table below to show the indicative level of annual spend (representative average for the recent past) of RTD funds in euros of the day in the following categories: Please try and complete it in the full detail requested but if this is not possible, as a minimum please complete the totals for the for work area categories (shaded boxes).

Work area (4 group)	Work area (9 group)	Indicative annual spend (euros)			
		Res	Dev	Dem	Total
Cells & modules	crystalline-Si				
	Thin film-Si				
	Other thin film				
	organic cells				
	Other materials				
	Sub-total				
Buildings	BIPV				
Systems	Inverters / BoS /networks				
	Stand-alone				
	Sub-total				
Other	Other				
Total					

Now please fill in critical success / problem factors tables overleaf.

Critical Factors

This section asks you to identify the most important factors which have contributed to the success of RTD activity in your country and also the factors which cause most difficulty in delivering a successful RTD activity in your country.

Please fill in the form below. Select only the five most important factors. For each factor selected, you are invited to summarise HOW and WHY the factor was important (only a few sentences per factor if possible). Please try and use the factors provided but if there is a factor missing please add this in yourself.

Critical success factor	Yes?	How / Why?
Organisational structure of programmes		
Interactions with PV industry		
Interactions with utilities		
Interactions with other stakeholders		
Other networking (national/international)		
Linkage / relevance to market		
Policy background		
RTD planning process		
Clear strategic plan		
Clear aims / objectives		
Continuity of budgets		
Continuity of programme personnel / structure		
Long term commitment to plans		
Continuous evaluation of programme and adaptability to changes		
Critical mass for activity area		
Quality of people & equipment (and other infrastructure) to deliver work		
RTD results dissemination		
'Image' of PV (eg public interest)		
Other (please specify)		
Other (please specify)		
Other (please specify)		

REPEAT the exercise above using the table below but this time to identify the 5 most problematic features which hinder progress on the RTD activity.

Critical problem factor	Yes?	How / Why?
Organisational structure of programmes		
Interactions with PV industry		
Interactions with utilities		
Interactions with other stakeholders		
Other networking (national/international)		
Linkage / relevance to market		
Policy background		
RTD planning process		
Clear strategic plan		
Clear aims / objectives		
Continuity of budgets		
Continuity of programme personnel / structure		
Long term commitment to plans		
Continuous evaluation of programme and adaptability to changes		
Critical mass for activity area		
Quality of people & equipment (and other infrastructure) to deliver work		
RTD results dissemination		
'Image' of PV (eg public interest)		
Other (please specify)		
Other (please specify)		
Other (please specify)		