2. EUROPE 112

2.1 OBJECTIVES, STRATEGIES AND INCENTIVES FROM THE EUROPEAN UNION AND FROM NATIONAL MEMBER STATES 112

2.2 EUROPEAN UNION 113

2.2.1 R&D Programmes 113

2.2.2 APAS 114

2.2.3 Joint Research Centre - JRC Ispra 115

2.2.4 DG XVII Demonstration programmes (THERMIE) 115

2.2.5 ALTENER Programme (Directorate General XVII) 117

2.2.6 VALOREN Programme (Directorate General XVI) 117

2.2.7 PHARE Programme (Directorate General I) 117

2.2.8 International Programmes (Directorate General VIII) 117

2.2.9 Networks 118

2.3 SUPPORT PROGRAMMES OF EU MEMBER COUNTRIES 119

2.3.1 France 119

2.3.2 The German PV programme 119

2.3.2.1 Objectives 119

2.3.2.2 Strategies 120

2.3.2.3 Actions 121

2.3.2.4 Funding and Incentives from BMFT 122

2.3.2.5 Single Federal State support programmes: 123

2.3.3 Spain 123

2.3.4 Greece 124

2.3.4.1 Objectives 124

2.3.4.2 Strategies 124

2.3.5 Italy 126
2.3.5.1 Present energy resources 126
2.3.5.2 Objectives 126
2.3.5.3 Strategies 127
2.3.5.4 Funding and Incentives 128

2.3.6 Netherlands 129
2.3.6.1 Objectives 129
2.3.6.2 Strategies 129
2.3.6.3 Funding and Incentives 130

2.3.7 Austria 131
2.3.7.1 Strategies 131
2.3.7.2 Funding and Incentives 132

2.3.8 Finland 134
2.3.8.1 Existing small-scale stand-alone PV systems 134
2.3.8.2 Market potentials in Finland 134
2.3.8.3 Photovoltaic research projects in Finland 134
2.3.8.4 Strategies 135
2.3.8.5 Incentives and funding 135

2.3.9 Switzerland 136
2.3.9.1 Objectives 136
2.3.9.2 Strategies 136
2.3.9.3 Funding and Incentives 137
2.3.9.4 Federal subsidies for strategic niche markets 137
2.3.9.5 Improvement of basic legal conditions by the federal government in the energy utilisation resolution (ENB) 137

2.4 OVERVIEW OF THE EUROPEAN PV INDUSTRY 139

2.4.1 The European PV Manufacturers 143

2.5 EUROPEAN MARKET OVERVIEW FOR MAIN APPLICATION SEGMENTS 145

2.5.1 Large and medium size PV power plants 145
2.5.1.1 Installed Capacities 1980-1994 145

2.5.2 Grid-connected small-scale applications 150

2.5.2.1 Capacity installed 1980-1994 150

2.5.2.2 Grid-connected small-scale applications (rooftops): today's European demand potential 152

2.5.2.3 Capacities installed in Europe since 1991 152

2.5.2.4 Grid-connected diffused applications (rooftops) European market forecast for year 2010 158

Table 2.1 - Summary of actions of European Union and of member countries addressing the PV sector 112

Table 2.2 - Total EC contribution for PV until 1993, technology development and applications (in MECU) 113

Table 2.3 - Summary of total R&D programme and expenditures on PV technology 114

Table 2.4 - List of THERMIE PV projects until 1992 115

Table 2.5 - Main projects carried out in the THERMIE frame 116

Table 2.6 - Examples of demonstration and pilot projects funded in Germany 121

Table 2.7 - BMFT research funding for renewable energy sources and for efficient use of energy 122

Table 2.8 - Areas of BMFT Funding (percent of total table 2.7.) 122

Table 2.9 - Expected Contribution Share of PV Power 124

Table 2.10 - Market development stimulation 130

Table 2.11 - Austrian Photovoltaic Rooftop Programme 132

Table 2.12 - Strategic actions and actors to improve target of Energy 2000 Programme in Switzerland 137

Table 2.13 - Number of European PV manufacturers per technology 139

Table 2.14 - Trends of shipments, growth and market shares for the European PV Industry 141

Table 2.15 - Overview of European Manufacturing Industry 143

Table 2.16 - Estimated market shares of major European PV producers 144

Table 2.17 - Large-medium size PV power plants: capacities started-up per year in Europe (1982-1994)..... 145

Table 2.18 - List of main Large-Medium size PV power plants installed in Europe (1982-1994) 146

Table 2.19 - Capacity of large-medium size PV power plants installed in Europe as share of same type total world capacity..... 148

Table 2.20 - Large-medium size PV power plants: cumulative installed capacity in Europe (1982-1994)..... 148

Table 2.21 - Grid-connected small-scale PV applications (rooftops) in Europe (1989-1994) 150

Table 2.22 - Capacity of grid-connected small-scale PV applications (rooftops) installed in Europe as share of same type total world capacity 151

Table 2.23 - Estimated net solar rooftop surfaces available in Europe (1992) 153

Table 2.24 - Estimated available net solar rooftop surfaces per capita in 1992 and 1990 154

Table 2.25 - Installable PV Rooftop Capacity in Europe year 1990 155

Table 2.26 - Today's potential PV Rooftop share as compared to Final Electricity Consumption..... 156

Table 2.27 - Forecast for year 2010 of available net solar rooftops in Europe 158

Table 2.28 - Forecast for year 2010 of installable PV rooftop Capacities in Europe 159

Table 2.29 - Forecast for year 2010 of potential PV Rooftop share in Europe as compared to Final Electricity Consumption..... 160

Figure 2.1 - Distribution of number of European PV manufacturers per technology (1994) 140

Figure 2.2 - Distribution of production capacity of European PV manufacturers per technology (1994) 140

Figure 2.3 - World market share distribution among European PV manufacturers per technology (1994) 141

Figure 2.4 - Estimated world market shares of major European PV suppliers 144

Figure 2.5 - Large-Medium size PV power plant capacities started-up per year in Europe in comparison with same capacity world-wide (1982-1994) 145

Figure 2.6 - Large-Medium size PV power plant cumulative capacity installed in Europe in comparison with same type total world capacity (1982-1994) 149

Figure 2.7 - Grid-connected small-scale PV applications (rooftops) capacity started-up per year in Europe, in comparison with same type total world capacity (1989-1994) 150

Figure 2.8 - Grid-connected small-scale PV applications (rooftops): cumulative capacity installed in Europe in comparison with same type total world capacity (1982-1994) 151

Figure 2.9 - Comparison between PV rooftop potential, final electricity consumption and hydropower share in Europe (1990) 157

Figure 2.10 - Comparison between PV rooftop potential energy contribution, final electricity consumption and hydropower share in Europe (forecast for year 2010) 161

1.

2. EUROPE

2.1 OBJECTIVES, STRATEGIES AND INCENTIVES FROM THE EUROPEAN UNION AND FROM NATIONAL MEMBER STATES

The following table 2.1 provides an overview over support actions addressing the PV sector implemented by the European Union as well as by member countries.

Table 2.1 - Summary of actions of European Union and of member countries addressing the PV sector

Country	*Organisation*	*Planning and Financing Tool*	*Large-medium PV power plant*	*Grid connected diffused PV*	*PV stand alone systems*	*R&D million ECU*	*TOTAL kWp*	*Reference Year*
			kWp					
	European Union	JOULE I				16,0		1992
		JOULE II				15,0		1994
		THERMIE	1.360		1.740		3.100	1992
			779	251	70		1.100	1994
		DG VIII			1.300		1.300	1993
		ALTENER					500.000	2010
		VALOREN						
		EUREKA					1.000	1994
France	AMFE							
Germany	BMFT	1000 Roofs PV Programme		5.625			5.625	1995
		ELDORADO Programme			500		500	1992
Greece	CRES							
Italy	ENEL	PEN					25.000	1995
Netherlands	NOVEM	Elektriciteit Plan			1.500		1.500	1994
				1.300			1.300	1996
				9.100			9.100	2000
				240.000			240.000	2010
Finland	NEMO					3,5		
Switzterland				2.000			2.000	1991
				50.000			50.000	2000
Spain		PAEE 91					15.215	2000
Portugal		PEN						
TOTAL EUROPE			**2.139**	**308.276**	**5.110**	**34,5**	**856.740**	

2.2 EUROPEAN UNION

Since 1975 the European Commission has been actively pursuing PV technology development and utilisation. The PV R&D activities were mainly implemented by Directorate General (DG) XII, while demonstration projects were carried on by DG XVII (THERMIE after 1990). Also international development programmes have been carried out by DG XII and DG XVII in cooperation with DG VIII.

The Commission provides direct financial support on a cost-sharing basis: for R&D projects up to 50% and for demonstration project (THERMIE) up to 35%. The amounts of EC contribution on PV technology and application until 1993 are estimated as follows in table 2.2:

Table 2.2 - Total EC contribution for PV until 1993, technology development and applications (in MECU)

Directorate General	*Amount*
DG XII	62,30
DG XVII	32,00
DG VIII	32,00
Total	**126,30**

2.2.1 R&D Programmes

Directorate General XII has funded the following R&D-programmes for PV technology:

- *JOULE I & II Programmes*:

  JOULE stands for "Joint Opportunities for Unconventional or Long term Energy supply" and has the specific objective to guarantee the supply of energy and to improve the quality of life, taking into account the energy-environment interactions and to stimulate the innovation in the field of energy technologies. JOULE I was operational from 1990 to 1992, while JOULE II has been completed in 1994, Both programmes have funded a consistent number of R&D projects for a total EC contribution of respectively 16,6 million ECU and 15,4 million ECU.

  For PV, the programme covered:

  * <u>PV device (cell) technology developments</u>

    The cell and material oriented part covered a broad range of subjects such as the improvement of classical X-Si solar cells, the investigation of the potentials of new materials, as well as the development of promising thin film single and multi-junction solar cells.

  * <u>PV system technology developments</u>

    Pilot plant development, follow-up and monitoring, experimentation, concerted actions, system applications and technology development projects were supported under this

programme section. "Concerted actions on PV systems technology" have provided support and accompanying actions to the pilot PV system projects. These concerted action project have provided horizontal support and pooling of experiences and expertise throughout Europe, and served to avoid the duplication of technical work by merging all European scientific results. Furthermore, advances in PV system technology, standardisation of performance terms, optimised design guidelines have resulted from these concerted actions.

Table 2.3 - Summary of total R&D programme and expenditures on PV technology

Programme	*Period*	*Activities*	*EC contribution (MECU)*
JOULE I	1990-1992	1. Follow on pilot plants experimentation	5,5
		concerted actions new applications technology development	
		2. PV cells-materials	11,0
JOULE II	1992-1994	1 System application and technology development	8,5
		2. PV cells and materials	7,0
		Total EC Contribution	**32,0**

2.2.2 APAS

The European Commission has recent]y launched the APAS programme as a preparatory action future implementation programmes. The main objectives of this programme were to develop methodologies for the integration of renewable energies into society. It also aimed towards a more realistic appraisal of the short, medium and long term potentials of renewable energies, as well as to highlight new opportunities for economic stimulation and regional developments. The program furthermore recognised the need for direct involvement of the local energy operators i.e. the European industry, the local utilities and the regional authorities. The project areas related to PV technology covered:

- Interaction of renewable energies in regions.
- Water desalination by renewable energies for the Mediterranean Countries,
- Urban planning rnaximising the use of renewable energies
- PV electricity generation in cooperation between Europe and the developing Countries.

The net budget of this action was about 25 million ECU, and projects have starting at the beginning of l995.

2.2.3 Joint Research Centre - JRC Ispra

The Joint Research Centre of the Commission, located in Ispra, Italy, plays a key role in testing of PV modules, the development PV technology standards and in the monitoring of PV system operation. Relevant results and outcomes have already been extensively presented in the chapter on standards and regulations.

2.2.4 DG XVII Demonstration programmes (THERMIE)

Next to the R&D programmes, a consistent number of PV projects has been funded by the Demonstration programmes of DG XVII and specifically THERMIE. The specific objectives of these demonstration programmes may be summarised as follows:

To prove the technical and economical viability of new technologies, they have to be applied at a sufficiently large scale and under real operating conditions in demonstration projects.

Furthermore spreading of technological know-how gained out of such projects was considered fundamental to allow the introduction of innovating technologies in the market. Specifically projects aiming a the market penetration of new technologies are being supported by the THERMIE programme.

For PV, emphasis is put on applications with acceptable costs such as telecommunications, remote pumping, remote buildings and energy supply for small villages.

In more recent years, also DG XVII has started to support grid connected PV systems. Since 1991, 60% of the PV projects accepted under the THERMIE programme have been grid connected systems. Projects ranged from large utility owned power plants such as the I MWp power plant at Toledo in Spain, to building integrated PV systems located throughout Europe.

The amount of monitoring data available from large grid connected THERMIE projects is limited since such projects have only recently been funded under the THERMIE programme. Up to 1992 the total EC contribution for demonstration PV projects has been roughly 32 million ECU. A summary list of projects is given in table 2.4.

Table 2.4 -List of THERMIE PV projects until 1992

Category	*Number of projects (through 1992)*	*Installed PV power (kWp)*
PV power stations	6	1.360
Houses and villages	41	708
Non-domestic buildings	11	148
Transport	2	

continued

Category	*Number of projects (through 1992)*	*Installed PV power (kWp)*
Farms and Agricultural	7	185
Pumping and water treatment	8	152
Lighthouses and buoys	6	81
Nature reserves	10	147
Telecommunications	7	137
Warning Signs & Environmental Sensors	12	182
TOTAL	**50**	**2.918**
Total EC Contribution		*32 MECU*

In 1994, 125 projects with an installed capacity of over 4,2 MWp had been undertaken. All the projects are monitored either by means of analytical monitoring, or the simpler, global monitoring, and collected data are sent regularly to JRC Ispra for analysis.

Table 2.5 - Main projects carried out in the THERMIE frame

Name	***Location***	***Application***	***kWp***
Grid connected system			
Mahon	Majorca	Grid connected	42
Magadino rail	Swiss	Grid connected	103
N 13-Chur	Swiss	Grid connected	106
Hybrid systems			
Gros Bessillon	France	Telecom	3,2
Mt Sistron	France	Telecom	7,6
Rappenecker	Germany	Isolated house	3,8
Oberling	Germany	Youth centre	1,5
Rotwandhaus	Germany	Alpin refuge	5,1
Haus Langer	Germany	Isolated house	1,8
PV only systems			
Puerto Penas	Spain	Rural elec	13.2
Lithari	Greece	Light house	4,7
Palmaiola	Greece	Light house	4,7
Siena Railway	Italy	Rail crossing	3,9
Los Arcos	Spain	Rural electrification	11,3
Rambla Blanco	Spain	Rural electrification	9,2

2.2.5 ALTENER Programme (Directorate General XVII)

The ALTENER Programme running from 1993 until 1997 aims to favour the development and penetration of renewable energies in the European Union. Goals are to increase the contribution of renewable energies in the European Union up to 8% of the total electricity demand, and to triple the electric energy production by renewables (large hydro electric power excluded) within year 2005.

2.2.6 VALOREN Programme (Directorate General XVI)

The VALOREN programme, running from 1988 to 1992, was dedicated to the improvement of energy supplies to less favoured regions in Europe. A substantial amount of PV-systems, mainly stand-alone and wind-hybrid systems for remote rural and house electrification have been installed under this program.

2.2.7 PHARE Programme (Directorate General I)

The PHARE programme has been set up to assist Eastern and Middle Europe with the necessary economic reforms. In this program, projects for technical assistance can be financed. Typical projects addressing the PV sector have included a marketing study and a training program on photovoltaic energy in Poland.

2.2.8 International Programmes (Directorate General VIII)

DG VIII implements development programme addressing the international community outside the European Union. Their activities are oriented primarily towards the developing countries through various cooperative agreements with the countries of the Lomé Convention and others. The present Lomé III Convention includes most African countries as well as Caribbean and Pacific Countries (ACP Countries). Funding for this 5-year programme (1986 - 1990) was provided by the European Development Fund (EDF), the European Investment Bank, etc.

Objectives of the development aid programme of the Commission include self-sufficiency in food supplies, better living conditions and the diversification and increase of productivity. In this frame, the introduction of PV provides a useful contribution, since allowing to catalyse responsible economic growth and development, adapted to and appropriate for local needs and culture. The single largest programme of its kind was started in 1989 to install PV-pumping and small PV-sources for community use in the Sahel region of Africa. Nearly 1.400 pumps powered by 600 W to 3,5 kW PV systems totalling a PV capacity of about 1.3 MWp have been installed and completed within the end of 1993.

The Commission contributed 32 million ECU for this programme which included the development of an infrastructure to support long-term operation, technical assistance and training of local users.

2.2.9 Networks

Several networks have been initiated under EU sponsorship as follows:

- The EUREC Agency (European Renewable Energy Centres Agency) is an economic interest group of 30 representatives of European research centres working in the field of renewable energies. The goal of this interest group is to facilitate and increase economic activities and the implementation of the R&D efforts in the field of renewable energies. Its strategy is based on joint projects in research, development and implementation. Increased exchange of information and personal in the frame of joint projects is considered an important tool. EUREC Agency is in the process of writing position papers on PV solar thermal, wind energy and biomass. These position papers will help the European Commission in implementing its R&D programmes.
- CERE (Communities of Europe for Renewable Energy) addresses specifically the needs of Municipalities throughout the Union, and favours developments and information exchange among these concerning renewable energy applications;
- EURE (European Utilities for Renewable Energy) is focused on the involvement of European utilities into renewable energies. The group is presently developing strategies aiming towards cooperation with utilities outside the European Union, both in developing countries and in Eastern Europe.
- READ (Renewable Energy in Architecture and Design) aims to create cooperation and information exchange among architects concerning urban planning issues and building integration of renewable energies.

The European Commission considers PV as a valuable contribution to electricity production in the future. It therefore supports R&D materials on cells and on PV systems, as well as demonstration. R&D is considered a collaborative effort between academic institutions and industry.

2.3 SUPPORT PROGRAMMES OF EU MEMBER COUNTRIES

2.3.1 France

The 5 year programme addressing photovoltaic technology of the **Agence de l'Environment et de la Maitrise de l'Energie (ADEME)** is aimed primarily to extend the penetration of the bulk-power PV market, and specifically:

- to lower the manufacturing cost and to improve conversion efficiency of PV cells and modules as regards the two main industrialised technologies: crystalline silicon and thin-film amorphous silicon. Basic research on alternative materials is also carried out with longer-term views.
- to develop the testing and technical qualification of photovoltaic power generating systems and specific low consumption loads (pumps, refrigerators, lights, household appliances) and to promote new standards.
- to demonstrate and evaluate the quality of services provided by photovoltaic systems in a given economic and sociological situation, through demonstration and dissemination programmes.

2.3.2 The German PV programme

2.3.2.1 Objectives

The goals of the German programme are twofold[1]:

- cost reduction for solar PV cells and modules by reduction of materials and processing costs and by improving module efficiencies;
- Improvement of efficiency and reliability of systems by the development of better components and by long-term field tests.

The German Federal Government has announced its intention of reducing the CO_2 emission by 25% until 2005.

This goal can be reached only by strict application of rational use of energy techniques and by saving energy strictly. Within such very short time frame, photovoltaic cannot be expected to contribute substantially in avoiding CO_2 production.

However on the long run PV is considered by German authorities to be a viable option for CO_2 free large-scale bulk power production.

Public funding of R&D in renewable energy technology in general and on Photovoltaics in particular will therefor remain substantial for the next future in Germany.

2.3.2.2 Strategies

Within the framework of EUREKA the umbrella project EUROVOLTAIC (started in 1992) aims to generate development and demonstration projects in the field of Photovoltaics, with the purpose to develop high technology products and systems contributing to increase the overall energy output and to enhance the competitiveness of European industries.

German Utilities are more and more getting involved in renewable energies, not only in terms of demonstration and pilot projects, but also in terms of shareholderships in the photovoltaic industry.

The BMFT (Bundesministerium fuer Forschung und Technologie - Federal Ministry for Research and Technology) is supporting a large variety of activities, ranging from basic research in new materials to final field tests of complete PV systems.

Projects are carried out by industries, research institutes and universities, while a research association has been formed by several research institutes in 1990, playing a particularly important part, especially in basic research on Photovoltaics.

- *Crystalline silicon*

  Actions aim to develop a technology for large scale production of high efficient solar PV cells and modules. Crystalline silicon technology is believed to represent the only mature technologies for terrestrial applications in the medium and high power range, and plays therefor an important part in BMFT funded projects.

- *Thin film cells*

  Since considered less mature, these technologies are still in the status of basic research: amorphous silicon and compound semiconductors (CIS, CGS, organic cells). A remarkable result of these activities has been the production of small area CIS cells with an efficiency of 14,8% in the laboratory.

- *Systems development and demonstration*

  Multiple areas are covered by systems development and demonstration projects, specifically:

  * small appliances
  * autonomous systems
  * grid-connected houses
  * large plants
  * systems for southern countries

2.3.2.3 Actions

Some of the larger PV system projects funded from Germany are listed in table 2.6.

Table 2.6 - Examples of demonstration and pilot projects funded in Germany

Type of project	*Company/site*	*Size*	
Hybrid System PV/Wind	Telefunken Systemtechnik/ Pellworm	PV wind	600 kWp 400 kW
Stand alone PV	Siemens Solar/ Flanitzzhütte/Bavaria		40 kWp
Grid connected	Telefunken Systemtechnik/ Noise Barrier at Motorway		32 kWp
PV and Wind applications	ELDORADO Programme	PV wind	500 kWp 20 MW
Solar filling station	Telefunken Systemtechnik/ RÜGEN		20 kWp
Grid connected	RWE/Toledo Spain		1.000 kWp

- *Thousand PV Roof Programme*

  The BMFT and the government of the Federal States jointly started a *Thousand PV Roof Programme* in September 1990. Originally the programme had been limited to the area of the old federal states, but in January 1992 the programme was extended also to the new federal states. The installation of 2.250 small (1-5 kWp) grid-connected PV-systems on the roofs of single and two family houses was supported by this programme. At present this programme is considered the backbone of PV demonstration activities in Germany.

  Besides BMFT and the State Governments, also utilities, the German Association of Utilities (VDEW), the Technische Überwachungsveirein (TÜV) Rheinland, the ISET Institute in Kassel and others are involved in elaborating results and carrying out the programme.

  Furthermore, according to the Federal Law of January 1991, Utilities in Germany are obliged to buy electric energy from renewable sources and to pay for solar and wind generated electricity at least 90% of their average selling price, which is at the moment roughly 17 Pfg/kWh (0,09 ECU/kWh).

- *The ELDORADO Programme*

  This programme aims towards the implementation of renewable energy projects in developing countries, and to test plants under real climatic conditions. Projects must be located in countries with southern climatic condition, and specifically in countries having signed scientific and technical co-operation agreements with BMFT. During the next 5 years, roughly 120 photovoltaic pumping systems for drinking water supply and irrigation, totalling a peak capacity of 500 kWp shall be installed under this programme. The wind part of the programme foresees to install a total wind-power capacity of 20 MW.

- *Environmental Investigations of PV technology*

  The environmental impact of the entire lifecycle of PV technology is being investigated, beginning with the manufacturing process up to the disposal of components after the end of their lifetime, and including also technologies for the recycling PV modules.

  Assessments are performed also and specifically concerning some thin film cell types like CdTe and CIS, and a related study of these subjects is expected to influence future decision making for German funding of PV technology.

2.3.2.4 Funding and Incentives from BMFT

In Germany the most important source of funding for the PV sector is the **Federal Ministry for Research and Technology** (BMFT). Funds spent by BMFT for renewable energies have steadily increased from 1986 to 1991.

The moderate decrease after 1992 is due to the general restricted budget situation, which resulted from the unification of the two parts of Germany (see table 2.7).

Table 2.7 - BMFT research funding for renewable energy sources and for efficient use of energy

Year	*BMFT research funding*		
	Total Programme	*of which Photovoltaics*	
	million US$	*million US$*	*%*
1986	341,9	125,5	36,7%
1987	305,8	108,0	35,3%
1988	313,8	124,5	39,7%
1989	442,2	155,1	35,1%
1990	428,2	153,5	35,8%
1991	513,9	172,9	33,6%
1992	494,2	153,4	31,0%
1993	494,2	182,6	36,9%
1994	461,0	142,2	30,8%
TOTAL	**3.795,2**	**1.317,7**	**34,7%**

The areas of BMFT funding are shown in the following table 2.8

Table 2.8 - Areas of BMFT Funding (percent of total table 2.7.)

Areas	*1990*	*1991*	*1992*	*1993*	*1994*

Crystalline silicon materials development	14,9	10,9	13,4		
Crystalline silicon cell and module development	26,7	20,5	19,0	54,5	100,0
Thin film technologies	39,6	41,3	30,0		
System development	10,2	9,1	6,0	8,0	
Demonstration projects	5,9	15,7	29,1	35,2	
General studies	2,7	2,5	2,5	2,3	

2.3.2.5 Single Federal State support programmes:

Also the single Federal States in Germany provide financing support, and have their own funding schemes for renewable energies. The main objectives of these single state programmes are to support the application of rational use of energy and renewable energy technologies.

2.3.3 Spain

The R&D activities of the Spanish national program focus primarily on the potentials for cost reduction in thin-film technologies of which the amorphous silicon research is considered the uppermost. This work is complemented by work in the quality control of components including modules, batteries, inverters and regulators.

There has been significant support of PV technology by local autonomous governments, with subsidised end-users and financed several pilot PV projects for field testing and demonstration. A significant number of small-scale stand-alone systems have thereby been installed in Spain for the electrification of remote and isolated houses in rural areas.

Furthermore the recent installation of the 1 MWp PV power plant near Toledo demonstrates the strong interest of Spanish utilities towards bulk power application of PV technology.

2.3.4 Greece

In March 1994 CRES (National Centre for Renewable Energy Sources) proposed to the Ministry of Industry, Energy and Technology the new national programme for the introduction of Renewable Energy Sources covering the period until 2005. The proposal was then to be evaluated by the national Energy Council in order to become the official programme of the country.

CRES was created in 1988 as a public organisation under the auspices of the Ministry of Industry, Energy and Technology, but it operates with financial and administrative independence.

2.3.4.1 Objectives

The major objectives of the Greek National Programme are:

- national energy independence from imports;
- environmental protection and avoidance of negative impacts from fossil fuels;
- preparation of actions in order to face in time the problems expected to arise from the depletion of national or imported fossil fuels resources

The national renewable energy programme covers wind-power, biomass, geothermal energy, active thermal solar systems, passive solar, photovoltaic technology and small hydropower.

2.3.4.2 Strategies

By year 2005 renewable energies are estimated to provide for a total energy contribution to the Greek energy balance from a realistic 8 % to an optimistic 13 %, considering an estimated national energy demand growth rate of 4%.

If a lower demand growth rate of only 3 % is assumed, the corresponding realistic contribution share increases to 9 % and the optimistic one to 15 %.

The following table 2.9 provides an overview over expected contribution shares of PV power, according to National Planning, for the years 2000 and 2005, considering an annual growth of 3 % of total final consumption.

Table 2.9 - Expected Contribution Share of PV Power

Year	*PV share in National RES Plan [1]*
1993	2,6%
2000	6,0%
2005	8,0%

[1] Total contribution of RES is estimated for year 2005 in 9% of the total consumption

If these goals will be achieved, the resulting beneficiary effects on employment are expected to be consistent, since new jobs will be required for the development of new products and technologies and for the necessary installation and maintenance work.

These new employment opportunities are considered to be remunerative and requiring a certain degree of technical expertise.

Furthermore, specifically as regards installation, maintenance and operating, these new employment opportunities will be diffused over the territory and favour economic and social development of rural and island areas.

2.3.5 Italy

2.3.5.1 Present energy resources

First of all, it must be noted that, at least in absolute terms, Italy is today the country with the largest installed PV capacity within the European Union (total installed capacity in Italy: 11,6 MWp).

Nevertheless, Italy's energy supply structure is characterised by an abnormally high dependence on energy imports of more than 80% of primary energy sources. Particularly oil imports constitute at present about 55% of total primary energy resources.

Besides a 10% hydropower share and 14% imports, electricity generation relies for the remaining majority part on imported oil and gas fired thermal power plants. Following a referendum in 1987 (after the Chernobyl disaster), Italy has shut down all operating nuclear power plants and stopped the construction of new nuclear facilities.

Moreover, the construction of coal fired power stations is also becoming increasingly difficult, due to environmental concerns of population and local authorities. In this frame, the development of renewable energy sources acquires a strategic importance for the country.

The Italian energy program on renewables assigns highest priority to PV technology, since solar irradiation is very favourable in Italy, while hydropower is considered near to saturation (practically all economically exploitable hydropower resources are already exploited) and windpower resources appear to be scarce.

The guidelines for the Italian PV program have been defined by the National Energy Plan (NEP) approved by the Italian Parliament in 1990.

2.3.5.2 Objectives

The NEP's main strategic objectives aim, on one hand, towards diversification of energy sources and supplier countries and, on the other hand, towards full exploitation of national energy resources, and specifically renewable energies. Accordingly the Italian NEP pursues the development of Photovoltaics as a national source for large scale electrical power generation. Envisaged objectives comprise:

- Development of new PV materials;
- Development of industrial manufacturing technologies for mass production of crystalline Silicon PV modules;
- Construction and operation of pilot plants for research and demonstration purposes;
- The in 1990 approved NEP set a goal **for year 1995 of 25 MWp of installed PV peak power capacity**. We know today that more than half of this goal has actually been reached, and Italy has thereby become definitely the country having the largest installed PV capacity within the European Union.

2.3.5.3 Strategies

ENEA, the Italian National Agency for New Technology, Energy and the Environment, and ENEL, the National Electricity Utility, are identified by the NEP as the main implementing authorities. ENEA was intended to play a leading role more in research and development activities, while ENEL was intended to operate primarily in application and demonstration.

ENEA research activities cover the following main areas:

- *PV device technology (cells/modules)*

  Research on crystalline silicon is carried out at the photovoltaic laboratories at Casaccia near Rome. Activities cover the whole fabrication cycle from material deposition up to module fabrication. Instead experimental activities on thin films, and specifically on amorphous silicon and copper indium diselenide, are carried out at CRIF laboratories in Portici near Naples. Efficiencies as high as 10% have been attained on 1 cm^2 amorphous silicon single junction p-i-n cells, while efficiencies of 4-5% have been achieved on large area (100 cm^2) monolithic integrated modules. The activities on copper indium diselenide (CIS) have been started very recently.

- *PV systems technology*

  The program on PV components and systems is carried out at the DELPHOS experimental facility at Monte Aquilone near Foggia (southern Italy), including experimental activities, testing and performance analysis of PV modules, DC/AC inverters as well as small and medium size systems, both stand alone and grid connected. Particular attention is paid to grid interface, operation and maintenance problems of grid connected PV plants. Small size grid connected systems, suitable for distributed generation (e.g. rooftops) are investigated by means of a dedicated testing station composed of several 2,5 kW systems employing different module and BOS technologies. Finally, innovative array architectures, based on low concentration and passive tracking are studied by means of small (1 kW) prototype systems.

  Following initial efforts dedicated mainly to stand alone systems suitable for the commercial market, ENEA activities are now focusing more on power generation by means of small and medium size grid connected plants.

ENEL, the national Italian utility, has carried out a pluri-annual comprehensive program for technical development, demonstration and application of PV systems, which has been implemented by the R&D department in co-operation with CREL and the distribution Department[2]. The main actions of the program have been:

- Identification and implementation of today already cost-effective PV applications namely electrification of isolated and remote utility customers. Today, if a remote customer applies for connection to the grid, it is common practice for ENEL to check first, whether it may be more convenient to serve the customer by means of a stand-alone PV system, rather than by extending the grid.
- Remote community electrification by means of PV power (e.g. on small islands) either in stand-alone configuration or in parallel to the local dieselpowered grid (PV acts in such case

as fuel saver). This application may be cost effective under certain conditions particularly unfavourable to diesel-power.

- Grid-connected PV rooftops for distributed generation.
- Design, construction and field testing of large-scale and scaleable PV power plants suitable for multimegawatt power generation[3]. The **3.3 MWp PV power plant at Serre**[4] (started-up in July 1994) near Salerno (Naples) is today the largest PV plant in Europe and represents therefor a remarkable demonstration not only for the technical potentials of PV technology but also for the interest and willingness of ENEL to play a key-role in the European PV scenario.

2.3.5.4 Funding and Incentives

In compliance with the lines of action prescribed by the NEP, in 1991 the Italian Parliament promulgated two specific laws (law n° 9 and Law n° 10) which, among other norms concerning energy conservation and renewable energies, promote the diffusion of PV plants by providing for government financial support to investors, who intend to build and operate a PV plant. Specifically law n° 10 (January 1991) allows to provide up to 80% public financing contribution for the construction of PV plants for residential, industrial and agricultural applications.

In addition, Laws n° 9 and n° 10 have introduced the obligation for ENEL to purchase any excess power produced by renewable energy self-producers. Furthermore the relevant purchase price is defined by a Interministerial Committee for Pricing (CIP = Comitati Interministeriale Prissy) at a level which is very enticing for self producers. In case of PV power, CIP defined pricing (CIP act n° 6 - 1992) is set at a price of 231 Lit/kWh (0,12 ECU/kWh) (unfortunately, however, such advantageous kWh price can not be accumulated with the 80% investment contribution foreseen under law 10).

In spite of the difficulties to obtain in practice the governmental investment contributions (unfortunately, the Italian parliament did not allocate the required budget amount for law No. 10 during latest years), the other possibilities to obtain public financing in the frame of national and/or EU regional development programs as well as other specific programmes for the diffusion of renewables (THERMIE) and for the exploitation of local resources (VALOREN project), during last years there has been a consistent and increasing number of PV projects and installations.

2.3.6 Netherlands

2.3.6.1 Objectives

In year 2010 the Netherlands plans to save yearly 560 GWh of fossil fuel by means of PV technology. Although this figure corresponds to less than 1% of the present electricity demand in the Netherlands, it will require the installation of more than 250 MWp of solar PV capacity. The goal of the Program is to create conditions to let photovoltaic solar energy play an important role in the Dutch energy supply of the 21st century. In 1994 half of the budget is devoted to solar cell R&D and the other half is going to PV system R&D and pilot projects. In 1995 a new framework programme will start in which the preparation for the market introduction of grid-connected systems via large scale pilot projects with specific learning goals will play a prominent role.

2.3.6.2 Strategies

PV is going to play an important role in the Netherlands energy supply in the 21st century, and accordingly both PV and other renewable energy sources scenarios are being studied by the ECN, to identify the most important conditions to work on, in order to reach the envisaged goal. NOVEM believes that both technology R&D as well as market development are equally necessary to minimise PV-costs and to maximise efficiencies and system performances. For this purpose, R&D is performed on solar cells but also specifically on PV systems by putting priority on the following issues:

- Integration in building constructions
- inverter R&D

The second important condition is believed to be market development. At present the market for PV systems is dominated by the demand for stand-alone PV systems. Accordingly NOVEM supports the development of relevant stand-alone applications both in the Netherlands and in developing countries. Besides, market support of both close to cost-effective stand-alone applications as well as grid-connected systems is provided by means of an investment subsidy of about 3 ECU/Wp. Furthermore the application of PV on buildings is believed to be the most promising solution for future widespread PV applications in the Netherlands. Other possibilities have been identified in centralised large-scale PV plants in the Netherlands as well as abroad (in the Sahara or in Kazakhstan).

The PV Programme of the Netherlands assigns highest priority to the development of decentralised grid-connected and roof-integrated PV-systems as applied to individual private houses. The program covers completely this development direction and contains already many realised projects as well as projects under preparation. The reasons for this choice may be summarised as follows:

- A small country like the Netherlands cannot follow all possible development directions for a new technology, but has to concentrate resources on identified priorities. Only if this is the case, complete and significant results can be expected to be achieved.

- Since the Netherlands present a high population density of high urbanisation level, PV rooftop applications allow to make use of the existing consistent building park, as well as to save on the available scarce ground surface. Also PV gains a higher value in economic terms if integrated into buildings in a functionally and aesthetically attractive way. Also up-stream electricity costs are thereby saved by the utility since the electricity is produced close to the user.
- According to the views of PV developer in the Netherlands, the best road to market penetration of PV is to create markets for stand-alone systems, as well as to penetrate the electricity production market via decentralised small-scale grid-connected systems. Only if PV costs become competitive with the prices of bulk electricity, it makes sense to go over to centralised large-scale PV applications.

2.3.6.3 Funding and Incentives

Since 1978 the Netherlands have a national R&D programme on solar energy. Until 1985 the budget allocations for PV were very small, aimed primarily to investigate only the potentials of the technology. From 1986 to 1990 the budget of the PV programme was increased to 1,4 MECU annually; which was sufficient to observe and to make a modest contribution to international developments.

Since 1990 the total financial effort of Dutch authorities to stimulate and develop PV has been raised to about 6 MECU yearly, subdivided as follows:

- Demonstration 0,9 MECU
- Market support 1,4 MECU
- R&D 3,7 MECU

To stimulate the market for photovoltaic systems in the Netherlands an investment subsidy of 4,5 ECU/Wp is given for stand-alone PV systems. The effects of this subsidy are shown in the following table 2.10.

Table 2.10 - Market development stimulation

Year	*Total Installed power in kWp*
1988	175
1989	349
1990	758
1991	1.007
1992	1.310
1993	1.500

Since the totally installed PV peak power capacity in the Netherlands increased up to 1,5 MWp, the adopted incentive scheme can be considered a success. Especially PV applications for holiday houses and caravans/mobile homes have become very popular. Other important

applications are PV pumps supplying drinking water for cattle, light buoys and energy supplies on board boats. The share of grid-connected PV system as compared to the total installed capacity in the Netherlands is still small, but it is rapidly increasing due to realisation of several pilot projects.

2.3.7 Austria

In the past ten years a total PV peak power capacity of more than 800 kWp has been installed in Austria, and the Austrian Electric Utilities are presently engaged in many further PV demonstration projects adding to the previous ones roughly 200 kWp.

In May 1992 Austria launched an important PV rooftop programme[5] aimed to promote the installation of grid-connected decentralised residential photovoltaic (PV) systems. Within 5 months proposals for PV projects totalling almost 160 kWp were approved for funding by the organising committee jury, and by the end of 1994 most of the envisaged residential PV installations have become operational. In spite of the low profitability of PV technology, people had simply decided to invest their money in solar cells and electronic components, and considering the success of the programme, discussions are presently going on how to step up the programme by further 100 kWp.

Since technical specifications limited only the size of the PV systems to 3.6 kWp each installation present particularities and is different in design and equipment from the others, and a wide variety of different types of solar modules and inverters have been adopted.

It was learned that system performance depended very much on the reliability of the solar inverter since, in the early stage of the Programme, several inverters had to be repaired or replaced.

A monitoring campaign was also implemented to gain information on the operational performance of the PV plants. This monitoring programme was organised and financed by the Austrian Ministry of Science and Research, and the analysis and evaluation of results will be one of the Austrian contributions to the work in the IEA Solar Heating and Cooling Programme, Task 16 Photovoltaics in Buildings and the new IEA Implementing Agreement on PV Power Systems.

2.3.7.1 Strategies

When a PV-system is connected to the utility distribution network, a two way flow of electric energy will be established.

The Austrian utilities have therefore adopted net metering: i.e. two separate, reverse blocked meters are adopted to measure sold and purchased electric energy.

PV-electricity is paid by utilities a price of 43.790 ECU/kWh in winter and 25.670 ECU/kWh in summertime. Instead, utility customers have to pay 130.615 ECU/kWh for consumed electricity.

A new regulation was expected to double this figures in mid 1994. The utility of the province “Lower Austria" EVN already uses the new higher tariff for PV systems and wind energy converters.

Because of these tariff regulations the homeowners try to operate the washing machine, the dish washer and other appliances at daytime hours with full sunshine to optimise direct use of PV power.

2.3.7.2 Funding and Incentives

As mentioned previously the Austrian “200 kW Photovoltaic Rooftop Programme" was started in May 1992.

It was sponsored as in the following table :

Table 2.11 - Austrian Photovoltaic Rooftop Programme

Authority	Total Financial Contribution	
Electric Utilities Association	3.880 ECU/kWp	(60.000 ATS/kWp)
Local Electric Utilities	647 ECU/kWp	(10.000 ATS/kWp)
Ministry of Commerce	647 ECU/kWp	(10.000 ATS/kWp)
Ministry of Science and Research financing the monitoring and evaluation programme with about	258.650 ECU	(4.000.000 ATS)

The total financial support for the owner of a grid-connected PV system is 5.173 ECU/kWp (80.000 ATS/kWp) of installed PV capacity. Furthermore several local district authorities have offered additional funding for residential PV systems (Upper Austria for example: 50 % of the total system costs).

The average specific system cost for the realised PV systems resulted to be 11.833 ECU/kWp ((183.000 ATS/kWp incl. VAT). Up to now module costs have resulted to dominate the overall system costs of residential PV systems.

Actually the PV module share in overall system cost was more than 50%, while inverters contributed 12 % to overall system costs.

Solar PV modules with a STC efficiency between 11 and 12,4 % were adopted, which resulted in relatively low array area requirements of 8 to 9 m^2/kWp. Larger installations resulted to be slightly cheaper although the specific module costs proved to be independent from the generator size.

The most widely used array mounting method was the stand-off mount configuration (60%), since applicable to both new and retrofit installations. Roof-integrated mounting was chosen by

only 11% of homeowners, since this mounting method required, although aesthetics more pleasant, special modules (laminates) and know how to be realised.

2.3.8 Finland

2.3.8.1 Existing small-scale stand-alone PV systems

- The smallest PV applications in Finland are typically stand-alone cottage systems with one PV module, battery, charge regulator and lamps (12 V). The nominal power of this one PV module is usually between 40-60 Wp. Systems for summer cottages, boats and caravans have mostly 1 or 2 PV modules.
- About 1.100 PV powered Navigational aids systems with 1 to 3 PV modules for different sea-buoys and beacons are already operating in the Finnish archipelago. Once completed, the presently ongoing PV Finnish installation campaign is expected to implement about 2.000 navigational systems with stand-alone PV power supply.
- Also other technology PV applications such as telephones, telecommunication relays/repeater stations, weather stations and other remote measurement stations are presently already operating in Finland with a stand-alone PV power supply system.

2.3.8.2 Market potentials in Finland

- About **200.000 non-electrified summer cottages exist in Finland**, and mostly will never be connected to the utility grid since too remote. Accordingly the potential market for this kind of application is estimated to be roughly 50.000-150.000 houses for 1-2 PV modules each, corresponding to an overall **market potential of 5MWp - 12MWp of installed peak power capacity**.
- Over **1.400.000 boats** exist in Finland. Of these at least 100.000 (boats) and 20.000 caravans can make use of PV for battery charging and for illumination purposes, etc. The corresponding **market potential amounts to 3MWp - 6MWp of installed peak power capacity**.
- If PV power is integrated with wind-power (able to compensate for lack of solar energy in wintertime) renewable energies are able to ensure a relatively constant contribution to the electricity demand of the country all over the year.

2.3.8.3 Photovoltaic research projects in Finland

In Finland energy research is mainly accomplished through the energy research programmes of the Ministry of Trade and Industry. The following PV research projects are presently being carried out:

- Imatran Voima (IVO) has built together with Neste Advanced Power Systems (NAPS) a 30 kWp battery buffered PV pilot plant.
- NAPS has different research and pilot PV projects, among which a plastic container office for research purposes with about 1 kW of PV modules.
- An electrically autonomous holiday cottage is powered by a 2 kW stand-alone system using amorphous PV modules.

- Microchemistry Ltd is carrying out research on amorphous Si and CdTe-thin films.

2.3.8.4 Strategies

The photovoltaic projects foreseen by the NEMO programme are:

- Grid-connected and building-integrated PV systems
- Demonstration of a solar hydrogen system;
- Industry co-funded projects:
  - Storage battery for photovoltaic systems;
  - Seasonal energy storage for PV-systems;
  - Development of novel PV module framing techniques;
  - Grid connected battery buffered solar power plant;
  - Grid connected inverter for photovoltaic systems;
  - Small autonomous PV powered house with air conditioning;

2.3.8.5 Incentives and funding

The NEMO programme 1988-1992 deals with advanced new energy technologies and systems. The budget of NEMO for all solar energy projects was 3,5 million ECU (19 FIM million).

2.3.9 Switzerland

2.3.9.1 Objectives

Swiss authorities have launched the so-called the **Energy 2000 Programme.**

Under this programme the concerted efforts of the entire Swiss national economy are intended to achieve **up to year 2000** the following ambitious objectives with respect to energy:

- to stabilise al least the total consumption of fossil fuel and CO_2 emissions at the levels of 1990 and following year 2000 to start reducing these levels;
- to reach a contribution of renewable energy sources in total energy consumption equal to 0,5% for power generation and 3% of fossil fuel consumption in the form of heat;
- to increase the use of hydropower by 5% and to increase the output of the existing nuclear power stations by 10%.

The participating organisations and authorities have split into 4 action committees in order to develop the individual objectives and strategies for action in the following fields:

- fuels;
- propellants;
- electricity;
- Renewable energy sources.

In the case of renewable energy sources priorities are assigned to:

- solar energy
- ambient heat
- organic substance

For the PV sector the targets of the Energy 2000 Programme are to expand the current 0,05 TWh/year of PV energy fed into the national grid, corresponding approximately 2 MWp of installed PV capacity at the end of 1991, to 50 MWp by the turn of the millennium.

2.3.9.2 Strategies

The objectives for Energy 2000 programmes can only be achieved if important economic structural conditions are improved. The fields of activity and the actors needed to achieve the objectives have been defined within the Swiss Photovoltaic technology Program (see table 2.12).

Table 2.12 - Strategic actions and actors to improve target of Energy 2000 Programme in Switzerland

	PV Actors			
	PV Industry	*Government*	*Utilities*	*Self-Producers*
Technology	product development	pay for basic research	P&D real market	P&D real market
Economics	economy of Volume or economy of Scale	pay subsidies	pay marginal and external cost	get marginal cost and solar bonus
Institutional Issues	instruction and training	information and education	metering (kWh) statistics	liberal building permits policy
Regulatory issues	quality assurance QA	regulatory policy	technical application	make attractive products

2.3.9.3 Funding and Incentives

- *Information and training by means of the PACER incentive programme:*

  Within the context of the National Programme of action for building and energy the PACER incentive Programme is concentrating on renewable energy sources. The PACER programme[6] in close co-operation with commerce and industry, schools and the Federal Government promotes the uses of renewable energy sources and is intended to provide engineers, architects and installation engineers with the knowledge needed to apply photovoltaic technology. The intention is also to introduce a different economic point of view which takes account of the external costs (environmental impact, etc.). In the field of photovoltaic applications, PACER offers training courses for PV electricians, development courses of photovoltaic engineers and video training material.

2.3.9.4 Federal subsidies for strategic niche markets

From 22 September 1992 the Federal Government is supporting all photovoltaic grid-connected installations built on school-buildings with a payment of about 3.020 ECU/kWp (4.000 US$/kWp). Gearing towards this group of buildings is a strategic choice. School-buildings are normally owned by the local authorities. This means that the benefits of using photovoltaic technology are brought to the attention of the local authorities, teaching staff and students in a positive manner.

2.3.9.5 Improvement of basic legal conditions by the federal government in the energy utilisation resolution (ENB)

The energy utilisation resolution passed by the Swiss Parliament on 14 December 1990 also creates new improved basic legal conditions for the use of photovoltaic technology. The public power supply companies are obliged to purchase the electrical energy produced by self-sufficient users and individual producers using PV, wind, combined heat and power and mini hydroelectric power stations and to reimburse them at an appropriate rate. If this power is

generated by means of renewable energy sources, the producer must be reimbursed at the reference price for new domestic installations (marginal costs). The Federal Government is currently drawing up recommendations and specimen contracts for input to the grid.

A special committee, based on equal representation, negotiates the applicable reference prices for reimbursement every year. These prices are then applied in the whole of Switzerland. It is expected that remunerations between ECU/kWh (0,21-0,29 US$/kWp) will be possible.

The Swiss government parties have reached a verbal political consensus and agreed that the economic burdens deriving to people from energy saving and renewable energy source exploitation should be compensated by imposing a resources and/or energy tax. The rapid introduction of a CO_2 energy tax is however hindered by need to find a consensus with the EU member states.

2.4 OVERVIEW OF THE EUROPEAN PV INDUSTRY

In year 1994 totally 18 European PV Industries were operating in the manufacturing of PV cells and modules (see table 2.13 and figures 2.1 and 2.2).

Attention should be paid to the fact that many of these European PV manufacturers operate with more than one production facility (production line) in order to be able to cover several different PV technologies (mono, polycrystalline and amorphous Si) as well as to provide not only for commercial production but also for R&D in manufacturing technology.

Accordingly the following table presents a total number of 19 production lines existing in Europe in 1994

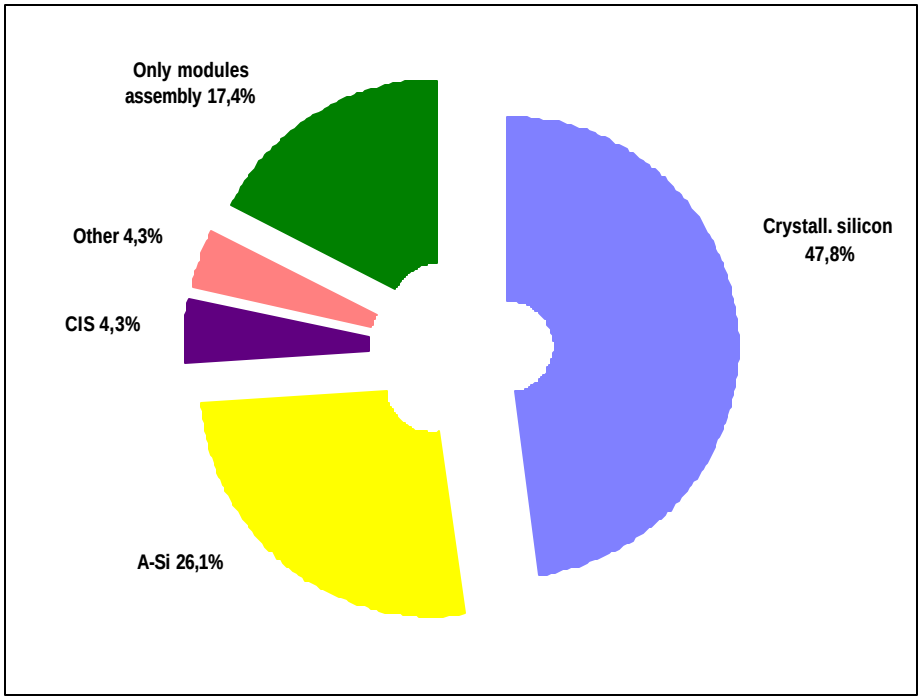
Table 2.13 - Number of European PV manufacturers per technology

Technology	*Manufacturing Facilities*	
	number	*capacity MWp*
Crystall. silicon	11	26,7
Ribbon		-
A-Si	6	5,0
CdTe		-
CIS	1	-
Other	1	-
TOTAL PRODUCTION LINES	**19**	**31,7**
Only modules assembly	4	4,1
TOTAL PRODUCERS	**18**	

Roughly half of the European production lines produce crystalline Silicon PV cells and modules (totally 11 production lines, of which 3 produce only monocrystalline Si, 1 only polycrystalline Si and 6 both mono- and polycrystalline Si).

The largest share within the remaining half of European production lines is dedicated to amorphous Si production (6 lines), but a total of 4 manufacturers provide only for final module assembly (lamination) and do not produce own PV cells.

Figure 2.1 - Distribution of number of European PV manufacturers per technology (1994)



Over the last five years, Europe has retained a consistent share in consumption of commercial power modules, evolving from a low 19% of market share in 1988 to a high 31% in 1994. The average market share during the period 1987-1994, calculated on the basis of cumulative shipments, was 25%.

Figure 2.2 - Distribution of production capacity of European PV manufacturers per technology (1994)

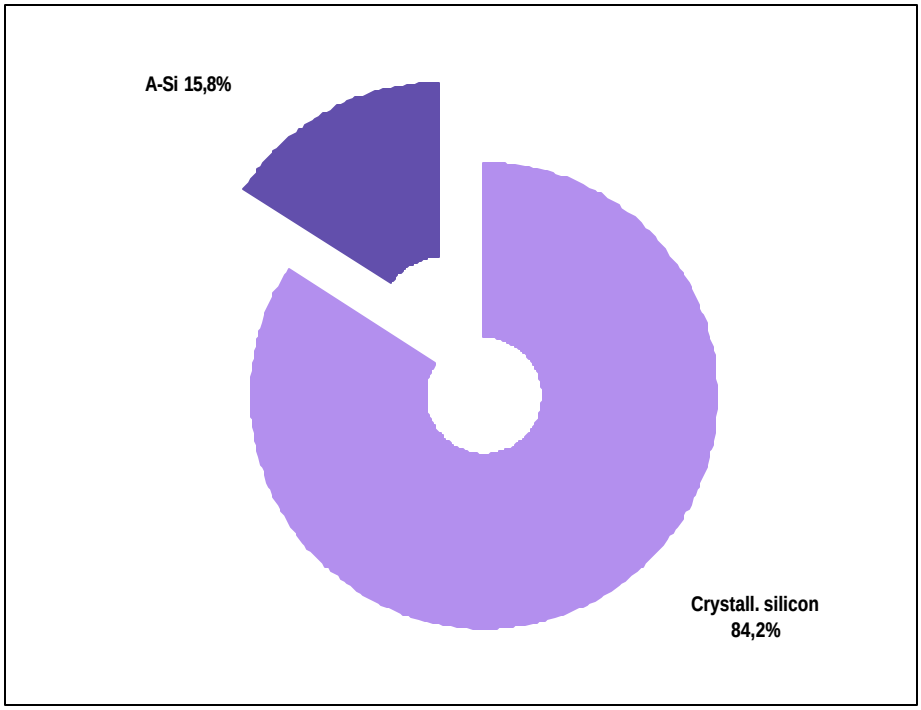
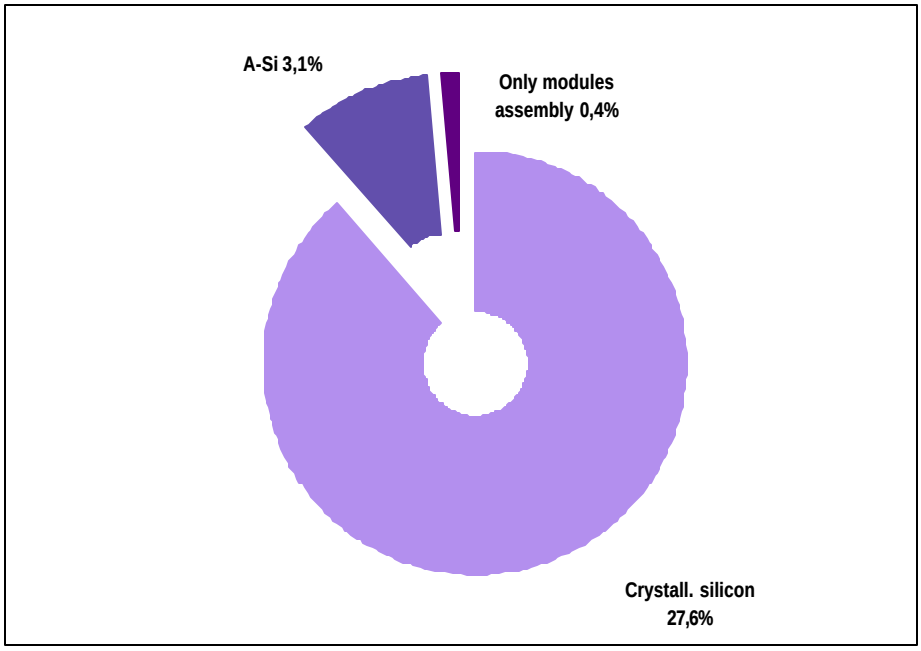


Table 2.14 - Trends of shipments, growth and market shares for the European PV Industry

PERIOD	CUMULATIVE SHIPMENTS			WORLD MARKET SHARE
	Total	Annual growth		%
	kWp	kWp	%	
1987	4.700			16,8%
1987- 1988	7.100	2.400	51,1%	20,9%
1988- 1989	7.900	800	11,3%	19,3%
1989- 1990	9.800	1.900	24,1%	20,4%
1990- 1991	12.100	2.300	23,5%	22,7%
1991- 1992	16.000	3.900	32,2%	28,2%
1992- 1993	16.900	900	5,6%	27,6%
1993- 1994	21.700	4.800	28,4%	31,1%
AVERAGE PERIOD VALUES			**25,2%**	**24,6%**

Shipments from European suppliers presented an annual growth rate of 25% from 1987 to 1994, growing from 4 MWp to about 22 MWp. This growth rate reflects the big effort and support received from the European Union and from EU member country governments, as well as increased price competitiveness and additional manufacturing capacities coming on-line. Table 2.14 shows the overall data referring to the period 1987-1994. Figure 2.3 shows the data referring to year 1994.

Figure 2.3 - World market share distribution among European PV manufacturers per technology (1994)



Note: Given percentages do not sum up to 100% since the world market shares of only European PV suppliers are presented

2.4.1 The European PV Manufacturers

The situation of the European PV module manufacturing industry in terms of principal operators, adopted technologies and production capacities is summarised in table 2.15.

Table 2.15 - Overview of European Manufacturing Industry

COUNTRY	*PRODUCER*	*CELLS*						*Only modules assembly*	*Capacity 1994[*]*
		Crystall. silicon	*Ribbon*	*A-Si*	*CdTe*	*CIS*	*Other*		*(in MWp/yr)*
Belgium	ENE	*							0,5
Belgium	SOLTECH							*	0,1
Denmark	SOLEL	*							1,0
France	PHOTOWATT	*							4,5
France	Solarcom							*	
France	NAPS			*					1,0
Germany	ASE	*							2,5
				*					1,0
Germany	FLAGSOL							*	1,0
Germany	NUKEM	*							1,0
							*		
Germany	SIEMENS Solar GmbH	*							2,0
				*					1,0
						*			
Italy	EUROSOLARE	*							3,0
Italy	HELIOS TECHNOLOGY	*							2,0
Netherland	R&S Engineering	*							4,0
Spain	ISOFOTON	*							0,2
UK	BP SOLAR International	*							6,0
Russia	Western Silicon (SOVLUX)			*					1,0
Sweden	GPV							*	3,0
UK	INTERSOLAR (CHRONAR)			*					
Croatia	Koncar Cells			*					1,0
TOTAL		**11**		**6**		**1**	**1**	**4**	**31,7**

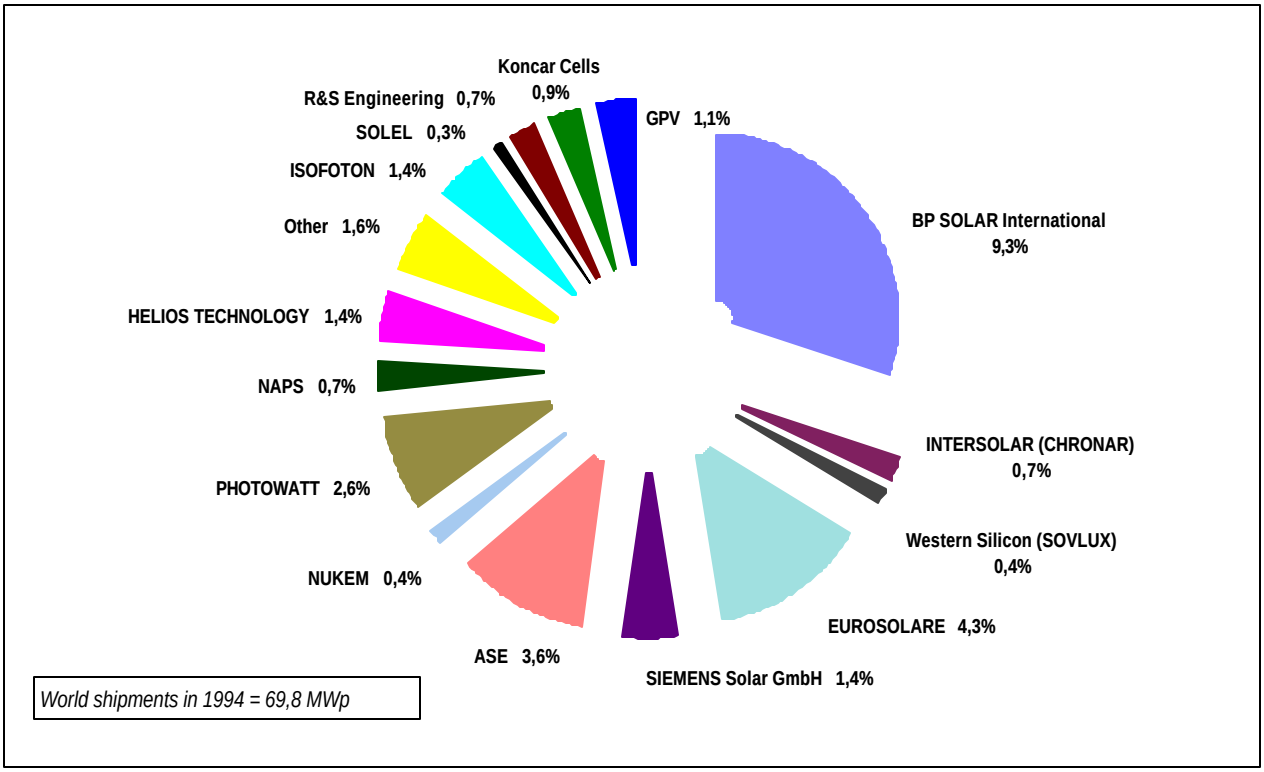
Note The data reported for BP Solar International include the capacity of the joint-ventures between of BP Solar International and associated company facilities: BP Solar Espana, BP Solar Australia, BP Thai Solar Corp., TATA BP Solar, BP Solar Arabia

The estimated market share of each European supplier in the same period, related to global world market, is shown in the following table 2.16 and illustrated in figure 2.4.

Table 2.16 - Estimated market shares of major European PV producers

COUNTRY	*PRODUCER*	*ESTIMATED MARKET SHARE*								
		1987	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*total 1987-1994*
Denmark	SOLEL								0,3%	0,1%
France	PHOTOWATT	2,7%	2,5%	2,7%	3,0%	3,0%	3,4%	2,3%	2,6%	2,8%
France	NAPS	1,8%	2,7%	1,0%	0,9%	1,1%	1,1%	0,8%	0,7%	1,1%
Germany	ASE	2,5%	2,7%	2,9%	2,9%	3,8%	4,9%	4,2%	3,6%	3,6%
Germany	NUKEM		0,6%			0,3%	0,4%	0,7%	0,4%	0,3%
Germany	SIEMENS Solar GmbH	1,1%	0,9%	1,2%	1,7%	2,3%	1,9%	0,7%	1,4%	1,4%
Italy	EUROSOLARE	1,4%	1,9%	1,7%	1,7%	1,7%	3,4%	3,9%	4,3%	2,7%
Italy	HELIOS TECHNOLOGY	1,4%	0,9%	2,0%	2,5%	2,8%	3,4%	2,1%	1,4%	2,1%
Netherland	R&S Engineering			1,0%	1,0%	0,9%	0,4%	0,3%	0,7%	0,6%
Spain	ISOFOTON	0,7%	1,2%	0,5%	1,0%	1,1%	1,4%	1,6%	1,4%	1,2%
UK	BP SOLAR International	3,9%	3,8%	3,7%	3,0%	3,6%	6,2%	7,4%	9,3%	5,6%
Russia	Western Silicon (SOVLUX)					0,3%	0,4%	0,4%	0,4%	0,2%
Sweden	GPV						0,5%	1,3%	1,1%	0,5%
UK	INTERSOLAR (CHRONAR)		2,7%	1,7%	1,2%	0,4%		0,2%	0,7%	0,8%
Croatia	Koncar Cells			0,6%	0,7%	0,8%	0,5%	1,0%	0,9%	0,6%
	Other	1,1%	1,2%	0,4%	0,5%	0,7%	0,4%	0,7%	1,6%	0,8%
TOTAL EUROPE		**16,7%**	**20,9%**	**19,3%**	**20,3%**	**22,6%**	**28,2%**	**27,5%**	**31,1%**	**24,5%**

Figure 2.4 - Estimated world market shares of major European PV suppliers



NOTE: Given percentages do not sum up to 100% since the world market shares of only European suppliers are presented

2.5 EUROPEAN MARKET OVERVIEW FOR MAIN APPLICATION SEGMENTS

2.5.1 Large and medium size PV power plants

2.5.1.1 Installed Capacities 1980-1994

Table 2.17 - Large-medium size PV power plants: capacities started-up per year in Europe (1982-1994)

	INSTALLED PEAK POWER (in kWp) PER YEAR START UP												
COUNTRY	*1982*	*1983*	*1984*	*1985*	*1986*	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	***TOTAL***
Austria						28	38	15	30	59	89		**259**
Belgium		63											**63**
Finland							30			30			**60**
France		144											**144**
Germany		300				663		280	440	143			**1.826**
Greece	50	125		23									**198**
Ireland		50											**50**
Italy			289		300	120	100	100	100	300	1.052	4.600	**6.960**
Netherland		50											**50**
Spain							100			42		1.260	**1.402**
Swiss						100				785	75		**960**
UK		30											**30**
Total EUROPE	**50**	**762**	**289**	**23**	**300**	**911**	**268**	**395**	**570**	**1.359**	**1.215**	**5.860**	**12.001**

Figure 2.5 - Large-Medium size PV power plant capacities started-up per year in Europe in comparison with same capacity world-wide (1982-1994)

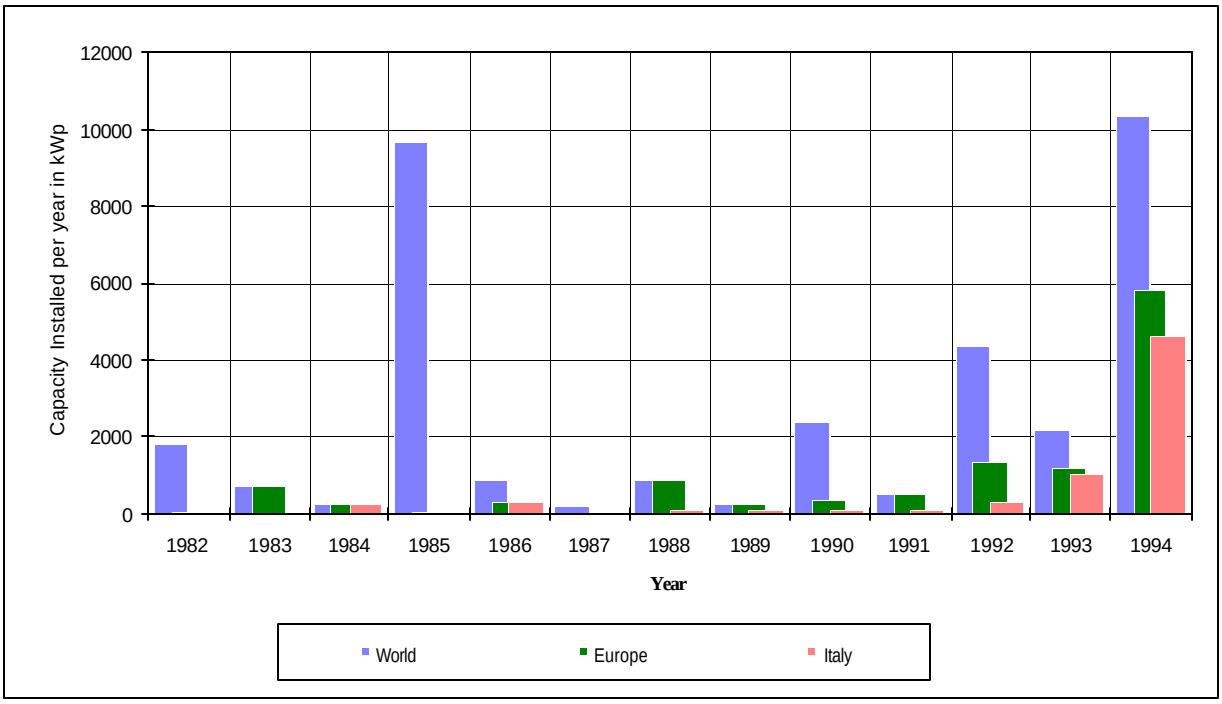


Table 2.18 - List of main Large-Medium size PV power plants installed in Europe (1982-1994)

PLANT	*TYPE*	*COUNTRY*	*INSTALLED PEAK POWER (kWp)*	*YEAR*
Chevetogne	LA	Belgium	63	1983
Mont-Bouquet	LA	France	50	1983
Nice Airport (destroyed)	LA	France	50	1983
Paomia-Rondulinu	LA	France	44	1983
1MW hybrid PV-wind Pellworm	GC	Germany	300	1983
1MW hybrid PV-wind Pellworm	GC	Germany	300	1991
Lake Neurath	GC	Germany	362	1988
Kobern Gondorf	GC	Germany	301	1988
Solar-Hydrogen Projekt - Neunburg	GC	Germany	280	1990
30 kWp PV Wendelstein Plant	GC	Germany	32	1992
Flanitzhutte	GC	Germany	40	1992
Fehmarn hybrid wind-PV-biogas	GC	Germany	140	1991
Rendsburg - Schleswing Holstein	GC	Germany	71	1992
Aghia Roumeli	VP	Greece	50	1982
100 kWp PV Kythnos Island Plant	GC	Greece	100	1983
PV Arki Island	LA	Greece	25	1983
PV Antikithyra	LA	Greece	23	1985
65 kW PV Tremiti	DS	Italy	65	1984
VULCANO	GC	Italy	100	1984
ZAMBELLI	WP	Italy	70	1984
Isola del Giglio	DS	Italy	45	1984
ADRANO	GC	Italy	9	1984
ADRANO	GC	Italy	52	1993
0,6 MW DELPHOS	GC	Italy	300	1986
0,6 MW DELPHOS	GC	Italy	300	1992
CETONA	LA	Italy	20	1988
NETTUNO	VP	Italy	100	1988
ENEA-CASACCIA	GC	Italy	100	1991
1 MW ELIO-1 PV Plant Vasto	GC	Italy	1.000	1993
3,3 MWp PV Plant - Serre	GC	Italy	3.300	1994
1,5 MW PV-Wind plant of Carloforte	GC	Italy	600	1994
Lamezia	GC	Italy	600	1994
EOLIE-Salina	DS	Italy	100	1994
SARDEGNA-Altanurra	GC	Italy	100	1990
LAMPEDUSA	DS	Italy	100	1989
Fota Island	GC	Ireland	50	1983
Terschelling Island	GC	Netherl.	50	1983
Tabarca Island	GC	Spain	100	1989
1 MW TOLEDO	GC	Spain	1.000	1994

PLANT	*TYPE*	*COUNTRY*	*INSTALLED PEAK POWER (kWp)*	*YEAR*
continued				
Mahon Majorca Island	GC	Spain	42	1992
Almeria Grid-connected PV back-up system	GC	Spain	160	1994
San Augustin Guadalix	GC	Spain	100	1994
Marchwood	CG	UK	30	1983
30 kWp PV Loser Altaussee Plant	GC	Austria	30	1991
Seewalchen PV motorways A1	GC	Austria	40	1992
Other plant grid connected	GC	Austria	28,0	1988
Other plant grid connected	GC	Austria	38,0	1989
Other plant grid connected	GC	Austria	15,0	1990
Other plant grid connected	GC	Austria	19	1992
Other plant grid connected	GC	Austria	89	1993
IVO PV Plant	GC	Finland	30	1989
30 kWp PV Kopparnäs Plant	GC	Finland	30	1992
Chur-Motorway N13	GC	Swiss	100	1988
500 kW PV PHALK Mont-Soleil	GC	Swiss	560	1992
Bellinzona-Locarno railway line	GC	Swiss	100	1992
Neufeld Berna	GC	Swiss	75	1993
100 kWp Plant SBB Magadino rail	GC	Swiss	103	1992
Marzili funicular railwayas	GC	Swiss	22	1992
TOTAL EUROPE			**12.001**	

GC Grid-Connected LA Local Application DS Desalination
VP Village Power WP Water Pumping

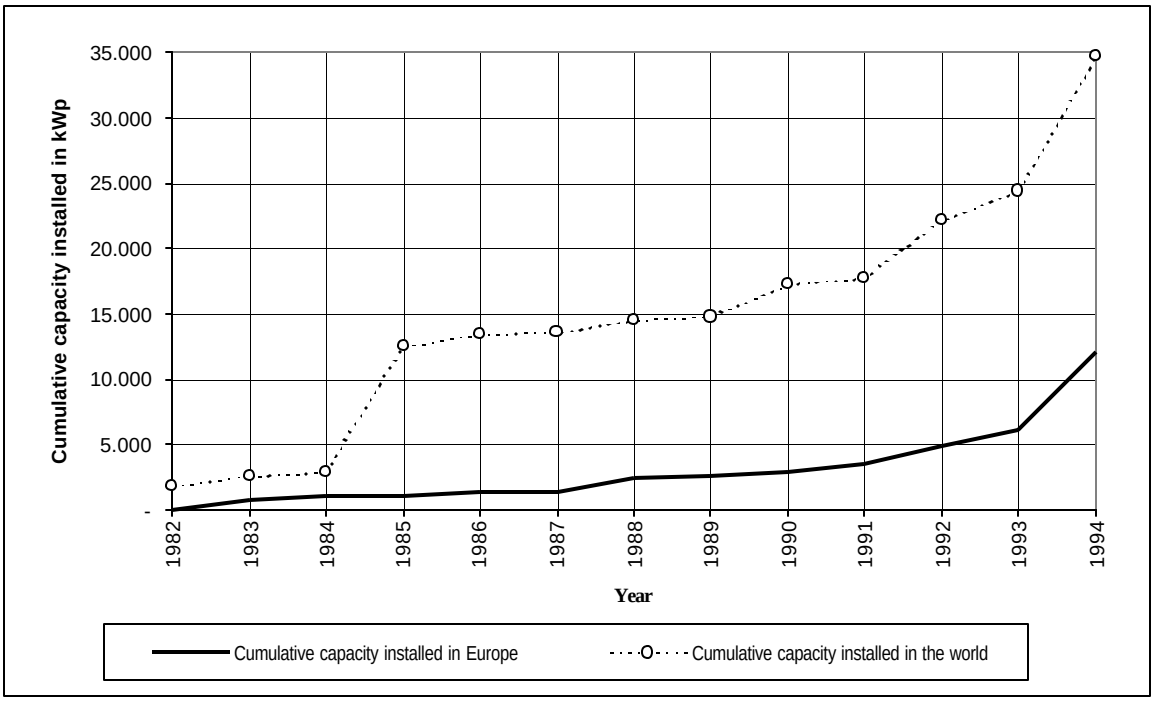
Table 2.19 - Capacity of large-medium size PV power plants installed in Europe as share of same type total world capacity

Year	% of installed world capacity	
	per year	cumulative
1982	2,8%	2,8%
1983	100,0%	31,7%
1984	100,0%	38,6%
1985	0,2%	9,0%
1986	33,3%	10,6%
1987		10,5%
1988	98,4%	16,1%
1989	100,0%	17,6%
1990	16,5%	17,4%
1991	100,0%	20,1%
1992	31,2%	22,3%
1993	54,9%	25,2%
1994	56,6%	34,6%

Table 2.20 - Large-medium size PV power plants: cumulative installed capacity in Europe (1982-1994)

	CUMULATIVE INSTALLED PEAK POWER (in kWp)											
COUNTRY	1982	1983	1984	1985	1986	1988	1989	1990	1991	1992	1993	1994
Austria						28	66	81	111	170	259	259
Belgium		63	63	63	63	63	63	63	63	63	63	63
Finland							30	30	30	60	60	60
France		144	144	144	144	144	144	144	144	144	144	144
Germany		300	300	300	300	963	963	1.243	1.683	1.826	1.826	1.826
Greece	50	175	175	198	198	198	198	198	198	198	198	198
Ireland		50	50	50	50	50	50	50	50	50	50	50
Italy			289	289	589	709	809	909	1.009	1.309	2.360	6.960
Netherland		50	50	50	50	50	50	50	50	50	50	50
Spain							100	100	100	142	142	1.402
Swiss						100	100	100	100	885	960	960
UK		30	30	30	30	30	30	30	30	30	30	30
Total EUROPE	**50**	**812**	**1.101**	**1.124**	**1.424**	**2.335**	**2.603**	**2.998**	**3.568**	**4.926**	**6.141**	**12.001**

Figure 2.6 - Large-Medium size PV power plant cumulative capacity installed in Europe in comparison with same type total world capacity (1982-1994)



2.5.2 Grid-connected small-scale applications

2.5.2.1 Capacity installed 1980-1994

Table 2.21 - Grid-connected small-scale PV applications (rooftops) in Europe (1989-1994)

Country	CAPACITY INSTALLED (in kWp) PER YEAR						
	1989	1990	1991	1992	1993	1994	TOTAL PER COUNTRY
Austria	-	-	-	200	-	-	200
Germany	-	-	-	4	2.027	2.022	4.052
Netherlands	3	-	25	-	20	364	412
Portugal	-	-	-	-	10	-	10
Swiss	-	-	-	-	-	1.760	1.760
UK	-	-	-	-	-	40	40
TOTAL EUROPE	**3**	**-**	**25**	**204**	**2.057**	**4.186**	**6.474**

[*] Year refers to start-up of installation

Figure 2.7 - Grid-connected small-scale PV applications (rooftops) capacity started-up per year in Europe, in comparison with same type total world capacity (1989-1994)

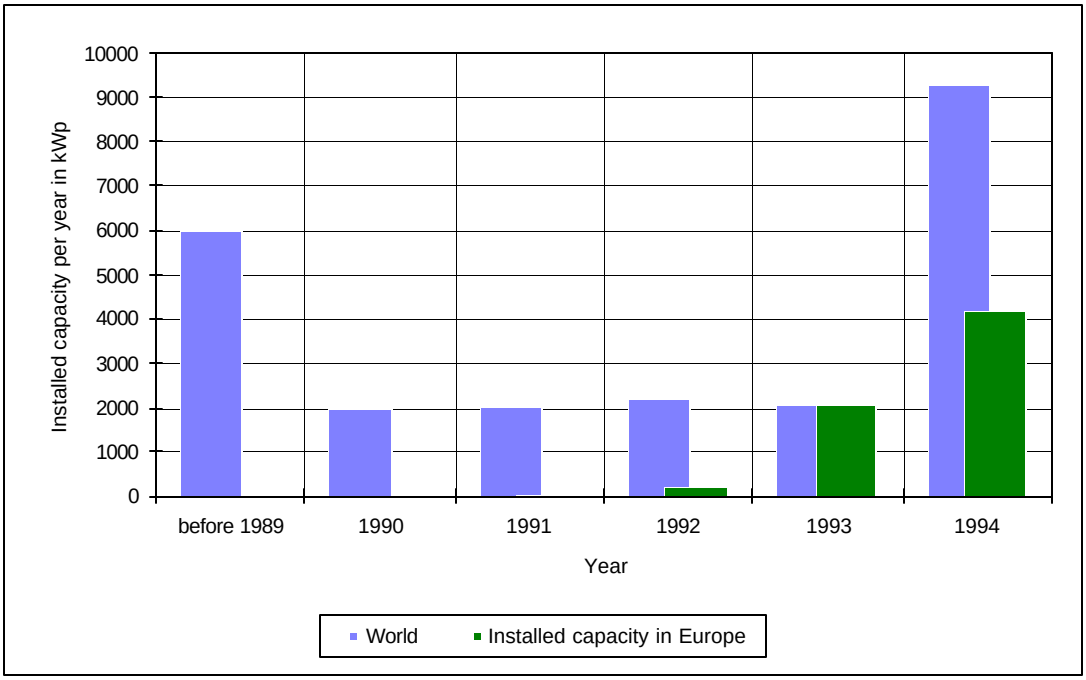
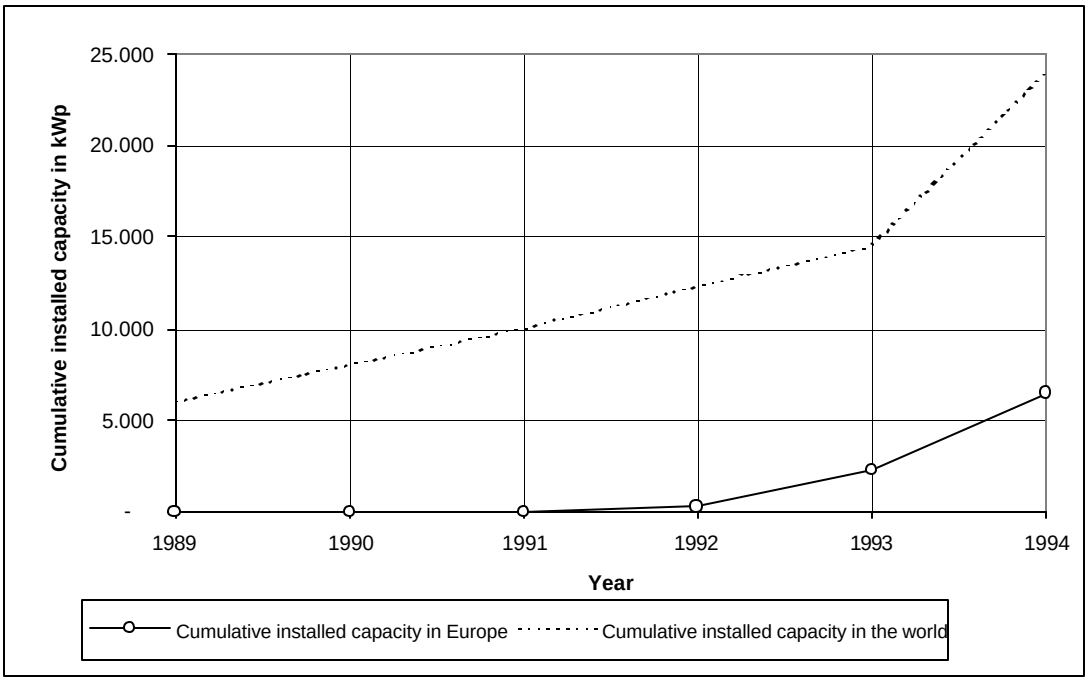


Table 2.22 - Capacity of grid-connected small-scale PV applications (rooftops) installed in Europe as share of same type total world capacity

Year	*% of installed world capacity*	
	per year	*cumulative*
1989	0,04%	0,04%
1990		0,03%
1991	1,23%	0,27%
1992	8,96%	1,87%
1993	94,27%	15,73%
1994	44,72%	27,08%

Figure 2.8 - Grid-connected small-scale PV applications (rooftops): cumulative capacity installed in Europe in comparison with same type total world capacity (1982-1994)



2.5.2.2 Grid-connected small-scale applications (rooftops): today's European demand potential

The market category of grid-connected small-scale PV systems embraces such typical applications as PV rooftops, PV building facades and building integrated PV facilities in general. Grass-root installations of grid-connected small-scale type are also included in this category, but at least in Europe their market share is not significant.

These systems are expected to become the backbone of the **distributed generation utility concept**, where the utility network is expected to provide no more exclusively for the distribution to consumers of power produced by few concentrated generation facilities, but to collect, at the same time, power from a large number of self-producers distributed over the territory.

2.5.2.3 Capacities installed in Europe since 1991

In Europe, grid-connected small-scale PV systems, namely PV rooftops, have started to be installed since 1991, primarily in German language countries including Germany, Austria and Switzerland.

Important work has been done in these countries to overcome institutional barriers such as safety and grid interfacing regulations limiting the possibility to adopt this technology.

If relevant financing support from public sources is provided, allowing to alleviate the economic losses suffered by investors, there appears to be a significant demand for such applications among private house owner and smaller enterprises.

Facade cladding and large building integration projects are just now (1993/1994) starting in Europe and they are expected to be very promising especially since they bring PV technology into the cities and allow to produce a significant impact onto public opinion;

The following table 2.23 presents the estimated net surface in km^2 available In Europe for solar rooftop installations.

The table 2.24 gives instead the figures per inhabitant for available solar rooftop surfaces for year 1992 and interpolation results for year 1990 (required for extrapolation calculations).

It must be emphasised, that **calculations do not take into consideration** that a consistent part of the available solar rooftop surfaces will be used for **concurrent thermal solar applications**, which obviously will have to be subtracted from the quantified rooftop surface potential.

Table 2.23 - Estimated net solar rooftop surfaces available in Europe (1992)

Countries	*Irradiation*	*Net Available Solar Surface*			
	kWh/ m2 year	*houses*	*offices & services*	*industrial buildings*	*TOTAL 1992*
		km2	*km2*	*km2*	*km2*
Austria	1.200	50	15,0	13	78
Belgium	1.000	43	20,0	14	77
Denmark	1.000	34	11,0	6	51
Finland	900	45	11,0	8	64
France	1.200	362	122,0	85	569
Germany	1.000	532	214,0	242	988
Greece	1.500	64	11,0	6	81
Iceland	800	2	1,0	0	3
Ireland	1.000	16	5,0	4	25
Italy	1.300	336	120,0	86	542
Luxembourg	1.000	2	1,0	1	4
Netherlands	1.000	63	30,0	21	114
Norway	900	34	10,0	8	52
Portugal	1.700	54	11,0	11	76
Spain	1.600	145	60,0	51	256
Sweden	900	78	20,0	13	111
Switzerland	1.200	42	18,0	12	72
United Kingdom	1.000	248	123,0	96	467
Europe		**2.150**	**803**	**677**	**3.630**

Table 2.24 - Estimated available net solar rooftop surfaces per capita in 1992 and 1990

Countries	*Available net Solar surface pro capita*					
	houses	*offices & services buildings*	*industrial buildings*	*TOTAL 1992*		*TOTAL 1990*
	m2/ inhabitant	*m2/ inhabitant*	*m2/ inhabitant*	*km2*	*m2/ inhabitant*	*km2*
Austria	6,3	1,9	1,6	78	9,9	77
Belgium	4,3	2,0	1,4	77	7,7	77
Denmark	6,5	2,1	1,2	51	9,8	50
Finland	9,0	2,2	1,6	64	12,8	64
France	6,3	2,1	1,5	569	9,9	562
Germany	6,6	2,7	3,0	988	12,3	973
Greece	6,2	1,1	0,6	81	7,9	80
Iceland	7,7	3,8	0,0	3	11,5	3
Ireland	4,6	1,4	1,1	25	7,1	25
Italy	5,8	2,1	1,5	542	9,4	541
Luxembourg	5,1	2,6	2,6	4	10,2	4
Netherlands	4,1	2,0	1,4	114	7,5	112
Norway	7,9	2,3	1,9	52	12,1	51
Portugal	5,5	1,1	1,1	76	7,8	77
Spain	3,7	1,5	1,3	256	6,5	255
Sweden	9,0	2,3	1,5	111	12,8	109
Switzerland	6,1	2,6	1,7	72	10,4	70
United Kingdom	4,3	2,1	1,7	467	8,1	464
Europe	**5,7**	**2,1**	**1,8**	**3.630**	9,5	3.596

By making the same assumptions as presented in corresponding paragraph for the total world potential of PV rooftops, the present (1990) potential for grid-connected (distributed) small-scale PV (rooftop) capacities has been calculated **for Europe** to be roughly **450.000 MWp (~ 1.200 Wp/inhabitant)** of installed PV capacity, whereas the produceable PV energy has resulted to be roughly **360TWh/year (~ 1000 kWh/year per inhabitant)**. The results obtained for each country are presented in tables 2.25 and table 2.26

Table 2.25 - Installable PV Rooftop Capacity in Europe year 1990

Countries	*Installable PV Capacity 1990*		*Producible PV Energy 1990*	
	MWp	*Wp/ inhabitant*	*MWh/year*	*kWh/year inhabitant*
Austria	9.614	1.217	8.075.962	1.037
Belgium	9.596	960	6.717.288	674
Denmark	6.301	1.212	4.411.010	858
Finland	7.984	1.597	5.029.920	1.008
France	70.295	1.225	59.047.628	1.041
Germany	121.600	1.509	85.120.000	1.073
Greece	9.948	966	10.445.461	1.032
Iceland	359	1.376	201.149	805
Ireland	3.125	893	2.187.500	625
Italy	67.586	1.169	61.503.169	1.067
Luxembourg	485	1.236	339.286	893
Netherlands	14.016	922	9.810.938	656
Norway	6.409	1.491	4.037.860	952
Portugal	9.568	976	11.385.750	1.154
Spain	31.885	815	35.711.673	917
Sweden	13.652	1.569	8.600.586	1.005
Switzerland	8.752	1.268	7.351.826	1.096
United Kingdom	57.981	1.003	40.586.784	707
Europe	449.157	1.182	360.563.789	957

On the basis of the above results, the produceable PV rooftop electric energy has then been compared with the overall final electricity consumption of same European countries, to quantify the share of overall consumption, which can be covered by PV rooftop power.

In Europe, the 1990 potential contribution of PV rooftop power would be roughly 1000 kWh/year per inhabitant equalling more than 16 % of final electricity consumption.

The following table 2.26 and related figure 2.9 show in addition a comparison with the present **hydropower contribution** to electricity consumption. The purpose of this comparison was to provide a rough quantification means for the maximum Solar PV power contribution, which the utility network would be able to absorb without need for significant changes in present network management techniques (for more details see corresponding chapter for whole world potential calculation).

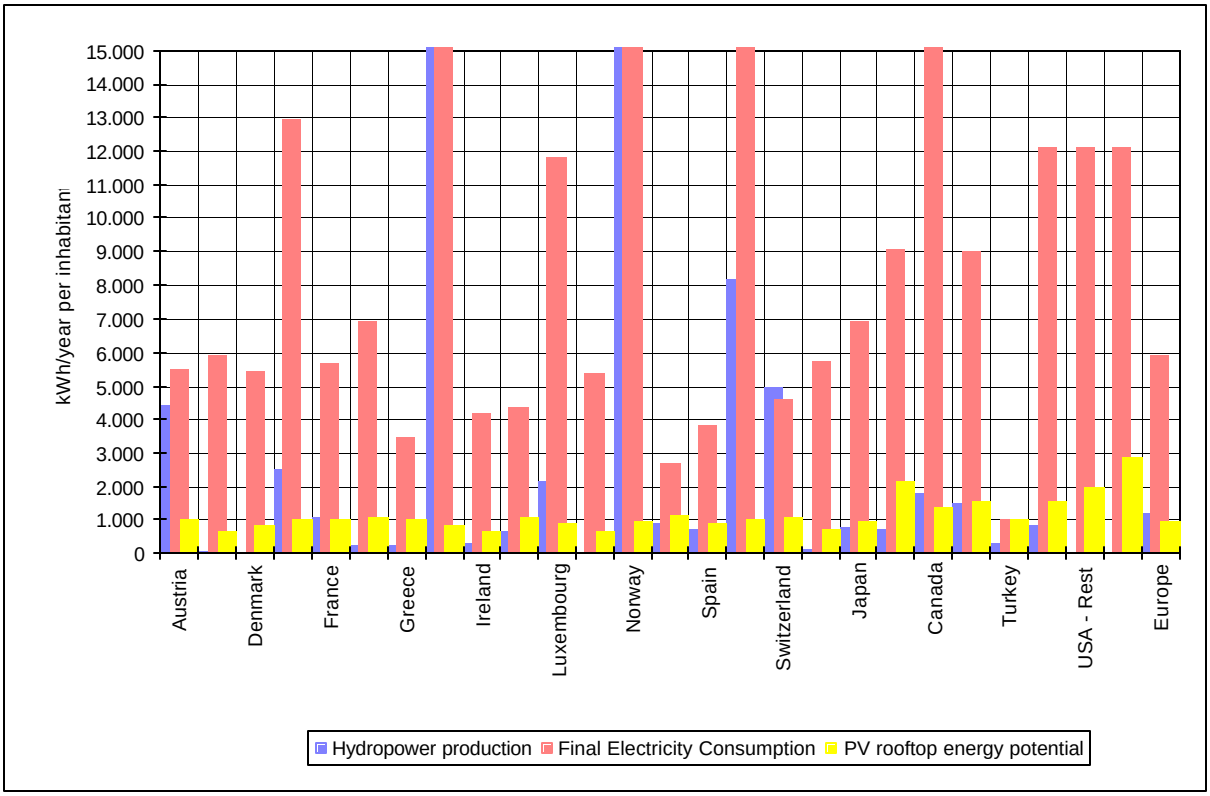
On the other hand, in case that distributed PV generation capacities are installed primarily in areas presenting a significant share of air conditioning consumption, this will, to a large extent, allow to compensate this kind of problem, since the resulting daily load profile meets the daily solar energy availability curve.

Table 2.26 - Today's potential PV Rooftop share as compared to Final Electricity Consumption

Countries	*Final Consuption of Electricity* *1990*		*PV Rooftop Potential Energy Share [*]* *1990*	*Actual Hydro Energy Share [*]* *1990*
	MWh/year	*kWh/year inhabitant*	*%*	*%*
Austria	42.657.000	5.476	18,9%	80,4%
Belgium	58.613.000	5.879	11,5%	1,4%
Denmark	27.881.000	5.424	15,8%	0,1%
Finland	64.656.000	12.957	7,8%	19,5%
France	321.946.000	5.675	18,3%	19,4%
Germany	548.852.000	6.916	15,5%	3,8%
Greece	35.093.000	3.468	29,8%	6,9%
Iceland	4.511.000	18.044	4,5%	93,5%
Ireland	14.515.000	4.147	15,1%	7,1%
Italy	250.624.000	4.347	24,5%	15,5%
Luxembourg	4.499.000	11.839	7,5%	18,2%
Netherlands	80.603.000	5.392	12,2%	0,1%
Norway	89.700.000	21.156	4,5%	127,9%
Portugal	26.841.000	2.719	42,4%	34,0%
Spain	147.711.000	3.791	24,2%	18,7%
Sweden	130.002.000	15.187	6,6%	53,7%
Switzerland	30.826.000	4.594	23,8%	107,0%
United Kingdom	330.866.000	5.763	12,3%	2,0%
Europe	2.210.396.000	5.870	16,3%	19,9%

[*] as compared to total final electricity consumption

Figure 2.9 - Comparison between PV rooftop potential, final electricity consumption and hydropower share in Europe (1990)



2.5.2.4 Grid-connected diffused applications (rooftops) European market forecast for year 2010

The potential market forecast for year 2010 specifically for grid-connected small-scale PV systems (rooftops and similar) has been extrapolated for Europe following same assumptions and procedures as presented in the corresponding chapter for the whole world potential calculation.

Tables 2.27, 2.28 and 2.29, as well as figure 2.10 produce a synthetic overview for Europe of results.

Table 2.27 - Forecast for year 2010 of available net solar rooftops in Europe

Countries	*Available net Solar surface year 2010*	
	TOTAL *km2*	*per capita* *m2/ inhabitant*
Austria	80	9,9
Belgium	79	7,7
Denmark	53	9,8
Finland	69	12,8
France	622	9,9
Germany	968	12,3
Greece	91	7,9
Iceland	3	11,5
Ireland	29	7,1
Italy	529	9,4
Luxembourg	4	10,2
Netherlands	127	7,5
Norway	56	12,1
Portugal	78	7,8
Spain	253	6,5
Sweden	116	12,8
Switzerland	74	10,4
United Kingdom	484	8,1
Europe	3.723	9,5

Table 2.28 - Forecast for year 2010 of installable PV rooftop Capacities in Europe

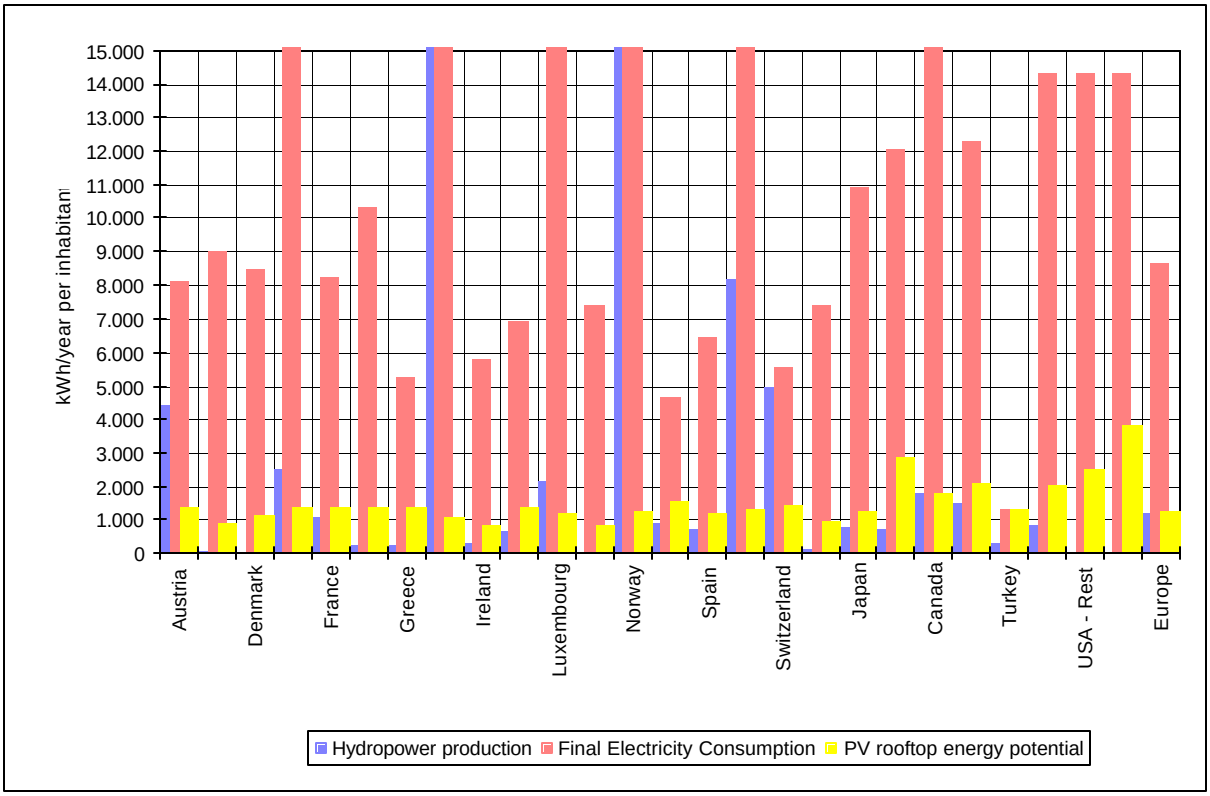
Countries	*Installable PV Capacity year 2010*		*Producible PV Energy year 2010*	
	MWp	*Wp/ inhabitant*	*MWh/year*	*kWh/year inhabitant*
Austria	13.241	1.638	11.122.629	1.376
Belgium	13.148	1.278	9.203.323	894
Denmark	8.752	1.627	6.126.082	1.139
Finland	11.390	2.124	7.175.555	1.338
France	103.174	1.645	86.665.891	1.381
Germany	160.664	2.034	112.464.956	1.424
Greece	15.141	1.305	15.898.363	1.370
Iceland	575	1.907	322.156	1.068
Ireland	4.869	1.185	3.408.049	830
Italy	87.745	1.556	79.847.648	1.416
Luxembourg	711	1.693	497.727	1.185
Netherlands	21.054	1.244	14.737.705	871
Norway	9.249	2.006	5.827.021	1.264
Portugal	12.866	1.287	15.311.039	1.531
Spain	41.930	1.086	46.961.150	1.217
Sweden	19.227	2.117	12.113.223	1.334
Switzerland	12.280	1.731	10.315.333	1.454
United Kingdom	80.281	1.340	56.196.799	938
Europe	617.662	1.584	494.194.649	1.268

Table 2.29 - Forecast for year 2010 of potential PV Rooftop share in Europe as compared to Final Electricity Consumption

Countries	*Final Consumption of Electricity year 2010*		*PV Rooftop Energy Share [*] year 2010*	*Hydro Energy Share [*][**] year 2010*
	MWh/year	*kWh/year inhabitant*	*%*	*%*
Austria	65.648.017	8.121	16,9%	52,2%
Belgium	92.732.900	9.010	9,9%	0,9%
Denmark	45.472.583	8.455	13,5%	0,1%
Finland	110.301.200	20.566	6,5%	11,4%
France	518.711.367	8.269	16,7%	12,1%
Germany	817.016.900	10.342	13,8%	2,5%
Greece	61.076.567	5.263	26,0%	4,0%
Iceland	7.691.033	25.495	4,2%	54,9%
Ireland	23.808.383	5.795	14,3%	4,4%
Italy	390.532.700	6.924	20,4%	10,0%
Luxembourg	6.526.633	15.540	7,6%	12,5%
Netherlands	125.729.400	7.431	11,7%	0,0%
Norway	128.611.167	27.898	4,5%	89,2%
Portugal	46.689.667	4.669	32,8%	19,6%
Spain	249.335.900	6.459	18,8%	11,1%
Sweden	204.576.700	22.522	5,9%	34,1%
Switzerland	39.483.450	5.566	26,1%	83,6%
United Kingdom	442.320.067	7.386	12,7%	1,5%
Europe	3.376.264.633	8.660	14,6%	13,0%

[*] as compared to total final electricity consumption
[**] hydro energy production (in MWh/year) assumed same as in year 1990

Figure 2.10 - Comparison between PV rooftop potential energy contribution, final electricity consumption and hydropower share in Europe (forecast for year 2010)



CHAPTER 2 - NOTES

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