

EXECUTIVE SUMMARY

Introduction

The main objectives of *Photovoltaics in 2010 (PV2010)* are to recommend a framework for the sustainable growth of the European Photovoltaic Industry in partnership with the increased production of European electricity from a renewable energy source (photovoltaics) and to increase international trade in European PV products. The time frame considered is to the year 2010.

This study has been undertaken in respect of the objectives of the European Union's ALTENER Programme. The specific target of ALTENER is to effect a 180m tonne reduction in carbon dioxide emissions by:

- doubling the use of renewable energy sources, from 4% of total consumption in 1991 to 8% in 2005
- trebling production of electricity in Europe from renewable energy sources
- securing a biofuels market share of 5% of total vehicle fuel consumption.

The Programme also aims to contribute to the better use of local energy sources, to ensure efficient allocation of public funds, to play a part in the completion of the Union's internal market and, importantly, to reduce dependence on imported energy.

The authors of this study have also given due attention to the conclusions and recommendations of other relevant EU renewable energy technology studies, programmes and policies.

The recommendations of the PV2010 study have been developed with direct input from the European Photovoltaics Industry Association (EPIA) and after a general invitation to the European PV industry to propose and prioritise initiatives.

The complete study is documented in 4 Volumes:

- Volume 1. Current status and a strategy for European industrial and market development
 - Summary Report (this Volume)
- Volume 2. A Strategic Plan for Europe
 - A strategic Action Plan to create a sustainable growth of the European PV industry and increased production of electricity from PV.

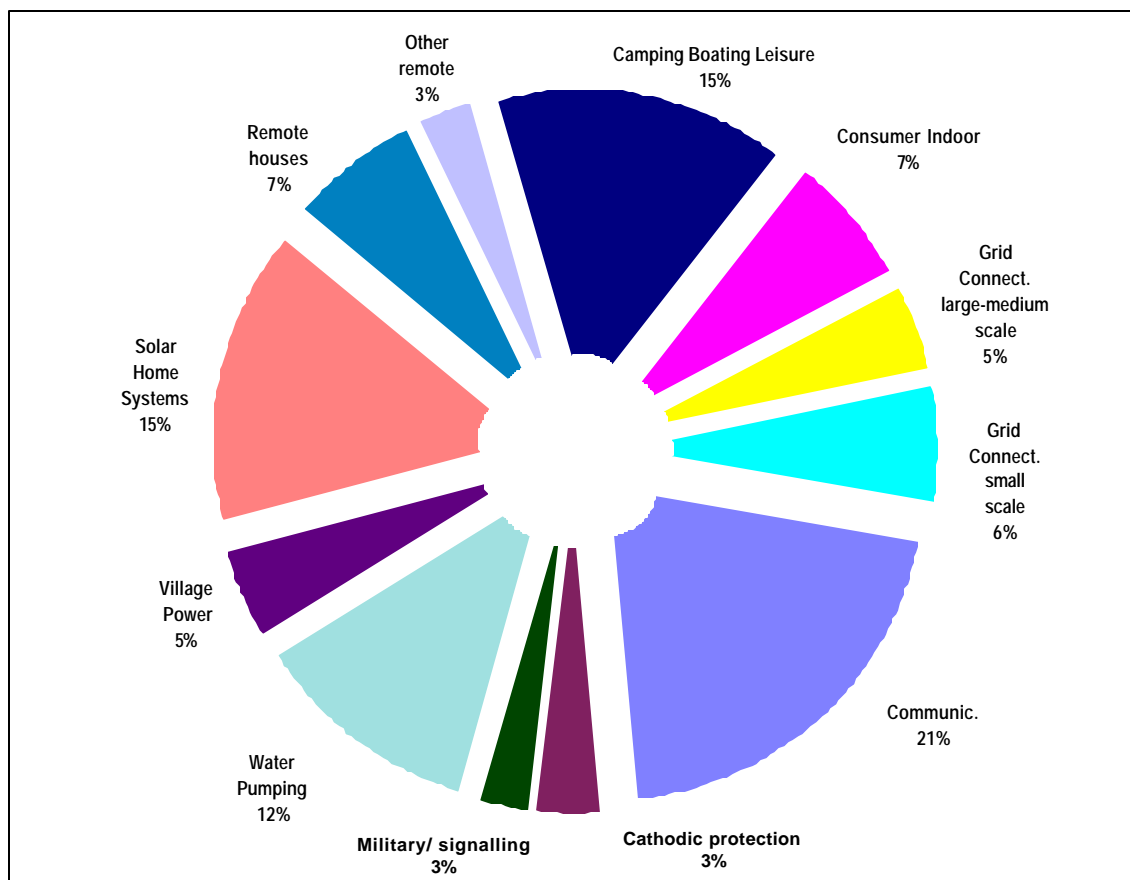
Volume 3. The World PV Market to 2010

- An overview of the world PV sector up to 1994 (applications history, perceived barriers to PV dissemination, existing and potential markets for PV)
- Market forecasts up to 2010 for various market stimulation scenarios
- In-depth analyses of PV industry programmes and applications by region (Europe, USA, Japan, Rest of the World)

Volume 4. Micro and Macro Economics for sustainable policies.

- A microeconomic analysis of the PV production process
- A macroeconomic analysis of PV generation plant and comparison to fossil-fuel generating plant

PV Industry shipment shares for main application segments (average 1990-1994)

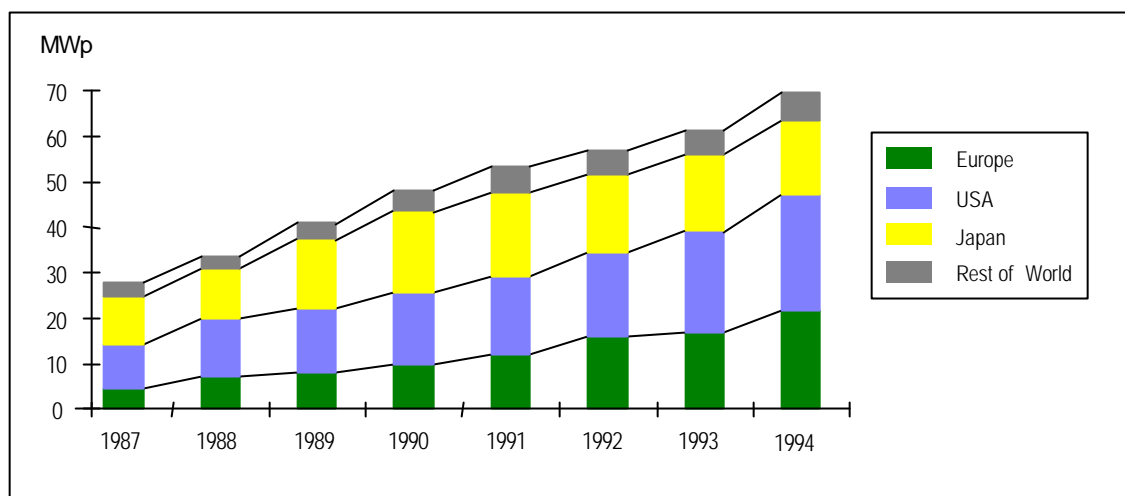


VOLUME 1 *Current Status and a Strategy for European Industrial and Market Development*

Status of European Photovoltaics

A historical review of the European position within the world PV market with respect to demand-side applications is presented. There has been consistent growth in world-wide demand for PV modules (about 15% annually), with the growth rate of the European PV industry somewhat above the world-wide average. Europe's 3-year average growth rate exceeds that of both the USA and Japan, and in 1994, shipments of some 22MWp gave European manufacturers a 31% share of the total PV market of 70MWp. This places Europe second only to the US in terms of annual production. The cumulative total of PV installed in Europe in 1994 was in the order of 70 MWp.

World PV Industry shipments



Analysis of global PV utilisation indicates that the communications sector has been the major area of application to date, accounting for approximately 21% (in terms of MWp) of PV sales. A significant proportion of today's PV sales is utilised for Solar Home Systems (15%) and camping, boating and leisure applications (also 15%).

The roof and building mounted facade grid-connected market represents the fastest growing market in Europe.

A survey of all known players in the European PV industry was conducted to assess the 1994 status. Details of manufacturing capacity and PV cell technology, plans for expansion, employment figures etc. are presented in Volume 1.

- The total European production line capacity in 1994 was 31.7 MWp, whilst shipments totalled some 21.7 MWp. 50% of shipments were exported outside Europe
- All manufacturers expressed an intent to install extra capacity in the future

- The number of people employed in manufacturing by European manufacturers is about 1680 in Europe, with a further 1045 employed outside Europe

The Photovoltaic Market: Demand Side Assessment

A brief overview of the existing market by demand-side application is presented. This is covered in more detail in Volume 3. The potential photovoltaic market is assessed according to end-use application. The major findings are:

- Economically, building mounted systems represent the first entry point for grid connected PV
- It is estimated that 618 GWp is potentially installable on roofs in Europe and more than 1100 MWp in the other OECD countries.
- The annual electricity production in Europe from PV roofs could be 500 TWh

Forecast of year 2010 installable building rooftop mounted PV

REGION	Installable PV GWp	Wp per Inhabitant	ELECTRICITY OUTPUT TWh/year
EUROPE	618	1584	494
USA	757	2344	903
JAPAN	174	1385	159
REST OF OECD	211	1564	230

- Grid support applications represent the next entry point for grid connected PV
- Large scale multi-megawatt PV is unlikely to compete economically with conventional power plant up to 2010
- With a rural population without access to electricity of more than 1 billion people in the developing world, the corresponding stand-alone rural development market potential is more than 16 GWp
- Stand alone PV for rural applications within Europe presents a potential market of some 150 MWp

Given the above market assessment, the priority markets for PV in Europe up to the year 2010 are seen to be:

Priority markets for PV in Europe - EU15

APPLICATION AREA	POTENTIAL (MWp) (Theoretical)	PROPOSED TARGET IN 2010	CUMULATIVE (MWp)
PV roofs	620,000	900	
PV facades on commercial and institutional buildings	included in above	400	
Other grid connect	-	400	
Isolated buildings and island communities	150	100	

The realisation of these targets, coupled with the cumulative installation of 200 MWp of PV by 2010 for “specialist” applications would guarantee a total of 2000 MWp of PV capacity installed in Europe by 2010.

Outside of Europe, the priority applications and markets are seen to be as follows:

Priority applications and markets for development outside of Europe

APPLICATION	REGION	COMMENTS
Solar home systems	India	-very high recent growth -international support -60M ECU PV project underway
Solar home systems Health care systems	Indonesia	-proven market -World Bank GEF project initiated -50 MW government target
Solar home systems Industrial (telecomms, nav aids etc.)	China	-high potential -indigenous industry outdated -World Bank projects under consideration
Solar home systems	Central Asia (CIS and Mongolia)	-high potential -many Nomadic families -international support developing -CIS PV industry underdeveloped
Solar home systems Health care systems Solar pumps	Southern Africa	-high potential -OPEC, US, EU support developing
Solar home systems Health care systems Solar pumps	Maghreb	- EU support - past initiatives (PV Euromed)

Market Forecast to 2010

An overview of the market forecast up to the year 2010, developed from a specialist computer based model of the world PV market is given. The various scenarios and associated predictions are presented in more detail in Volume 3.

Assuming business continues to develop at the same rate as experienced in the last decade, (ie 15% annually on average), annual shipments are expected to reach 630 MWp in 2010, with the two largest markets expected to be

1. solar home systems in developing countries
2. grid-connected, mainly building mounted systems in industrialised countries

The Photovoltaic Market: Supply Side Assessment

The various PV technologies available are reviewed. Prospects for future improvements in module efficiencies are proffered, and a scenario for crystalline silicon power module evolution to the year 2010 is described.

Improvements in module efficiencies through management and engineering of the wafer production process would result in significant reductions in the cost of solar cells and accordingly reductions in the cost of PV modules. It is estimated that ten years from now, the

industrial cost of PV modules could be reduced from today's figure of around 3.3 ECU/Wp to 1.8 ECU/Wp .

The factors which contribute to the cost of generating electricity from PV and fossil-fuelled plant are considered, including an assessment of the "negative" aspects of both power sources. The appropriate costs of these negative aspects are evaluated and are added to the basic industrial cost of generation for both PV and fossil-fuels. This procedure allows the overall costs of the respective forms of power generation to be compared directly. This analysis, which is presented more fully in Volume 4, indicates that PV will be cost competitive with fossil-fuels as a support to the grid in terminal sites where the PV kWh cost is around 0.26 ECU/kWh and this could occur around the year 2001. The use of PV to meet peak hour demands will be possible around 2005 where the cost will decrease below 0.18 ECU/kWh.

Market Development Issues

Prior to presenting the Strategic Action Plan for the development of the European Industry and Market, the principal barriers to the dissemination of PV in Europe are presented

In industrialised countries where consumers are already grid-connected, high system costs are a major stumbling block. Insufficient support from utilities and governments and a failure to consider PV above, or even alongside, conventional power sources are also substantial barriers to the uptake of grid-connected systems, whilst a general uncertainty or caution on the part of planners, designers and users is another area for improvement.

In developing countries, where PV installations have already been proven to be reliable and cost-effective, there are different obstacles. For example, many potential users have difficulty in financing purchases. There can also be a lack of awareness of the potential for PV applications, a scarcity of technical skills, and a general lack of infrastructure which makes planning, implementation and support for projects difficult.

Action Plan for Europe

In view of the proposed solutions to the various barriers, the Strategic Action Plan is outlined. The Plan calls for the following:

- Targets for installed PV in Europe by 2010
 - and resulting carbon dioxide saving contribution
- Target for European manufacturing capacity by 2010
 - and resulting employment generation
- Proposed programmes and recommended policies

These are presented in more detail in Volume 2.

VOLUME 2 A Strategic Action Plan for Europe

A Strategic Action Plan for Europe

The strategic plan calls for the following targets:

PARAMETER	YEAR 2010 TARGET
Cumulative installed PV capacity in Europe	2000 MW - PV roofs 900 MW - PV facades 400 MW - PV grid plant 400 MW - Isolated homes 100 MW - Other 200 MW
Manufacturing capacity	1000 MW/yr
European share of international PV trade	>40%
Solar homes supplied to the developing world	20 million

Proposed Programmes

To meet these targets the Plan recommends the following programmes:

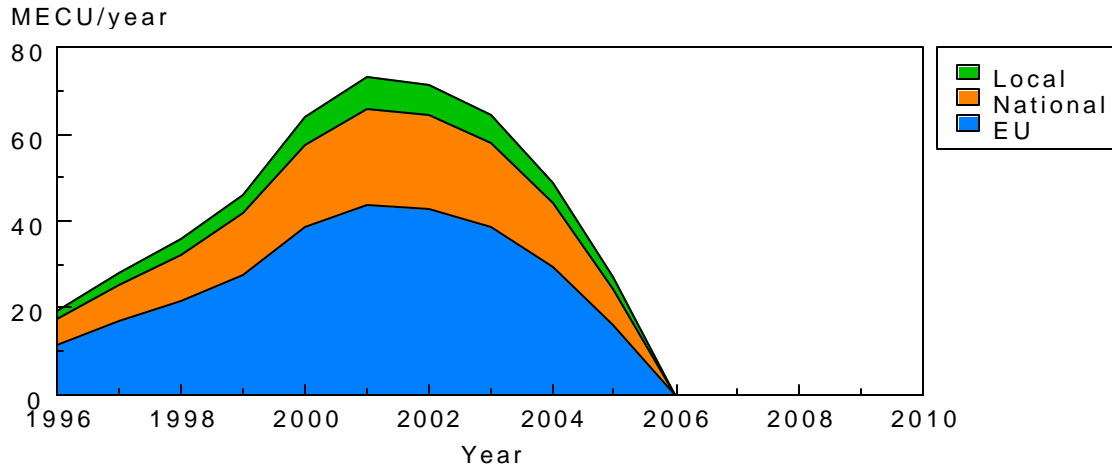
- A European 500 MW grid connect programme

The benefits of PV as a source of electricity in Europe are more than sufficient to justify a major programme of public support, aimed at developing the market to the targeted 2000 MWp installed by 2010 and a commercially sustainable market of around 350 MWp/yr.

To meet the overall target of 2000 MWp installed in Europe by 2010 a 10 year (1995-2005) transitional market enablement programme is proposed with the following key projects:

- 100,000 PV roof project
(average size = 3 kWp, total = 300 MWp)
- 2,000 PV building facades project
(average size = 50 kWp, total = 100 MWp)
- large scale power plant
(0.1-1 MWp range, total = 100 MWp)
(including noise barriers)

Transitional support contributions to the proposed EU 500 MW grid connect project



- European 100,000 isolated building project

To counter the identified barriers to the widespread dissemination of stand-alone PV, the following enablement measures are proposed:

- Promotion of PV to potential users
- Financial incentives at the regional or national level

- 20million Solar Home System Developing World Programme

A temporary transitional support programme is recommended:

ACTIVITIES RECOMMENDED
Establishment of a European Renewable Energies Export Council to facilitate export promotion missions
Support and secondments to GEF, World Bank, ADB, IADB
Project identification missions

- Manufacturing partnership investment programme

The study team supports the proposal of the Madrid Conference for a partnership investment programme for new large-scale manufacturing plant

- Increased R&D support programme

Building on the benefits associated with existing programmes of support (eg JOULE), it is recommended that this support continue up to 2005 with priority on:

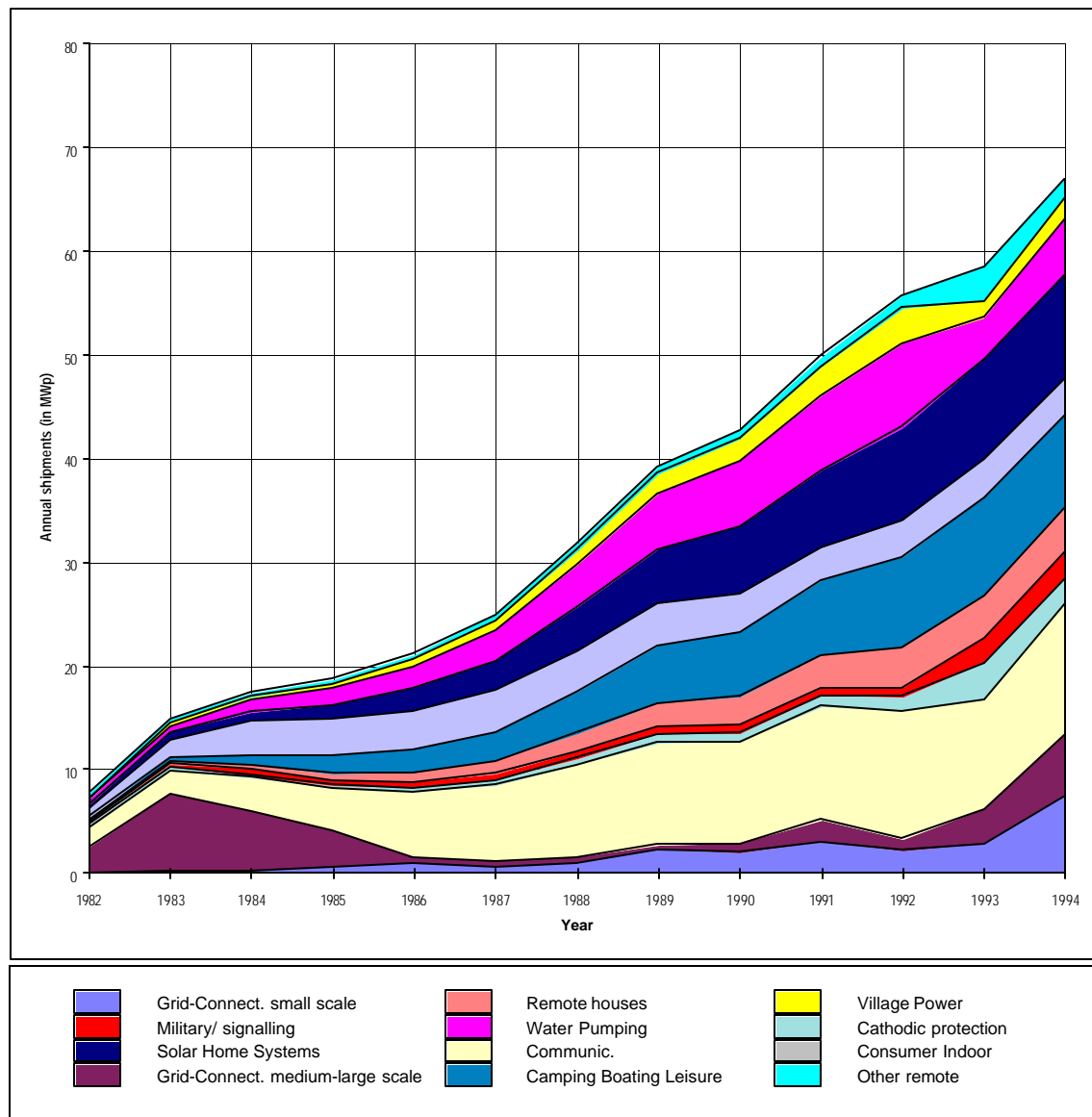
- new, low-cost manufacturing techniques
- product standardisation and certification

VOLUME 3 *The World PV Market to 2010*

World PV sector overview

The world PV market assessment presented in this volume provides a quantification and characterisation of the PV market during the period from 1982 to 1994 both in terms of supply side characteristics, i.e. annual shipments, manufacturing capacities, market shares of PV industries and related geographical areas of origin, as well as the demand side in terms of installed PV generator capacities subdivided into the principal application market segments and geographical areas of destination.

Actual world PV market development



Outcomes and results of the world PV market investigation are presented for the four main geographical areas of interest, namely Europe, USA, Japan and the rest of the world (ROW).

The roles of the key international organisations who are contributing to the development of the PV market are outlined. This includes, for example, the International Energy Agency, the World Bank, CENELEC and the Commission of the European Union whose support for activities in the areas of R&D, demonstration, dissemination, programme implementation, definition of standards, guidelines and safety measures etc. have assisted PV market evolution to date.

Objectives, strategies and specific PV incentive programmes being (or having been) implemented by the related governmental and international authorities are presented for the investigated geographical areas and countries, as well as the technical regulations and standards being adopted by the PV sector and related areas of conflict.

A detailed quantification and characterisation of the supply side of the PV market, i.e. of the PV industries of the presented areas is given including the list of all manufacturers, adopted technologies, manufacturing capacities and the historic trends of annual shipments for the period from 1982 to 1994.

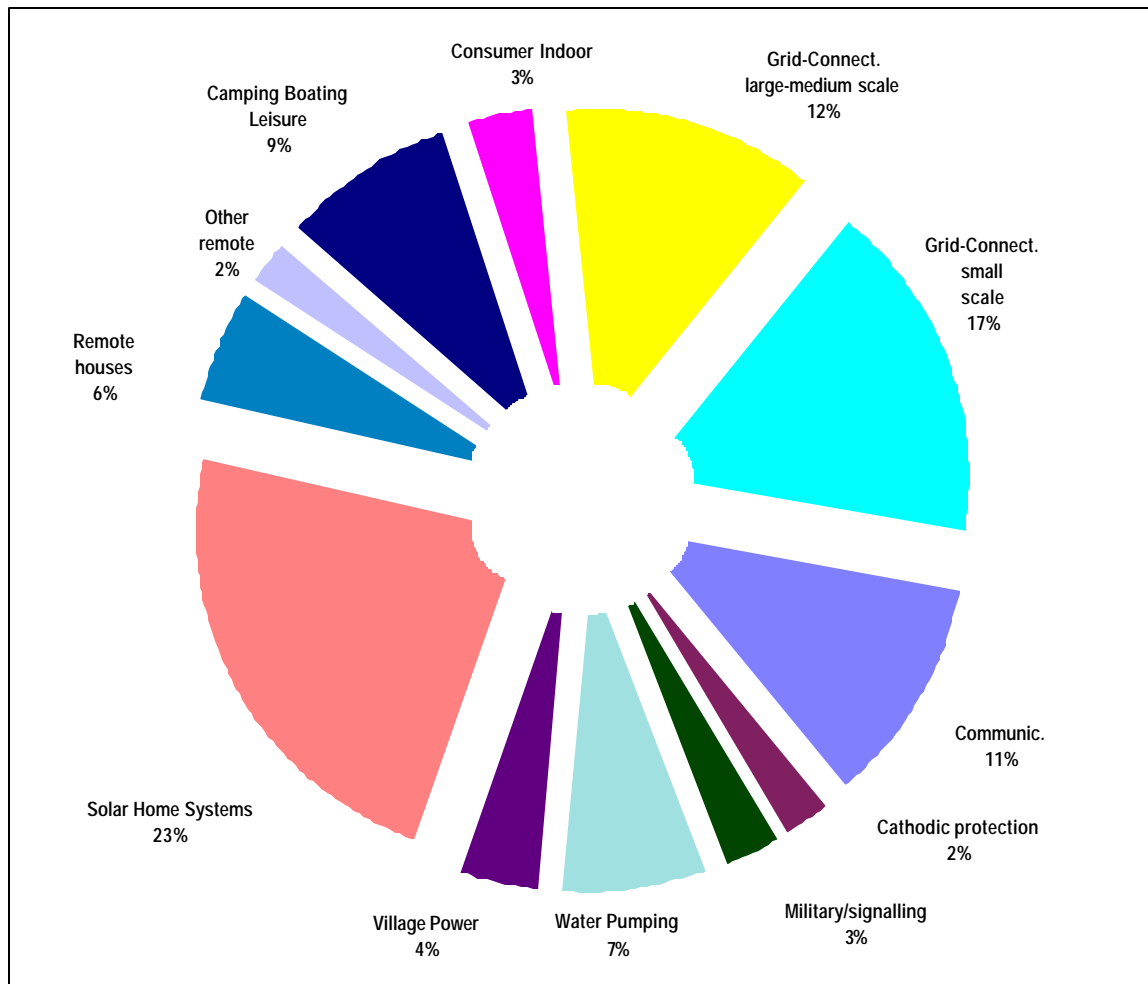
The demand side of the investigated geographical area is presented by quantifying the historic evolution of PV shipments per main application segment. Specifically the grid-connected market is presented subdivided into the larger-scale utility bulk power market segment and the small-scale rooftop/building integration market segment. The stand-alone market is subdivided into its main market categories, namely remote industrial, remote rural and consumer/leisure, which in turn are further subdivided into their specific sub-market segments down to the level of communication applications, Solar Home systems, PV pumping, village power, etc.

For each of these market segments, the shipments and the presently installed capacities are quantified and characterised, as well as the geographical areas of destination. Furthermore an estimate for the related demand potential is given, and the specific market barriers are identified and discussed.

Market forecasts

Between the present day and 2010, demand side requirements are expected to change so that a far higher proportion of PV sales will be for grid-connected applications - ie. power plants or rooftop/facade integration. Predictions for the year 2010, suggest that the major applications for PV will be Solar Home Systems (23%), Small-scale grid-connection (17%), large-scale grid-connection (12%), communications (11%).

The Business as usual 2010 market forecast by application (Total 3,900 MWp installed)



An integrated computer based world PV market model was used to develop market scenarios and to extrapolate these to the year 2010. The model incorporates the correlations between interdependent market parameters, such as between shipments and manufacturing capacities, installed PV generation capacities, market shares, investments required for manufacturing capacity increases, generated employment, etc.

Five different scenarios for PV market development are presented, assuming market growth rates of 15% (business as usual), 20%, 25%, 30% and 35% (extreme growth). The associated investment needed to achieve the manufacturing capacity increase and predictions for PV sector employment creation for each scenario are also presented.

Even to achieve the “business as usual” market development, the PV industry will have to invest some 7-8% of annual sales to meet the required increase in manufacturing capacity.

Enhanced market growth scenarios to 2010

What is required		to reach in year 2010 a whole world PV market scenario of:				Europe (assuming 32% of capacity installed in EU)	
World PV market growth rate	Investment for manufacturing capacity increase	Annual shipments	Cumulative installed capacity	PV sector Employment	Remarks	Cumulative installed capacity	PV sector Employment
% year	% of sales	MWp/year	MWp	Employed		MWp	Employed
15%	7,2%	630	3.900	152.000	Business as usual, will develop spontaneously	1.200	32.000
20%	9,3%	1.240	6.300	261.000	Achievable by eliminating market barriers	2.000	56.000
25%	11,1%	2.380	10.200	453.000	Requires consistent market stimulation	3.300	98.000
30%	12,8%	4.460	16.700	783.000	Requires breakthrough in technology and costs	5.300	170.000
35%	14,4%	8.160	27.300	1.345.000	Extreme scenario	8.700	294.000

The scenarios assume that Europe will succeed in strengthening its market position so that in 2010 35% of the total PV generation capacity will be installed in Europe. To reach this goal, the market share and manufacturing capacity of the European PV industry will have to be significantly higher than 35% to allow for exports to other parts of the world.

VOLUME 4 *Micro and Macro Economics for sustainable policies*

This volume presents the current status of photovoltaic technologies. In particular an in depth analysis of the crystalline silicon production process together with a detailed sensitivity analysis have been carried out by means of a specially developed computer model.

A strategy for the development of the photovoltaic technology has been formulated and one possible technological evaluation to the year 2010 is described to achieve a kWh cost < 0.20 ECU.

An analysis of the Balance of System (B.O.S.) cost was also undertaken together with a comparison between the PV-kWh cost and the Fossil Fuel-kWh cost.

The analysis of the present status of photovoltaic technologies leads to the following final conclusions.

Crystalline silicon based PV modules

The crystalline silicon technologies, mono and poly, are at present the only ones able to produce PV modules which can be used for large scale power plants for electricity generation.

The present production cost of these modules is about 3.3 ECU/Wp for integrated production plants from wafer to module with production volumes of about 2 - 3 MWp/year/shift. Actions aimed first at increasing the overall process yield, which is currently rather low and afterwards improving the conversion efficiency, will be able to reduce the costs to about 1.8 ECU/Wp.

This result is obtained through the optimisation of the processes and of the existing plants without introducing new design devices which could certainly produce better efficiencies (up to 18%) but which at the same time would need new investments.

An increase of the plant production volumes has a limited effect on the production costs which are above all else affected by the material costs which account for 50% of the module cost. Therefore, any volume increase should be justified by a real market demand rather than by hopes to achieve decreases in costs.

In order to take best advantage of cost reductions arising from economies of scale, the optimum plant would have a production of 10 MWp/year/shift.

Alternative technologies

To further decrease module costs below 1.8 ECU/Wp it is necessary to develop technologies different from the traditional crystalline silicon. It will therefore be necessary to carry out considerable investments in Research and Development to overcome the threshold of 1.8 ECU/Wp and to allow further PV diffusion into the energy market.

B.O.S. problem

The present B.O.S. cost of large grid connected plants is about 2800 ECU/kWp, representing about 46% of the present plant cost.

The analysis of the data gathered from recent European plants foresees a decrease of B.O.S. cost down to about 2250 ECU/kWp. This situation is very negative because it makes the efforts carried out at technological level to decrease the module Wp costs almost useless. To overcome this the B.O.S. cost decrease must correspond to the module cost decrease, so that the plant cost would be made of two approximately equal components.

As far as the B.O.S. component related to the area required for mounting is concerned, a positive solution could be to use PV in pre-existing structures or those which have to be built for other purposes: roofs, terraces, platform shelters, buildings façades.

This analysis has as a main result the fact that the present module and B.O.S. technologies are able to reach the objective of the ALTENER Programme which foresees 500 MWp installed in Europe in 2005, a module cost of about 1.8 ECU/Wp, a B.O.S. cost of 1 ECU/Wp for a kWh cost equal to 0.18 ECU/kWh (1994 money value).

To enable the research results to be transferred to production, investments to improve the production lines and a reasonable time to start the new production process are needed.

These results would not be sufficient, however, to achieve the objective suggested at the Madrid Conference "An Action Plan for Renewable Energy Sources in Europe" of 16 TWh/year of PV electric energy in Europe by 2010.

To reach this objective, it is necessary to produce electricity at a cost no higher than 0.12 ECU/kWh which corresponds to a module cost no higher than 0.8 ECU/Wp, a B.O.S. cost of 1 ECU/Wp, a module efficiency of at least 120 Watt/m², and a plant life-time of at least 25 years. See Volume 4 for a detailed analysis.

The present technology is not able to ensure these performances but the new alternative technologies are very promising and they could meet the desired objectives as long as considerable investments are rapidly carried out.

At the same time it is necessary to sustain the market with demonstration plants of suitable dimensions to monitor results step by step. The projected ALTENER target of 500 MWp to be installed in Europe by 2010 could be viewed in this context and suitable case studies should be undertaken.