International Energy Agency

Co-operative Programme on Photovoltaic Power System

Task 1

Exchange and dissemination of
information on PV power systems

National Survey Report of PV Power Applications in Portugal

2002

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May 2003

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i Foreword

The International Energy Agency (IEA) founded in November 1974, is an autonomous body within the framework of the organisation for Economic Co-operation and Development (OECD), which carries out a comprehensive programme of energy co-operation among its 23 members countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems Programme (IEA-PVPS) is one of the collaborative R & D agreements established within the IEA and, since 1993, its participants have been conducting a variety of joints projects in the applications of photovoltaic conversion of solar energy into electricity.

The twenty participating countries are Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), Finland (FIN), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), The Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), The United Kingdom (GBR), and The United States (USA). The European Commission is also a member.

The overall programme is headed by an Executive Committee composed of one representative from each participating country , while the management of individual research projects (tasks) is the responsibility of Operating Agents. Eight Tasks have been established, and currently five are active. Information about these task can be found on the public website www.iea-pvps.org. A new task concerning urban-scale deployment of PV systems is being developed.

The objective of Task 1 is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of photovoltaic power systems.

ii Introduction

This report gives information about the most important achievements in the PV power field in Portugal during 2002.

It is only a summary of the most important developments and applications of photovoltaic power systems and does not pretend to be complete in any way.

iii Definitions, Symbols and Abbreviations

For the purpose of the National Survey Reports, the following definitions apply:

PV power system market: The market for all nationally installed (terrestrial) PV applications with a PV power capacity of 40 W or more.

Installed PV power: Power delivered by a PV module or a PV array under standard test conditions (STC) – irradiance of 1 000 W/m^2, cell junction temperature of 25 ºC, AM 1,5 solar spectrum – (also see ´Peak power´).

Peak Power: Amount of power produced by a PV module or array under STC, written as W.

PV System: Set of interconnected elements such as PV modules, inverters that convert d.c. current of the modules into a.c. current, storage batteries and all installation and control components with a PV power capacity of 40 W or more.

Module manufacturer: An organisation carrying out the encapsulation in the process of the production of PV modules.

Off-grid domestic PV power system: System installed in households and villages that are not connected to the utility grid. Usually a means to store electricity is used (most commonly lead-acid batteries). Also referred to as ´stand-alone PV power system´.

Off-grid non domestic PV power system: System used for a variety of applications such as water pumping, remote communications, telecommunication relays, safety and protection devices, etc. that are not connected to as the utility grid. Usually a means to store electricity is used. Also referred to as ´stand-alone PV power system´.

Grid-connected distributed PV power system: System installed on consumers premises usually on the demand side of the electricity meter. This includes grid-connected domestic PV systems and other grid-connected PV systems on commercial buildings, motorway sound barriers, etc. These may be used for support of the utility distribution grid.

Grid-connected centralised PV power system: Power production system performing the function of a centralised power station.

Turnkey price: Price of an installed PV system excluding VAT/TVA/sales taxes, operation and maintenance costs but including installation costs. For an off-grid PV system, the prices associated with storage battery maintenance/replacement are excluded. If additional costs are incurred for reasons not directly related to the PV system, these should be excluded. (E.g. If extra costs are incurred fitting PV modules to a factory roof because special precautions are required to avoid disrupting production, these extra costs should not be included. Equally the additional transport costs of installing a telecommunication systems in a remote area are excluded).

Field Test Programme: A programme to test the performance of PV systems/components in real conditions.

Demonstration programme: A programme to demonstrate the operation of PV systems and their applications in real conditions.

Market deployment initiative: Initiatives to encourage the market deployment of PV through the use of market instruments such as green pricing, rate based incentives, etc. These may be implemented by government, the finance industry, utilities, etc.

NC: National Currency

Final Annual yield: Total PV energy delivered to the load during the year per kW of power installed.

Performance ratio: Ratio of the final annual (monthly, daily) yield to the reference annual (monthly, daily) yield, where the reference annual (monthly, daily) yield is the theoretical annual (monthly, daily) available energy per kW of installed PV power.

1 Executive Summary

There´s a new trend for photovoltaics in Portugal based in national investment subsidies and a legal framework for feed-in tariffs for the production of electricity from PV systems.

However, there´s few critical barriers still remain for the widespread of PV in the built environment: PV price, equipment and installer´s certification, low voltage grid interconnection legislation, building codes for PV integration.

A total of 383 kW of PV power has been installed until the end of 2002. Nearly all the photovoltaic applications done in Portugal were stand-alone (186 kW), followed by off-grid non domestic (124 kW), and grid connected installations (73 kW). The rate of growth of the total installed capacity between 2001 and 2002 was 30 %.The average annual growth in the period from 1995 to 2002 was 35 %.

System prices for on-grid turnkey applications costs maintains steadily at 7 € per each W installed.

2 The implementation of PV Systems

The PV power system is defined as the market of all nationally installed (terrestrial) PV applications with a capacity of 40 W or more. A PV system consists of modules, inverters, batteries if required and all installation and control components for modules, inverters and batteries.

2.1 Applications for photovoltaic

The breakdown of the percentages per each PV application is as following:

- 49 % in the domestic sector
- 32 % in the service sector (TV and telephone transmitters, parking meters, water pumping)
- 19 % in grid connected systems

Under the Programme "Harmony" that succeeded to the previous "Sunflower" Programme, BP Solar has increased the number of filling station with grid-connected PV systems in Portugal. This Programme represents the most visible PV private initiative in Portugal and is responsible for 95 % of the overall building integrated PV power installed in Portugal.

The effect of the new government framework for the deployment of photovoltaic is still not visible in the market development. The market seems to stabilise at around 300 kW installed power per year, mainly in stand-alone applications.

2.2 Total photovoltaic power installed

The total cumulative PV power for each sub-market on the 31 December of each year from 1992 onwards is listed in Table 1. These figures are based in surveys carried out by DGE (Government Directorate General for Energy), EDP (electrical utility) on a yearly basis, and rely on the data provided by PV system installers and the main institutions/organisations/companies which promote PV in Portugal.

Sub-market/application	31 Dec. 1992	31 Dec. 1993	31 Dec. 1994	31 Dec. 1995	31 Dec. 1996	31 Dec. 1997	31 Dec. 1998	31 Dec. 1999	31 Dec. 2000	31 Dec. 2001	31 Dec. 2002
Off- grid domestic	138	171	202	255	321	384	434	484	639	718	901
Off-grid non-domestic	31	38	46	69	91	126	176	176	237	273	375
On-grid distributed	-	10	10	12	12	17	38	184	268	319	392
On-grid centralised	-	-	-	-	-	-	-	-	-	-	-
TOTAL	169	219	258	336	424	527	648	894	1144	1210	1668

2.3 Major projects, demonstration and field test programmes

The most significant projects realised in 2002 were:

PV Electrification of 6 post guards in the Island of Madeira - A demonstration programme aiming the installation of stand alone PV power systems in six post guards in the Madeira archipelago. The installed PV power range between 300 W to 1600 W. Two of this installations are complemented with small wind generators of 1500 and 400 W. This programme was oriented by the Regional Civil Engineering Laboratory and totally supported by the Regional Government of Madeira.

The BP "Harmony project" - This project succeeds to the former "Sunflower project", and consist, as previously, in the integration of PV modules on BP filling station canopies. 5 grid-connected systems, were installed during 2002, with power ranging from 7,2 kW to 26,54 kW. Part of the energy generated by the PV system is for self-consumption while the remaining is injected to the public grid. So far about 350 kW have been installed by BP Solar in Portugal.

Photo 1. - Thin film photovoltaic modules integrated into BP filling station

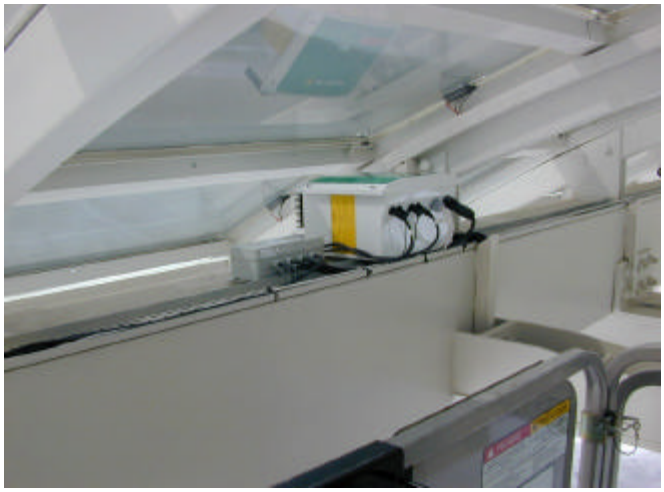

Photo 2. – PV modules electrical connections and support structure

Project Date plant start up	**Technical data/economic data**	**Objectives**	**Main accomplishments until the end of 2002 / problems and lessons learned**	**Funding**	**Project management**	**Remarks**
"PV electrification of 6 post guards in the Island of Madeira"	6 off-grid PV systems: • 4 Autonomous and independent PV systems with a total power installed of 1,5 kW each • 1 hybrid system with a PV power system of 1,5 kW complemented with a 400 W wind turbine • and 1 hybrid system with a PV power system of 300 W complemented with a 1,5 kW wind turbine Batteries cells capacity ranging from 1200 to 1500 Ah (C100) Total project cost : 80000 €	To supply electricity from renewable energy sources (PV, wind) to power	No major problems were encountered related to the system installation	The total funding of the project was provided by the Regional Government of Madeira	Regional Civil Engineering Laboratory	
The BP "Harmony project"	5 Grid –connected PV systems integrated into BP filling stations with a total installed power of 73 kW (7,2 kW + 13,29 kW + 26,58 kW + 18,24 kW + 7,68 kW)	To develop standard canopy integrated PV system on filling stations	Realisation of 5 canopy integrated PV systems	The project was supported by BP Solar and by the POE Programme.	BP Solar	Although the utility is mandated to buy electricity provided by PV systems at higher rates, up to date the generated electricity is supplied freely to the grid.

Section 2.4 Highlights of R&D

PV R&D activities mainly address amorphous and thin film silicon technologies and are carried out by:

- Universities, namely CENIMAT - the department of Materials Science, Faculty of Sciences and Technology from the New University of Lisbon, LAFS - Laboratory of Photovoltaic Applications and Semiconductors from the University of lisbon, and the Department of Ceramics and Glass Engineering/ UIMC from the University of Aveiro

- Public Research Laboratories - INETI – National Institute for Engineering and Industry Technology

- Private Research Institutions - INESC Porto - Institute for Systems and Computers Engineering

Dissemination and demonstration actions concerned mainly remote electrification and professional system applications (TV and telephone repeaters, parking meters, water pumping), as well as some grid-connected systems. They involve Energy Agencies (ADENE and regional agencies) and solar associations like SPES- Portuguese Solar Energy Society and APISOLAR – Portuguese Solar Industry Association, but also Universities and Public Research Laboratories.

Non government institutions and private companies are also involved in PV implementation

The largest Portuguese electrical utility (EDP) also participated in a number of PV projects, as part of R&D activities on New Energy Technologies, including demonstration projects supported by the EU, either in stand-alone and on-grid distributed systems.

Section 2.5 Public budgets for market stimulation, demonstration/field test programmes and R&D

There´s no specific programme in Portugal aiming the support of projects in the photovoltaic domain. The available funding programmes are mostly generics covering several economic sectors and scientific domains.

Demonstration initiatives may apply to the measure MAPE of the Operational Programme for Economic Activities (POE) which support projects in the energy sector, aiming energy diversification, improved energy efficiency and increased use of renewable energy.

Research and Development projects are funded by the Portuguese Foundation for Science and Technology under the Programme POCTI - Operational Programme for Science, Technology and Innovation.

The programme PRAI - Regional Programme of Innovative Actions supports demonstration initiatives and transfer of technology at a regional level, namely for the Centre Alentejo and Azores regions. This programme aims to reduce the technology gap between regions.

Table 3 Total public budgets (in €) for R&D, demonstration/field test programmes.

	R&D	Demo / Field test	Market
National	92688000	Not applicable*	-
State/regional	-	11186000	-
Total	92688000	-	-

* The total budget of the MAPE programme covers the years 2000-2006, therefore it was not possible to desegregate the budget for 2002.

Regarding fiscal incentives, deductions to the tax total amount is allowed for buyers of new renewable energy equipment up to 30% the equipment cost, with a maximum ceiling of 700 Euros. For corporate income tax purposes depreciation of the investment in solar equipment can be write off in four years.

3 Industry and growth

3.1 Production of photovoltaic cells and modules

Shell Solar has a factory located in Évora, manufacturing mono and multi-crystaline PV modules, mainly for exports. Only cell assembling and encapsulation fabrication is performed in this plant. The cells are imported from Shell´s manufacturing plants in Amarillo in the United States (mono-crystaline) and in Germany (multi-crystaline). In 2002, Shell Solar manufactured more than 8000 mono-crystalline modules, with a total output of 10,8 MW.

This manufacture plant had initially a production capacity of 5 MW which was progressively increased to 15 MW. Shell Solar plans to expend even further its production capacity up to 40 MW until 2010.

Table 4: Production and production capacity information for the year for each manufacturer

Cell/Module manufacturer	**Technology**	**Total Production (MW)**		**Maximum production capacity (MW)**	
		Cell	Module	Cell	Module
Shell Solar	mc- SI	-	10,8	-	15

Table 4a: Typical module prices (€/W) in 2002

Year	**2001**	**2002**
Modules price (s) *	4	3,5

* this price varies widely upon the size of the order

3.2 Manufacturers and suppliers of other components

AUTOSIL is the only one solar type and stationary battery manufacturer, since SPAT – Portuguese Society of Tudor Accumulator, S.A., no longer produce stationary lead-acid batteries in Portugal.

A dozen companies are supplying and installing PV modules and BOS components imported from the EU, USA and Japan. A few of theses companies produce power electronics for stand-alone PV applications (small charge regulators, ballasts, etc...).

3.3 System prices

Table 6: Turnkey Prices of Typical Applications

Category/Size	**Typical applications and brief details**	**Current prices per W in €**
Off-grid up to 1 kW	Telecommunications, water pumping	Typically 12
Off-grid > 1 kW	Domestic	Typically 10
Grid connected	1-5 kW mounted system	Typically 6,5
Grid connected Up to 10 kW	Filling stations integrated system	-
Grid connected > 10 kW	Filling stations integrated system	-

Table 6a.: National trends in system prices for off-grid applications

Year	1998	1999	2000	2001	2002
Price €/W	11-13,5	10-12,5	9-11	9-11	9-11

3.4 Labour places

Apart from Shell Solar manufacture plant there's no significant direct labour places involved in the PV market. The small companies that provide support services have no more than two employees mainly involved in PV issues. However several new companies are being created stimulated by the recent new government framework for photovoltaics.

A considerable effort has being made in R&D. It is now an important source of jobs accounting with 17 % of direct labour places. CINEMAT is taking the lead with a permanent senior staff composed with 14 full professors, researchers and post-graduates in engineering.

The following table shows the actual labour places within the PV energy sector:

Research and development : *(universities and private-public research institutions)*	29
Manufacturing of PV modules:	90
All other: *(electricity companies, installation companies, consulting companies specialised in PV, local & regional authorities)*	47
Total labour places:	**166**

4 Framework for deployment (Non technical factors)

The Portuguese energy system is characterised by:

A strong dependency on imported fossil fuels (about 85 % of the primary energy consumption), and consequently a high energy bill

The highest GDP energy intensity among the European Union (EU) member countries, reflecting the low efficiency of the energy system.

Aiming at simultaneously assuring the security of supply, reducing the energy bill and preserving the environment, the E4 strategy relies upon three main lines of action:

- Diversifying the access to energy sources available in the market and increasing the security of services provided by energy suppliers;

- Promoting the improvement of energy efficiency, thereby contributing to reduce GDP energy intensity and the external energy bill, on one hand, and responding to climate change, on the other hand, laying special emphasis on the opportunities and means of optimising demand-side efficiency

- Promoting the use of endogenous energy sources, namely hydro, wind, biomass, solar (both thermal and photovoltaics) and waves, establishing a highly dynamic compromise between technical and economical viability and environmental constraints.

While in the past 5 years the main priorities were focused on the introduction of natural gas (aiming at progressively substituting oil and coal in the energy balance) and liberalisation of the energy market (by opening this former state owned sector to competition and private investment), the emphasis for the next 8-10 years will be put on energy efficiency (supply and demand sides) and exploitation of endogenous (renewable) energy.

4.1 New initiatives

A set of initiatives (legislation, incentive schemes) have been introduced in 2001/2002 aiming at stimulating the market (private investors), not only for RES electricity, but also for CHP, solar thermal use and building energy efficiency, namely:

- Decree-Law defining the conditions regulating the awarding and management of grid interconnection points for Independent Power Producers.

- National programme for supporting wide diffusion of solar energy efficiency and use of endogenous energies in the framework of the POE Programme (operational Programme for Economical Development).

The Portuguese strategy for the promotion of renewables, introduced by the E4 Programme (Energy Efficiency and Endogenous Energies), created a favourable legal framework and incentive schemes which will likely contribute to meet the targets agreed under the EU Directive on the promotion of electricity from RES in the integral electricity market. Under this Programme a goal of 50 MW of photovoltaic power generation was settle for 2010.

Among the government initiatives introduced in the framework of the E4 Programme, the new (revised) legislation promoting renewable electricity deserves special emphasis: the tariff rates are now differentiated by technology. For PV, the new buy-back rates of 0,29 €/kWh (systems over 5 kW) and 0,51 €/kWh (systems under 5 kW), make investments considerably more attractive than the former tariff (0,06 €/kWh).

However for the interconnection of PV micro-generators to the low voltage public grid, a new legal figure as been created: producer-consumer, allowing single persons to qualify as independent power producers, but obliging self-consumption up to 50 % of the total produced energy. The tariff rate was maintained at about 0,29 €/kWh.

Financial incentives for renewables and energy efficiency applications are available under the Support Measure for the Use of Energy Potential and Streamline Consumption (MAPE), integrated within the POE Programme (2000- 2006) – III EC Framework Programme. The last amendments that have been introduced in 10 April 2002 make this measure consistent with the objectives of the E4 Programme. Besides grid-connection projects grants are now also provided to autonomous photovoltaic applications up to 40 % of the total eligible costs (maximum eligible limit: 3 000 €/kW), with a maximum of 1 500 k€ per application. The non-reimbursable part accounts for 50 % of the total subsidy, reaching 100 % when the promoter is a public entity. The total indicative budget for renewables and co-generation projects is 350 M€ for the whole period.

There´s no special technical specifications for the connection to the grid developed so far. It is possible that interconnection of small scale generators to the distribution system will not be well accepted by the utility since it may adversely affect the grid stability and reliability. Besides the lack of building codes for PV integration, it may be one of the most important barrier for the widespread of PV in the built environment in Portugal.

4.2 Indirect policy issues

Portugal ratified the UN Framework Convention on Climate Change on 21 December 1993. In the European Environment Council of 17 June 1998 Portugal was allowed to increase its emissions by 27% for the 2008-2012 period over the 1990 levels. On 26 December 2001, Portugal decided to proceed with the implementation of the Kyoto Protocol resolutions.

Under its obligations in regard to the Kyoto Protocol the Portuguese government published in March 2002 the first version of the National Plan for Climate Change (PNAC). This national programme should specifies the national climate policies, quantifies the reduction required to achieve the Kyoto targets, and propose measures and targets aiming the control and reduction of greenhouse gases emissions.

It is a privileged technical and political instrument that involves several economic public and private organisations toward a new framework for sustainable development in Portugal.

4.3 Standards and codes

No specific PV standards are available for PV (European or IEEE standards apply in general). Only generic guidelines are provided by the Independent Power Producer Law, not specific for photovoltaic interconnection with the grid.

5 Highlights and prospects

The introduction of the new PV development framework has already contributed to an increased interest in PV applications, of which 2 initiatives deserve a special emphasis:

- The first building (facade) integrated, grid-connected PV system (12 kW) has been designed by INETI and will be installed and demonstrated at the campus of INETI with the support of the POE programme.

- The world largest PV power plant project (64 MW) is currently under preparation.

The 50 MW target for PV power generation defined under the E4 Programme may be reached earlier with the 64 MW power plant approval.

A new facility is foreseen for the manufacture of the modules in the South of Portugal. This new plant will boost the total production capacity of PV modules in Portugal which is actually 15 MW.

This new trend may force the Ministry of Economy to review the actual target for photovoltaics, increasing further the national goal up to 150 MW.

Further highlight is the fiscal penalisation due to the European fiscal harmonisation of the TVA which lead to the increase of the rate from 5 % to 12 % for renewable energy equipment.