International Energy Agency

CO-OPERATIVE PROGRAMME ON PHOTOVOLTAIC POWER SYSTEMS

Task I
Exchange and dissemination of information on photovoltaic power systems

National Survey Report of PV Power Applications in *Country* *1999*

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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 member countries. The European Commission also participates in the work of the Agency.

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

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 seven are active.

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

ii Introduction

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to facilitate the exchange and dissemination of information on the technical, economic and environmental aspects of photovoltaic power systems for application by utilities and other users. An important deliverable of Task 1 is the annual International Survey Report on PV power applications. This report gives information on trends in PV power applications in the twenty member countries, and is based on the information provided in the National Survey Reports which are produced annually by each Task 1 participant. The guidelines given in this document are intended to assist national experts and other participants of Task I in the preparation of their annual PVPS National Survey Reports.

iii Definitions, symbols and abbreviations

For the purposes of this report, the following definitions apply:

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

PV system: Modules, inverters, batteries and all installation and control components for modules, inverters and batteries with a PV capacity of 40 Wp or more.

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

Off-grid domestic: PV systems installed in households and villages which are not connected to the utility grid.

Off-grid non-domestic: PV systems used for a variety of applications such as water pumping, remote communications, safety and protection devices, etc. which are not connected to the utility grid.

On-grid distributed: A PV 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.

On-grid centralised: PV systems used for support of the utility distribution grid performing the function of a centralised power station.

Turn-key price: Price of an installed PV system excluding VAT/TVA/sales taxes, operation and maintenance costs but including installation costs. For an off-grid system, the prices associated with battery maintenance/replacement should be 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 the interior of Greenland should not be included.)

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 to the general public and potential users/owners.

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. They may be implemented by government, the financing industry, utilities etc.

NC: National Currency

Final annual yield is defined as the total energy delivered to the load during the year per kWp installed.

Performance ratio is defined as the ratio of the final yield to the reference yield, where the reference yield is the theoretically available energy per year per kWp installed.

1 Executive summary

The utilisation of photovoltaics per capita within the UK continues to be small in comparison to many other developed nations, however the total installed capacity has increased from 173kWp in 1992 to just over 1MWp in 1999. In the last year the increase in the total installed capacity of PV in the UK jumped by an encouraging 64%. The increase in grid connected systems installed in the UK has continued in 1999 with the largest increase in capacity being in this sector of the market largely due to the ongoing BP Solarex Sunflower project.

The domestic and building integrated use of PV continued to grow in 1999 with the average size of installations increasing by a discernible measure.

The UK PV industry remains significantly active in the global view, carrying out research, development, consultancy and installation work all over the world. Significant market incentives from the government have failed to emerge in 1999, though a reduction for tax in some sectors of PV materials market is to be introduced in 2000. The introduction of new electricity trading arrangements in the UK and division of the roles of supplier and distributor will change the way in which electricity is traded. These changes will open up possible opportunities for small scale renewable generators if the role of aggregators for small scale renewable generation sources are favourably viewed.

The UK is a significant player on the global PV scene. PV companies and the British Photovoltaic Association are concerned that the current size of the home market is inadequate to sustain the UK PV industry. During the year, there has been active lobbying of the UK Government to increase their financial support for PV and to provide market incentives. With a viable home market, the UK should be able to increase its share of the rapidly expanding world market. This would provide increasing revenues, extra jobs and growth of our skills in PV. It would also assist with the reduction in the cost of PV systems PV could then take a fuller part in the Government's programme to generate 5% of all electricity from renewables by 2003 and 10% by 2010.

This is the second annual UK National Survey Report on PV power systems produced as part of Task I of the IEA Implementing Agreement on photovoltaic power systems. The information contained in this report, and those of the other participating countries, will be used to produce the IEA-PVPS International Survey Report for 1999.

2 The implementation of PV systems

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

2.1 Applications for photovoltaics

Grid-connected PV power systems in the UK range from demonstration systems of a few hundred watts up to commercial systems of many tens of kilowatts. In 1999 the PV application area with largest increase in use has been in the grid-connected sector of the market. This increase was largely due to BP Solarex installing roof mounted grid connected PV systems on 23 of its new garage forecourts.

With the exception of a small number of PV arrays used for test and demonstration purposes, all the grid connected systems in the UK are either mounted on buildings or form an integral part of a building. There are no centralised grid-connected PV power systems used for the purpose of power generation in the UK.

The UK market for domestic, off-grid applications is smaller than for non-domestic and on-grid applications include providing power for:-

- Remote holiday homes
- Caravans
- Boats
- Leisure items such as garden fountains.

Off-grid, non-domestic uses include:-

- Marine applications such as lighthouses, light ships and light buoys
- Telecommunications equipment such as repeaters and telephones in remote areas
- Traffic and weather monitoring stations
- Gas distribution control systems, data logging and automatic meter reading
- Water and sewage monitoring
- Cathodic protection of pipelines and other metal structures against corrosion
- Track greasing systems to reduce wear on railway lines
- Agriculture and forestry
- Information terminals and ticket machines
- Any form of remote instrumentation

2.2 Total photovoltaic power installed

The total cumulative installed PV power for the UK sub-markets of on/off-grid domestic, on-grid distributed and on grid centralised on the 31 December of each year from 1992 to 1999 are shown in Table 1.

Table 1 The cumulative installed PV power in 4 sub-markets.

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

	kWp	kWp	kWp	kWp	kWp	kWp	kWp	kWp
off-grid domestic	7	47	52	57	69	83	108	119
off-grid non-domestic	166	213	232	252	279	316	254	276
on-grid distributed	0	6	54	59	75	190	328	736
on-grid centralised	0	0	0	0	0	0	0	0
TOTAL	173	266	338	368	423	589	690	1131

2.3 Major projects, demonstration and field test programmes

2.3.1 Nottingham University Jubilee Campus building.

Completed in 1999 the new Jubilee campus is a contemporary low-energy design campus building utilising 54 kWp of mono-crystalline panels. The aim of the campus building is to be a model of sustainable development to the large numbers of students passing though the building, thereby raising awareness of the benefits of PV installations of this type. The total project cost, for the campus development, was £25.5M for which the University received funding assistance from the EU THERMIE programme and the DTI totalling £750,000 for the low-energy building specification.

2.3.2 The Earth Centre, Conisbourough

The Earth Centre is located in South Yorkshire and was built to create a visitor attraction focussed on environmental issues whilst being educational and entertaining. The centre has Europe's largest PV weather canopy, and the largest PV power system in the UK, which has been built using funding from the DTI's new and renewable programme, the Millennium Commission and the EU THERMIE programme. The canopy consists of 970m^2 high efficiency monocrystalline cells which provide 107 kWp to the adjacent exhibition building (equating to 30% of the total load). The first phase of the development opened in 1999 and completion of the canopy is expected in early 2000. Future plans for the project consist of a focussed promotion of PV systems and technology to target groups consisting of families, businesses and educational establishments. Problems encountered with the project have been caused by the complexities of the financial and commercial arrangements arising from meeting the

criteria of all the projects sponsors.(For more information visit:www.earthcentre.org.uk)

2.3.3 G8 Solar Pavilion, Birmingham/S.Wales

A showcase Solar Pavilion incorporating a 15 kWp PV system was opened at the recent G8 summit in Birmingham. The system , designed and installed by a consortium including BP, Ove Arup and Pilkington glass, uses energy saving glass and a solar heat reclamation system. Since the G8 summit in Birmingham this system has been relocated to South Wales.

2.3.4 BP Amoco Solar Sunflower project

This international project continues with the installed capacity in 1999 having a major impact not only on the figure for the grid connected PV but the total installed capacity with an additional 400kW being installed in 1999. 23 new garage forecourts have been equipped with plans for existing BP Amoco forecourts to be converted in the near future.

2.3.5 Bowater House, Sandwell Council, West Midlands

A 1960's tower block has been fitted with 4kW of monocrystalline PV modules as part of Sandwell councils commitment to Local Agenda 21. The project was solely funded by Sandwell MBC Housing department with the aim of combating fuel poverty amongst its tenants. 36 flats have been refurbished and the 4kW PV arrays, costing £84,000 are mounted on the rain screen cladding on the buildings façade.

Table 2: Summary of major projects, demonstration and field test programmes

Project Date plant start up	Technical data/Economic data	Objectives	Main accomplishments until the end of 1999/problems and lessons learned	Funding	Project management	Remarks
Nottingham university - Jubilee campus building 1999	54 kWp grid connected mounted on pitched roof. Integrated into a new building costing £25.5M	To build a new landmark campus which will be a model of sustainable development.		EU THERMIE Programme and DTI	Ove Arup	
Earth Centre, Conisbourough 1999-2000	107 kWp grid connected canopy. The Earth Centre PV canopy cost £1.6M	Educational and entertaining centre focussed on environmental issues	complex financial and commercial arrangements have caused problems	DTI, Millennium Commission and the EU THERMIE	Ecofys, NPAC, Pilkington	Largest PV Installation in the UK
BP Sunflower project - BP Service Stations Countrywide, 1999	PV panels fitted on 23 petrol station forecourts. Total output: 400 kWp installed at the 23 sites in 1999.	To project a 'Green Image' and to raise public awareness of PV power systems.	Fitted to new garages. Form part of a US$50m project by BP to install PV power systems at 200 service stations worldwide.	BP Solarex BP Amoco Filling stations	BP Solarex	The largest contribution to the UK installed capacity to date.
SCOLAR Programme 1999 installations	PV systems for installation in schools and colleges. 100 installations planned. 500-690Wp. Mostly mono-crystalline silicon.	Raise pupils' awareness of the issues. Provide an educational resource Download performance data to the Internet. Participation in a nation-wide strategy.	Two 690W systems installed in 1999: London & Plymouth Difficulty finding new schools to take on scheme.	Foresight Technology Challenge Programme: 40%, Schools/Colleges: 40%,Partners: 20%	SCOLAR Consortium, HGa.	
G8 Solar Pavilion	15kW system - roof mounted	Showpiece PV system built for G8 summit meeting	Relocated to Baglan bay, S.Wales	BP Chemicals BP Sloarex	BP Chemicals	Originally located in Birmingham (1998)
Bowater House, Sandwell	4kW tower block Façade £84,000 cost	To combat fuel poverty by sustainable redevelopment	Complete - 36 flats	Sandwell MDC Housing Department	Ove Arup, BP Solarex	
Greenwich pavilion	12 kWp flat hangar roof using BP Solarex modules	Using Semi-transparent modules to create a functional 'dining terrace'	Completed	Millenium commission	Buro Happold, Richard Rogers, Active Cladding	

Section 2.4 Budgets for market stimulation, demonstration/field test programmes and R&D

Table 3 Budgets (in National Currency) for R&D, demonstration/field test programmes and market incentives.

	R & D	Demo/ Field test	Market
National/federal	£2.4M		
State/regional	-	-	-
Total	£2.4M		

Research and development of PV technologies is undertaken at a number of universities including Cardiff, Dundee, Durham, Imperial College London, Loughborough, the Open University, Reading, Southampton, Northumbria and Ulster. Funding for this work comes, primarily, from the UK government through the Engineering and Physical Sciences Research Council (EPSRC). A number of manufacturers and consulting companies are also involved with research, development and technology transfer in the field of PV. The main PV demonstration programme is called SCOLAR. The first PV systems under the SCOLAR programme were installed in schools and colleges in 1998. The aim is to have 100 SCOLAR installations at schools across the UK.

3 Industry and growth

3.1 Production of photovoltaic cells and modules

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

Module manufacturer	Technology (sc-Si, mc-Si, a-Si, CdTe)	Total Production (MWp) Cell Module	Maximum production capacity (MWp)

1 Intersolar	a-Si	1.5 MWp	2.5 MWp

Intersolar manufacture amorphous thin-film silicon PV cells and assemble them into modules in their factory at Bridgend in South Wales. Intersolar also distribute crystalline cells made by a variety of manufacturers. Production capacity was increased to 2.5MWp per annum in 1999 and a further increase to 3.0 MWp is planned for 2000. Intersolar is also a member of the SCOLAR consortium. Certification of modules is to IEC 61646 or equivalent. Intersolar also has ISO 9000 certification.

Crystalox based in Wantage near Oxford pioneered development of multi-crystalline silicon directional solidification as a production process for the PV industry and delivers automated equipment to many of the world's leading PV companies. In addition the company is also producing multi-crystalline silicon ingots and wafers for customers in Europe and Japan. Recent expansion of its ISO9001 certified facilities has increased capacity to 10MW, at the end of 1999, with further expansion scheduled for 2000.

3.2 Manufacturers and suppliers of other components

Table 5 Price of inverters for grid-connected PV applications.

Size of Inverter	<1 KVA	1-10 KVA	10-100 KVA	>100 KVA
Average Price per kVA (NC)	£800	£575	£525	-

Dulas Engineering is a worker-owned company specialising in renewable energy design and supply. A complete service is offered from supply of control equipment and inverters to complete systems for large building integrated PV.

Invertec Ltd supply a range of inverters for PV applications. Traditionally a low-voltage lighting manufacturer, now becoming a key-player in the PV industry in the UK

NADA (formerly Micro-Tech Ltd) based at Gateshead, Tyne & Wear, specialize in the manufacture of inverters for use with PV modules. The inverters that they manufacture range in size from units of a few hundred VA that are suitable for use in PV ac modules to units in the 10-100kVA range designed as central inverters for large PV systems.

National Power launched their Regensys energy storage system in 1999. The system is a redox flow cell with modular characteristics making it suitable for integration with large-scale renewable sources of generation. The cell has high cycle efficiency and low standby losses. The cell uses sodium bromide and sodium polysulphide to exchange energy across a bipolar regenerative membrane stack. The reversibility of the process, without degradation, makes the system attractive as a future way of storing energy generated by renewable resources. A 1MW system has been under test in Wales for several years.

3.3 System prices

Table 6: Turnkey Prices of Typical Applications

Category/Size	Typical applications and brief details	Price per Wp in £ (Stirling)
OFF-GRID Up to 1 kWp	Modules for the leisure market, schools and remote instrumentation/lighthouses	£10
OFF-GRID >1 kWp	Remote homes, housing schemes and some lighthouses	£8.5
OFF-GRID >1 kWp Specific case	PV/diesel hybrid system for remote off-grid farm	£13.75 inc. diesel system
ON-GRID Specific case	1-3 kWp roof tile system with turn key installation incl liason with architects/planners/ and utilities	£7
ON-GRID Up to 10 kWp	Building integrated PVPS on domestic and commercial buildings – utilising higher grade materials	£8
ON-GRID >10 kWp	BIPV systems on commercial buildings, filling stations and industrial buildings	£6

A survey of suppliers and installers of PV systems in the UK showed a general trend of cost reduction, although prices varied widely. Table 6 shows the turnkey prices for typical

applications. The general sentiment amongst suppliers/distributors on the cost of PV systems is that a cost reduction of somewhere in the order of 10% was seen in 1999.

4 Framework for deployment (Non-technical factors)

4.1 New initiatives

The British government's budget in early 2000 included a cut in value added tax (VAT) on energy saving materials from 17.5% to 5%. The reduced rate will be applicable some PV system installations in the UK with effect from April 2000.

4.2 Indirect policy issues

The introduction of new electricity trading arrangements in the UK and the division of the roles of electricity supplier and distribution network operator will change the way in which electricity is traded in the future. These changes along with the ending of the NFFO (Non-fossil fuel obligation) agreements will open up possible opportunities for small scale renewable generators if the regulatory framework is adapted to favour the smaller generator, as it must be adapted to allow fair competition. Electricity users will have greater freedom in the new electricity market and will have the choice of many suppliers, some providing energy exclusively from renewable sources of generation at a premium rate.

Renewable energy sources and more efficient forms of generation will be rewarded in the UK by means of the climate change levy. The levy will provide an incentive for business users to choose electricity from renewable sources, having the knock-on effect of encouraging the development of renewable generation sources.

4.3 Standards and codes

The grid connection of PV systems to the electricity network has been addressed by the development of the engineering recommendation G77 entitled: *"Recommendations for the connection of inverter-connected single-phase PV generators up to 5 kVA to public distribution networks"*. The recommendation will be used by regional electricity companies, PV system installers and PV equipment manufacturers to ensure that this category of PV installation meets laid down specifications on safety, operation and a range of other issues.

4 Future trends

The future trend for the UK utilisation of PV power systems looks set to continue in an upward direction particularly for grid connected systems. The use of PV in Building integrated programmes is on the increase with several larger scale projects planned for the year 2000, such as the Equinox Office block in London which will have a capacity of approximately 200 kWp. The UK Government's introduction of a domestic field trial will also have a significant contribution to the PV scene within the UK in and beyond the year 2000. Other planned developments in the residential PV sector are planned such as the Peabody trust 313 kWp installation which has been awarded EU Framework 5 funding approval.

Lobbying of UK Government departments continues with the aim of creating a viable home market in PV, in this way the UK should be able to increase its share of the rapidly expanding world market.

Annex A Exchange rate

The average exchange rate of the Pound sterling to the U.S Dollar in 1999 was:

£1 = $1.60

Annex B Method and accuracy of data

The information for this survey report has been drawn from many sources, the prime source was the database of PV installations in the UK. Information from this database, and other sources, was collated in a spreadsheet and sorted into the required categories and the necessary quantities summed. The estimated accuracy of the data is ±10%.