International Energy Agency

CO-OPERATIVE PROGRAMME ON PHOTOVOLTAIC POWER SYSTEMS

Task 1

EXCHANGE AND DISSEMINATION OF INFORMATION ON PV POWER SYSTEMS

National Survey Report of PV Power Applications in the United Kingdom

2001

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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 (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 joint 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 of America (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 seven are active.

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 has been prepared under the auspices of IEA-PVPS Task 1. An important deliverable of Task 1 is the annual International Survey Report (ISR) *'Trends in Photovoltaic Applications'*. The ISR presents summary information on trends in PV power applications in the twenty member countries, based on the information provided in the National Survey Reports (NSR) of each participating country.

This National Survey Report of PV Power Applications in the UK has been produced following discussions with, and input from, organisations and individuals involved in the development and implementation of PV Technology in the UK. It represents an overview of the key developments and achievements in the UK PV sector during the year 2001.

iii Definitions, symbols and abbreviations

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

Demonstration Programme: A programme to demonstrate the operation of PV systems and their application to potential users/owners.

DNO: Distribution Network Operator.

DFT: Domestic Field Trial - Demonstration programme of PV for use in residential applications, supported by the DTI.

DTI: (UK Government) Department for Trade and Industry.

EPSRC: The Engineering and Physical Sciences Research Council. EPSRC funds research and postgraduate training in universities and other organisations throughout the UK.

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

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

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

Grid-connected distributed PV power system: 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. These may be used for support of the utility distribution grid.

Installed PV power: Power delivered by a PV module or a PV array under STC – (also see 'Peak power').

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.

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

NC: National Currency (GBP - Pound Sterling)

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 the utility grid. Usually a means to store electricity is used. Also referred to as 'stand-alone PV power system'.

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

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.

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

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 Wp or more.

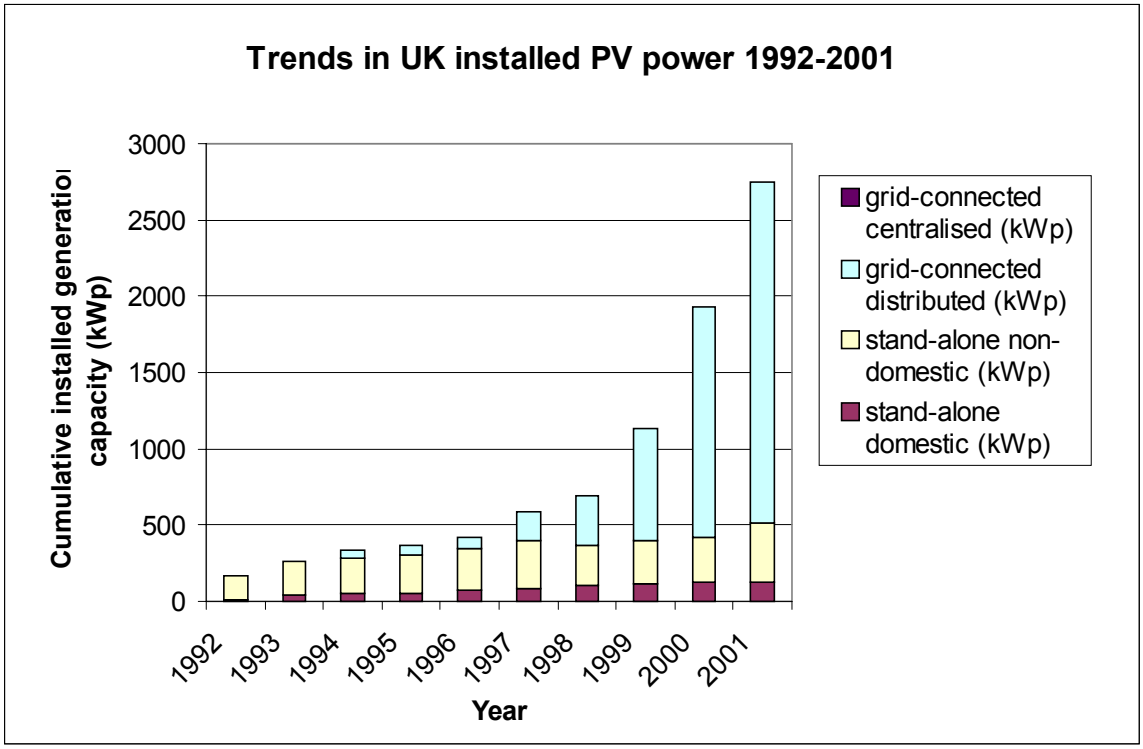
STC: Standard Test Conditions – irradiance of 1,000 W/m^2, cell junction temperature of 25°C, AM 1.5 solar spectrum

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 are excluded.

1 Executive summary

1.1 Installed PV power

There was a very small increase (3 %) in the annual installed generation capacity in 2001 compared to 2000. However, the cumulative installed PV generation capacity increased by over 42 % during the year. Very strong growth - over 220 % - was noted in the off-grid commercial application sector. This is a 'real' (i.e. unsubsidised) market. Also noteworthy was the rapid expansion of the grid-connected residential sector which is estimated to have grown by 250 %, compared to the 2000 estimate. The vast majority of installers reported significant increases in new installed generation plant in 2001 compared to their activity in 2000.



1.2 Costs & prices

Module prices are typically in the range GBP 3 to 3.5 per W for reasonable volume orders. For small orders (few modules) retail prices range from approximately GBP 3.8 up to GBP 5.4 per W.

Overall system prices have shown a slight increase in real terms (in the order of 7 %) since 2000. This trend is believed to be a result of continued heavy demand for modules in Japan and Germany keeping import prices high. The exception is for large-scale (>20 kW) simple commercial building sector which has remained at about GBP 4 /Wp installed - a reduction in real terms of about 2.5 %.

1.3 PV production

The UK's only major indigenous cell manufacturer, Intersolar, has not increased production (1.6 MW) or production capacity (3.0 MW) over that reported in 2000. The company has been reported to be planning a new manufacturing facility with a production capacity of 15 MW. Indications early in 2002 suggest that the company may choose to locate this on the Continent.

Crystalox, producers of multi-crystalline silicon blocks, increased production by 200 % in 2001 (compared to 2000); sufficient for 30 MW of cells. The company, now the UK's largest employer in the PV sector, increased production capacity to 58 MW in 2001 and plans to expand to 90 MW by end of 2002.

1.4 Budgets for PV.

Budgets for Academic Research and Development (funded through the Engineering and Physical Sciences Research Council) appear to have reduced by almost 30 % since 2000, although the cross-disciplinary nature of fundamental PV research makes assessment of the true figures difficult to quantify.

Budgets for Pre-competitive R&D and Demonstration / Field Trials (supported by the Department for Trade & Industry) amounted to GBP 1.52 million in 2001. This is an apparent reduction of 34 % from the 2000 figures, but this does not present an accurate reflection of the encouraging developments in the policy environment and step-change increase in government support for photovoltaics announced during 2001.

Funding for Field Trials launched in 2001 for the residential and large-scale building sectors amounts to GBP 9.4 million. This will support over 820 kW of new PV generation capacity on domestic buildings and 1.15 MW on public buildings by April 2003.

The first phase of the Major Demonstration (Solar Grants) Programme launched in spring 2002 will provide GBP 20 million over three years to support PV systems on at least 3,000 homes and 140 larger non-domestic buildings.

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

UK installed photovoltaic generation plant contributed an estimated 1.4 GWh to UK total energy supply in 2001. This remains very small < 0.0005 %, compared to total electricity consumption of just over 340 TWh[1]. Nevertheless, PV provides an invaluable cost-effective service in an increasing variety of niche applications, particularly where power requirement is relatively small and/or accessibility is poor. There is also sustained expansion in the distributed grid-connected sector.

2.1.1 Stand-alone applications

Until the mid-1990s, the use of renewable energy for professional applications in the UK was limited to mountain-top telecoms equipment and light-house or harbour beacons. Since then, the number of applications using solar generators has advanced significantly. Table 1 presents an overview of stand-alone applications for photovoltaics in the UK, categorised by end-users.

Table 1: overview of stand-alone applications for photovoltaics in the UK

END-USERS	TYPICAL APPLICATIONS
INSTITUTIONAL	
Environment Agency, British Waterways	• Lock and sluice operation • Water pumping • Water quality monitoring
Local Councils	• Parking meters and "pay & display" machines • Car park security lighting • Street/path lighting
Highways Authorities	• Emergency phones • Road-side information and hazard warning signs • Mobile units for temporary warning signs • Speed cameras • Remote junction/crossroads lighting • Powered 'cats-eyes' • Vehicle weigh-in-motion measurement • Traffic and pollution monitoring

[1] Digest of UK Energy Statistics 2001.

END-USERS	TYPICAL APPLICATIONS
Rail network	• Remote rail stations – lighting • Point greasers • Signalling and warning signs
Harbour Authorities / Trinity House	• Lighthouses • Offshore (buoy-mounted) navigation beacons • Harbour navigation beacons and warning signs
Met Office	• Weather stations - wind speed, temperature, etc. • Air quality monitoring
National Trust, Youth Hostel Association, etc.	• Remote visitor centres / hostels • Wardens' huts and workshops
Universities, Research Laboratories	• Remote monitoring of equipment
UTILITY	
Gas suppliers	• Unmanned oil/gas platforms • Remote meter reading • Gas pressure and flow measurement • Valve operation
Electricity suppliers	• Remote meter reading • Monitoring of HV cable insulation
Water companies	• Remote meter reading • Valve operation • Anti-freeze heating ("trace" heating) • Water level measurement • Water pumping, treatment and purification • Energy recovery in water supply lines
Telecoms companies	• Mobile phone local transmitters • Telecoms repeater stations
COMPANY	
Farming and agriculture	• Electric fencing • Pest control - flashing lights, bird-scarers • Waterpumping for livestock drinking water • Lighting for stables and out-houses • Fish farm pond aeration • Fish farm feeding systems • Greenhouse lighting & heating
General	• Alarms for remote buildings • Area lighting • CCTV
INDIVIDUAL	
Leisure boats	• Electric boat battery-charging
Camping & remote homes	• Battery charging (lighting/TV)

2.1.2 Grid-connected applications

Prior to 2001, the majority of grid-connected PV installations in the UK were either large-scale demonstration projects, several of which were part-funded under

European Commission programmes (JOULE and Thermie), or initiatives of private individuals or companies wishing to demonstrate their environmental concern/credentials.

Up to the end of 2000, over 60 % (950 kW) of the total UK grid-connected PV capacity had been installed by BP on its own filling stations and other premises around the UK. Residential systems accounted for approximately 6-7 % of total UK grid-connected PV.

BP has continued its own programme of installations in 2001, but last year also saw an important boost for the residential PV sector with the completion of several clusters of PV houses under the DTI's PV Domestic Field Trial (See section 2.3.1). The new programme, together with sustained orders from individual homeowners and some cluster developments outside the DFT resulted in an estimated additional 280 kW (250 % annual increase) in installed residential PV.

2.2 Total photovoltaic power installed

The year-on-year total cumulative installed PV power for the UK sub-markets (stand-alone domestic, stand-alone non-domestic, and grid-connected distributed) from 1992 onwards are presented in Table 2.

Note, there are no centralised grid-connected PV power generation systems in the UK.

Table 2: The cumulative installed PV power in 4 sub-markets.

Sub-market/application	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
stand-alone domestic (kWp)	7	47	52	57	69	83	108	119	121	135
stand-alone non-domestic (kWp)	166	213	232	252	279	316	254	276	302	385
grid-connected distributed (kWp)	0	6	54	59	75	190	328	736	1 506	2 226
grid-connected centralised (kWp)	0	0	0	0	0	0	0	0	0	0
TOTAL (kWp)	173	266	338	368	423	589	690	1 131	1 929	2 746

The 2001 data is interesting in two respects:

- firstly the very strong growth of the off-grid commercial application sector is noteworthy. This is a 'real' (i.e. unsubsidised) market.

- secondly the slow-down in annual growth in the grid-connected sector following exponential increases since 1996 seems odd, particularly given the strong growth in the residential sector as noted in 2.1.2. This is explained by the recent dominance of BP Solar in the UK figures; in particular, 2000 saw the completion of a number of large in-house projects and the end of the company's 'sunflower' programme (high-efficiency crystalline PV on filling stations, averaging over 17 kW per system). Sunflower has been superseded by the thin-film 'Harmony' programme where the average system size is 12.8 kW. Although BP installed a comparable number of systems on its facilities in each of the last two years, the smaller average system size somewhat skews the overall data. Encouragingly nearly all other UK installers have reported a significant upturn in the grid-

connected sector, typically increasing their annual installation rate by upwards of 100 %.

There was a very small increase (2 %) in the annual installed generation capacity in 2001 compared to 2000. However, the cumulative installed PV generation capacity increased by over 42 % during the year.

2.3 Major projects, demonstration and field test programmes

2.3.1 Domestic PV Field Trials

Installation and commissioning of the first four clusters of houses to be fitted with PV under the DTI's Domestic Field Trial (DFT) were completed in 2001. The trial aims to provide an opportunity for utilities, building developers and other key players to learn about the practicalities of PV implementation. In total, nine sites, constituting over 160 dwellings and over 220 kW generation capacity will benefit from the GBP 1.4 million funding provided under the first round of the DFT. Though seven of the developments are new-build properties, all are on brownfield sites, and there is a wide range of building type, ownership and geographical location. Six of the projects are for social housing schemes.

In October, a further GBP 4.0 million was assigned for a second round of the DFT. The additional funds will support over 600 kW of additional PV on a further 379 dwellings in 23 projects around the UK, including four developments in Scotland and two in Northern Ireland. The second round also includes a high proportion of social housing projects (16), and will investigate some novel integration approaches for the UK, including various solar roof tile systems.

2.3.2 Large-Scale BIPV Field Trial

A call for tender for large-scale BIPV projects - initially explored in 1999 - was issued in November 2001. The announcement earmarked GBP 3 m for 12-15 large projects (i.e. >20 kW), with the objectives of raising awareness of and creating confidence in the application of the technology, increasing UK capabilities in the application of the technology, providing opportunities for UK industry and assessing the potential for BIPV in the near term and its role in future energy policies and strategies.

In March UK Energy Minister, Brian Wilson, announced GBP 4 million funding for 18 projects totalling almost 1.15 MW on public buildings across the UK. The extra funding was made available due to the large number of quality schemes proposed.

All the designs are for true building integrated systems, and modules and inverters will be required to conform to appropriate certification standards.

The supported projects include a 280 kW colonnade using semi-transparent cadmium telluride modules, linking the buildings of the new Science Campus at Cambridge University, and a 107 kW, thin film PV array integrated into the roof of a new international sports facility in Birmingham. The latter complex is due to host the world indoor athletics championships soon after completion.

2.3.3 BP 'Harmony' programme

As in 1999 and 2000, BP's ongoing international programmes to equip its petrol stations with PV generators accounted for a major part of the total installed grid-connected generation capacity in the UK in 2001. 339 kW of thin-film (double-junction amorphous silicon) PV modules were incorporated in filling stations under the company's 'Harmony' initiative.

2.3.4 BedZED

BedZED, the Beddington Zero Energy Development developed by Peabody Trust working with architect Bill Dunster , is an environmentally-friendly, energy-efficient mix of housing and work space in Beddington, Sutton. BedZED, one of the four DFT projects to be commissioned in 2001, will only use energy from renewable sources generated on site. It is the first large-scale 'carbon neutral' community - i.e. the first not to add to the net amount of carbon dioxide in the atmosphere.

The site of a former sewage works, BedZED now comprises a total of 82 x 1, 2, 3 & 4 bedroom flats and houses as well as offices space and will eventually include an on-site shop, cafe, sports facility, healthy living centre and childcare facility.

Passive solar design, very high insulation standards and controlled ventilation with heat recovery minimise the need for space heating, while energy efficient appliances keep electricity demand 60 % lower than for typical UK households.

Power onsite is mainly provided by a combined heat and power unit fuelled by waste timber from local tree surgery. To avoid oversizing the CHP unit a 109 kW photovoltaic installation provides power for 40 electric cars - some communal, some taxi, some privately owned. The PV system comprises conventional roof-integrated modules plus laminates installed within double-glazing units on the conservatory areas. The PV component is part funded by the European Commission (35 %) and partly by the DTI (25 %).

2.3.5 Big Brother House

Undoubtedly the most 'visible' PV installation in the UK has been the 16 kW system installed on the Big Brother House. Channel 4 Television's Big Brother programme, which was aired nightly during a 10 week period in summer 2001, has a huge public following.

The 144 AstroPower modules (141 are active; 3 cover a door from the outside of the house to the storeroom) supplied and installed by Solar Century form a spectacular wall of solar cells on the front of the house. Housemates walk past the solar facade on entry and eviction from the house. The array was also used as the backdrop for the credits at the end of all TV broadcasts.

Table 3: 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 2001/problems and lessons learned	Funding	Project management	Remarks
Domestic Field Trial 2000-2002	£1,4m assigned for 9 cluster projects - total >220 kW for >160 residences	To use the design, construction and monitoring of the installations as a learning opportunity for utilities, building developers and other key players. Geographical spread and technologically varied systems will maximise lessons learned.	Four developments totalling 69 kW commissioned as at end 2001. Two further systems giving an additional 52.5 kW in progress for commissioning in 2002.	Up to 100 % DTI (some projects have secured complementary EC funding)	BRE (leader), EMC Ltd., IT Power, NPAC	The installation process in each case has run smoothly. Any delays experienced have been due to the main building programme or to the complexities of monitoring.
Domestic Field Trial - Phase II 2001-2003	£4m assigned for 23 developments - total >600 kW for 379 dwellings	As above, with increased regional distribution allowing introduction of new players, including new DNOs	Project Management Contractor appointed Two developments totalling over 50 kW for 26 residences underway	As above	BRE (leader), NPAC, EMC, EA Technology	
BP Harmony	BP Programme to install thin-film PV on its own filling stations.	International programme - to project a 'green' image and raise public awareness of PV power systems	Total of 384 kW installed on 30 stations as at end of 2001.	BP / BP Solar	BP Solar	Successor to 'Sunflower' programme which resulted in 734 kW on 43 filling stations around the UK
Beddington Zero Energy Development (BedZED)	Total 109 kW of BP Solar modules and semi-transparent laminates in double glazed units. Various inclinations and orientations	PV provides power for 40 recharging points for electric vehicles. The development is designed as the first large-scale 'carbon-neutral' community.	Attention to cable routing and fitting detail of sealed double-glazed units at design stage allowed straightforward installation by glazing installers. First residents took Occupancy in November	Peabody Trust EC (35 %) DTI (25 %)	Peabody Trust	One of the projects part-supported (25 %) under the DTI's DFT project. Additional funding from EC (35 %).
Big Brother House	137 m^2 16 kW Astropower modules. Vertical Facade Installation	PV promotion opportunity via popular television show.	Installation took 2 days with a manpower of 6.	Channel 4 TV	Solar Century	

2.4 Highlights of R&D

Academic research in the UK is largely funded by the Engineering and Physical Sciences Research Council (EPSRC). In addition to companies' internal research activities, some pre-competitive industrial Research and Development projects are supported by the DTI mainly under the renewable energy programme.

EPSRC's PV research priorities are ostensibly defined under the Renewables & New Energy Technology programme, although some funding is provided for unsolicited research proposals. Current projects within the engineering sector range from the development of components for building integrated systems and development of more stable amorphous silicon cells to investigation into network effects of large-scale (widespread) PV generation. At a more fundamental level, several institutions are currently investigating organic dye solar cells including the applicability of nanocrystalline films, while novel cell materials and process techniques are also popular academic research topics.

In respect of industrial activity, a major announcement at the end of 2001 was the award by the DTI of GBP 460 000 to a UK consortium comprising Intersolar (UK's only PV cell manufacturer) Plasma Quest (plasma deposition), West End Technology (supplier of vacuum equipment) and Exitech (laser scribing equipment) for design / development of highly automated, low-cost thin film manufacture. The process is reliant upon Plasma Quest's innovative plasma sputter deposition technology for rapid production of high-quality thin films.

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

Table 4: Public budgets (in GBP Million) for R&D, demonstration/field test programmes and market incentives.

		R&D	Demo / Field Test	Market
National	DTI	1.52		
	EPSRC	1.84	-	-
Regional		Not Available		
Total	(£)	3.36		

Budgets for Pre-competitive R&D and Demonstration / Field Trials (supported by the Department for Trade & Industry) amounted to GBP 1.52 million in 2001. This is an apparent reduction of 34 % from the 2000 figures, but this does not present an accurate reflection of the encouraging developments in the policy environment and step-change increase in government support for photovoltaics announced during 2001 (see section 4.1.4).

EPSRC figures are calculated pro-rata from total project budgets and may not necessarily reflect actual spend committed during 2001. Additionally, EPSRC is providing 3.9m over 3 years for a national consortium investigating carbon-based electronics. This could generate important results for the PV sector amongst others, but has not been included in the above figures.

Information on Local Authority spending on incentives for PV has not been accessible.

3 Industry and growth

3.1 Production of photovoltaic cells and modules

Table 5: Production and production capacity information for the year for each module manufacturer

Module manufacturer	Technology (sc-Si, mc-Si, a-Si, CdTe)	Total Production		Maximum production capacity	
		Cell (MWp)	Module (MWp)	Cell (MWp)	Module (MWp)
Intersolar	a-Si	1.6	1.6	3	3

- The UK has only one major manufacturer of PV modules: Intersolar manufactures thin-film amorphous silicon cells and modules at its factory in Bridgend, South Wales. The company operates to ISO 9001 Quality Assurance procedures.

  Intersolar has developed a unique High Rate Deposition (HARD) Process. This produces solar cells on a standard sheet of float glass, which acts as the cover glass. The cell is laid down starting from the front in the following process steps:
  - Deposition of a transparent front contact surface
  - Laser Isolation of the front contact into separate solar cell strips
  - Deposition of the thin film silicon solar cell junction
  - Laser isolation of the junction into separate solar cell strips
  - Deposition of the reflective rear contact and isolation into cell strips.

  This produces solar plate which is then tested for performance. Depending on whether it is then used for solar modules or cut plate, it will then proceed to either:
  - Cut plate coating and cutting
  - Edge isolation, lamination and module framing.

  Production capacity has remained static at the level reported in 2000 at 3.0 MW. A large proportion of Intersolar's production is exported. The production figure also includes cells produced for a variety of consumer products manufactured in-house.

  Intersolar has recently developed a PV product for slate roofs. The 'Electra-Slate' incorporates a 1.4 W thin film solar cell (at 46 V). Each Electra-Slate fits to the next by means of an integrated plug in connector, allowing easy installation. The product is undergoing a variety of relevant tests for roofing products, and for solar panels.

The company has been reported to be planning a new manufacturing facility with a production capacity of 15 MW. Indications early in 2002 suggest that the company may choose to locate this on Mainland Europe. The firm is also preparing for flotation on the stock market.

- 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.

  The company also produces multi-crystalline silicon blocks, and increased production by 200% in 2001 (compared to 2000) sufficient for 30 MW of cells. These are wafered by PV Silicon in Germany. The company, now the UK's largest employer in the PV sector, increased production capacity to 58 MW in 2001. The firm, which is accredited to ISO 9001, is aiming for a production capacity of 90 MW by the end of 2002.

- Module prices are typically in the range GBP 3 to 3.5 per W for reasonable volume orders. For small orders (few modules) retail prices range from approximately GBP 3.8 up to GBP 5.4 per W.

3.2 Manufacturers and suppliers of other components

Approximate price ranges for a range of inverter sizes are presented in Table 6.

Table 6: Price (in GBP) of inverters for grid-connected PV applications

Size of Inverter	<1kVA	1-10kVA	10-100 kVA	>100kVA
Av. Price per kVA (£)	600-1040	420-760	~300	-

- BecoSolar of Dartmouth manufacture a range of controllers and building customised systems for industrial, commercial, leisure and domestic uses, particularly for the off-grid sector, often for harsh environments.
- Dulas Engineering of Machynlleth is a worker-owned company specialising in renewable energy system design and supply. The company designs and manufactures a range of robust electronic control equipment in-house. Dulas is also UK agent for Fronius inverters.
- Invertec Ltd, traditionally a low-voltage lighting manufacturer, supplies a range of inverters for stand-alone PV applications.
- Futronics Power Designs Ltd, based in Hertfordshire, manufactures the 'Sustain' range of inverters for stand-alone applications.
- I-Power of Gateshead produces a range of Stand-Alone and Grid Linked Inverters for (PV) Applications.
- Labcraft of Romford is a specialist manufacturer of low voltage fluorescent lighting and inverters for PV and other alternative energy applications.
- Mastervolt UK is the UK sales and distribution arm of Mastervolt, headquartered in Amsterdam. The company designs and manufactures inverters, battery chargers and related components, and distributes batteries and modules.
- Solar Century of London is the main UK agent for a number of innovative roofing products including UniSolar's flexible shingles and structural standing seams,

Pfleiderer's roof-tile integrated 'Terra Piatta' system, SES-Atlantis's Sunslates and Powerlight's insulated 'Powerguard' system for flat roofs.

- SolarGB of Bradford produces a wide variety of products incorporating the latest in LED technology powered by small PV cells including amber flasher units, bollards, traffic lights, street lights and road studs (powered cats-eyes).
- Sollatek of Slough manufactures low-voltage DC lights and battery charge controllers for stand-alone applications, predominately for the export market.
- SunDog Energy of Penrith is sole UK stockist of the Redland Integrated PV Roofing System. The 35 W panels come with a unique mounting system that integrates directly into a tiled roof, using standard battening and requiring no visible brackets or supporting structure. A basic system consists of 20 panels.
- Wind & Sun of Leominster is the main agent and authorised service centre for Xantrex-Trace inverters in the UK. The company also supplies SMA, Fronius and MicroSine ('OKE') inverters for grid-connect applications.

3.3 System prices

Table 7: Turnkey Prices of Typical Applications

Category/Size	Typical applications and brief details	Price per Wp in £
OFF-GRID Up to 1 kWp	Modules for leisure market (holiday homes, boats, caravans)	~10
OFF-GRID >1 kWp	Remote homes with battery storage or backup generator; Pumping Systems	~8.5
ON-GRID Specific case	1-3 kWp domestic roof mounted	5.5-8.5
	1-3 kWp domestic roof integrated (e.g. slates or tiles)	7.3-12.4
ON-GRID up to 10 kWp	Roof or ground-mounted systems (e.g for commercial building retrofits)	5.6-9.5
ON-GRID >10 kWp	e.g. 20 kWp roof mounted system (on filling stations, commercial / industrial buildings)	~4
	One-off true building-integrated designs will be more expensive	6.7

Table 8: National trends in system prices (current and constant GBP) for 1-3 kW domestic roof mounted system

YEAR	2000	2001
Price /Wp: Current	5.0 - 7.0	5.5 - 8.5
Constant	5.13 - 7.18	5.5 - 8.5

3.4 Labour places

An estimate of (full-time equivalent) labour places related to the photovoltaics sector in the UK is presented as Table 9.

Table 9: Estimated PV-related labour places in the UK

Research and development (not including companies)	65
Manufacturing of PV system components, including company R&D	170
All other, including within electricity companies, installation companies etc.	125

Of the 'All other' category, approximately 85 labour places are in the system supply and installation and/or distribution sectors.

4 Framework for deployment (Non-technical factors)

4.1 New initiatives

4.1.1 Promotional initiatives

VAT on professional installations of PV systems has been set at 5 % since April 2000.

TXU-Europe (Eastern Energy) under an agreement with Greenpeace is continuing to offer net-metering of up to 1000 residential PV systems under the '*Solarnet*' scheme.

To date, most promotional initiatives have been undertaken by private companies. Solar Century have been particularly active in raising the profile of solar electricity through adverts in the quality national press and appearances on national radio and television.

4.1.2 Utility perception of PV

Most of the 13 regional Distribution Network Operators now have direct experience of grid-connected PV systems. One - TXU-Energi - is reportedly about to install a 200 kW system on its UK headquarters.

Naturally, given the current low-level of PV penetration in the UK, the DNOs do not see solar electricity as a business priority at this time. Nevertheless, there is a general interest in PV issues and all DNOs are keeping a watching brief to see how the sector develops. Several DNOs have reported a recent increase in public enquiries since the solar grants (MPD) scheme was announced.

Engineering Recommendation G77-1 '*Recommendations for the connection of inverter-connected single-phase PV generators up to 5 kVA to public distribution networks*', which was developed through a consultation process involving representatives of the electricity industry and of the PV industry, has been issued as a working document with the acceptance of all DNOs. The recommendation, which incorporates procedural forms for application to connect to the electricity network and for commissioning of small PV systems, will streamline and simplify the connection procedure for both DNOs and installers.

4.1.3 Public perceptions

A number of important policy announcements, including speeches by the Prime Minister and the Energy and Environment Ministers, have helped to raise the public profile of PV and other renewable energy technologies. Likewise the continuing promotional efforts of BP, Intersolar and - in particular Solar Century - appear to be having a positive impact on public opinion.

The British Photovoltaic Association (PV-UK) noted a substantial increase in traffic to its website over the year. Since the announcement of the MDP, and particularly in the

early part of 2002, with the formal clarification of the solar grants scheme, nearly all installers have noted a step increase in enquiries from the general public.

4.1.4 Major new projects / initiatives

As indicated in section 2.3, the two rounds of the Domestic Field Trial with a total budget of GBP 5.4 million are expected to result in over 820 kW of additional PV for the residential sector by 2003. At the same time, the GBP 4,0 million Large-Scale BIPV Field Trial will add some 1.15 MW of new PV generation capacity on public buildings across the UK.

In March 2001, GBP 10 million was allocated by the DTI to the first phase of the Major PV Demonstration Programme (MDP). Following recommendations from the Cabinet Office review of renewable energy in November, a further GBP 10 million was allocated to the MDP over the next 3 years out of the Prime Minister's GBP 100 million Renewables Fund. It is expected that the first phase of the MDP will result in at least 3,000 homes and 140 larger non-domestic buildings receiving solar PV systems.

The scheme, which will be administered by the Energy Savings Trust, comprises two application streams:

- Stream 1 – individual or small-scale applications (systems from 500 W to 5 kW) will be dealt with on a rolling basis.
- Stream 2 – medium or large-scale company or group applications of 5 kW to 100 kW dealt with in three-monthly tranches.

The maximum eligible subsidies are initially as follows:

- Public Sector buildings - 65 % of the nominal cost
- Large profit making organisations - 35 %
- all others, including SMEs and homes (Stream 1), - 50 %.
- for large-scale commercial buildings (Stream 2) - maximum public funding (including from EU sources) for private sector bids - 50 %.

The subsidy level is expected to diminish over time. All grant applications require the use of approved products and accredited installers and designers.

4.1.5 Other new issues

A 120 MWh (8 hours @ 15 MW) 'Regensys' energy storage system (reversible electrochemical reaction using concentrated solutions of sodium bromide and sodium polysulphide) is under construction in Cambridgeshire. This has the potential for helping to balance electricity demand and supply and could be of major benefit to intermittent power generation sources including (large-scale) photovoltaics. Commissioning is due in Spring 2002.

4.2 Indirect policy issues

The UK's New Electricity Trading Arrangements (NETA) were introduced at the end of March 2001. Restructuring of the England and Wales trading arrangements has led to a reduction in wholesale electricity prices for the consumer. However the

arrangements for penalising generators that failed to deliver to their contracted supply agreement have not been helpful for renewable electricity generators. The intermittent nature of most renewables makes forecasting very difficult and leaves generators open to under-supply penalties or diminished value for over-supply. Modifications of the trading arrangements to protect renewables and small generators are currently under discussion. As the arrangements only apply to wholesale generation, PV has been largely unaffected, except in as much as the reduction in retail electricity price implies a divergence from economic viability for PV power.

The 'Climate Change Levy' (CCL) on business use of energy was introduced on 1st April 2001. The levy on electricity is initially set at 0.43 p/kWh, plus VAT and is set to rise year-on-year. Renewable energy, however, is exempt from the levy and businesses that sign up to a green tariff can avoid paying the CCL. To avoid being charged the levy, businesses need to sign a contract with a supplier containing a 'renewable source declaration'. This ensures that for every kWh that is used, a kWh of electricity is generated from renewable energy sources. However, the CCL itself is unlikely to stimulate significant growth in PV, as for the foreseeable future, PV generated electricity will remain significantly more expensive than conventional electricity (even with the levy imposed) and other renewable energy technologies such as wind and landfill gas that are closer to the bulk electricity price.

A new Renewables Obligation was introduced in the UK on 1st April 2002. This aims to see 5 % of UK electricity generated from renewable energy sources by 2003 and 10 % by 2010. All suppliers of electricity in the UK will need to supply a set percentage of electricity from renewables, or pay a penalty. For each 10 MWh of electricity produced from accredited renewable energy schemes, the generator will be awarded a 'Renewables Obligation Certificate' (ROC) which can then be sold to an electricity supplier as evidence of a renewables purchase. Suppliers that fail to purchase sufficient ROCs must buy-out of their obligation. The penalty/buy-out price is 3 p/kWh. The obligation should encourage development of near cost-effective renewable energy schemes, but is unlikely to promote photovoltaic generation capacity in the near to medium term.

4.3 Standards and codes

Engineering Recommendation G77 '*Recommendations for the connection of inverter-connected single-phase PV generators up to 5 kVA to public distribution networks'* has been issued as a working document with the acceptance of all DNOs and representatives of the PV industry

Grid-interconnection of PV systems rated above 5 kW is governed by Engineering Recommendation G.59/1, Amendment 1 (1995), *'Recommendations for the Connection of Embedded Generating Plant to the Regional Electricity Companies' Distribution Systems*'.

The Distribution Network Operators are currently considering a new engineering recommendation focusing on network connection of domestic-scale (probably < 3 kW) distributed generation systems. 'G 83' is expected to have a generic first section addressing the network requirements of all distibuted micro-generators

(including PV and micro-CHP), complemented by a series of annexes focusing on technology-specific issues. The annexes will be developed in consultation with the relevant industry representatives.

The DTI has recently issued a new publication ' Photovoltaics in Buildings - a guide to the installation of PV systems' to supply system installers with information to ensure that a mains-connected PV system meets current UK standards and best practice recommendations.

The Government's national planning policy with regard to renewable energy is set out in *Planning Policy Guidance note (PPG) 22: Renewable Energy* which gives local planning authorities guidance on a range of issues that affect the siting of all renewable energy projects. A new annex of PPG22 presenting specific information pertaining to photovoltaic installations was finalised in 2001.

5 Future trends

The Domestic Field Trial, Large-scale BIPV Field Trial and first phase of the new Major Demonstration Programme have assured a continued healthy rate of grid-connected PV installation for the next three years. Beyond this, the future development of the sector is heavily dependent upon the performance of existing manufacturers, installers and suppliers.

A more expansive programme requires a pool of reputable and well-qualified technicians and the involvement of key players from the building and planning sectors, as well as timely delivery of quality products and services. The programmes do appear to have been structured to encourage the former. The industry can not afford to underperform on the latter.

6 Annex A Method and accuracy of data

The information for this survey report has been drawn from many sources. The assistance of Oliver Paish and John Green, and co-operation of all parties who provided information for the 2001 survey is gratefully acknowledged.

Data was gathered directly from most of the UK industry players via e-mail questionnaire and personal discussions. The British Photovoltaic Association (PV-UK) and Altechnica provided access to their information for comparisons. The various data was collated in a spreadsheet, sorted into the required categories and totalled.

The estimated accuracy of the year 2001 data is ± 10 %, except for data relating to the new installed generation capacity in the grid-connected distributed sector and UK production where the accuracy is estimated to be ± 5 % or better.