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 Denmark 2002

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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 Tasks (research projects / activity areas) is the responsibility of Operating Agents. Information about the active and completed tasks can be found on the IEA-PVPS website www.iea-pvps.org.

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, environmental and social aspects of photovoltaic power systems. 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 present 2002 National Survey Report gives a brief overview of progress made in the field of PV power systems in Denmark during 2002.

iii Definitions, symbols and abbreviations

For the purposes 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 Wp 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^{o}C, 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 Wp.

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.

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 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 centralized PV power system: Power production system performing the function of a centralized 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 application to 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. 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.

EA: Danish Energy Authority

1 Executive summary

Installed PV power
By the end of year 2002 Denmark (including Greenland) had about 1,6 MWp installed, an increase of only about 100 kWp compared to 2001. The explanation is, that 2002 is "between programmes". The now completed Sol-300 project (750 kWp) finished most of its installations before 2001 and the new SOL 1000 project (up to 1 MWp) only started in reality late 2002 with the first installations expected early 2003. Grid-connected distributed systems constitute at about 86 % the majority of PV systems in Denmark.

Costs & prices
The now completed Sol-300 project[1] exhibited turn-key system prices for "roof-tops" of almost 40 DKK/Wp installed. The new SOL 1000 project demonstrates a turn-key system price for "roof-tops" of around 34 DKK/Wp. The few individual PV systems implemented during 2002 have demonstrated turn-key system prices in the range of 40 to 80 DKK per Wp installed. This indicates, that without umbrella projects to reduce costs and to coordinate implementation, PV system prices are still quite high reflecting an immature market.

PV production
During 2002 a producer of float-zone silicon announced its intention to supply the international PV industry with high purity, low-cost silicon. The module production in 2002 is at about 100 kWp a slight increase compared to 2001. There is no manufacturing of PV inverters or batteries in Denmark, although PV inverters have been developed during 2002 with a view to go on the international market mid 2003. The building industry is showing a limited, but careful interest in developing PV-building integrated components and systems.

Budgets for PV's
In 2002 the Public Service Obligation (PSO) of the Danish electric utilities made about 15 mill DKK available for applied research in PV's. Beside this and the SOL 1000 project there has during 2002 been no other public support available for PV.

Government Policy & Programmes
The general support programme for renewable energy (UVE) was cancelled early 2002 and at the same time the Energy Research Programme (EFP) was reduced to 1/3 of its former size – this following a change of government ultimo 2001.

Late 2002 the net-metering scheme for grid-connected PV systems was extended to 2006. Also late 2002 the government announced a new funding system for research, which would include about 120 mill DKK for renewables over a three year period starting 2003, the extent to which this may benefit PV research yet unknown.

Late 2002 the two Danish electric network operators, also responsible for the PSO facility, in dialogue with the Energy Authority (EA) commissioned a study on PV

[1] Data collection and data analysis continue until mid 2004

technology, the aim being to identify niches, if any, for future Danish R&D efforts. This study was completed in April 2003 and will be followed by a national PV strategy to be elaborated by the EA.

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

The national electric grid covers practically all of Denmark and leaves little room for stand-alone applications besides the usual low-power niche applications such as signalling, week-end cottages, garden lights, telemetry & telecommunication and urban furniture such as parking meters and information displays.

Grid connected PV applications are seen as the largest potential in Denmark, in particular building integrated applications on single family houses, apartment buildings, commercial and office buildings. The public interest for building integrated PVs is increasing, and most efforts are focused on developing and demonstrating PVs in the context of existing buildings.

2.2 Total photovoltaic power installed

The total cumulative installed PV power for each sub-market on the 31 December of each year from 1993 (no Danish data for 1992) onwards is shown in Table 1.

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

Sub-market/ appli-cation	31 Dec 1993 kWp	31 Dec 1994 kWp	31 Dec 1995 kWp	31 Dec 1996 kWp	31 Dec 1997 kWp	31 Dec 1998 kWp	31 Dec 1999 kWp	31 Dec 2000 kWp	31 Dec 2001 kWp	31 Dec 2002 kWp
off-grid domestic	10	10	15	20	25	35	40	50	50	50
off-grid non-domestic	70	75	85	120	125	140	150	155	160	165
grid-conn. distribut.	5	15	40	105	272	330	880	1 255	1 290	1375
grid-conn. Centraliz.	0	0	0	0	0	0	0	0	0	0
TOTAL	85	100	140	245	422	505	1 070	1 460	1 500	1 590

2.3 Major projects, demonstration and field test programmes

Renewable energy technologies have high priority in the national Danish energy plan, Energy 21 and its associated follow-up measures. The goal is partly to reduce the emission of CO_2 by 20 % before year 2005 and partly to diversify the energy sector now being based on fossil fuels. At present about15 % of the gross national energy consumption originates from renewable energy sources. Energy 21 outlines scenarios, where i. a. photovoltaics (PV) may contribute to about 7-10 % of the national electricity consumption of Denmark in year 2030. However no specific goals for PV deployment have yet been set.

The government is presently developing a new climate strategy focussing on “as much environmental benefit per investment as possible”. The extent to which this – together with the ongoing deregulation of the electricity sector - will influence the domestic energy scene including renewables and PVs is yet not clear.

PVs have been included in the three-year Solar Energy Action Plans of the EA since 1992. A three-year plan for 2001-2003 has not been produced. The Danish Energy Authority was expected to prepare new strategies for solar energy and PVs during 2001, however no official documents on this were published. Since 1992 the Renewable Energy Development Programme of the EA has supported about 125 PV projects, and by the end of 2002 about 1.6 MWp have been installed, mostly in the context of demonstrations plants. The Sol-300 project encompassing 750kWp on

single family houses with all commissioned by end of 2000 received its main support from the PSO facility of the Danish network operators.

In 2002 the most high profile project has been the SOL 1000, targeting up to 1000 kWp of BIPV. The project was launched 2001 and created quickly a list of 3.500 potential participants. During 2001 and part of 2002 the project was semi-dormant due to uncertainties of the available government support. However mid 2002 the funding was secured, although at a reduced level compared to the original budget. This lead to a reduction of the targeted 1 MW to around 600 kW and to an increase in end-user payment to 60 % of the investment. Even under these new conditions the project was quickly subscribed to the limit, and the first installations took place in the spring of 2003. Turn-key PV system costs for standard roof-top systems in the project are around 34 DKK/W.

The SOL 1000 project has as accompanying measure a R&D project package named SOL 2000 A funded by the PSO facility of the Danish network operators.

A special support programme for PV applications in the commercial sector, funded by the CO_2 tax on electricity, was set up early 1998. The support includes a subsidy of up to 36 % for the turn-key costs and the calculation of the actual subsidy will be in favour of high yield installations. However, little use has been made of this subsidy scheme so far as the commercial sector to some extent obtains refunding of the taxes on electricity, and the value of the solar electricity (substitution principle) is consequently low.

Net-metering for privately owned PV systems was established mid 1998 for the present for a pilot-period of four years. Late 2002 this scheme was extended until end of 2006. Analysis of ownership issues and tariffs for apartments sharing one common PV installation has been initiated.

In 2002 the EA and the network operators Elkraft System and ELTRA agreed to compile a joint paper on the prioritising of the PSO facility support to PVs. This is seen as a first step towards a national strategy for PV expected to be completed during 2003.

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 2002/problems and lessons learned	Funding	Project management	Remarks
Sun-City project with 30 roof top installations on single family houses 1997	Grid-connected power: 60 kW multicrystalline PV cells area: about 500 m^2 orientation: SE to SW turnkey cost: 50DKK/W	To obtain experience with a high penetration of grid-connected PV systems (roof tops) To obtain experience with roof integration on existing buildings To lower system costs	No negative grid impact found. High interest in roof top's at consumers. Mounting methodologies and kits not very well developed. Tun-key system cost reduced considerably	Elsam/Elfor (utilities) Danish Energy Agency (now Danish Energy Authority)	VOH (now EnergiMidt) (utility)	Easy to understand system performance monitoring established in each house (the Energy Guard). Reduction of 6-10 % in electricity consumption at households involved
Solgårds project with 107 kWp integrated in a block of apartments 1997	Grid-connected power: 107 kW singlecrystalline PV cells area: 890 m^2 orientation: SE to S	To demonstrate high quality / visibility integration of PVs in a block of apartments. Development of institutional models for a joint PV system for many apartments	Very high quality (and cost) integration on roof and façade. Architectural success. Ownership model difficult to implement.	Danish Ministry of Housing	Byfornyelses-selskabet Danmark (urban renovation company)	Architectural objectives achieved at the penalty of high cost.
Sol-300 project with 300 roof top installations on single family houses 1998	Grid-connected power: 750 kW three main suppliers: BP, Solarex & Shell turnkey cost: 40DKK/W	To reduce system cost by professional bulk procurement. To demonstrate PV roof top's. To build capacity in PV system deployment at utilities	Turn-key system cost reduced considerably. Optimization of mounting kits initiated.	Public Service Obligation (PSO) funds (the utilities) The Danish Energy Agency (now Danish Energy Authority)	Encon (now EnergiMidt) (utility)	Implementation completed by end of 2000; monitoring ongoing
The 3-year Support Programme for apartment buildings and institutions	Grid-connected, building integrated systems on apartment buildings and institutions; support of 30 mill DKK allocated for three years	To increase the deployment of PVs on apartment houses and institutions; to foster the development of Danish products and components for building integrated PVs.	Programme initiated late 1999: first call for proposal launched with dead line March 2000, third and fourth call launched in 2001. Project discontinued in 2002; no more funding.	The Danish Energy Authority	According to individual projects	Continuation into 2002 cancelled due to change of government and consequent unavailability of funds
SOL 1000 project aiming at 1000 roof-top systems 2001	Grid-connected, BIPV power: about 1 MW average turn-key system cost: 34 DKK/W	To continue the Sol-300 project achievements and to bridge the gap towards development of a commercially sustainable market	Project started mid 2001. Project preparations initiated, but implementation of plants no expected until early 2003.	The Danish Energy Authority	EnergiMidt (utility)	Delayed due to uncertainties as to government funding; effective start in the fall of 2002. Reduced funding and scope: 600-700 kW

SOL 2000 A – a R&D project package accompanying SOL 1000	A package of 5 R&D projects in support of the SOL 1000 project	To carry out R&D activities in support of the SOL 1000 project mainly in the fields of new roof and façade integration concepts and systems	Projects are ongoing according to plan; results expected during 2003	PSO facility	EnergiMidt	

Section 2.4 Highlights of R&D

R&D on PV cell manufacturing (mono-X Si) has taken place at the Technical University of Denmark for more than a decade. This R&D effort led to the establishment of the first Danish PV cell/module manufacturer in 1992. The company folded mid 1996 after a period in receivership, and is now reconstructed as a module assembling plant. Research into Si cell production with focus on surface layer structure and contacts at the Danish Institute of Microelectronics has been stopped. However, as part of the Three Year Programme R&D activities into PEC cells (Grätzel type cells) has been initiated at the Danish Institute of Technology in collaboration with Risoe National Laboratory and the Roskilde University Center. This initiative has in 2002 received additional support from the Public Service Obligation (PSO) facility. It is attempted to develop PEC cells/modules and at the same time have control over the transparency of the module – which should constitute a unique building element.

Mid 1995 the Photovoltaic System Laboratory (PVSyslab) was established in collaboration between Risoe National Laboratory and the Danish Institute of Technology. The main function of PVSyslab is to certify the quality of PV systems and to help industry develop better products, systems and recommended practices for design and installations. The PVSyslab has established R&D PV plants and has put examples of building integrated PV technology on display. The PVSyslab has established a national database for demonstration systems. The PVSyslab is now integrated into the Solar Energy Centre Denmark. The Solar Energy Centre Denmark has also entered the field of technology cooperation with developing countries and is presently engaged in Nepal. During 2002 the Solar Energy Centre has lost its government support, but reduced support has been indicated from 2004 and 5 years ahead.

Inverter technologies are being R&D' for both fuel cell and PV applications. Efficiencies of up to 98 % have been reported using transformer-less, high integrated designs, and efforts to develop smaller units, about 2 kW and smaller, are ongoing. In 2002 a new company Powerlynx with links to Danfoss has emerged focussing on the development of new inverter technology. Products are expected mid 2003.

Stimulated by the in 2002 cancelled Three Year Programme 2000-2002, which supported up to 40 % of R&D costs in BIPV, Danish building industry has exhibited increasing interest in the integration of PV’s in existing and new building components, and new products have emerged or are being developed.

In 2003 the company Topsil, a manufacturer of high purity (float zone - FZ) Silicon for the semiconductor industry, announced its intention to produce low cost FZ Silicon for PV cells. Expected cell efficiency of +20 % has been hinted at. Topsil has established contact to several leading cell manufacturers.

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

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

	R & D	Demo/ Field test	Market
National/federal *)	15	5	0
State/regional	0	0	0
Total	15	5	0

*) including PSO facility

Note

Countries of Euroland must use the euro (EUR).

3 Industry and growth

3.1 Production of photovoltaic cells and modules

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

Cell/Module manufacturer	Technology (sc-Si, mc-Si, a-Si, CdTe)	Total Production (MWp)		Maximum production capacity (MWp)	
		Cell	Module	Cell	Module
1 Gaia Solar	mc-Si & sc-SI	-	0,1	-	0,330 (per shift)
2					
3					
4					
5					
Thin film manufacturers					
1					
2					
TOTALS					

Gaia Solar produces modules (laminates) based on imported cells. Modules are of the standard glas-EVA-Tedlar design. Product range is 27-150 Wp with 55-110 Wp modules being most typical. Normal warranty: 5 years. Company open for custom design modules. Certification to IEC 61215.

A few other companies have shown interest in manufacturing window-integrated PVs, but so far the throughput is estimated as negligible.

Typical PV module cost range between DKK 30 – 50/Wp.

Limited (no figures) export in connection with official development aid.

Table 4a: Typical module prices (NC) for a number of years

Year	1992 *)	2000	2001	2002
Module price(s):	-	30-50	30-50	21-45

*) data only registered from 2000 and onwards

3.2 Manufacturers and suppliers of other components

In 2002:

No manufacture of inverters for grid-connected PV systems in Denmark

No battery producers in Denmark with PV related products.

Three companies produce (on a small scale) charge controllers and PV related electronics for stand-alone PV systems.

One company is looking into development and manufacturing of support structures.

One company has developed, but not yet really marketed, a roof-integration package.

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)				

NOTE: Euroland countries must use the euro (EUR).

3.3 System prices

Table 6: Turnkey Prices of Typical Applications

Category/Size	Typical applications and brief details	Current prices per Wp in NC
OFF-GRID Up to 1 kWp	Telemetry, emergency phones, etc.	70-90
OFF-GRID >1 kWp	Professional remote: telecom & navigational aids etc.	150-200
GRID-CONNECTED Specific case	1-3 kWp roof-mounted system (roof-tops)	40
GRID-CONNECTED Up to 10 kWp	Façades & gables	50-70
GRID-CONNECTED >10 kWp	Roofs (single projects with high visibility)	40-100

NOTE: Euroland countries must use the euro (EUR).

Table 6a: National trends in system prices (current NC) for (*specify application, for example from table 6 above*)

YEAR	1997	1998	1999	2000	2001	2002
Price /Wp: (For roof-tops)	50	50	40	40	40-80	34*)

*) target figure for SOL 1000

3.4 Labour places

a)	Research and development (not including companies):	8
b)	Manufacturing of PV system components, including company R&D:	12
c)	All other, including within electricity companies, installation companies etc.	10

3.5 Business value

Total business value is estimated (personal estimate – no way of getting solid data) to 10 mill US $ (estimate from the PVPS Annual Report, section on Denmark)

4 Framework for deployment (Non-technical factors)

4.1 New initiatives

General

No new initiatives during 2002.

In 2002 Denmark joined the EU network PV-EC-NET aiming at the analysis and coordination of PV R&D programmes in the EU member countries and the activities of the EU Commission. This work is ongoing, but one preliminary result is, that the active engagement of the Danish utilities in PVs is seen as a national strength in comparison with other member countries.

Utility perception of PV (ownership of and liability for PV systems; non-utility production of electricity; grid support; peak load reduction; etc.)

The Danish utilities exhibit growing interest for PV's as a potential future business area. The future focus is on PV roof-tops including small, modular do-it-yourself systems in the range of a few hundred Watts. Ideas for ownership, financing and repayment are being developed.

Changes in public perceptions of PV

The SOL 1000 project launched mid 2001 has revealed high public interest in PV's: even with only a 40 % investment incentive and net metering the interest to join SOL 1000 is quite high and beyond the project budget. It is expected, that small do-it-yourself (DIY) kits can be sold without any incentives beyond net metering. In 2002 the process of adapting rules and regulations to allow DIY kits was started. The first systems on the market are expected late 2003 or early 2004.

Major new projects or initiatives

The SOL 1000 project is regarded as a major Danish initiative targeting – in its present reduced form - about 600-700 kW new BIPV before end of 2004. Continued cost reductions, increased end-user payments and a trend towards smaller systems are expected.

Planned developments

The net result of the new Danish governments reduced interest in public support for renewable energy is yet not clear by end of 2002. The energy policy is not revised/publicised and the government climate strategy highlights the Kyoto Protocol flexible mechanisms as the cheapest way to meet CO_2 reduction targets. Domestic measures such increased use of RE is seen as more expensive.

It appears, that increased government support may be available for R&D activities into renewables as such; however the share – if any – for PVs is not yet known, but should get more clear during 2003.

Other new issues

Efforts to introduce architects to PV's are ongoing. Architectural competitions among architectural students were carried out successfully during 2002. PVs are not included in the curricula for some architects.

4.2 Indirect policy issues

None.

4.3 Standards and codes

Certification scheme for PV components and systems are established; certification of installers are established and ongoing

5 Highlights and prospects

The most positive news in the field of PV's in Denmark in 2002 has been the announcements of industry to move into inverters and into FZ Silicon.

Annex A Method and accuracy of data

The PV scene in Denmark is of very limited size, and most information is available via either the Danish PV Advisory Group to the Energy Agency (the Government), the Danish PV Society including some 50 professionals involved in PV technology or the SolarEnergyCenter Denmark

No official statistics deal with PV technology. In general terms the Danish PV data given in this report is based on personal knowledge of the local PV scene and on information received orally from professionals working in the PV field and channeled through the three above fora.