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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 2003

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i Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the organisation for Economic Co-operation and Development (OECD), which carries out a comprehensive programme of energy co-operation among its 23 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. Nine tasks have been established, and currently six are active. Information about these tasks can be found on the public website www.iea-pvps.org. The new task concerning urban-scale deployment of PV systems is now underway.

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

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 (ISR) 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 (NSR) which are produced annually by each Task 1 participant. The present 2003 National Survey Report gives a brief overview of progress made in the field of PV power systems in Denmark during 2003.

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 W or more.

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

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

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

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

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

Off-grid non-domestic PV power system: System used for a variety of applications such as water pumping, remote communications, telecommunication relays, safety and protection devices, etc. that are not connected to 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.

1 Executive summary

Installed PV power
By the end of year 2003 Denmark (including Greenland) had about 1,9 MW installed, an increase of about 300 kW compared to 2002. The ongoing SOL 1000 project originally targeting 1 MW, but now – due to budget reductions – targeting about 650 kW accounts for 250 kW in 2003. Grid-connected distributed systems constitute at about 88 % 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/W installed. The ongoing SOL 1000 project demonstrates a turn-key system price for "roof-tops" of around 34 DKK/W. The individual PV systems implemented during 2003 have demonstrated turn-key system prices in the range of 40 to 80 DKK per W installed. This indicates that without umbrella projects to reduce costs through volume and coordination of implementation, PV system prices are still quite high reflecting an immature market with few actors.

PV production
During 2003 the producer of float-zone silicon Topsil announced its first commercial order to supply international PV industry with high purity, low-cost silicon. Modules using this feedstock have been tested at NREL in the USA exhibiting efficiencies > 20 %. In 2003 the inverter developer and manufacturer Powerlynx, a company with links to the Danfoss group, announced that it has received its first commercial order in the multi-million € range.
The module production in 2003 is at about 125 kWp, an increase of 25 % compared to 2002. There is no production of PV batteries in Denmark. The building industry is showing a limited, but careful interest in developing PV-building integrated components and systems.

Budgets for PV.
During 2003 the government announced additional financial support to the new national R&D initiative started in 2002. Over a 3-5 year period more than 150 mill DKK will be allocated to renewables; however it is still too early to say to which extend PVs can benefit from the new R&D initiative. In 2003 the Public Service Obligation (PSO) of the Danish electric network operators made about 15 mill DKK available for applied research in PV's, but the extent to which these funds have been allocated to actual projects is not yet clear. The SOL 1000 project targeting 650 kW[2] is ongoing and implemented about 250 kW in 2003.

Governement Policy & Programmes
Denmark has presently no national energy plan, but the governments energy policy builds on a vision of a fully liberalised energy market supported by a framework, which underpins high consumer and environment protection, energy efficiency, subdued development in energy prices and high security of supply both in the short and long term. The vision focus inter alia on the ongoing development of efficient energy technologies both nationally and in the EU, and the government wish to strengthen the research community and the development of new and promising energy solutions.

[1] Data collection and data analysis continue until mid 2004
[2] Original target of 1000 kW reduced due to budget cuts

The Kyoto protocol and the consequent EU agreement on GHG reduction targets has lead to a Danish commitment to reduce GHG emissions by 21 % in the period 2008-2012 compared the base year 1990. The market for CO_2 certificates is seen as the most cost-effective way to reach this target.

Renewable energy is not only a future option, but very much a present and considerable element in the energy supply: by end of 2003 about 25 % of the national electricity consumption is expected to be generated by renewable energy sources. Ongoing research, development and demonstration of new energy solutions including renewable energy sources have high priority in the vision, the two main objectives being the development of a future environmental benign energy system and a high degree of security in the energy supply many years ahead. Photovoltaic technology (PV) is not specifically mentioned in the governments energy policy, but during 2003 the Danish Energy Authority (EA) in collaboration with the electricity sector, the industry and other key stakeholders has elaborated a draft national strategy on PV. This PV strategy has been finalised early 2004, and includes the fields of research, development and demonstration.

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 W 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. In Greenland stand-alone PV's play a major role as power source for the telecommunications network.

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 1992 onwards should be entered in Table 1.

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

Sub-market/ appli-cation	31 Dec 1993 kW	31 Dec 1994 kW	31 Dec 1995 kW	31 Dec 1996 kW	31 Dec 1997 kW	31 Dec 1998 kW	31 Dec 1999 kW	31 Dec 2000 kW	31 Dec 2001 kW	31 Dec 2002 kW	31 Dec 2003 kW
off-grid domestic	10	10	15	20	25	35	40	50	50	50	55
off-grid non-domestic	70	75	85	120	125	140	150	155	160	165	170
grid-conn. distribut.	5	15	40	105	272	330	880	1 255	1 290	1375	1675
grid-conn. centraliz.	0	0	0	0	0	0	0	0	0	0	0
TOTAL	85	100	140	245	422	505	1 070	1 460	1 500	1 600	1900

2.3 Major projects, demonstration and field test programmes

Denmark has no unified national PV programme, but a number of projects has been supported mainly by the Danish Energy Authority and via the Public Service Obligation (PSO) of Danish electric network operators.

PVs have been included in the action plan of the Danish Energy Authority (EA) since 1992 and have received increasing attention in the consecutive three-year Solar Energy Action Plans. Since 1992 the Renewable Energy Development Programme of the EA has supported about 125 PV projects, and by the end of 2003 about 1,9 MW have been installed mostly in the context of demonstration plants. A three-year plan for 2001-2003 has not been produced, however the Danish Energy Authority in collaboration with the electricity sector, the industry and other key stakeholders has during 2002-03 elaborated a draft national strategy on PV. This PV strategy has been finalised early 2004 following a public hearing, and includes research, development and demonstration.

A 300 roof-top's project including 750 kWp was launched early 1998 and was completed by end of 2001 although the monitoring is ongoing up till mid 2004. The project received its main support from the PSO facility of the Danish electric network operators. A 1000 roof-top programme was launched late 2001 as a follow up; this programme targets a mix of general cost reductions, increase in end-user payment and promotion of small roof-tops. Only a few weeks after the announcement of the programme, the SOL 1000, more than 3000 house owners had registered their interest. However, uncertainty about the programme due to change of government and increased demand for end-user payment have introduced a delay of almost a year in the programme implementation. By the end of 2002 the programme reported a portfolio of some 1300 house owners expressing firm interest in the programme and by end 2003 about 350 kW have been implemented stimulated by net-metering and an investment subsidy of 40 % of the turnkey system cost; average turnkey system cost is € 4,50/W.

In 2003 the most high profile project has been the SOL 1000, now targeting about 650 kWp of BIPV. Turn-key PV system costs for standard roof-top systems in the project are around 34 DKK/W (€ 4,50). The SOL 1000 project has as accompanying measure a R&D project package named SOL 2000A 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.

A new utility initiative has been launched in 2003 by Copenhagen Electric: the sale of certified PV produced electricity without any subsidies or other external support. The utility contracts to buy all electricity from new PV systems for the next 20 years at commercial terms, and tries to sell same electricity to the consumers in small standard packages including a certificate. Even though the end-user cost of the certified PV electricity is 3-4

times that of standard electricity – ironically partly because of the present tax and duty structure – the scheme reports a small but growing success.

Preparations have been initiated for a SOL 5000 project targeting 5 MW over an 8 year period and building bridge towards a market situation with no investment subsidy. In the context of this eventual future project the net-metering scheme is expected to be made more permanent.

2.4 Highlights of R&D

As part of the so called Three Year Programme R&D activities into PEC cells (Grätzel type cells) was initiated in 1999 at the Danish Institute of Technology in collaboration with Risoe National Laboratory and the Roskilde University Center. This initiative has in 2003 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, if successful, should constitute a unique building element.
R&D efforts into polymer based PV cells have in 2003 been continued at the Risoe National Laboratory with progress both as to efficiency and life time being reported.

R&D efforts are beginning to exhibit commercial results in terms of export as mentioned above. A commercial break through was announced in 2003 by the company Topsil. It is now seeing the first commercial results of its R&D into low-cost float-zone processing and shall supply on a commercial base float-zone Si for high efficiency (> 20%) PV cells. Inverter technologies has been R&D' for some years for both fuel cell and PV applications. For the latter a commercial break through was also announced in 2003 by the Danfoss related company Powerlynx, which reports to have received its first multi-million € order.

Some medium to large scale industrial corporations long established in the building industry, such as Velux Industries and Dansk Eternit, continue their R&D into how to integrate PVs in their main stream products. The products are currently under field tests in the context of demonstration projects. New companies are also exhibiting interest in this field.

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

Table 2 Public budgets (in National Currency) for R&D, demonstration/field test programmes and market incentives.

	R & D	Demo/ Field test	Market
National/federal*)	25	5	0
State/regional	-	-	-
Total	25	5	0

*) including estimates of potential PV share of R&D and PSO funds for renewable energy

3 Industry and growth

3.1 Production of feedstocks and wafers

Table 3: Production and production capacity information for the year for feedstock producers and wafer manufacturers

Manufacturer	Process & technology	Total Production (t or MW)	Maximum production capacity (t/yr or MW/yr)	Product destination
1. NA	-	-	-	-

3.2 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 (MW)		Maximum production capacity (MW/yr)	
		Cell	Module	Cell	Module
1 Gaia Solar	mc-Si & sc-Si	-	0,125		0,330/shift
Thin film manufacturers	-	-	-	-	-
Other products	-	-	-	-	-
TOTALS	-	-	0,125	-	-

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. The company is open to 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 *)	2000	2001	2002	2003
Module price(s):	30-50	30-50	21-45	21-45

*) data only registered since 2000

3.3 Manufacturers and suppliers of other components

In 2003:

As mentioned above the company Powerlynx has announced multi million € commercial orders for its newly developed inverter system specially designed for large scale OEM customers. No public information available on technology, performance and prices.

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.

3.4 System prices

Table 5: Turnkey Prices of Typical Applications

Category/Size	Typical applications and brief details	Current prices per W in NC
OFF-GRID Up to 1 kW	Telemetry, navigational aids, emergency phones, etc.	70-90
OFF-GRID >1 kW	Professional remote: telecommunication links, etc.	150-200
GRID-CONNECTED Specific case	1-4 kW roof-mounted system (roof-tops)	33-36
GRID-CONNECTED Up to 10 kW	Facades and gables	50-70
GRID-CONNECTED >10 kW	Roofs (typically single projects with high visibility)	40-100

Table 5a: National trends in system prices for PV roof-tops

YEAR	1997	1998	1999	2000	2001*)	2002	2003
Price /W:	50	50	40	40	40-80	33-36	33-36

*) in between programmes Sol 300 and SOL 1000

3.5 Labour places

a)	Research and development (not including companies):	10
b)	Manufacturing of PV system components, including company R&D:	25
c)	All other, including within electricity companies, installation companies etc.	20

Information on labour places is based on the authors best estimate.

3.6 Business value

Total business value is estimated (authors estimate – no way of getting solid data) to about € 50 mill.

4 Framework for deployment (Non-technical factors)

4.1 New initiatives

General

A national PV strategy for research, development and demonstration has been drafted and has been completed primo 2004. The strategy is expected to lead to a more coordinated and concerted effort in the field of PV's.

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 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.

One utility has started sales of green PV electricity reflecting true costs (no subsidy elements).

Changes in public perceptions of PV

The SOL 1000 project launched mid 2001 has demonstrated continued 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 and the first systems on the market are expected in 2004.

Investigations have shown, that the previously recorded reduction of in average 10 % in household electricity consumption as consequence of having a PV roof-top is still to be found after 5-7 years.

Planned developments

As a follow up to the new national PV strategy a new national PV advisory group will be formed, and this group is – among other things – expected to develop action plans minting out the recommendations in the strategy and to prepare PV deployment plans.

Other new issues

Initial moves have been taken to prepare for a SOL 5000 project which over a period of 8 years is expected to bridge the gap between the present (SOL 1000) investment subsidy of 40 % and a market situation with no investment subsidies. In the course of the eventual SOL 5000 about 5 MW PV systems is expected to be implemented.

4.2 Indirect policy issues

In general terms little can be said here. However, the actions and initiatives following the World Summit on Sustainable Development (WSSD) in Johannnesburg, such as the EU Energy Initiative, may result in a sharper Danish focus on the potential role of PV's in support of meeting the millennium development goals and may indirectly strengthen the deployment of PV technology.

4.3 Standards and codes

Certification scheme for PV components and systems are established; certification of installers are established and ongoing.
The new EU Directive on Energy Consumption in Buildings is expected to lead to national regulations in favour of BIPV.

5 Highlights and prospects

An ambitious new programme or project is being investigated: SOL 5000. The programme intends over an 8 year period to bridge the gap between the present 40 % investment subsidy and a market situation with no investment subsidy. If successful this will lead to a situation, where PV deployment in Denmark is only supported by the net-metering scheme.

A national PV strategy including research, development and demonstration has been drafted and finalized early 2004. This is expected to lead to a much more consistent and concerted Danish effort in the field of PV's.

Annex A Method and accuracy of data

The PV scene in Denmark is of limited size, and most information is available via either the Danish PV Advisory Group to the Energy Authority (the Government), the Danish Solar Energy Group (part of the Federation of Engineers) including some 50 professionals involved in PV technology and the SolarEnergyCenter Denmark (Institute of Technology).

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 Danish Task 1 team of the local PV scene and on information sought and received from professionals working in the PV field and collected through the three above fora.