International Energy Agency

Implementing Agreement

on

Photovoltaic Power Systems (IEA-PVPS)

National Survey Report of PV Power Applications in Denmark in 2007

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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 21 participating countries are Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Malaysia, Mexico (MEX), the Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), Turkey, the United Kingdom (GBR) and the United States of America (USA). The European Commission and the European Photovoltaic Industry Association are also members.

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 ***Trends in photovoltaic applications*** report. This report gives information on trends in PV power applications in the PVPS member and other countries and is largely based on the information provided in the National Survey Reports which are produced annually by each Task 1 participant.

The present report is the Danish National Survey Report for 2007.

The public PVPS website also plays an important role in disseminating information arising from the programme, including national information: www.iea-pvps.org.

iii Definitions, Symbols and Abbreviations

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

Demonstration Programme: Programme to demonstrate photovoltaic (PV) electricity production to various potential users/owners.

Field Test Programme: Programme to test the performance (eg yield and reliability) of photovoltaic (PV) systems/components in real conditions.

Final annual yield: Total photovoltaic (PV) electricity delivered to the load during the year per kW of rated PV power installed.

Grid-connected centralized PV system: Power production system performing the function of a centralized power plant. The power supplied by such a system is not associated with a particular electricity customer, and the system is not located to specifically perform functions on the electricity grid other than the supply of bulk power. Typically ground mounted and functioning independently of any nearby development.

Grid-connected distributed PV system: System installed to provide electricity to a grid-connected customer or directly to the electricity grid (specifically where that part of the electricity grid is configured to supply power to a number of customers rather than to provide a bulk transport function). Such systems may be on or integrated into the customer's premises often on the customer (demand) side of the electricity meter, on public and commercial buildings, or simply in the built environment. They may be specifically designed for support of the utility distribution grid.

Market deployment initiative: Set of means to encourage the market deployment of PV through the use of market instruments such as green pricing, feed-in tariffs, tax credits, capital subsidies etc. These may be implemented by government, the finance industry, utilities, etc.

Off-grid domestic PV system: System installed to provide power mainly to a household or village not connected to the (main) electricity utility grid(s). Often a means to store electricity is used (most commonly lead-acid batteries). Also referred to as 'stand-alone PV power system'. Can also provide power to domestic and community users (plus some other applications) via a 'micro-grid', often as a hybrid with another source of power.

Off-grid non-domestic PV system: System used for a variety of industrial and agricultural 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 system'.

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 rated PV power.

Photovoltaic (PV) module manufacturer: An organisation carrying out the encapsulation of PV cells in the process of the production of PV modules.

Photovoltaic (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').

Photovoltaic (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 (if any) and all installation and control components with a PV power capacity of 40 W or more.

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

Rated power: Available power delivered by a PV module or array under standard test conditions (STC), written as W.

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 telecommunications system in a remote area are excluded).

1 Executive summary

Installed PV power

By the end of year 2007 Denmark (including Greenland) had about 3,1 MW installed, an increase of almost 200 kW compared to 2006. The SOL 1000 project originally targeting 1 MW, but finally – following budget reductions – reaching about 600 kW was completed end of 2006, leaving Denmark without any incentives for reducing the investment cost of PV systems. Grid-connected distributed systems constitute at about 90 % the majority of PV systems in Denmark.

Costs & prices

The completed SOL 1000 project demonstrated a turn-key system price for "roof-tops" of around 34 DKK/W. However, high demand world wide for PV modules during 2006 and 2007 has lead to limited supply of modules and slightly increasing module prices, and system cost figures for 2007 vary widely due inter alia to the time of contracting and the size of the actual plant. The individual PV systems implemented during 2007 exhibit turn-key system prices in the range of 40 to 80 DKK per W installed.

PV production

During 2007 the producer of float-zone silicon Topsil continued its commercial activities to supply international PV industry with high purity, low-cost silicon. Modules (brand: Sunpower) using this feedstock have been tested at NREL in the USA exhibiting efficiencies > 20 %. In 2007 the inverter developer and manufacturer Danfoss[1] Solar Inverter also reported ongoing and increasing commercial activities in the multi-million € range.
The module production (Gaia Solar) in 2007 is at about 500 kW, approximately the same as in 2006. The main markets for Gaia Solar are Germany and Sweden. There is no production of PV batteries in Denmark. The building industry is showing a limited, but growing interest in developing PV-building integrated components and systems in particular in connection with highly industrialized building processes.

Public budgets for PV.

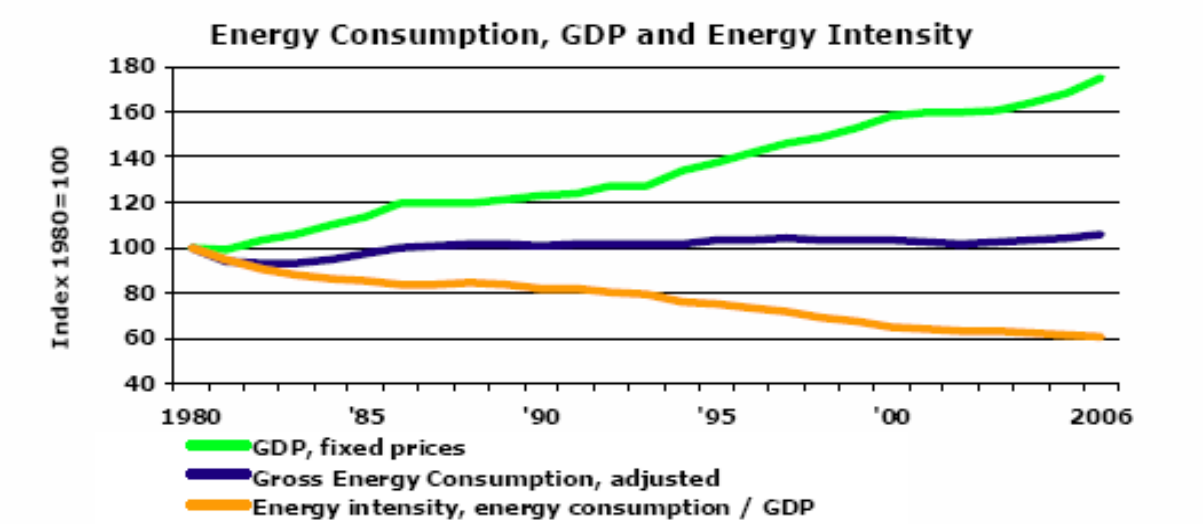
In early 2007 the government confirmed its commitment to support renewables, and a new energy plan "A Visionary Energy Policy" reaching up to 2025 was launched[2]. Public funding for R&D into energy is expected to be doubled from about 0,5 billion DKK in 2007 to 1 billion by 2010. Over a 3-5 year period more than 150 mill DKK will be allocated to R&D in renewables; however it is still too early to say to which extend PVs effectively can benefit from these initiatives. In 2007 the Public Service Obligation (PSO) of the Danish transmission system operator, the so called ForskEL programme, funded about 13,5 mill DKK for applied research projects in PV's, and the Energy Research Programme (EFP) – now in transition to the Energy Development and Demonstration Programme EUDP - funded about 3 mill DKK for PV R&D activities.

[1] Previously named Powerlynx

[2] Complex negotiations and a general election prevented the energy plan to be politically accepted until February 28 2008; the February 28 agreement includes a special provision of 100 mill. DKK for PV, wave power and other emerging RE technologies.

Government Policy & Programmes

As mentioned above the Danish government launched a new energy plan in early 2007, "A Visionary Energy Policy" reaching up to 2025. The energy plan focus on 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 energy plan further focus 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. The energy plan also focus on energy conservation and on increasing the penetration of renewables[3] in the total energy supply to 30 % by 2025. The overall objective is not to let the gross energy consumption increase and to decrease the use of fossil fuels by 15 %, this way continuing the trend of the last 25 years as illustrated below. Over the last 25 years Denmarks economy has grown by 75 % with almost constant gross energy consumption.



Note: Energy consumption for international maritime traffic (international bunkering) is not included in the individual country's energy consumption under international rules for energy statistics, but is calculated separately; therefore it does not appear on the figure.

Photovoltaic technology (PV) is for the first time mentioned in the government's energy plan, see footnote 2 on the previous page; how this will be minted out is not yet clear but is expected to pass the Parliament as legislation before mid 2008.

Early 2004 the Danish Energy Authority (EA) in collaboration with the electricity sector, the industry and other key stakeholders finalized a national strategy on PV after a public hearing. This PV strategy includes the fields of research, development and demonstration. Deployment activities in support of the PV strategy are expected to be developed in the coming years. Early 2006 a national workshop reviewed the PV strategy and it was consequently revised during 2006 in terms of an addendum to the original strategy. A more comprehensive revision of the PV strategy is expected in 2008.

[3] Only technology specific targets for wind energy and for biofuels.

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 Application of PV systems

The national electric grid covers practically all of Denmark and leaves little room for stand-alone applications besides the traditional 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 remote signalling and for the telecommunication network extending more than 2 000 km on the western coast line.

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. The EU directive[4] on energy consumption in buildings has in 2005 been minted into a revised national building code – moved into force early 2006 – which specifically mentions PV and allocates PV electricity a factor 2,5 in the calculation of the "energy foot print" of a building. However, due to the inertia in the construction sector, it is yet too early to see any real impact on PV deployment allthough a number of pilot buildings have been realized during 2007.

2.2 Total photovoltaic power installed

The PV power installed in 4 sub-markets during 2007 is shown in Table 1.

Table 1 - The PV power installed in 4 sub-markets during 2007.

Sub-market/ application ##	off-grid domestic	off-grid non-domestic	grid-connected distributed	grid-connected centralized	total
PV power installed in 2007 (kW)	20	30	125	0	175

The total **cumulative** installed PV power for each sub-market on the 31 December of each year from 1992 onwards is shown in Table 2.

[4] EU directive: Directive 2002/91/EC of 16.12.02

Table 2 - 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	31 Dec 2004 kW	31 Dec 2005 kW	31 Dec 2006 kW	31 Dec 2007
off-grid domestic	10	10	15	20	25	35	40	50	50	50	55	65	70	80	100
off-grid non-domestic	70	75	85	120	125	140	150	155	160	165	170	190	225	255	285
grid-conn. distribut.	5	15	40	105	272	330	880	1 255	1 290	1 375	1 675	2 035	2 355	2 565	2 690
grid-conn. centraliz.	0	0	0	0	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	2290	2 650	2 900	3 075

The main Danish PV market sector, grid-connected distributed, exhibited very little progress due to lack of national promotional measuers.

2.3 PV implementation highlights, major projects, demonstration and field test programmes

During 2007 no national PV promotional activities were found resulting in a very low progress rate for the otherwise main market sector, the grid-connected distributed, typically roof-top systems. Only the regional distribution utility EnergiMidt provided incentives in their own concessionary area in terms of an investment subsidy of up to 40 % of the investment cost of a grid-connected PV system.
The off-grid professional and private market sectors developed almost as in the previous years.

For a more historical overview or context, please refer to the Danish National Survey Report covering 2006 and previous years (www.iea-pvps.org).

2.4 Highlights of R&D

During 2007 R&D efforts in the fields of organic dye sentizied PV cells (PEC), polymer cells and "PV cells-architecture-lights" continued with steady progress in all fields.

Basic research into PV cells based on mono-X Si is ongoing at the University of Aarhus in a partnership with industry.

For a more historical overview or context, please refer to the Danish National Survey Report covering 2006 and previous years (www.iea-pvps.org).

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

Table 3 - Public budgets for R&D, demonstration/field test programmes and market incentives.

	R & D	Demo/Field test	Market
National/federal	25 mill DKK	-	-
State/regional	-	-	-
Total	25 mill DKK	-	-

Mainly funding from the PSO Elforsk and the EFP/EUDP programmes. Funding for more basic research is in principle also available for PV's, but few if any projects are benefitting from this during 2007.

3 Industry and growth

3.1 Production of feedstocks, ingots and wafers

Table 4 - Production and production capacity information for the year for silicon feedstock, ingot and wafer producers

Manufacturers	Process & technology	Total Production	Maximum production capacity	Product destination?	Price??
	Silicon feedstock	*tonnes*	*tonnes/year*		
Topsil	sc-Si ingots (float-zone)	*10 tonnes*	*10 tonnes/year*	Exports	No data
	mc-Si ingots	*tonnes*	*tonnes/year*		
	sc-Si wafers	*MW*	*MW/year*		
	mc-Si wafers	*MW*	*MW/year*		

3.2 Production of photovoltaic cells and modules

Module manufacturing is defined as the industry where in the process of the production of PV modules the encapsulation is done. A company may also be involved in the production of ingots, wafers or the processing of cells, in addition to fabricating the modules with frames, junction boxes etc. The manufacturing of modules may only be counted to a country if the encapsulation takes place in that country.

Give in Table 5 the following information for the year:

Table 5 - 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)** Cell	Module	**Annual maximum production capacity (MW)** Cell	Module
Silicon wafer based manufacturers					
Gaia Solar	mc-Si & sc-Si	**-**	**0,5**	**-**	**0,5**
Thin film manufacturers					
Cells for concentration					
TOTALS		**-**	**0,5**	**-**	**0,5**

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 W modules being most typical. Normal warranty: 5 years. The company is open to custom design modules. Certification to IEC 61215.

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

Most modules are exported to Germany and Sweden.

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

Table 6 - Typical module prices in national currency for a number of years

Year (only data since 2000)	2000	2001	2002	2003	2004	2005	2006	2007
Module price(s): Typical	30-50	30-50	21-45	21-45	30-50	30-50	40-60	25-50
Best price	-	-	-	-	-	-	-	

During 2007 the price of PV modules exhibited a trend towards falling prices.

3.3 Manufacturers and suppliers of other components

Balance of system component manufacture and supply is an important part of the PV system value chain. For 2007 the situation in Denmark is briefly described below.

The company Danfoss Solar inverters has reported +20 million € commercial orders for its recently developed inverter system specially designed for large scale OEM customers. However, no detailed information is publicly available on technology, performance, volume and prices.

The company Grundfos produces its special variable frequency inverter system for its water pumping systems. However, no detailed information is publicly available on technology, performance, volume 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.

The company Velux Industries has developed and marketed a roof-integration package. However, no detailed information is publicly available on technology, performance, volume and prices.

3.4 System prices

Table 7 - Turnkey Prices of Typical Applications

Category/Size	Typical applications and brief details	Current prices per W in DKK
OFF-GRID Up to 1 kW	Telemetry, navigational aids, emergency phones, etc.	70-90
OFF-GRID >1 kW	Professional remote: Greenland tele-communication links, etc.	150-200
GRID-CONNECTED Specific case	1-4 kW roof-mounted system (roof-tops)	35-45
GRID-CONNECTED Up to 10 kW	Facades and gables	50-85
GRID-CONNECTED >10 kW	Roofs (typically single projects with high visibility)	50-100

Table 7a - National trends in system prices (current DKK) for roof-tops

YEAR	1997	1998	1999	2000	2001*)	2002	2003	2004	2005	2006	2007
Price /W:	50	50	40	40	40-80	33-36	33-36	33-36 #)	33-36 #)	35-45 #)	33-40

*) in between programmes Sol 300 and SOL 1000

#) only for system on long term contract, e.g. SOL 1000. Other (few) systems exhibit price increases, which vary widely.

3.5 Labour places

a) Research and development (not including companies): 15

b) Manufacturing of PV system components, including company R&D: 200
c) All other, including within electricity companies, installation companies etc. 25

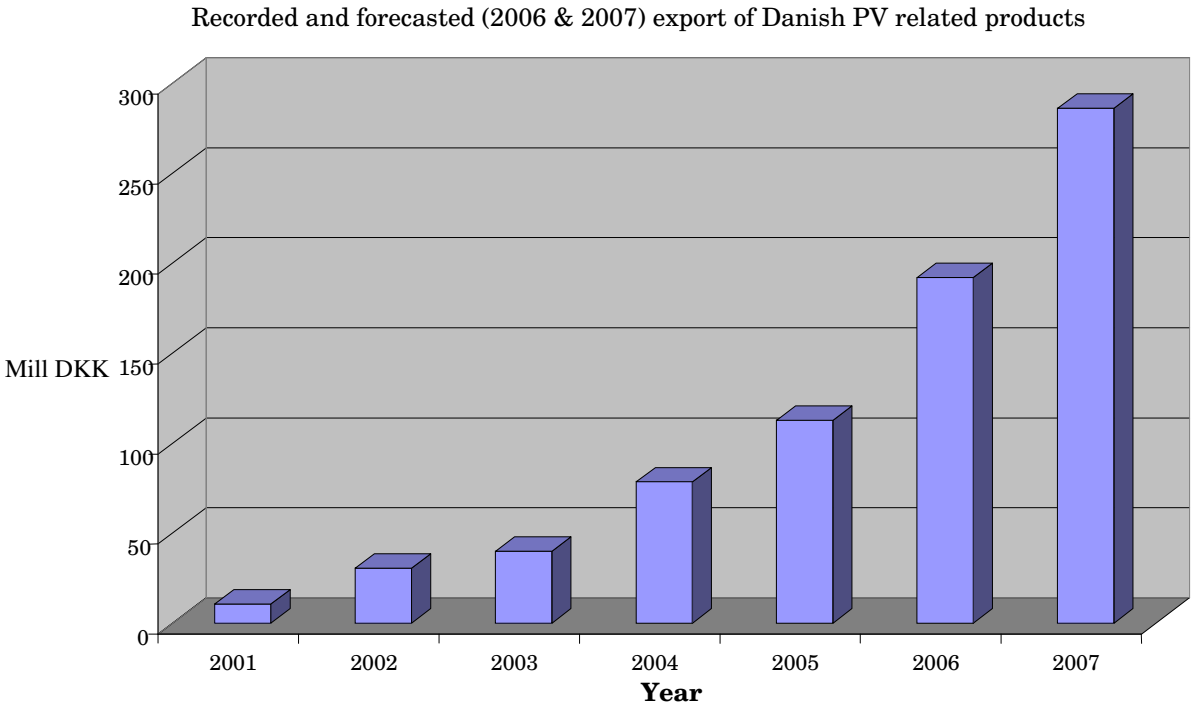
Information on labour places is based on the author's best estimate – no official statistics available.

3.6 Business value

Table 6: Value of PV business
(Table 6 cannot be completed due to lack of data)

Total business value is estimated (author's estimate – no way of getting solid data) to about 350 million DKK.

Estimate by the Danish Federation of Industries (DI) on PV related export for 2006 points at approx. 200 mill DKK. The trend in PV related exports is illustrated below[5].



[5] Source: The Energy Industry, Danish Federation of Industries.

4 Framework for deployment (Non-technical factors)

4.1 Support measures and new initiatives

Table 9 - PV support measures

	Ongoing measures	Measures that commenced during 2007
Enhanced feed-in tariffs	-	-
Capital subsidies for equipment or total cost	-	-
Green electricity schemes	-	-
PV-specific green electricity schemes	-	-
Renewable portfolio standards (RPS)	-	-
PV requirement in RPS	-	-
Funds for investment in PV	-	-
Income tax credits	-	-
Net metering	National scheme	-
Net billing		-
Commercial bank activities eg green mortgages promoting PV	-	-
Electricity utility activities eg network support	Energinet.dk monitoring and metering programme	EnergiMidt regional investment support programme
Sustainable building requirements	-	-

As previously mentioned the political energy agreement of February 28 2008 includes a special provision for support to large scale demonstration of e.g. PV's; this is expected to be minted in legislation before mid 2008.

4.2 Indirect policy issues

The European Commission has early 2007 established binding targets for RE implementation in the EU as such. However, no targets for countries nor technology specific targets have yet been set.

The Danish government has as previously mentioned – also early 2007 – set binding RE targets for the country for 2025. However, few technology specific targets have been set and none for PV.

The extent to which these overall RE targets may stimulate the deployment of PV's in Denmark is very uncertain.

The EU Directive on energy in buildings has lead to obligatory building codes in the EU member states including Denmark. The new Danish building codes were introduced in 2006, and may in the future promote PV's as PV's enter favorably into the calculation of a

buildings energy “foot print”. This is expected - with time - to stimulate the use of BIPV in Denmark, but the building sector is quite “conservative”.

4.3 Standards and codes

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

The aforementioned EU Directive on energy consumption in buildings has lead to national building codes in favour of BIPV. The revised Danish building codes has move into force early 2006 and includes a factor of 2,5 for BIPV when calculating the energy “foot print” of a building, see also section 4.2.

5 Highlights and prospects

Efforts are ongoing to establish relative large scale deployment/demonstration programmes, which over a 7-8 year period can bridge the gap from the present need of an investment incentive of approx. 30 % to 0 %. The need of an investment incentive is based on consumer polls indicating, that many owners of residential houses can accept a pay-back time for a PV roof-top system of 20-25 years, but not higher. The above mentioned new funding possibilities for large scale PV demonstrations expected to be minted in legislation before mid 2008 may provide the necessary means to launch such a programme.

Such a programme would have an overall budget of approx. 200 mill DKK and require a public support amounting to approx. 50-60 mill DKK.

The national Danish PV strategy is expected to be revised during 2008.

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 associated "PV Dialog Group" broadly representing Danish PV stakeholders, 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).

A new Danish PV Industrial Federation started in April 2008 may with time provide a new forum for data.

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 sought and received from professionals working in the PV field and collected through the above four fora.

Annex B Country information

The following brief description of the Danish scene in which PV activities take place is based on the author's estimates and opinion.

The national electric grid covers practically all of Denmark and leaves little room for stand-alone applications besides the traditional 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 telecommunication network extending more than 2 000 km along the west coast.

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.

For private households the retail price of electricity is constituted by a number of elements, one example seen from the point of view of a distribution utility is given in table B.1.

Table B.1: Elements of a typical Electricity Retail Price

• Category:	• Name:	• DKK/100
• Production	• Market price at high voltage level	• 26,31
• Grid, System and Public Service Obligation (PSO)	• Distribution grid	• 14,08
	• Medium voltage grid	• 2,37
	• System	• 3,12
	• PSO	• 12,60
• Taxes (to the state)	• Electricity tax	• 53,60
	• CO2 tax	• 9,00
	• Distribution tax	• 4,00
• Sub-total	•	• 125,08
• VAT	• 25 % VAT	• 31,27
• Price /kWH	• Retail price	• 156,35

Certain industries and commercial operations can get certain taxes refunded.

Average household electricity consumption is estimated to 4 400 kWH/year, and for private households electricity is typically metered at a constant flat rate. Net-metering (allowing the meter to run “backwards”) is permanently set by law for PV systems up to 6 kW and under certain conditions to prevent misuse.

For single family houses PV roof-top systems are seen as an integrated part of the house with regard to taxing, insurance, mortgage etc. Typical mortgage interest is in the range of 2-5 % depending on type of loan.