DENMARK

PV TECHNOLOGY STATUS AND PROSPECTS

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Fig. 1 - Reflections in the dark modules which are customized to be a natural part of the roof in colour and shape.

GENERAL FRAMEWORK

The Danish government proposed a new energy plan, early in 2007, called Energy Vision 2025. However, this plan has not yet been politically accepted, as general elections in the fall of 2007 interrupted the political negotiations, which are now only expected to be completed during the first quarter of 2008. Until then Denmark follows the energy plan launched in March 2005.
This energy plan focuses 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 focuses on the ongoing development of efficient energy technologies both nationally and in the EU, and on the government wish to strengthen the research community and the development of new and promising energy solutions. With regard to renewable energy (RE) the plan sets quantifiable targets for the overall contribution from RE, but no technology specific targets. The market forces are supposed to promote the most suitable and competitive RE technologies.

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 2007 more than 25 % of the national electricity consumption was generated by renewable energy sources including incineration of waste. Ongoing research, development and demonstration of new energy solutions including renewable energy sources have high priority in the present energy plan, 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; both at favourable cost to the consumers.

Photovoltaic technology (PV) is not specifically mentioned in the government's energy plan, but 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 envisaged to be developed in the coming years and an overall framework for the coordination of PV development and deployment in Denmark is thus envisaged to be in place inside a few years. The PV strategy was updated mid 2006 by the way of an annex outlining the need of long term operational targets and support mechanisms for demonstration. A full update is expected early 2008.

Key actors have been identified as: utilities – carrying out small and large R&D and in particular demonstration projects; transmission system operators – identifying potentials and unresolved issues related to PV in a large network; universities and institutions – carrying out R&D activities on PV technology and its application & integration; professional consultants – catalysing a broad range of PV projects; industry – developing and manufacturing PV components and systems; NGO's – disseminating information and the general public – exhibiting a steady interest in and willingness to buy PVs, if conditions can be established resulting in a simple pay-back time of 20 years or less.

Fig. 2 - The customized PV modules from the Danish module manufacturer GAIA Solar are made especially to fit with the roof in the PV-Danmark project.

NATIONAL PROGRAM

Denmark has no unified national PV programme, but a number of projects supported mainly by the Danish Energy Authority and via the Public Service Obligation (PSO) of Danish transmission system operator, Energinet.dk. In late 2006, a new support mechanism, the Energy Development and Demonstration Programme (EUDP), to be administered by an independent board and with the Energy Authority as secretariat was announced. A first call for proposals was closed in September 2007, and a few PV projects received support by end of 2007, but the extent to which PV really can benefit from this new instrument is not yet known.

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.

By the end of 2007 about 3 MW has been installed in the context of various projects and demonstrations plants supported by various instruments. A 1 000 roof-top programme was launched late 2001; this programme targeted 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 3 000 house owners had registered their interest. However, uncertainty about the programme due to change of government and increased demand for end-user payment introduced a delay of almost a year in the programme implementation. By the end of 2002 the programme reported a portfolio of some 1 300 house owners expressing firm interest in the programme and by end 2006 about 700 kW have been implemented stimulated by an investment subsidy of 40 % of the turnkey system cost, average turnkey system cost being 4,40 EUR/W. The SOL 1000 programme was extended until end of 2006. The average system size in the project is for the private households 1,8 kWp. Since end of 2006 there are no longer any instruments in Denmark to bring down investment cost of PV systems in general, only the distribution utility EnergiMidt supports PV installations inside its concessionary area.

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 40 % for the turn key system costs. The calculation of the actual subsidy will be in favour of high yield installations. The programme was not been very successful, as the commercial sector seem to regard an incentive of 40 % as inadequate.

Net-metering for privately owned PV systems was established mid 1998 for a pilot-period of four years. Late 2002 the net-metering scheme was extended another four years up to end of 2006. Net-metering has proved to be a cheap, easy to administrate and effective way of stimulating the deployment of PV in Denmark; however the relative short time window of the arrangement has so far prevented it from reaching its full potential. During the political negotiations in the fall of 2005 the net-metering for privately owned PV systems was made permanent; however net-metering alone appears not on its own to be able to stimulate private PV installations.

RESEARCH & DEVELOPMENT, DEMONSTRATION

During 2003, the government has announced additional financial support to the new R&D programme started in 2002. Over a 5 year period more than 150 MDKK was allocated to renewables; however, as the focus of the programme is on university research activities, it is so far only to a limited extend PVs have benefited from the programme. In 2004, the government increased the PSO allocation for R&D into environmentally benign electricity generating technologies from 100 MDKK per year to 130 MDKK per year. Since then the government has pledged itself to increase the funding for R&D in new energy technologies up to 2010 and a few R&D PV projects have indeed benefited from support during 2007 with most of the funding going to basic R&D at universities.

In 2004 the EA became part of the new EU supported PV RTD network PV-ERA-NET focussing on EU level and national level coordination and optimization of PV RTD programmes. Denmark has in the context of the PSO system in 2007 decided to enter the first

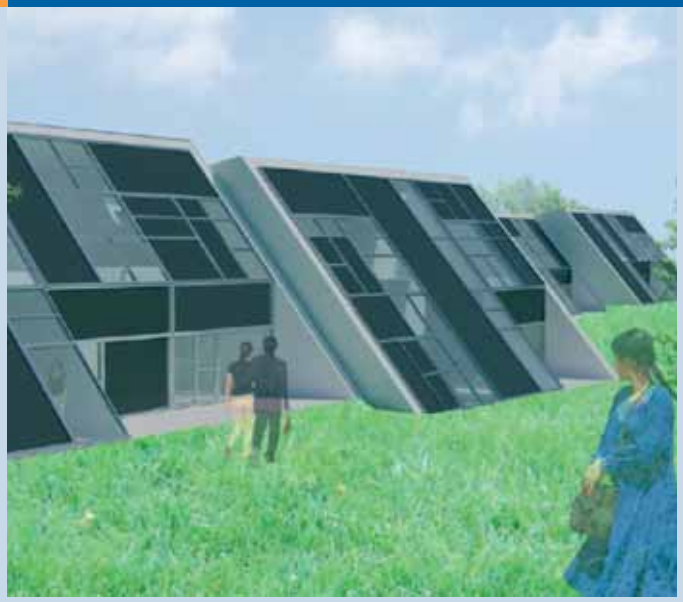

Fig. 3 - One of many ideas to make a house optimized for PV generated by students from Aarhus School of Architecture.

Fig. 4 - Different ways to integrate PV in a prefabricated building are demonstrated in the SOL-IND project, led by EnergiMidt.

Joint Call on PV R&D in the framework of the PV-ERA-NET, and is considering joining a second Joint Call now under preparation.

R&D activities into PEC cells (Grätzel type cells) are ongoing at the Danish Institute of Technology. This activity has in 2002-04 been supported by the PSO of the Danish network operators. This R&D activity has now attracted commercial finance and a new company has been formed. Ongoing support has been granted from 2007 and onwards for continued R&D activities in this field. At the Risoe National Laboratory basic research into polymer based PV cells is ongoing with progress reported in both efficiency and in particular in stability and life time.

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 their installation including certification of installers and to help industry develop better products. The PVSyslab is also engaged in PV system monitoring and in the upkeep of a national knowledge base on applied PV technology. The PVSyslab has ongoing activities in the field of technology cooperation with developing countries; in particular in the setting up of local quality assurance schemes and test laboratories.

The first Danish book on PV and architecture focussing exclusively on Danish buildings, design, architecture and products was published in the fall of 2005 by the publishing branch of the Danish Architects Federation. Several more publications have followed and the Aarhus School of Architecture has included BIPV in its curriculum.

Municipal-based PV interest groups have been formed in two municipalities: Solar City Copenhagen and Solar City Horsen. These groups are quite active and more similar groups are expected.

IMPLEMENTATION

The potential for large scale deployment of PVs in Denmark has been identified as building integrated systems.
The SOL 1000 programme ran by the utility EnergiMidt, which as mentioned above intended to demonstrate low cost and architectural acceptable integration of PV technology primarily on existing single family houses, has by end of project ultimo 2006 implemented a bit more than 700 kW in total. There was a focus on the gradual increase of end-user payment, this way paving the way to a commercial market with no investment subsidy; the highest acceptable end-user payment appeared to correspond to a simple pay-back time for the owner of about 20 years. A third objective was to disseminate information and experience on PV roof-top deployment to the Danish distribution utilities. Several projects for building integrated PV systems including commercial buildings, apartment buildings and schools have been implemented, typically in the range of 2-15 kWp. The “small,” “do it your self” PV plants were also introduced with a size of 250Wp, and since 2005 about 150 of these system have been sold and installed; a major weakness in this context is the requirement to use a professional electrician for the grid hook-up, which increases the cost of the system considerably.

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 success.

Also in Copenhagen the so called Valby Initiative has progressed. Valby is region of Copenhagen undergoing extension changes and refurbishment, and a PV initiative targeting about 300 MW has long been in preparation. The initiative has been integrated into actions in the EU Concerto Programme. The Carlsberg brewery in the centre of Copenhagen is moving out of town leaving a large area for new urban development. BIPV are reported to be strongly represented in this development.

INDUSTRY STATUS

R&D efforts are beginning to exhibit commercial results in terms of export. The company Topsil, which using a float-zone technique produces high purity Silicon (Si) ingots for the semiconductor industry, announced in 2002 their intention of developing a low-cost float-zone manufacturing technology, that would enable the company to offer high purity Si to the PV industry. It was in 2004 seeing the first commercial results of its R&D into low-cost float-zone processing and is expected to continue to supply SunPower in the US with float-zone Si for high efficiency PV cells.
Inverter technologies have been R&D'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 in 2007 to have underpinned and significantly strengthened the commercial breakthrough announced in 2003. Powerlynx, which now employs more than 200 people, was fully acquired by Danfoss in 2007, and is now called Danfoss Solar Inverters.

PV Si cell production stopped in Denmark in 1996. A single Danish module manufacturer (Gaia Solar) with an annual capacity of about 0,5 MW per shift has existed since 1996. A few other companies producing tailor-made modules such as window-integrated PV cells can be found.

Some medium to large scale industrial corporations long established in the building industry 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.

A project on the integration of PV's in industrialized residential buildings was completed in 2005 with good results. In particular the collaboration with the Aarhus School of Architecture proved to be successful with PV's entering the curricula. The objective of integrating PV's in industrialized building processes has been continued in 2007 via a new project.

There is no PV relevant battery manufacturing in Denmark at present.

A few companies develop and produce power electronics for PVs, mainly for stand-alone systems for the remote-professional market sector such as telecoms, navigational aids, vaccine refrigeration and telemetry.

A number of companies are acting as PV system integrators, designing and supplying PV systems to the already competitive international market sector of remote stand-alone applications.

Consultant engineering companies specializing in PV application in developing countries report a slowly growing business area.

MARKET DEVELOPMENT

Market development incentives already in place are mentioned above under National Program.

Total PV business volume in 2007 is very difficult to estimate with any degree of accuracy primo 2007 due to the commercial secrecy surrounding the above mentioned new business developments in the fields of Si feed stock and inverters. However, an increase from 40 MEUR in 2006 to 45 MEUR in 2007 is a "best guess" mostly due to exports.

The cumulative installed PV capacity in Denmark (including Greenland) is by end of 2007 estimated to about 3 MW; an increase of about 3 % compared to 2006.

FUTURE OUTLOOK

The increasing government funds allocated to R&D into renewables are expected to give a boost also to the PV sector, but – if left alone - may lead to an imbalance between R&D efforts and demonstration, as the eventual R&D results need support to be demonstrated and reach the market. However, it is the hope, that the earlier mentioned effort to establish and up-date a national PV strategy and consequent deployment schemes may succeed in creating a more coordinated and unified approach to PV in Denmark. However, funding for large scale demonstrations has proven to be difficult to find in the existing support structure of the Danish Energy Authority and the PSO system. In 2007, the newly introduced EUPD programme, which focus on technology development and large scale demonstrations, does not specifically mention PV as a target technology, and the benefit of this programme to the PV sector is not yet clear.

It is regarded as obvious that without funding and clear public support to large scale demonstration of PVs for yet some years to come, the sector risks to go on diminishing because of an insufficient home market.

However, the trend towards commercial sustainability for PVs is seen as ongoing and with the objective realistically within reach. Projections and scenarios completed during 2007 indicates, that with the continued global technical and economic development of the PV technology, with now a permanent net-metering scheme in Denmark and with unchanged development of the Danish end-users increasing willingness to invest in PVs, a market for PV roof-tops in Denmark without any investment subsidy will emerge around 2014-15; given that the necessary demonstration activities can be continued in the period up to 2013. The source of funding for such a demonstration effort has still to be found, and the ongoing political energy negotiations exhibit some hope for the PV sector.