# National Survey Report of PV Power Applications in Sweden 2003


Prepared for the IEA PV Power Systems programme, funded by the Swedish PV R&D programme SolEl 03-07

**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 Sweden

**2003**

**Prepared by**

***Ulf Malm and Lars Stolt***

***Ångström Solar Center, Uppsala University***

***P.O. Box 534, SE-751 21***

***Uppsala, Sweden***

***3 June 2004***

***The making of this report was funded by the Swedish National Programme on Photovoltaic Power Systems, SolEl 03-07, and was carried out within a framework, Ångström Solar Center, funded by the Swedish Energy Agency and The Foundation for Strategic Environmental Research***

## TABLE OF CONTENTS

## *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. This National Survey Report is an important part of this work.

Each country participating in Task 1 produces a National Survey Report where the current status of PV applications in the concerned country is described. While the reports are important documents for the domestic audience, they are also used in the compilation of an international report, *TRENDS IN PHOTOVOLTAIC APPLICATIONS: Survey report of selected IEA countries*. This international report gives a comprehensive picture of the PV markets in the IEA-PVPS countries, and is used by various analysts, business people and policy makers.

The public PVPS website also plays an important role in disseminating information from the programme, including the national information in this report. The information from other tasks in IEA-PVPS is also published on this website, in the form of guidelines, best practice reports and more. This website is managed by Task 1 and has the address http://www.iea-pvps.org.

### *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.

***Summary in Swedish - Sammanfattning på svenska***

Generellt kan sägas att den svenska solcellsmarknaden inte har förändrats drastiskt under 2003, även om ett antal företag har utvecklats, och det nya systemet för elcertifikat introducerades.

Installerad effekt

Den totala mängden solcellssystem, mätt i toppeffekt i Watt, som installerades under 2003 uppgick till 284 kW, vilket är aningen mer än föregående år (en ökning med 7 %). Detta stärker bilden av en marknad som mor eller mindre är konstant kring 250 KW.

Aningen mer nätanslutna solceller installerades under 2003 än under ett genomsnittligt år, men detta varierar i regel kraftigt i och med att ett större projekt kan motsvara 10 % av den svenska marknaden. Det viktigaste marknadssegmentet på den svenska solcellsmarknaden är annars icke nätanslutna system för privat bruk. Dessa system installeras framförallt på sommarstugor där elnätet inte finns tillgängligt.

Kostnader och priser

Priset på ett solcellssystem is Sverige har inte ändrats speciellt mycket under 2003 utan ligger på en nivå som är något högre än i flera andra länder i IEA-PVPS. Detta tros bero på en mycket begränsad marknad jämfört med de länder som har omfattande subsidier för installation av solceller.

Tillverkning

Två nya företag som producerar moduler har startat i Sverige under 2003, ScanModule AB och PV Enterprise Sweden AB. Detta betyder att det idag finns fyra modultillverkare, Gällivare Photovoltaic AB och ArcticSolar AB samt de två nya företagen. Sammanlagt producerades 11 MW solcellsmoduler i Sverige, vilket innebär att Sverige är ett exportland inom solcellssektorn. Främst exporteras moduler till Tyskland.

Under 2003 påbörjades uppskalning av deponeringsprocesser för $Cu(In,Ga)Se_2$ tunnfilms-solceller i företaget Solibro AB, vilket startats av forskare vid Ångström Solar Center. Företaget siktar på att introducera sina moduler på marknaden om fyra till fem år.

Allmänna medel till solceller

Den allra största delen av allmänna medel som går till solceller utgörs av finansieringen för Ångström Solar Center. Detta beror på att medan det saknas generella subsidier för installation av solcellssystem, har Ångström Solar Center varit en mycket fokuserad och relativt välfinansierad forskningssatsning.

Ytterligare allmänna medel till forskning och utveckling administreras genom projektet SolEl 03-07, vilket leds av elföretagens forskningsföretag Elforsk AB. SolEl 03-07 finansieras av såväl Energimyndigheten som stiftelser och industrin.

Framtidsutsikter

Under 2004 kommer ett ROT-bidrag för energieffektiv ombyggnad att utredas, där ett avdrag på 70 % av investeringskostnaden för solceller i offentliga byggnader kommer att finnas med. Dessutom utreds förutsättningarna för en generell subsidie för att stödja framväxten av solcellsmarknaden av Energimyndigheten. Utredningen kommer att presenteras för näringsdepartementet under juni 2004.

Generellt ökar de industriella aktiviteterna på solcellsområdet i Sverige, och under de kommande åren kommer mängden solcellsmoduler som tillverkas i Sverige att öka, då de nyetablerade företagen ökar sina produktionsvolymer.

## *1 Executive summary*

In general the PV market in Sweden during 2003 has not changed drastically, although there has been some developments of new business and the start of a scheme for renewable energy certificates.

### 1.1 Installed PV power

The installed PV power in Sweden during 2003 amounted to 284 kW, which means that the market volume increased by approximately 7 % compared to 2002. This enforces the picture of a more or less constant market size, over a longer period of time. The average market size from 1993 to 2003 was 253 kW.

During 2003, more power was installed in the sub-market grid-connected distributed than in an average year, but because this market segment is quite small, single projects can have a large impact on these numbers.

In general the trend with a majority of the PV power installed in the sub-market off-grid domestic continues. These systems are mainly used for electrification of remote summer-houses without grid-connection.

### 1.2 Costs & Prices

The prices per watt for a PV system in Sweden has remained relatively unchanged during 2003, still at a level higher than the average in the IEA-PVPS countries. This is believed to be due to the limited market, and the absence of a market deployment initiative for grid-connected applications on a larger scale, like several other countries have.

### 1.3 PV Production

In 2003, the business activities in the area of module manufacture increased, with two new producers, ScanModule and PV Enterprise Sweden in addition to the already established companies GPV and ArcticSolar. These four companies produced a total amount of 11 MW of PV modules, which means that Sweden is producing considerably larger amounts of PV modules than what is sold in Sweden, and nearly all modules are exported, predominantly to the German market.

An offshoot from Ångström Solar Center, the company Solibro AB, started up-scaling the deposition processes for manufacture of thin-film $Cu(In,Ga)Se_2$ modules during 2003. The company aims for market introduction in four to five years.

### 1.4 Budgets for PV

The public budgets for PV in Sweden is dominated by the grants for research and some demonstration projects. This is much due to the fact that there is no market deployment initiative for PV in Sweden. The single largest budget item in solar cell research was the funding for the research programme Ångström Solar Center.

There were also public money awarded to the research programme SolEl 03-07, which is jointly funded by government bodies and private companies.

## 1.5 Prospects

During 2004 a subsidy system for energy effective refurbishments in public buildings will be explored, where a 70 % subsidy for PV will be included. Furthermore, a general market deployment initiative is under consideration, and the Swedish Energy Agency will present an investigation into this issue during June 2004.

In general, the business activities in the PV area is increasing in Sweden, and during the coming years the amount of PV modules produced in Sweden will increase as the newly established companies get their operations up to speed.

# *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

In general the applications for PV in Sweden is dominated by the use of stand-alone PV systems in the domestic market. The largest part of these systems are small, and predominantly used to supply electricity to recreational homes where there is no grid available.

Because of the low density of the population of Sweden, there are several areas where, although the grid supplies all permanent dwellings, remote summerhouses are too far from the grid to justify connection. This kind of situation is ideal for the use of a stand-alone PV system.

Apart from the off-grid domestic market described above, there are some installations that are off-grid non-domestic and a few grid-connected systems. The off-grid non-domestic systems applications include PV supplying electricity for telecommunications systems, lighthouses and warning lights on pylons for high voltage power lines. The grid-connected systems are mostly demonstration projects that have been installed to demonstrate the technology and to conduct research. These research and demonstration facilities are mostly owned by building companies and electricity utilities. Their motives for acquiring these systems have been to learn more about the difficulties and possibilities with distributed electricity generation. Some installations have also been made in public buildings, with the motive to promote awareness of renewable energy solutions.

There have also been incentives for the use of building integrated PV in the form of a competition for the best environmentally friendly building and special grants for demonstration projects. There are, however, no general incentives or subsidies for PV, which results in a comparatively slow development of the PV market in Sweden.

## 2.2 Total photovoltaic power installed

The total amount of PV power installed in Sweden during 2003 was 284 kW, which means that the market grew by circa 7 % compared to the year before. However, over the last ten years the market size has been rather constant with a slight upturn in the last three years. The cumulative installed PV power for the years 1992 through 2003 is given in Table 1. This information is also illustrated in Figure 1.

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

| Sub-market/ application | 1992 kW | 1993 kW | 1994 kW | 1995 kW | 1996 kW | 1997 kW | 1998 kW | 1999 kW | 2000 kW | 2001 kW | 2002 kW | 2003 kW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| off-grid domestic | 590 | 760 | 1020 | 1285 | 1452 | 1640 | 1823 | 2012 | 2216 | 2376 | 2595 | 2814 |
| off-grid non-domestic | 205 | 265 | 293 | 304 | 364 | 394 | 433 | 448 | 465 | 507 | 544 | 573 |
| grid-connected distributed | 5 | 15 | 24 | 31 | 33 | 93 | 114 | 124 | 124 | 149 | 158 | 194 |
| grid-connected centralized | - | - | - | - | - | - | - | - | - | - | - | - |
| TOTAL | 800 | 1040 | 1337 | 1620 | 1849 | 2127 | 2370 | 2584 | 2805 | 3032 | 3297 | 3581 |

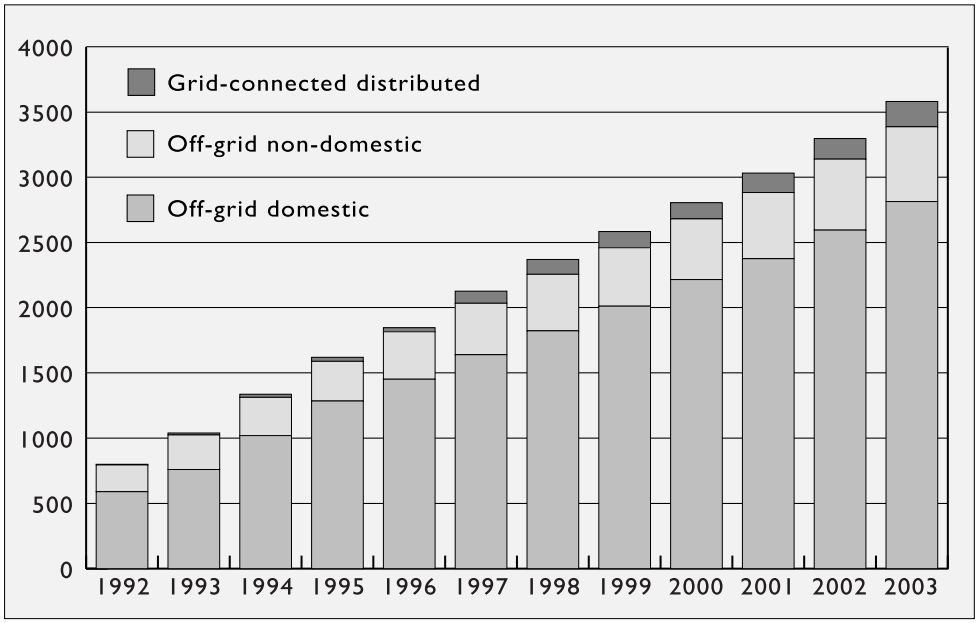


**Figure 1: The cumulative installed capacity divided into sub-markets**

As in previous years, the majority of PV systems installed were in the category off-grid domestic, amounting to circa 80 % of the total market. This market, which builds heavily on the use of stand-alone PV systems for electrification of rural summerhouses, mostly consists of small systems of approximately 100 W. This sub-market has been highly stable during the past ten years with a market share of approximately 80 %.

The second largest sub-market is the off-grid non-domestic market, for which the market share has decreased somewhat in relative terms. Ten years ago the share of the cumulative installed power that was in this sub-market was circa 25 % compared to 17 % today. This market has, however, varied a lot from year to year.

The smallest sub-market is the grid-connected distributed market. Its share of the installed PV power has grown slowly over the last ten years from below one per cent to above five per cent. As stated earlier the sub-market size varies from year to year, depending on single projects, as one major project can account for ten per cent of the total Swedish PV market in a single year.

## 2.3 Major projects, demonstration and field test programmes

There has only been one major PV system project brought into use during the year 2003. This is a building called *Holmen*, an apartment building in the Hammarby Sjöstad area in Stockholm. In general the installations in Hammarby Sjöstad dominate the grid-connected PV systems market in Sweden during the last few years, and two houses there were brought into use during 2002. There will be more systems started during 2004.

*Holmen*

The building Holmen incorporates PV in several parts of the outer layer. There are PV modules integrated into the façade, the balcony railings and the windows of the upper floor apartments. Most of the modules are mounted vertically and are facing south-south west (205º). The total amount of installed PV in the building is 17,6 kW:

The motive for installing this system was to demonstrate building integrated PV, and to study the overall energy economy of the building. There were two investment subsidies given to this project. One was the price for the best environmentally benign building in the Hammarby Sjöstad area and the other was through the EU project PV-NORD.


**Figure 2: The building Holmen in the Hammarby Sjöstad housing area.**

The modules used were chosen after consultation with the architects, who felt that the blue colour of the standard poly-crystalline silicon solar cell modules did not work with the colour scheme of the building, but opted for a slightly less efficient brownish type of modules, which blended better with the rest of the façade.

Several lessons have been learned from the project, e.g. the importance of bringing in the PV system in an early stage of the design process and the importance of co-operation between the architects and the PV-experts. There were also issues with the communication between the PV-expert and the contractor, highlighting the need for increased learning because of the differences in their background.

In Holmen, the original design featured a different PV system, which would not have been feasible due to shading issues with neighbouring houses. As it is today there are some shading issues, where there are kinks in the wall where the balcony rails and PV windows are. Because of this some of the modules were not connected.

*Future projects in Hammarby Sjöstad*

There are a few PV projects still to be brought into use in the Hammarby Sjöstad area. There is one building similar to Holmen, described above, where the PV system will be started in 2004. Another project involving building integration of PV systems in Hammarby Sjöstad is Lysande, owned by Familjebostäder. This building incorporates 22,4 kW of PV integrated in solar screens on the south west façade and on the roof. It will have a reference building next to it, so that a comparison in energy consumption can be made between the building featuring PV and the one that does not. This project is, like the Holmen project above, co-funded by the EU project PV-NORD.

The last project with PV in Hammarby Sjöstad (that is planned so far) was initiated by SBC (Sveriges BostadsrättsCentrum, The Swedish Tenant-ownership Centre). The project involves hybrid PV/solar thermal modules (PV/T) with concentrator modules, and the system is supposed to supply one apartment with all its need for heating and electricity

*USHER*

A major project that is not in the Hammarby Sjöstad housing area is the USHER project (Urban integrated Solar Hydrogen Economy Realisation project) in Visby on the island of Gotland. Originally it was supposed to be an integrated project with Visby and and Cambridge, England, but due to troubles with the integration the project was terminated prematurely by the European Commission, which was one of the financiers. The municipality of Visby, will attempt to go ahead with its part of the project with funding from the Directorate General for Energy and Transport (DG-Tren).

The content of the project is the combination of three key renewable energy technologies in a demonstration system including 2 500 $m^2$ of PV arrays, delivering the electricity needed to an electrolyser that will produce hydrogen and oxygen from water. The hydrogen will be used to power three city buses in Visby, while the oxygen can be used for laboratories or be sold externally.

## 2.4 Highlights of R&D

There is research on photovoltaic energy conversion and related issues in a few universities in Sweden, with the most focused initiative at Uppsala University, where there is a research programme called Ångström Solar Center. At Ångström Solar Center there are three subprogrammes concerned with research on thin-film Cu(In,Ga)$Se_2$ solar cells (CIGS), nano-structured solar cells (Grätzel cells) and electrochromic windows.

In the CIGS group there is extensive research on several aspects of thin-film solar cells, including processing issues, stability of the material, optimization of absorption and module manufacture. The group holds the current world-record for thin-film modules, with 16,6 %

conversion efficiency for a 16 $cm^2$ mini-module. The research today is more directed towards up-scaling and improvement of the manufacturing processes than maximizing the single cell efficiency, in order to facilitate a transition to commercial scale PV module manufacture.

The group working with nano-structured solar cells is conducting research on the manufacturability of the solar cells, with focus on cheaper and continuous rolling techniques. They also perform research on more basic principles of the nano-structured solar cell and try to improve efficiency and stability. A continuous manufacture technique can result in lower costs per watt, although the conversion efficiency is lower than for earlier generations of solar cells, i.e. bulk silicon and traditional thin-film cells (e.g. amorphous silicon, CIGS and CdTe).

There is also related research on nano-structured solar cells at the IVF Industrial Research and Development Corporation, an R&D company owned by an association of Swedish industrial companies and the Swedish government.

As for research on building integrated PV there is activity in this field at the Division of Energy and Building Design, Lund Institute of Technology, where focus is on energy use in buildings with passive and active solar design. The division is also involved in projects within the framework of IEA-SHC (Solar Heating and Cooling Programme).

There is also research and development conducted within the Swedish national co-financed programme on PV systems and applications, SolEl 03-07. This programme is divided into two parts, one research oriented and one concerned with development and demonstration projects. The research part of the programme is funded and managed by Formas, the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning.

The development and demonstration part of the programme is funded by a number of private companies and the Swedish Energy Agency. The activities in this programme are co-ordinated by the utility companies' co-operative development company, Elforsk AB. Within the framework of this research programme other companies, including the government owned utility company Vattenfall, conduct research.

Vattenfall has developed a solar thermal collector, MaReCo (Maximum Reflector Collector), which also has been adjusted to PV creating a hybrid system with combined PV and solar thermal system. This hybrid system is being tested in the SBC project in Hammarby Sjöstad described in section 2.3. At Vattenfall research is also conducted on improving the performance of PV at higher latitude with reflectors evening out the electricity production over the year.

Some PV research is also conducted at the Solar Energy Research Center (SERC), University of Dalarna, where the focus is mostly on tracking and concentrating systems. Thermal PV applications are also studied, where special PV arrays are used in combination with e.g. biofuel burners.

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

As there is no market deployment initiative for PV in Sweden, all of the public budgets for PV goes to demonstration / field test programmes and R & D. The largest single budget item is the funding for the Ångström Solar Center, which totals circa 20 MSEK, of which

15 MSEK goes to the PV research. Furthermore, there is funding for PV research to Ångström Solar Center from the EU and from Nordic Energy Research (an organization under the Nordic Council of Ministers).

There are public funds from the European Union to research on PV and demonstration projects. Apart from the EU funding to the research at Ångström Solar Center, the company IVF takes part in a three-year project on nano-crystalline dye-sensitized solar cells. The project PV-NORD is also co-funded by the EU, together with the governments of the countries included in the project (Sweden, Denmark, Norway, The Netherlands and Finland).

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

| | R & D | Demo/ Field test | Market |
|---|---|---|---|
| National | 17 | - | - |
| Regional | - | - | - |
| Total | 17 | - | - |

The issue with a market deployment initiative is being examined in Sweden and there are plans for government promotion of PV in the future. The Swedish Energy Agency will explore the possibilities for such a scheme during the first half of 2004, and will hand over this work to the government in the beginning of June.

There are also plans for a general subsidy for PV in public buildings. These plans were included in the spring economic government bill 2004 and will comprise a 70 % rebate on PV systems installed in public buildings during 18 months from 1 January 2005.

## *3 Industry and growth*

### 3.1 Production of feedstocks and wafers

There is no production of feedstock or wafers in Sweden.

**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 |
|---|---|---|---|---|
| n/a | n/a | n/a | n/a | n/a |

## 3.2 Production of photovoltaic cells and modules

There are four companies in Sweden, producing PV modules. All of them buy the cells from abroad and assemble the modules, which are then to a large extent exported. The largest module manufacture company in Sweden is GPV, Gällivare PhotoVoltaic AB. The company is also the oldest of the PV manufacture companies and was started in 1992 in Gällivare in the north of Sweden. A majority of the shares in the company was acquired by the German company SolarWorld AG in 1999. In 2001 and 2002 SolarWorld AG bought the remaining shares so that GPV today is a fully owned subsidiary of the German company, which is vertically integrated owning Deutsche Solar wafer production company, Deutsche Cell solar cell manufacturing company and module production operations in GPV, Gällivare, and in Freiberg, Germany. GPV installed a fully automated assembly line for PV modules in 2003, which makes it one of the most modern manufacture facilities in the business, but at the same time the possibility to produce non-standard modules semi-automatically was preserved. In 2003 the company shipped 5,5 MW worth of modules, and the sales amounted to 16 MEUR according to the SolarWorld annual report. GPV is certified for quality in accordance with ISO 9001 and 14001.

In Gällivare there is another module manufacture company, called ArcticSolar AB, which was started in 2001, and has increased its production volume steadily since the start to approximately 3,75 MW during 2003. This company is partly owned by a German company, Alfasolar Vertreibsgesellschaft mbH (45 %), while the rest is owned by the Finnish company Naps Systems Oy (45 %) and the manager of the company (10 %). The modules produced at ArcticSolar, which are almost exclusively exported, are sold in Germany under the Alfasolar label.

Two new PV module manufacture plants commenced production in Sweden during the year 2003. One is the company ScanModule AB, which is a subsidiary of the Norwegian company Renewable Energy Corporation (REC). The business idea of REC is that the company will have a fully vertically integrated business chain with production of solar grade silicon, wafers, cells and finally modules manufactured by ScanModule. ScanModule started operations in 2003 in Arvika, Sweden, but did only reach a moderate level of production (0,8 MW) in the first year.

The fourth PV module manufacture company is PV Enterprise Sweden AB, started by the former head of GPV, in Vilshult in the county of Blekinge. The company both sells modules under the own label and manufactures for other companies (OEM production). During 2003 the production amounted to 1 MW of modules, but this will most likely increase as the company's operations get up to speed.

As the amount of installed PV capacity per annum in Sweden is considerably lower than the amount of produced modules, a large part of the modules are exported. The part of the production that is exported varies from manufacturer to manufacturer, but in general it is more than 95 %.

All the four module manufacturers in Sweden use the same basic mode of operation, buying predominantly multi-crystalline cells on the international market. Two of the companies are, as mentioned, fully owned by foreign companies that also have cell production subsidiaries. These companies buy cells from their sister companies while the other two buy them from the European market.

In the near future it is likely that the Swedish module production will increase in volume, as the two youngest companies, ScanModule and PV Enterprise Sweden extend their production. GPV are also prepared for a production increase with the new production line inaugurated in May 2003.

An additional industry initiative in Sweden during 2003 was the start of operations for the company Solibro AB, in Uppsala. The company, which is an offshoot from the Ångström Solar Center research programme, will start with up-scaling of the processes for $Cu(In,Ga)Se_2$ thin-film solar cell modules. The aim is to have the modules on the market within four to five years. Solibro AB is funded by three large corporations, ABB, Sydkraft and Vattenfall and two investment funds, The Sixth AP Fund and Energy Future Invest. The Swedish Energy Agency co-finances the technology development in the company.

**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 |
| GPV | mc-Si | - | 5,5 | - | 17,5 |
| ArcticSolar | mc-Si | - | 3,75 | - | 14,5 |
| ScanModule | mc-Si | - | 0,8 | - | 5,0 |
| PV Enterprise Sweden | mc-Si | - | 1,0 | - | 12,0 |
| TOTALS | mc-Si | - | 11,05 | - | 49,0 |

## 3.3 Manufacturers and suppliers of other components

There are no manufacturers in Sweden that produce PV specific balance of systems components, such as inverters, storage batteries, supporting structures or DC switch-gear.

## 3.4 System prices

The trends in the prices for PV systems in Sweden are difficult to survey since the market is quite small, but the general trend is that prices are quite stable or possibly decreasing slowly. Most systems sold fall into the category off-grid up to 1 kW, used for electrification of summer houses.

**Table 5: Turnkey Prices of Typical Applications**

| Category/Size | Typical applications and brief details | Current prices per W in SEK |
|---|---|---|
| OFF-GRID<br>Up to 1 kW | Electrification of remote summer house | 100 |
| OFF-GRID<br>>1 kW | - | - |
| GRID-CONNECTED<br>Specific case | For example: 1-3 kW roof-mounted system, if available | 60* |
| GRID-CONNECTED<br>Up to 10 kW | - | - |
| GRID-CONNECTED<br>>10 kW | Specific case: the Holmen project with BIPV in Hammarby Sjöstad | 200 |

* Not including installation

## 3.5 Labour places

The majority of the people who work with PV in Sweden are employed by the four module manufacturers, where a total of 115 people work. The second largest group is the people involved in research and development, mainly at Ångström Solar Center, where approximately 25 people worked with PV during 2003. Within electricity and installation companies, distributors and the government approximately 15 people worked mainly with PV. This makes a total of 155 labour places. This information was in most cases acquired through direct communication with the relevant companies and organizations.

## 3.6 Business value

In Sweden the PV industry mainly consists of companies importing cells bought from abroad, assembling the cells to modules. Most of the modules are exported. In order to calculate a rough figure of the business value the value added per watt is estimated to 5 SEK. With a total module production of 11 MW, this makes a total value added for the manufacturing industry of 55 MSEK

In retail the value added per watt can be estimated to approximately 40 SEK. With a total installed capacity of 250 kW in Sweden during 2003, this results in a value added in retail of 10 MSEK. In total this makes the value of the PV business in Sweden 65 MSEK. *N.B. This*

*is only an estimate based on quite crude assumptions and should not be taken as an exact number of the value added, but as an indication to the business value of PV in Sweden.*

## *4 Framework for deployment (Non-technical factors)*

### 4.1 New initiatives

At the moment there are no general subsidies for PV in Sweden, although there have been examples of public funding for specific project directed at increasing the know-how and awareness of PV, i.e. pure demonstration projects.

However, there are investigations in Sweden on how the PV market can be supported as a means of promoting renewable energy sources for the future. A report has been commissioned by the Ministry of Industry, Employment and Communication from the Swedish Energy Agency on the status of PV applications, the industry activities and possible promotion schemes. This report will be delivered in June 2004 as a basis for a decision on whether Sweden will implement a market deployment initiative.

The 2004 spring economic government bill to the Swedish parliament included an incentive for energy efficiency refurbishing of public buildings with a 30 % investment subsidy. However, for installing solar cells in public buildings the subsidy will be 70 %. This scheme is meant to be executed from the 1 January 2005 and is set to run for 18 months. There will be an upper limit to the subsidies of 100 MSEK, which corresponds to approximately 1,7 MW of installed capacity. This is equal to half of the cumulative installed capacity in Sweden today.

*Utility and public perceptions of PV*

The Swedish utility and electricity companies are in general positive to the introduction of PV, and some of the major demonstration projects that have been built during the past few years were partly funded by these companies. Their motives for participating in these projects have been to create know-how on the emerging technology and to study the potential impact of PV on their business.

The utility and electric companies are also involved with development and demonstration projects on PV through their collaborative development company, Elforsk AB. Elforsk is the co-ordinating party in the Swedish national co-financed programme on PV systems and applications SolEl03-07, which includes the participation in IEA-PVPS activities.

In general, the public perception of renewable energy in Sweden is quite positive. For PV, however, there is a widespread misconception that the Swedish weather and seasonal circumstances disqualify the use of PV for other applications than for marine use or for electrification of remote summerhouses. There is also the issue with storage since there is obviously more power from the sun in the summer, while the electricity is most needed in winter for heating. The use of air-conditioning in domestic buildings is not very widespread, while direct electric heating is. However, the large fraction of hydropower in the Swedish energy mix (~50 %) allows for substantial indirect seasonal storage of PV electricity.

### 4.2 Indirect policy issues

*Electricity certificates*

In May 2003, a new scheme for the promotion of renewable energy sources was launched. This scheme is based on electricity certificates. For every MWh of renewable electricity energy that an electricity company produces, it receives one certificate. The consumer is

then required to buy certificates in proportion to the amount of energy they consume. When a private consumer buys electricity from an electricity company, their certificates are generally handled by the electricity company.

In 2003 the consumers were required to buy certificates amounting to 7,4 % of the consumption, i.e. for every MWh consumed, 0,074 electricity certificates would have to be bought. In 2004 the amount of mandatory certificates will be increased to 8,1 % and at the end of the scheme, in 2010 it will be 16,9 %.

The price of the certificates is decided by the market mechanisms of supply and demand. If there are fewer certificates issued than requested the consumer will be forced to pay a fee to the government, which will be equal to 150 % of the volume weighted average of the certificate prices during that year. Initially there is also a cap on how high this fee can be. The result from the first year with this system is that many companies have chosen to pay the fee to the government instead of buying certificates as this has been the cheaper option.

The Swedish certificates can be exported to RECS, the European Renewable Energy Certificate System, but the RECS certificates cannot be imported to the Swedish certificate system.

The downside of the certificate scheme, as far as PV is concerned, is that a multitude of renewable energy techniques are treated in the same way. This will most likely lead to an expansion of the cheapest type of renewable energy production, while others are not significantly influenced. There is also an issue with the fairly short horizon of the certificate scheme. As it is, the electricity certificates will go on until 2010, which is a quite short period of time considering the level of investments that is required for a producer to start renewable energy production.

*Taxes*

The energy tax has been steadily increased since the beginning of the 1980-ies, with a 14,6 % increase to 0,227 SEK/kWh as of the 1 January 2003. The increase will continue with a 6 % increase as of the 1 January 2004, so that approximately 55 % of the electricity price is made up of the taxes (energy tax and value added tax).

There are also several taxes levied on the discharge of hazardous substances, such as carbon dioxide, sulphur and nitrous oxides. The carbon dioxide tax was increased by 19 % in the beginning of 2003 to a level of 0,76 SEK/kg of $CO_2$. This tax is levied on oil, coal, natural gas, kerosene, LPG and petrol. However, fuels used for electricity production, rail road and air traffic as well as shipping is freed from this tax. Agricultural businesses also have a general tax relief of 75 %.

The sulphur tax has not been changed since 2002 and is 30 SEK/kg discharged sulphur for coal and peat, and 27 SEK per cubic meter and per mille sulphur in oil. Although the taxes on environmentally hazardous discharge have been raised over the past few years, their level is still too low to have a significant impact on the PV market.

*Programmes to promote the use of PV in foreign non-IEA countries*

Since 1998 the Swedish International Development Cooperation Agency, SIDA, has been working with rural electrification in Zambia. The aim of the project is to provide electricity to parts of the country where there is no electric grid. In these parts the main supply of energy has traditionally come from kerosene and batteries. The result of the project is that a

number of so-called ESCOs (Energy Service Companies) have been established. These companies operate PV arrays on their customers homes, and the customers pay a fee for the electricity they receive. This is an alternative financing scheme that solves the problem with the initially very high investment costs for a solar home system. The fees paid by the customers include all maintenance costs like battery replacement. According to Ellegård et al. (*Renewable Energy*, **29**:1251, 2004) some of the lessons learned in this project include the following: People are willing to pay for this service even if it is more expensive than what they paid previously for kerosene. The maintenance organisation must be close to the end user. It was also found that to provide credit through traditional means, i.e. banks, was impossible due to high interest rates and to the fact that the banks were not present in the rural areas concerned.

### 4.3 Standards and codes

There are no specific standards or codes for the connection of PV power systems to the national grid, but the general regulations for electric power installations should be followed as far as possible. If the system voltage of the PV generator is higher that 120 V DC a fence is required around the modules. The Swedish regulations allow the DC part of the system to be ungrounded if the system voltage is lower than 250 V. Electricity delivered to the grid has to follow the European standard EN 50.006 (with the Swedish equivalent SS 421 18 11).

Concerning the regulation for connecting small electric power production units to the grid there is a report called AMP (Swedish name: *Anslutning av mindre produktionsanläggningar till elnätet*) from Swedenergy (the trading organisation of the Swedish power producers, electricity distribution and trading companies). In this report, which was originally written for wind power generators, the regulations that apply when a small generator is connected to the Swedish distribution network can be found. The system must be disconnected during power loss in order to avoid islanding. An application to the local electricity distributor must be made before the power producing system is connected.

There is no standard method for metering when connecting a PV system to the grid, and several different solutions can be seen in the projects in Hammarby Sjöstad. At Holmen, described in section 2.3 the electricity from the PV arrays is fed to the service side of the internal grid in the building. In this way the electricity from PV is used for lighting in stairwells and corridors and for operating elevators. The peak power of the PV system is estimated to be lower than the consumption of service electricity at all times, resulting in no power from PV being fed into the public grid. In other projects in Hammarby Sjöstad the grid-connection has been solved differently, either with a double meter system or with one meter being allowed to go backwards.

*Building permits*

Small PV-arrays for domestic use do not require a building permit, while larger installations do. In general there have not been problems with acquiring building permits for the larger PV systems that have been installed, but on some occasion concerns have been voiced about reflections off of PV arrays disturbing traffic.

## *5 Highlights and prospects*

*Highlights*

The most important development in the PV industry in Sweden during 2003 is the increase of manufacture activities, with the number of module manufacturers increasing from two to four. The domestic market has increased by 7%, which enforces the picture of a market in

slow but constant growth. The share of the grid-connected systems in the cumulative installed power increases slightly, but the off-grid domestic system still dominates the market with approximately 80 %.

An important policy development was the start of the electricity certificates scheme on 1 May 2003. Although it is not likely that this will benefit PV in particular, it is a more forceful way to promote the change from non-renewable to renewable energy than what was used before. The goal of the certificates scheme is to increase the renewable electric energy production by 10 TWh by the year 2010.

In the field of R&D, the results from the research at Ångström Solar Center has been turned over to the newly started company Solibro AB, where the technology will be developed for commercial production. The company is primarily working with the up-scaling of the processes for the deposition of thin-film $Cu(In,Ga)Se_2$ solar cells, which will be ready for the market in four to five years.

*Prospects*

For the future of the PV market in Sweden there have been two major policy developments, including the proposal from the government that there will be a 70 % investment subsidy for PV installations in public buildings starting on 1 January 2005. This initiative could increase the cumulative installed power in Sweden with up to 50 % in a few years.

The second interesting policy issue is the inquiry into the possibilities for a general market deployment initiative for PV in Sweden by the Swedish Energy Agency. This enquiry will be put forward to the government in the beginning of the summer 2004.

With the two new companies producing modules in Sweden, it is likely that the annual production will increase in the coming years as they get their operations up to speed.

## *Annex A Method and accuracy of data*

The method primarily used to acquire data for the amount of installed PV power, was to send enquiries to the installers in Sweden asking about the amount of PV they had sold during the year. Since Sweden has a quite small PV market, this method is believed to yield an adequate accuracy as to the installed capacity in a year. However, this year one of the important installers did not answer the enquiry, so that their amount of installed PV systems had to be estimated on the basis of previous data and the general development of the market. The data on older installations, from before 1992, is less accurate and is probably the limiting factor when estimating the total accuracy.

The accuracy of the market size figures is estimated to be $\pm$15 %, while the estimated accuracy of the cumulative installed PV power is $\pm$20 %.

The amount of PV modules produced in Sweden during the year is surveyed in a similar fashion as the installed capacity, with enquiries to the four module producers. The accuracy of the figures is estimated to approximately $\pm$15 %.

Other data were collected from various open sources, such as reports and internet sites. Information was also gathered through personal communications.