National Survey Report of PV Power Applications in Sweden 2005



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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 2005

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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 Cooperation 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 nineteen participating countries are Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), 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 five are active. Information about these tasks can be found on the public website www.iea-pvps.org. A new task concerning PV hybrid systems is now being developed.

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

This National Survey Report of photovolatic (PV) power systems reflects the status of the PV market, the industry and policy that influences PV applications in Sweden. One of the purposes of this report is to be part of the basis for the IEA report "Trends in Photovoltaic Applications", which is jointly written by the members of the IEA-PVPS Task 1. This international report reflects PV power applications in the participating countries, which account for a majority of the total World PV market (production and applications). A brief description of PV power applications in the non-IEA countries is also given.

Furthermore, this national report is directed at the domestic PV community, and other national stakeholders that have an interest in PV. The report sets out to describe the PV applications, markets, stakeholders and policies in Sweden 2005, in a comprehensive way. The report also provides important statistics on how much PV is installed in Sweden, as well as the amount of PV modules produced in the Swedish PV industry.

iii Definitions, symbols and abbreviations

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 1000 W/m², cell junction temperature of 25 °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 to provide power mainly to a household or village not connected to the (main) 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 'mini-grid', often as a hybrid with another source of power.

Off-grid non-domestic PV power 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 power system'.

Grid-connected distributed PV power system: System installed to provide power 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 demand side of the electricity meter, on public and commercial buildings, or simply in the built environment on motorway sound barriers etc. They may be specifically designed for support of the utility distribution grid. Size is not a determining feature – while a 1 MW PV system on a rooftop may be large by PV standards, this is not the case for other forms of distributed generation.

Grid-connected centralized PV power system: Power production system performing the function of a centralized power station. 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.

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.

SEK: The national currency of Sweden, i.e. the Swedish krona.

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.

Sammanfattning på svenska – Summary in Swedish

Installerad effekt

Solcellsmarknaden i Sverige är relativt stabil, med majoriteten av den installerade effekten i marknadssegmentet off-grid domestic. Denna trend fortsätter även 2005, med 280 kW installerat i det segmentet. I marknadssegmentet off-grid non-domestic installerades 31 kW, vilket är i samma storleksordning som föregående år.

I och med att det nya investeringsbidraget för solceller i offentliga byggnader infördes från den 15 maj 2005 ökades intresset för nätanslutna system, men endast ett fåtal system installerades under året och endast ett kopplades in på nätet. Intresset kommer att ge utslag i antalet installerade system under 2006, eftersom ett antal anläggningar planerades och började byggas under 2005, men kom inte att kopplas in förrän under 2006.

Priser

Bristen på celler som modultillverkarna erfarit har inte fått fullt genomslag på priset på den för Sverige vanligaste systemtypen, d.v.s. mindre system för elektrifiering av t.ex. sommarstugor. Priset på ett sådant system var mer eller mindre oförändrat jämfört med föregående år. För större order (direkt från fabrik) verkar modulpriset ha ökat och detta kommer att få genomslag på systempriser under 2006.

Tillverkning

Allteftersom efterfrågan från marknaden, i synnerhet den tyska, ökar kraftigt så har de svenska modulproducenterna, vilka utgör nära nog hela den svenska solcellsindustrin, strävat efter att utöka sin produktion. För två av företagen, GPV och ScanModule, har denna expansion lyckats tack vare att de har försetts med celler från systerföretag inom respektive koncern. De två mindre företagen, ArcticSolar och PV Enterprise Sweden, har haft problem att möta efterfrågan eftersom de har haft svårt att få tag på tillräckliga mängder celler. Totalt uppgick mängden moduler som producerades i Sverige under 2005 till 38,5 MW, vilket innebär en ökning med nästan 50 % jämfört med 2004.

Allmänna medel till solcellsverksamhet

De allmänna medlen för forskning och utveckling inom solcellsområdet var något lägre under 2005 jämfört med 2004. Detta berodde mestadels på att forskningsprogrammet Ångström Solar Center avslutades och den finansiering som följde programmet, från Energimyndigheten, låg på en något lägre nivå.

Även om det första stödsystemet för solceller i Sverige sjösattes i maj 2005 utbetalades inga stödpengar under 2005. De reserverade stödpengarna, totalt 100 MSEK, krediteras anläggningsägarens skattekonto först när anläggningen

är färdig att användas, och endast en anläggning med stöd kopplades in under 2005 men stödpengarna hann inte utbetalas.

1 Executive summary

1.1 Installed PV-power

The PV market in Sweden is reasonably stable, with the bulk of the installed capacity in the segment off-grid domestic. This trend continues in 2005, with 280 kW installed in that market. The installed power in the non-domestic off-grid sector was 31 kW, which is similar to previous years.

With the start of the first market deployment initiative for PV, in May 2005, there was an increase in grid-connected applications. However, only a few systems were installed during the year, and only one came on stream in 2005. The large interest will register in the numbers for 2006, since several systems were planned and built in 2005 but were not started until early 2006.

1.2 Costs & prices

The cell shortage that the module manufacture companies have experienced has not yet had an impact on the prices for the most common type of system in Sweden, typically a kit for remote electrification. The prices for these systems are more or less unchanged. The module prices for large orders (factory gates) seem to have increased, though, and this will probably impact retail prices in 2006.

1.3 PV production

As the demand from predominantly the German market is increasing steeply, the module manufacturers that make up the bulk of Swedish PV industry have increased their production as much as possible. For two of the companies, GPV and ScanModule, expansion has been possible due to cell supply from sister companies, while the remaining two companies, ArcticSolar and PV Enterprise Sweden have struggled to find enough cells to cover their needs. In total 38,5 MW of PV modules were assembled in the Swedish plants, corresponding to an increase by nearly 50 %.

1.4 Budgets for PV

The public budgets for PV research and development were slightly lower in 2005, compared to 2004. This was mostly due to the fact that the research framework Ångström Solar Center was finished.

Although the first Swedish market deployment initiative for PV was launched in 2005, no public funds were credited in this system during the year. The subsidy funds are credited to the tax account of the PV system proprietor after the system has been taken into use, and only one system eligible for support was finished in 2005 but the funds were not credited until 2006.

Table 1: The cumulative installed power in four sub-markets

| | | Sub-mark | et/application | | |
|------|------------------------------|----------------------------------|---------------------------------------|---------------------------------------|---------------|
| Year | Off-grid domestic [kW] | Off-grid non-domestic [kW] | Grid-connected distributed [kW] | Grid-connected centralized [kW] | Total [kW] |
| | [KVV] | [KVV] | [KVV] | [KVV] | [KVV] |
| 1992 | 590 | 205 | 5 | - | 800 |
| 1993 | 760 | 265 | 15 | - | 1 040 |
| 1994 | 1 020 | 293 | 24 | - | 1 337 |
| 1995 | 1 285 | 304 | 31 | - | 1 620 |
| 1996 | 1 452 | 364 | 33 | - | 1849 |
| 1997 | 1 640 | 394 | 93 | - | 2 127 |
| 1998 | 1823 | 433 | 114 | - | 2 370 |
| 1999 | 2012 | 448 | 124 | - | 2 584 |
| 2000 | 2 2 1 6 | 465 | 124 | - | 2805 |
| 2001 | 2 376 | 507 | 149 | - | 3 032 |
| 2002 | 2 595 | 544 | 158 | - | 3 297 |
| 2003 | 2814 | 573 | 194 | - | 3 581 |
| 2004 | 3 070 | 602 | 194 | - | 3 866 |
| 2005 | 3 350 | 633 | 254 | - | 4 2 3 7 |

2 The implementation of PV systems

2.1 Applications for photovoltaics

Traditionally, the PV market in Sweden has been dominated by the off-grid market segment, mostly due to a large number of summer houses with no access to the grid. In these locations off-grid PV is an economically viable option to provide a limited amount of electricity that can cater for illumination, radio etcetera. The dominance of the off-grid market could also be described in terms of the absence of a market for grid-connected applications. The number of grid-connected installations in Sweden are quite few, and most often they are installed for learning or demonstration purposes. There are economic and legislative barriers for a breakthrough for grid-connected PV. This will be described more in detail further on in this text.

The off-grid market can be divided into two sub-categories, domestic and non-domestic. The electrification of summer homes falls in to former category, while the latter includes stand-alone applications for e.g. telecommunication and navigation equipment. The domestic sector is approximately ten times as large as the non-domestic one, but both are relatively constant in size, and self sustained on market terms.

Before 2005 there has been no general subsidy for PV installations in Sweden, and as a consequence of this the market has evolved slowly compared to some other countries. There have been one-off contributions from local environment investment programmes and in connection with EU projects, which has led to larger grid-connected installations, mostly for demonstration purposes. However, starting in May 2005 there is an investment subsidy in the form of a tax rebate for PV systems in public buildings. This has not resulted in many

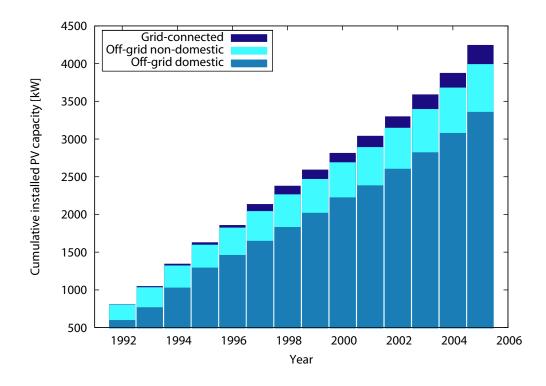


Figure 1: The cumulative installed capacity in sub-categories from 1992 to 2005

finished installations during 2005, but several systems have been planned. All the grid-connected systems in Sweden can be classified as distributed, i.e. the systems are not used as power stations, but are integrated with the built environment.

2.2 Total photovoltaic power installed

As mentioned earlier, the off-grid market in Sweden has been quite stable but not very voluminous during the past decade, and 2005 is no exception. The amount of PV installed in the off-grid sectors in 2005 was 311 kW. Looking more closely at this number, 280 kW was installed in the domestic category, while 31 kW was installed for non-domestic applications. Adding this power to the cumulative total, the installed PV power in off-grid applications at the end of 2005 was 3983 kW. These numbers, and corresponding numbers for previous years, are detailed in Table 1. These numbers are also illustrated in Figure 1.

For grid-connected application, the market in Sweden is quite unstable, shifting in volume with single projects. Typically, only a handful of projects are realized each year, and some years there are no systems taken into use. Previously, the installed grid-connected PV power in a single year has never exceeded 60 kW, and in that year (1997), one large installation in Sweden accounted for all of that. During 2005 only one project in the new subsidy programme has been taken into use, and a few projects without investment programme support.

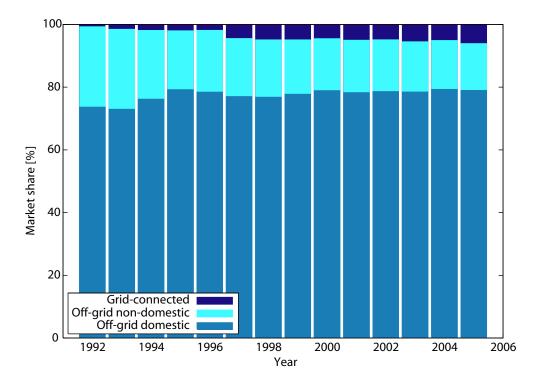


Figure 2: The relative market share of the different market segments over time.

Even with this little impact from the subsidy system in its first year the market size for grid-connected system, 60 kW, equalled the record. This record will definitely will be surpassed in 2006 when more systems in the subsidy programme are finished. In Figure 2 the relative share of the different market segments are illustrated. From this it is evident that the market shares have been quite stable over the years. The high share of off-grid systems is much like in comparable countries (without major deployment initiatives), but in the numbers for 2006 the share of systems that are grid-connected will increase drastically.

2.3 Major projects, demonstrations and field test programmes

During the past few years, the focus of PV for grid-connected applications has been on the housing area Hammarby Sjöstad in Stockholm. There, several high profile projects have been carried out, most of them with some support from the local environment investment programme or through a competition for the best sustainable building in the area. There are no new PV projects planned for this area.

2.3.1 Demonstration of grid connection and PV electricity retail

One project that has been interesting for grid-connected applications was installed at the company ABB's facilities in Västerås. The aim of this project was to discern what barriers there are for grid connection and electricity retail on the scale of a typical domestic roof-top system. The results from this $3\,\mathrm{kW}$ project was that the legislation that applies when feeding electricity into the grid raises obstacles for smaller scale systems. According to the electricity act, the utility company that has the local grid monopoly must provide grid access for an electric energy production unit. At the same time, the utility company is allowed to take out a fee to cover the costs for the connection and the metering and reporting. In this case, the annual fee for the grid connection is $3\,500\,\mathrm{SEK}$. With a small system like the $3\,\mathrm{kW}$ system at ABB, the fixed charge distributed on the electric energy produced results in a higher cost, $1,4\,\mathrm{SEK/kWh}$, than the price that can be obtained on the Swedish electricity market.

2.3.2 The city of Malmö

In the city of Malmö several projects involving PV has been launched, as a part of a programme to strengthen Malmö's environmental profile. One of these projects, a demonstration system in Augustenborg, was completed during 2005. This installation was partly (50%) funded by a local programme for environmental investments and comprises PV modules as solar shading as well as standard modules placed in racks on the roof. This first system is mostly for demonstration purposes and in the building design, there are other elements of renewable energy supply, e.g. from solar thermal absorbers. Further installations on municipal buildings in Malmö are planned for 2006, with support from the investment programme described in the following section.

2.3.3 Investment subsidy for PV on public premises

The investment subsidy that was launched in May 2005 has only resulted in one major project that has been realized in 2005, but in total 42 applications were made during the year, and 23 of these were preliminarily accepted in 2005. The projects that had not been accepted before the end of 2005 were most often submitted to the authorities very late (in the last week of the year), and were accepted in early 2006.

One of the projects with funding from the investment programme, and the only one that was finished in 2005, was a 45 kW system on Alléskolan, an upper secondary school in Hallsberg. The system is integrated into a south-facing façade.

Although only one of the projects proposed in 2005 were taken into use during that year, some were nearly finished and were subsequently started in early 2006. One of these was a 64 kW system on a primary health care centre in Fjärås, Halland. This health care centre has a strong environmental profile, with all the energy needs covered by renewables. The PV system, which is the

largest installation to date in Sweden will produce more electric energy than what is consumed in-house, making it a net producer on a yearly basis. This makes the installation rather unique on the Swedish PV scene.

2.3.4 Ekosol

A novel project type, for Sweden, is led by the company Ekosol AB in Strängnäs, with partner companies from the PV, building and financial sectors. In the first stage, 16 houses with roof integrated PV will be built in Strängnäs. The novelty of the project is in the marketing strategy, which means that the extra cost of the PV system is offset by a zero cost for heating the house. The idea is that the PV system will produce the same amount of energy on a yearly basis that a heat pump consumes when heating the house. Since there are legislative and economic barriers that inhibit the application of grid-connected PV on a small scale in Sweden (cf. section 2.3.1), alternative solution are sought. Ekosol rents the system from the house owner for a fixed fee, and sells the electric energy to the grid. The customer receives a rebate on the mortgage interest that corresponds to the interest cost for the PV system.

2.4 Highlights of R & D

The R & D within the field of PV in Sweden has been more oriented towards process technology for thin-film module manufacture and novel devices, like dye-sensitized cells, than power systems aspects. But as the PV market in Sweden has started to grow during 2005, with support from the new subsidy system, more interest has been directed towards systems issues. The research in this area is mostly conducted within the R & D programme SolEl 03-07, which is jointly funded by the Swedish Energy Agency and market stakeholders, e.g. utility companies, PV module producers, housing developers. There is also a research centre, Solar Energy Research Center (SERC), at Dalarna University College in Borlänge, where several aspects of solar energy is studied. Most of the research is conducted on solar thermal systems, but there are also projects on thermal photovoltaics.

The most extensive research programme on photovoltaics was the Ångström Solar Center at Uppsala University, which ended at the end of March 2005. This research programme, funded by the Swedish Energy Agency and the Foundation for Strategic Environmental Research, was active during eight years and incorporated research groups working with thin-film Cu(In,Ga)Se₂ and dye sensitized solar cells. The two research groups are continuing their work in a different framework, with individual support grants from the Swedish Energy Agency. In 2004 the total energy research budget was severely decreased, but it was restored to the previous level during 2005, allowing for more long term funding for PV.

The group working with thin-film Cu(In,Ga)Se₂ (CIGS) based solar cells remains at Uppsala University, focusing mainly on process development and optimization for high efficiency thin-film modules. Apart from the Swedish

Energy Agency, the research is funded by the EU and Nordic Energy Research. The group is closely linked to a spin-off company, Solibro AB, that aims at commercializing the CIGS technology developed at Ångström Solar Center. During 2005 a proof-of-concept has been shown for the deposition of the CIGS layer, and the company is scheduling market introduction in 2008.

The research group that works with dye sensitized solar cells has moved from Uppsala University to the Royal Institute of Technology in Stockholm, where it now forms the Center of Molecular Devices (CMD). Since the beginning of 2005, the CMD has established a close co-operation with the industrial R & D institute IVF, which has conducted research on dye-sensitized solar cells and related devices since 1997.

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

2.5.1 Budgets for PV research

The public budget for PV research in Sweden is distributed through the Swedish Energy Agency, as a part of the national energy research programme. Most of the funding goes to the two research groups formerly in the Ångström Solar Center described in section 2.4. The group working with CIGS thin-film technology receives 6 MSEK while the CMD receives 4 MSEK per year, from the Swedidh Energy Agency. Furthermore, the groups receive additional funding from commercial partners and institutions like the E.U. and the Nordic council of ministers.

The Swedish Energy Agency also jointly funds the national solar electricity R&D programme SolEl 03-07 with 1,85 MSEK per year. This programme, which is managed by the utility companies' joint R&D company Elforsk, is co-funded by industrial stakeholders, e.g. utility and energy retail companies as well as housing developers and PV industry.

Furthermore, the Swedish Energy Agency funds technology development in the spin-off company Solibro. This support, which is directed towards the up-scaling of processes in an early phase of commercialization, amounts to 6,2 MSEK per year. The motivation for this is to promote the development of a PV industry based on CIGS thin-film technology in Sweden.

2.5.2 Budgets for market stimulation

The first general market deployment initiative for PV in Sweden was launched in May 2005, as part of a programme for energy rationalization measures in public buildings (officially named *Incentive for energy and environment investments on public premises*). In the part of the programme that includes support for PV the aim is to facilitate energy efficient conversion in public buildings by granting a tax deduction of 30% for the real estate owner for most of the included measures, but with an increased support of 70% for PV. The applications are submitted to and handled by the regional authorities.

During the first year of the support programme, 42 applications were submitted, of which three were for installation on Swedish embassies abroad. Out of the 39 applications for projects in Sweden, all were preliminarily accepted for support, either in 2005 or in the beginning of 2006. The support system is engineered so that a preliminary application is made and then the system is installed. Subsequently 70% of the investment cost is credited to the real estate owners tax account, following a second application. During 2005 only one system was actually installed connected to the grid, and no funds were credited. Most of the systems, for which applications were made in 2005, will be finished in 2006 and the support will be paid out after that.

2.5.3 Budgets for demonstration / field test programmes

One project that was funded by a local investment programme for sustainable development was a demonstration project in a city area with a sustainable profile in Malmö. PV was installed on a municipal service building as a first demonstration system in a plan to extend the use of solar energy, thermal and PV, throughout the city of Malmö. In this specific case 50% or 0,6 MSEK was financed by the local investment programme for sustainable development. Several systems will be installed within the framework of the investment programme in 2006.

The Swedish Energy Agency has supported the development of the Ekosol project described previously (cf. section 2.3.4) as a first step towards lowering the barriers for the introduction of grid-connected BIPV for one-family houses. The Energy Agency funds 25% of the project, which corresponds to 1,2 MSEK.

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

| _ ' 0 | | | |
|----------------------|------------|------------------------|---------------|
| | R&D [MSEK] | Demo/field test [MSEK] | Market [MSEK] |
| National Regional | 18,05 - | 1,2 0,6 | - |
| Total | 18,05 | 1,8 | - |

3 Industry and growth

The Swedish PV industry can be divided into two categories, the manufacturing industry and the downstream market with installers, consultants etcetera. The manufacturing industry consists of module manufacture companies that import cells and produce modules. These companies have lately been expanding to meet the demands of the German market, and are almost exclusively exporting their products. The installers and consultants are quite few to date, but the number of companies in the business increases with the increased interest that the investment subsidy system entails.

3.1 Production of feedstocks and wafers

There is no production of feed-stock or wafers in Sweden, and in the short to medium term it is very unlikely that any such operations would be established.

3.2 Production of photovoltaic cells and modules

There is no commercial production of solar cells in Sweden today, but in the future it is probable that the company Solibro AB will start full-scale production of thin-film modules. This would, by definition, include the solar cell manufacture process.

3.2.1 Gällivare Photovoltaic AB

The oldest and largest module production company in Sweden is Gällivare Photovoltaic AB (GPV) in Gällivare in the north of Sweden. Today the company is a fully owned subsidiary of the German company Solar World. Cells are imported from Germany and the sister company, Deutsche Cell, and are assembled to modules of varying sizes and models. The modules are most often exported to the German market, and are type approved by TÜV. A special module type, designed for the US market, has been incorporated into the line-up. These modules are type approved by the Underwriters Laboratories (UL). The expansion of production over the past few years continued during 2005 and the total sales volume for the year 2005 amounted to 17 MW. Out of this only a few kW were sold directly to Swedish customers.

3.2.2 ArcticSolar AB

Another module manufacture company located in the northern community of Gällivare is ArcticSolar AB, which is jointly owned by the Finnish company NAPS, the German company Alfasolar and the general manager. The company has experienced rapid expansion over the five years since the company was founded, but recently this expansion has been curtailed by the increasing difficulty to obtain cells for the modules. The work force has been cut during 2005 in order to adjust to the decreased production volume. The silicon shortage issue is especially severe for a company like ArcticSolar that is not part of a vertically integrated company. All of the modules are exported, e.g. catering for the German market. Modules are exported and sold by NAPS and Alfasolar, using their respective brands. The modules are type approved by TÜV in Germany.

3.2.3 Scanmodule AB

In Arvika, close to the Norwegian border, the company REC has established its module production operation, with the subsidiary ScanModule AB. This company is, like GPV, part of a vertically integrated organization (called Renewable Energy Corporation, REC), which incorporates all stages of the PV

| | | | o capac.c, | | , | | |
|---------------|------------|------|------------|---------------|------|-----------|----------------|
| | | Т | otal produ | ction (MW) | Max | kimum cap | acity $(MW)^*$ |
| Manufacturer | Technology | Cell | Module | Concentrators | Cell | Module | Concentrators |
| GPV | mc-Si | - | 17 | - | - | 17 | _ |
| ArcticSolar | mc-Si | - | 3,5 | - | - | 20 | - |
| ScanModule | mc-Si | - | 14 | - | - | 22,5 | - |
| PV Enterprise | sc-Si | - | 3,6 | - | - | 20 | - |
| | mc-Si | - | 0,4 | - | - | - | - |
| Total | | - | 38,5 | - | - | 79,5 | _ |

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

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value chain from silicon ingot production to systems installation. A company that is developing solar grade silicon processes is also part of the REC conglomerate. This situation ensures that ScanModule can obtain cells for its production, which has increased steeply during the past years. The company has expanded rapidly since the start of operations in 2003 and this resulted in a total amount of shipped modules of 14 MW. This means that ScanModule is the most rapidly evolving PV company in Sweden. During 2005 the company was granted 10 MSEK in regional support for a large expansion of the workforce, and this will enable the company to expand further during 2006.

3.2.4 PV Enterprise Sweden AB

The fourth module manufacture company in Sweden, PV Enterprise, is situated in the south-east, in Vilshult, Blekinge. It was started in 2003 by the founder and previous manager of GPV. Like the other companies it has experienced strong growth during the past few years in order to cope with demand from the market, especially in Germany. Like ArcticSolar, it lacks a link to a cell manufacture company. This has led to severe problems in the production, since cells have been difficult to obtain. Due to this bottleneck the plant has been standing still for several months during 2005.

3.2.5 General trends

The most important trend during the past few years has been the strong expansion of the PV module manufacture business. However, in 2005 the expansion has been curbed somewhat due to silicon shortage, and this will probably continue through 2006. The resulting increase in module prices has not yet had an impact on the Swedish market, but it will probably lead to increased system prices in 2006.

^{*}The number for maximum capacity is difficult to obtain, as it is regarded a sensitive issue by some companies

Table 4a: Typical module prices (SEK/W, excl. VAT) for a number of years

| | | Year | | | | |
|----------------|------|------|------|------|--|--|
| Module prices | 2002 | 2003 | 2004 | 2005 | | |
| Large orders | 30 | 26 | 26 | 32 | | |
| Single modules | 75 | 70 | 70 | 70 | | |

3.3 Manufacturers and suppliers of other components

There are no manufacturers of PV specific balance-of-system components in Sweden today, but as the PV business grows companies that manufacture general electrical equipment start to show an interest in the PV market. One example of this is the installation made by ABB, as a first step towards making specific PV system components.

3.4 System prices

Since the Swedish market has been dominated by the off-grid sector it is difficult to give a general picture of the prices in other market segments. Furthermore, in the one-off systems that have been installed in Sweden the total system cost has often been influenced by e.g. learning costs in the project management and the price of custom-made modules. In the investment subsidy system, a larger number of systems have been planned and this makes it slightly easier to generalize on the price for a grid-connected system. The building proprietors that receive the subsidy are required to report some parameters that will allow a statistical analysis. The typical prices for various types of systems are given in Table 5.

In the off-grid market it is easier to give a comprehensive picture of the price structure, since these systems often are delivered in ready-made packages with all necessary balance-of-system components. That market has also been quite stable over the years making it possible to discern price trends. In Table 5 the price for an off-grid system of approximately 100 W is given for a number of years.

3.5 Labour places

During the past few years of expansion in the module manufacture industry in Sweden, the number of employees in this sector has increased. Since the number of employees in R & D and in the installation companies has not increased significantly during the same period, the share of the PV work force that is employed in module manufacture has also increased.

In total the average number of employees in the manufacturing companies during 2005 was 210, while the number of people employed in R & D, mainly in academia, amounted to approximately 30. 15 poeple were working in retail, installations and other parts of the professional PV community. This means

Table 5: Turnkey Prices of Typical Applications

| Category/range | Typical application | SEK/W |
|--|--|-------|
| Off-grid Up to 1 kW | Remote electrification, domestic or professional | 100 |
| Off-grid (>1 kW) | - | n/a |
| Grid-connected specific case | Case: Demo installation at Augustenborg, Malmö | 104 |
| $\begin{array}{l} {\sf Grid\text{-}connected} \\ (\leq \! 10 {\sf kW}) \end{array}$ | Typical roof-mounted system | 55 |
| Grid-connected $(\geq 10 \text{kW})$ | The largest type of BIPV system in Sweden | 50 |

Table 5a: National trends in system prices (SEK/W) for off-grid applications (small systems)

| YEAR | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---------------|---------|---------|---------|--------|--------|--------|
| Price [SEK/W] | 110-150 | 100-140 | 100-130 | 90-110 | 90–110 | 90–110 |

that out of the 255 people that were employed in PV related activities, 80% were working in the module manufacture. This is very much in line with what is expected since there is substantial module manufacture in Sweden but little activity in the applications for PV.

The information about the number of employees is obtained chiefly through enquiries directly to the companies concerned.

3.6 Business value

The majority of the business value in the Swedish PV value chain lies in the module production. This is easily demonstrated looking at the number of people employed in the different stages of the chain. A different way to illustrate the relative importance of the parts of the PV value chain is to estimate the business value for the different parts. This is done in Table 6, from which it is evident that the business value of the installed capacity is small compared to exports. N.B. This estimate is not to be used as an exact figure for the PV business value but as a rough estimate that can be used to discern trends over time. The major change in 2005 compared to 2004 is, for instance, the increased module production leading to increased value of business in that part of the value chain.

Table 6: Value of PV business

| Sub-market | Capacity installed in 2004 [kW] | Price [SEK/W] | Value [MSEK] |
|---|---------------------------------|----------------------------|--------------------------|
| Off-grid domestic Off-grid non-domestic Grid-connected | 280 31 60 | 100 100 55 Totals | 28 3,1 3,3 34,4 |
| Export of PV products Change in stocks held Import of PV products | | | 1 230 n/a 1 020 |
| | | Value of PV business | 244 |

4 Framework for deployment (Non-technical factors)

4.1 New initiatives

The most important change concerning market deployment in 2005 was the launch of the investment subsidy programme that started in May. In this deployment initiative 100 MSEK has been reserved for tax rebates for PV systems in buildings used for public purposes, i.e. schools, churches, hospitals, community centres and so on. The proprietor of the building, on which the PV system is installed, receives a tax credit of $70\,\%$ of the investment cost when the installation comes on-line. The costs eligible for support include materials, installation and external project management costs. The maximum amount per building is $5\,\mathrm{MSEK}$.

From the start of the programme to the end of 2005, the interest has been good with a total of 42 applications corresponding to approximately a third of the 100 MSEK allocated within the programme. Looking at the applications, the size of system and the building type varies widely, from several small systems on schools in Stockholm with $2\,\mathrm{kW}$ each, to systems of 60 to $80\,\mathrm{kW}$, which can be considered large by Swedish measures ($80\,\mathrm{kW}$ corresponds to $30\,\%$ of the cumulative installed grid-connected PV power prior to the launch of the investment subsidy system).

4.1.1 Utility and public perception of PV

Traditionally, the public perception of PV in Sweden has been positive but there is a common misperception that there is not enough sun in Sweden for PV to be a viable option. This may be true in the winter, with short days and little sunlight, but with the long days in summer the yearly total in southern Sweden is as high as in continental Europe. Previously, PV has been something for the technically interested, for learning or demonstration purposes, but this has changed slightly with the investment subsidy programme. The programme has attracted building proprietors with no technology-specific interest in PV,

but only in the sustainable energy generation.

The utility companies' perception of PV varies from company to company. Some are involved in PV research and active in the PV community, while others are not particularly interested. One of the barriers that hinder PV implementation for grid-connected applications is the price for the grid-connection and metering, as described in section 2.3.1. This barrier probably reflects rather the local monopoly situation on the Swedish utility market than the utility companies' perception.

4.2 Indirect policy issues

4.2.1 Electricity certificates

Since May 2003, there has been an electricity certificate system in Sweden, which is designed to act as a market regulated support system for new renewable electric energy production. In this system, the proprietor of a facility for new renewable electricity production is eligible for one certificate per MWh energy delivered. The consumers are required to buy a number of energy certificates in proportion to the electric energy used. This quota is increased year by year, so that the demand for electricity certificates is increased. The increased demand for certificates drives the certificate price and thus enables renewable energy production at a premium cost. The quota in 2005 was 10,4%, meaning that for every MWh consumed 0,104 certificates must be bought. If the consumer fails to buy enough certificates a fee equalling 1,5 times the average certificate price has to be paid. The electricity retail companies handle the quotas of private consumers.

In a review of the certificate system, it has been suggested that the system must be stable in a longer perspective. In its original form it was set to be terminated by the end of 2010, but concerns have been raised that this will inhibit major investments in renewable energy production. In early 2006, the Swedish government proposed an extension of the system to 2030, with a more aggressive and long-term target. The system will also be revised with the aim to simplify the system for the consumer.

For PV the certificate system has made little impact, with only one installation connected. This system is more of a one-off occurrence, built for demonstration purposes. The average price for a certificate corresponded to 0,234 SEK/kWh (in 2004), which is far from enough to make PV installations economically viable. Predominantly biofuels and to some extent wind and small scale hydro power has benefited from the electricity certificate system, as they represent relatively cheap renewable power generation.

4.2.2 Taxes

There are a number of taxes on energy and on fuels used for energy production. These have been increased over the past decade with the aim to shift the tax revenue from traditional income taxes to taxes that promote sustainability and

reductions in energy consumption. In this scheme, there is a general energy tax and a $\rm CO_2$ tax. While the energy tax on electricity and fuels for transportation, i.e. petrol and diesel oil, was increased at the beginning of 2005, the $\rm CO_2$ tax was left unchanged after a series of years with annual raises.

For electricity, the energy tax is $0.194\,\mathrm{SEK/kWh}$ in the north of Sweden, and $0.254\,\mathrm{SEK/kWh}$ in the south. For oil, the energy tax is $735\,\mathrm{SEK/m^3}$ and the $\mathrm{CO_2}$ tax is $2\,609\,\mathrm{SEK/m^3}$, which amounts to a total of $0.334\,\mathrm{SEK/kWh}$. There is also sulphur tax on oil with high sulphur content and on coal.

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

There are two programmes funded by the Swedish International Development Cooperation Agency (SIDA), which aim for rural electrification in Zambia and services for telecommunications in Uganda. In Zambia SIDA has financed a project that provides access to funding, business support and technical training for local companies that operate solar home systems in rural parts of the Eastern Province. In Uganda, SIDA is involved in financing, through providing securities, for a telecommunications company that uses PV powered mobile phone stations to provide communication services to rural areas.

4.3 Standards and codes

Due to the low level of penetration in the Swedish market, there are few codes and regulations that are specific for the PV technology. In the standard *Electrical installations of buildings - Rules for design and erection of electrical installations* there are six pages, under the title *Requirements for special installations or locations - Solar photovoltaic (PV) power supply systems* (section 712), which detail the rules for installing PV systems. This standard, SS 436 40 00 is to a large extent a translation of the IEC standard 60364. According to a report from the SolEl programme (Elforsk report 04:08), these guidelines are not extensive enough to provide the support needed at the installation of a PV system.

Due to the lack of regulations specific to PV, general rules for electrical installation must be interpreted for PV installations. These regulations include, the ELSÄK FS-2004:1 directions for high current installations and the standards for electric installations mentioned in the previous section (SS $436\,40\,00$). For instance, with a d.c. voltage of $120\,\mathrm{V}$ or more, sufficient protection measures has to be taken.

There is also a report from the trade organization of the Swedish power producers, electricity distribution and trading companies (Swedenergy), that describes how small production units should be connected to the utility grid. The report, called AMP, is more focused on production facilities in the range of several hundred kW, predominantly wind power stations, but there are some wordings that are specific for PV on the subject of islanding. According to the electricity act the local utility company must connect an electric energy

production facility if there are no special circumstances, but an application to the utility company has to be made before the production unit is connected to the grid.

As described in section 2.3.1 the grid connection issue is far from resolved in Sweden. The cost for the grid connection is very high, especially for smaller systems, and there are no direct guidelines on what kind of metering should be used, although the electricity act specifies that both consumed and produced electric energy must be measured and reported individually if there is energy delivered to the grid. Most of the systems installed in the new market deployment initiative are grid connected but with so small energy production compared to the in-house consumption that electricity is never delivered to the grid. In this way the metering issue is more or less avoided.

4.4 Building permits

If the PV modules are mounted on the roof of a building (retro-fitted) in general no building permit is needed, but if a designated mounting structure is used a special permit may be needed depending on the size of the system. In PV integration into new buildings a building permit for the whole project is called for, where the PV part is not treated as a separate entity but as a part of the general application. In some cases objections have been raised against the appearance of the PV modules on façades.

5 Highlights and prospects

5.1 Highlights

The most important development in PV applications in Sweden during 2005 was the introduction of the market deployment initiative, which is the first general subsidy for PV in Sweden. The programme has increased the interest in grid-connected applications, although only one installation came on stream in 2005. Applications for approximately 30 of the allocated 100 MSEK were filed in 2005, which indicates that the quota will be filled in late 2006. The programme is open through the end of 2007. A clear change in stakeholders and project size is seen. Stakeholders with no specific technical interest have emerged and several projects of about 60 kW have been planned. Before the investment subsidy programme the largest installation in Sweden comprised 60 kW.

The industry, more specifically the module manufacture companies, have been trying to expand as much as possible, with ScanModule leading the expansion in 2005. ScanModule was almost as large as the market leader GPV. These two companies are part of vertically integrated organizations, so that their access to upstream material is reasonably secure. The two smaller companies (ArcticSolar and PV Enterprise Sweden) lack this advantage and have had troubles finding enough cells for the modules. This has forced them to reduce

the production volumes.

5.2 Prospects

Since the interest in the new deployment initiative has been considerable, it is likely that the cap of 100 MSEK will be reached before the deadline of 31 December 2007. The market stakeholders that are emerging due to the market deployment initiative may pull out of the market if the deployment initiative is not extended. In the spring government economical bill there is a proposal for an extension of the programme by one year and 50 MSEK, but it is difficult to predict the future of the investment subsidy programme. Without an extension the market will most likely return to its previous state with few grid-connected projects and mostly off-grid systems for the recreational market.

For the industry the demand for modules from predominantly the German market will lead to plans for further expansions. However, the possible silicon shortage may hamper this development, although it may be less of a problem for the vertically integrated companies. Especially ScanModule is expanding aggressively, with a drastic increase in the number of employees during the first half of 2006. In the coming years the company Solibro in Uppsala will commercialize the thin-film CIGS technology, which is yet in a pre-commercial state. The company aims to have modules on the market in two years time, but for full-scale production substantial financing is needed.

ANNEX

A Methods and accuracy of data

The numbers on installed capacity during 2004 were collected by surveying the importers, distributors and retailers of PV modules and systems. While most of the important players in this market have been surveyed, it is possible that there are small companies importing modules directly, which are not accounted for. There may also be an issue with end-users buying directly from abroad via the Internet. The estimated margin of error in these numbers is $\pm 10\%$.

The numbers on the amount of modules produced in Sweden, are obtained using similar surveying methods, but with the difference that there are only four manufacturers to take into account. These numbers are estimated to be well within a margin of error of $\pm 10\,\%$. The number on production capacity are somewhat less reliable, since this is considered sensitive information by some companies.

The rather complex calculation of the value of business is largely an estimate, since all the required information could not be obtained from the concerned market players. The margin of error here is estimated to $\pm 20\%$.

Other sources of information include both personal communication and published sources, like technical reports and internet web-sites.

B Country information

This information is simply to give the reader some background about the national environment in which PV is being deployed. It is not guaranteed to be 100% accurate nor intended for analysis, and the reader should do their own research if they require more detailed data. More information can be acquired from e.g. the Swedish Energy Agency (www.stem.se), Swedenergy (www.svenskenergi.se) and Statistics Sweden (www.scb.se).

- i) The retail price for electricity for a typical household customer, with a yearly consumption of 20 000 kWh, was 1,10 SEK during 2005. This includes energy price, distribution fees, energy tax, electricity certificates and value added tax. (From the report *Energimarknad 2005* from the Swedish Energy Agency) For industrial customers, the average retail price during 2004 was approximately 0,40 to 0,60 SEK/kWh, including electricity price, distribution fees and energy tax, but no VAT. The difference between industrial and domestic customers does not lie in the electricity price, but in the energy tax and, most important, the distribution fees.
- ii) The typical household electricity consumption for a flat is $2\,000\,\mathrm{kWh/year}$. For a detached house with direct electric heating, which is very common in Sweden, the typical yearly consumption is $20\,000\,\mathrm{kWh}$. The electricity consumption per capita is $16\,200\,\mathrm{kWh}$, which is high in an international comparison, due to high penetration of electric heating and a large electricity intensive industry.
- iii) For households, the customer pays for the electricity and for utility fees based on projected consumption, which is then reviewed when the meter is read. The meter should be read at least once per year, but a transition to remote metering is under way and in 2009 this will be mandatory. The tariff typically consists of electricity cost, distribution fees, energy tax, fees for electricity certificates and VAT. For industrial customers, time-of-use tariffs are common.
- iv) The average household income is 370 000 SEK, while the median household income is 304 000 SEK (from Statistics Sweden)
- v) The typical mortgage interest rate for private customers, with a solid security like real estate property, is 3% (adjustable-rate mortgage). The fixed-rate mortgage rates, with similar securities, vary roughly from 3% (1 year) to 5% (10 years).
- vi) The nominal voltage for household electricity is $230\,\mathrm{V}$. For long distance transmission lines the voltage is typically $200\,\mathrm{kV}$ or $400\,\mathrm{kV}$, while in regional networks the voltage varies between $20\,\mathrm{kV}$ and $130\,\mathrm{kV}$. The local area distribution network voltage is typically $10\,\mathrm{kV}$.

vii) Since 1996 the Swedish electricity market is open for commercial competition in the retail sector, while the distribution network is owned by local monopoly utility companies. The backbone distribution network is owned and managed by Svenska Kraftnät, a state-owned utility company.

Some companies are vertically integrated, with generation, distribution and retail operations, but there has to be a formal separation between the retail and distribution parts of the comapany. There are three large companies like this, dominating the market; Fortum AB, E.ON and the state-owned Vattenfall AB. There are also a number of smaller generation companies with retail operations, some with and some without a distribution network. There is a Nordic electric energy exchange, Nord Pool, where also some actors from Germany and Poland take part.

- **viii)** The diesel fuel price in Sweden is typically 10,50 SEK/l, of which roughly 5,70 SEK is made up of taxes.
- ix) The typical yield from a PV system is 600 to 800 kWh/kW with some examples of yields above 800 kWh/kW. (These numbers were extracted from data on energy production obtained from installations primarily in the Stockholm area.)