National Survey Report of PV Power Applications in Sweden 2006

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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 2006

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i Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the organisation for Economic Co-operation and Development (OECD), which carries out a comprehensive programme of energy co-operation among its 23 member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems Programme (IEA-PVPS) is one of the collaborative R & D agreements established within the IEA and, since 1993, its participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The 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 and the European Photovoltaic Industry Association are also members.

The overall programme is headed by an Executive Committee composed of one representative from each participating country, while the management of individual research projects (tasks) is the responsibility of Operating Agents. Ten tasks have been established and currently six are active. Information about these tasks can be found on the public website www.iea-pvps.org. A new task concerning PV environmental safety and health 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.

Sammanfattning på svenska – Summary in Swedish

Installerad effekt

Den viktigaste utvecklingen på solcellsmarknaden i Sverige under 2006 var den kraftiga ökningen av nätanslutna system. Tidigare år har oftast endast fåtalet system, om totalt mindre än 50 kW, installerats, men i och med investeringsstödets genomslag har detta ändrats. Den totala mängden nätanslutna solceller som installerades i Sverige under 2006 uppgick till 300 kW. Detta betyder att marknaden för denna typ av system matchar den för fristående system som traditionellt dominerat i Sverige.

Den fristående marknaden, framförallt för privathushåll, var i stort sett oförändrad under 2006 jämfört med föregående år. Marknaden inom detta segment är helt självbärande på rationell ekonomisk grund, och de flesta system installeras på sommarstugor, båtar och husvagnar. Det finns även en liten men stabil marknad för professionella tillämpningar för solceller, till exempel för kommunikationsutrustning och fyrar, vilken omslöt 32 kW under 2006. På marknaden för privata fristående system såldes total 280 kW under året.

Priser

Eftersom den svenska solcellsmarknaden är liten, är det svårt att urskilja pristrender. Priserna styrs i mycket av de större marknaderna i Europa. I och med introduktionen av investeringsstödet för allmänna byggnader har mängden större projekt ökat och fler intressenter har gått in på marknaden. Det betyder att det finns möjlighet till pressning av priser genom konkurrens. En effekt av stödet är att det fokuseras mer på priset för anläggningar och inte enbart på inlärning och demonstrationsvärden vilket varit fallet med flera tidigare projekt.

Tillverkning

Majoriteten av de anställda i solcellsbranschen i Sverige arbetar på de fem modultillverkande företagen, vilka expanderar kraftigt. Den tillverkade volymen moduler ökade med 44% från 2005 till 2006. *REC ScanModule AB* är det företag som expanderar kraftigast, och som idag är det största solcellsföretaget i Sverige. Sent under 2006 etablerades ett femte modulproducerande företag, *n67 Solar AB*, som dock inte producerade några större volymer före årsskiftet. De företag som saknar systerföretag som förser dem med celler har haft vissa problem med att hålla jämna steg med efterfrågan, och har därigenom hindrats i sin expansion. I vissa fall har det även lett till minskade produktionsvolymer. Detta har även lett till att företagen har slutit mer långsiktiga kontrakt med celleverantörer.

Allmänna medel till solcellsverksamhet

Tidigare har i princip alla allmänna medel till solcellsverksamhet gått till forsknng och utveckling, och då främst på komponentnivå. Detta ändras också i och med investeringsstödet, även om endast fyra projekt fick sitt stöd utbetalat under 2006. Med det större antal projekt som realiserats under 2006 så kommer troligen mängden utbetalade medel att öka kraftigt under 2007. Totalt gick 14 MSEK till forskning och utveckling på

solceller, medan 6,8 MSEK distribuerades som marknadsstöd genom investeringsstöd-systemet.

1 Executive summary

1.1 Installed PV-power

The most important development in Swedish PV applications during 2006 was the strong increase in grid-connected systems installed. Previously, only a few project often totalling less than 50 kW were installed each year, but with the impact of the investment subsidy for public buildings this has changed. The total amount of grid-connected PV installed (in the distributed kind) amounted to 300 kW in 2006, which means it was the first year when grid-connected and off-grid markets were equal in size.

The off-grid market, most importantly the off-grid domestic one, was rather unchanged in 2006 compared to previous years. This market segment is self sustained on rational economic grounds, with most applications for remote summer homes, boats and camper vans. There is also a small but rather constant off-grid non-domestic market, e.g. for telecommunications equipment and lighthouses, that totalled 32 kW. The domestic off-grid market volume amounted to 280 kW during 2006.

1.2 Costs & prices

Since the PV market in Sweden is very small it is difficult to see clear pricetrends. Prices are often dictated by the larger European markets. With the introduction of the investment subsidy for public buildings the number of larger projects has increased, and more stakeholders have entered the market. This means that there is a potential for price reductions, due to increased competition. One effect of the support is that more projects have been focused on low cost instead of learning or demonstration purposes, leading to lower average prices.

1.3 PV production

The majority of the people working with PV in Sweden are employed by the module manufacturing industry, which is expanding rapidly. The produced volume of PV modules increased by 44% compared to 2005. *REC ScanModule AB* is the company with the most aggressive expansion, and is now the largest module manufacturer in Sweden. Late in the year, a fifth module production company, *n67 Solar AB*, was established but did not reach any substantial production volumes. The companies without secure supply of cells from sister companies have had difficulties securing enough cells to meet demand in production. In some cases there has been negative growth in production volumes. This leads to more long-term contracts between module manufacturers and cell suppliers.

1.4 Budgets for PV

Previously nearly all the public funds for PV in Sweden have been allocated to research and development, mostly on the device level. This is also changing with the investment subsidy, although only four projects received their funds during 2006. With all the projects realized in 2006, it is highly likely that the funds to market development will increase substantially in 2007. In 2006 14 MSEK of public funds were allocated directly to PV R&D, while 6,8 MSEK were distributed as market support through the investment subsidy system.

2 The implementation of PV systems

2.1 Applications for photovoltaics

The applications for PV in Sweden have historically been dominated by the off-grid domestic market, primarily for vacation cottages in remote locations. In parallel with this, the off-grid non-domestic market has also had a stable basis, while the market for grid-connected PV installations has been quite fickle, with no or just few projects each year. The complete dominance of off-grid applications was broken during 2006, due to the support measure for PV in public buildings that was put in place in 2005.

Off-grid applications The market for off-grid domestic PV has been relatively stable over time, catering for the needs for electricity in remote vacation cottages, in camper vans or in boats. The systems typically comprise one or two modules, with a total nominal power of 20 to 150 W, batteries for storage and a charge regulator. This kind of system is sold as a kit by dedicated solar energy companies as well as by general hardware stores and retail outlets with focus on boating.

The primary applications for off-grid non-domestic PV applications are to provide power for lighthouses, telecommunications equipment, etcetera, in remote locations. This area of applications is limited, but the market has been stable over time.

Grid-connected applications The market for grid-connected centralized PV applications has been non-existent in Sweden, since there is little economic rationale for using PV as a bulk power generating technology with the present prices of PV systems and electric energy. Traditionally, the electricity price in Sweden has been quite low with Hydro and Nuclear Power providing 90 % of the electric energy supply. This, combined with the fact that the seasonal variations in insolation and electricity demand does not coincide, accentuates the difficulties for PV to compete as a means of large scale centralized generation.

For grid-connected distributed PV applications, the Swedish market has been slightly on-and-off in character, with several projects being finished one year, and no projects the next. This is primarily due to the fact that most systems installed have been parts of demonstration projects, with the specific aim to investigate the feasibility of using PV in the built environment. These projects have most often been initiated by electricity or building companies for learning purposes, and not purely for electricity generation. Some of the projects have been supported by local subsidies for environmentally sustainable building technology.

2.2 Total photovoltaic power installed

The most important driver in the PV market in Sweden is the investment subsidy for public buildings, which was launched in May 2005. It will run through 2008, with a cap of 150 MSEK, equalling approximately 3 MW if fully subscribed. The support has boosted the grid-connected market so that it matched the off-grid market for the first time, in 2006. During the year, the issue of the cost for grid-connection has been debated in the PV community. The legislation for grid-connection of renewable electrical energy production units will be investigated during 2007. Due to the investment subsidy the awareness of PV

with property managers, architects, builders, etc., has increased, although from a very low level. Previously, PV concerned mostly energy and building companies, but with the introduction of the support system more stakeholders have become involved in the PV business.

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

Applications:	Off-grid domestic	Off-grid non-domestic	Grid-connected distributed	Grid-connected centralized	Total
1992-12-31 (kW)	590	205	5	-	800
1993-12-31 (kW)	760	265	15	-	1 040
1994-12-31 (kW)	1020	293	24	-	1 337
1995-12-31 (kW)	1 285	304	31	-	1 620
1996-12-31 (kW)	1 452	364	33	-	1 849
1997-12-31 (kW)	1 640	394	93	-	2 127
1998-12-31 (kW)	1 823	433	114	-	2 370
1999-12-31 (kW)	2 012	448	124	-	2 584
2000-12-31 (kW)	2 216	465	124	-	2 805
2001-12-31 (kW)	2 376	507	149	-	3 032
2002-12-31 (kW)	2 595	544	158	-	3 297
2003-12-31 (kW)	2 814	573	194	-	3 581
2004-12-31 (kW)	3 070	602	194	-	3 866
2005-12-31 (kW)	3 350	633	254	-	4 237
2006-12-31 (kW)	3 630	655	555	-	4 850

Off-grid markets The size of the off-grid domestic market has been more or less unchanged since IEA-PVPS Task 1 started collecting these data in 1992. Each year a few thousand systems of typically 50 to 150 W are sold, totalling around 250 kW. This segment is sustainable and market driven, with practically no subsidies. The few subsidies that do exist in this market are contributions to electrification in remote areas for permanent dwellers. In 2006, this market segment totalled 280 kW.

The non-domestic market is, like the domestic one, self-sustainable on purely economic grounds. It is small but has been relatively constant over time, and during 2006 32 kW was installed.

Grid-connected markets The grid-connected market consists solely of distributed applications, with no installed capacity in the centralized category. Ever since a general investment subsidy for public buildings was launched in 2005, a considerable increase in the interest for grid-connected PV has been registered. The subsidy has had a major impact on the number of projects realized in 2005, and even more so in 2006. During the year, 300 kW was installed in the segment grid-connected distributed. This means that for the first time in the history of PV applications in Sweden, as much power was installed in the grid-connected market segment as in the off-grid sector. This is the same effect as has been seen in other countries, with increased installed power in the grid-connected sector as a result of subsidy programmes.

Figure 1: Kajplats 305, a student union building at Malmö University College. One of the several projects realized in Malmö.

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

Malmö The city of Malmö in the southernmost part of Sweden has shown interest in PV for a couple of years, and has executed several projects within the investment subsidy programme. These projects illustrate the effect of increased system size due to the programme. Previously, the size of a typical grid-connected system in Sweden was a few kW, with notable exceptions in the IKEA system installed in 1997 and some projects in Hammarby Sjöstad. With the introduction of the investment subsidy, more projects ranging from 20 to 80 kW have been realized, and this is true also in Malmö. By the end of 2006 the system at the Technology and Maritime House in Malmö was the largest PV system in Sweden with 68,9 kW.

Fjärås primary health care centre Eksta bostads AB is a municipal housing company that has been working with a strategy involving solar thermal and biomass since the late 1970-ies, and was one of the first property managers to apply for the investment subsidy when it was launched in 2005. This resulted in a 64 kW installation on the roof of a primary health care centre in Fjärås, which was the largest PV installation in Sweden when it was inaugurated in April 2006. The system is clearly aimed at low cost, with standard modules

mounted on top of the roofing tiles. The health care centre only uses renewable energy, and over the course of a year a surplus of electricity is produced and exported to the utility network.

Figure 2: The primary care centre in Fjärås, which was the largest PV system in Sweden when it was inaugurated early in 2006.

Stockholm The city of Stockholm decided early to fund an additional 30 % of the project cost for PV systems, if municipal companies were interested in applying for the investment subsidy. In total this would make the investment funded to 100 % for the owner of the system, and this led to a number of projects being planned, although several property managers still were reluctant to embrace PV technology. A few of these projects have been delayed, since there have been problems obtaining building permits. In connection with a project at Kulturhuset, permission was denied due cultural heritage reasons.

Fläckebo kyrka A congregation in the Church of Sweden, *Västerfärnebo-Fläckebo församling*, has installed PV on the roof of one of the buildings by the Fläckebo church. The project has received wide media coverage, since the congregation originally wanted the PV on the roof of the church itself but was turned down due to cultural heritage reasons. The decision was appealed twice and is now at the highest judicial level. In the meantime the PV has been installed on the roof of a nearby building, but the plans for PV on the church remain. The decision in this matter can be important for PV implementation in Sweden since

the Church of Sweden has shown interest in new energy technologies and have plenty of roof space to cover with solar cells.

2.4 Highlights of R&D

Thin-film solar cells The bulk of the device level reasearch on solar cells was previously collected in the programme *Ångström Solar Center* at *Uppsala University*. The research programme ended in 2005, but the name lives on with a group working on $Cu(In,Ga)Se_2$ thin-film solar cells. This group is concentrated on process and device development using co-evaporation technique. Key themes are process scalability, removal of Cd-containing layers, device stability and module integration. The results from the group are on the verge of being commercialized by the spinn-off company *Solibro AB*, which aim for full production and market introduction in 2008.

Dye-sensitized solar cells The largest research effort on dye-sensititzed solar cells is represented by a research team, previously in the Ångström Solar Center framework, located at the Royal Institute of Technology in Stockholm. This group, *Center of Molecular Devices*, perform both basic research and process development for production. The production process development is carried out in cooperation with the *IVF Industrial Research and Development Corporation*, jointly owned by the Swedish government and an organization of industrial enterprises.

Energy & Building Design At the *University of Lund*, research is conducted primarily on solar energy integration into buildings. One of the research themes is low concentration PV and hybrid systems with combined PV and solar thermal systems.

Polymer and Organic Solar Cells *The Center of Organic Electronics* led by *Linköping University* is working on polymer and organic solar cells. With the relatively low efficiency of these devices, typically one or two per cent, their prime application is envisioned as power supplies embedded in e.g. electronic papers or books. In a longer perspective more large scale applications could be possible.

Policy research At the division for *Environmental Systems Analysis*, *Chalmers University of Technology* in Gothenburg, several aspects of technology policy for PV have been studied. The research group has e.g. studied the effects of support mechanisms for emerging energy technologies like PV.

SolEl 03-07 PV R&D is conducted by *The Swedish national co-financed programme for PV systems and applications, SolEl 03-07*. The objectives of the programme include increased competence in industry and academia in the areas of PV systems as energy sources and building components. Other objectives are to support testing and development of interesting applications for PV and to disseminate information on PV systems with focus on cost reductions.

2.4.1 Industrial research

The major industries in the PV sector are the module manufacturing companies. However, in this section the focus is on the highlight of research in the industrial companies not yet in commercial production.

Arontis Solar Concentrator AB The newly formed company *Arontis Solar Concentrator AB*, based in Härnösand, is developing a system for concentrating hybrid photovoltaics, in close colaboration with several industrial partners. The system is based around a low concentrating parabolic trough design, with a water cooled receiver at the bottom. The troughs are operated with a fixed azimuth and variable tilt angle in order to track the sun. Prototypes of the concentrating system *Solar8* have been installed and it will be introduced on the market in 2007.

Solibro AB The company *Solibro AB* conducts development of large scale processing and module integration of $Cu(In,Ga)Se_2$ thin-film solar cells. The company was founded as a spinn-off from the thin-film solar cell group in Ångström Solar Center, and is located in Uppsala. In November 2006 a joint venture with German solar cell manufacturer Q-Cells GmbH, called Solibro GmbH, was announced. This provided additional funding for a full-scale manufacturing facility that will be located in Thalheim, Germany. The industrial research part of operations will remain in Uppsala.

Midsummer AB A second company, *Midsummer AB*, working with $Cu(In,Ga)Se_2$ thin-film solar cells announced in November 2006 that large scale cell production will commence in 2007. The technology used is somewhat different from that chosen by Solibro and Ångström Solar Center. Metals are sputtered onto a substrate and subsequently annealed with Se to form $Cu(In,Ga)Se_2$. Instead of integrating the cells into modules monolithically, discrete cells will be sold as replacements for Si wafer cells in traditional module processing.

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

The primary channel for public energy R & D funding is through *The Swedish Energy Agency*. The Energy Agency has co-funded some demonstration projects, as well. The market support for PV in public buildings that exists in Sweden is administered by *The National Board of Housing, Building and Planning* and the regional governments.

2.5.1 Budgets for PV research

The bulk of the funds for PV research in Sweden is directed towards device level research, mostly through the activities at Ångström Solar Center and Center of Molecular Devices. Furthermore, public funding is routed through the R & D programme SolEl 03-07, which is co-funded by the Swedish Energy Agency and several stakeholders in the PV business.

2.5.2 Budgets for market stimulation

The only public funding for PV market stimulation, on a national level, is the investment subsidy for public buildings. In 2006 6,8 MSEK was credited to the tax accounts of four property owners. Although several more projects were completed in 2006, only these four projects received their final acceptance in 2006.

2.5.3 Budgets for demonstration/field test programmes

Demonstration projects may receive public funding from the Swedish Energy Agency directly, or from the SolEl 03-07 programme. Previously there have also been regional

support demonstration projects involving environmentally sustainable investments. In 2006 there were no major demonstration projects of this kind funded by public resources.

Table 2 Public budgets for R&D, demonstration/field test programmes and market incentives.

	R & D	Demo/Field test	Market
National/federal	14	-	6,8
State/regional	-	-	-
Total	14	-	6,8

3 Industry and growth

3.1 Production of feedstocks, ingots and wafers

There is no production of feed-stock or wafers in Sweden, and there are no plans for such industrial activities in the near future.

3.2 Production of photovoltaic cells and modules

There are five module manufacturing companies in Sweden, which all work with imported cells. They export the great majority of their production, as the total production volume by far exceeds the domestic sales volumes. Presently there is no commercial solar cell production in Sweden, but there are plans for production of thin-film Cu(In,Ga)Se_2 cells by the company Midsummer AB (se section 2.4.1).

3.2.1 Gällivare PhotoVoltaic AB

Gällivare PhotoVoltaic AB (GPV) was the first module manufacturing operation set up in Sweden. It was started in 1991 in Gällivare, in the north of Sweden, and is today a part of the vertically integrated German company *SolarWorld AG*. This has helped the company to handle the shortage of cells experienced on the world market during 2005 and 2006. The maximum production capacity in the facilities amounts to 50 MW per year, with an output in 2006 of 17 MW.

3.2.2 ArcticSolar AB

ArcticSolar AB is also located in Gällivare, and is owned jointly by the German company *alfasolar Vertriebsgesellschaft mbH*, the Finnish company *Naps Systems Oy* and the manager of the company. Since ArcticSolar is not part of a vertically integrated organization, cells for the modules have to be bought on the world market. This has led to constricted production volumes. In 2006 the company delivered 3,1 MW of modules, while the maximum production capacity was 20 MW per year.

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	Concentrators	Cell	Module	Concentrators
1 GPV	mc-Si	-	17	-	-	50	-
2 ArcticSolar	mc-Si	-	3,1	-	-	20	-
3 ScanModule	mc-Si	-	33	-	-	45	-
4 PV Enterprise	mc-Si	-	2,3	-	-	20	-
5 n67 Solar	mc-Si	-	-	-	-	-	-
TOTALS		-	55,4	-	-	135	-

3.2.3 REC ScanModule AB

REC ScanModule AB in Arvika was established in 2003 by Norwegian *REC ASA*, as their module production company. The company has undergone rapid expansion during the past few years, and is now the largest module manufacturer in Sweden. This has been possible thanks to the supply of cells from the sister company *REC ScanCell AS* in Norway, although the competition for cells has also affected the production volumes of ScanModule. The output during 2006 amounted to 33 MW, while the yearly production capacity was 45 MW/year. The company exports all modules produced, with middle and southern Europe as the primary markets. During 2007 more automated production technology will be introduced, in conjunction with a capacity expansion to 100 MW per year.

3.2.4 PV Enterprise Sweden AB

PV Enterprise Sweden AB is one of the younger module manufacturing companies in Sweden, started in 2002 by the former head of GPV. Since the start, its growth has been hampered by the supply of cells, and 2006 was no exception in this respect. In 2006 the company showed negative growth due to the cell supply problems, ending up at a yearly production of 2,3 MW, with a maximum capacity of 20 MW. The production has been restructured and automated, and late in 2006 a more long term cell supply deal was signed with *JingAo Solar* of China, which will allow for more stable supply conditions in 2007 and 2008. PV Enterprise Sweden was the first Swedish PV company to perform an IPO, and the company was subsequently listed at the *First North* stock market in December 2006.

3.2.5 n67 Solar AB

A fifth module manufacturing company, *n67 Solar AB*, was established in Sweden in 2006, but did only produce negligible volumes before the end of the year. It is located in Porjus, approximately 40 km from Gällivare accentuating the concentration of PV industries in that

area. Like the other companies, sales is mainly directed towards the European markets. The company specializes in large area modules, with models starting at 200 W.

3.2.6 General trends

One of the most important trends with the PV manufacturing companies is the problem to obtain enough cells to meet the market demand. This has been more difficult for the independent manufacturers, while the ones integrated in larger corporations, that control most of the value chain, have been able to source cells from sister companies. A trend emerging in the wake of the shortage of cells on the market is that the companies try to secure cell supply by more long term contracts.

The forceful expansion of production capacity in recent years has been paired with increased automatization in production, and more use of clean room facilities. Although production becomes more automated, the number of people employed in module production has increased steadily although there have been set-backs in some companies.

Table 4a: Typical module prices for a number of years

Year	2002	2003	2004	2005	2006
Large orders (SEK/W)	30	26	26	32	30
Single modules (SEK/W)	75	70	70	70	65

3.3 Manufacturers and suppliers of other components

There are no manufacturers of switch gear, support structures, electronics, or other balance-of-system components specific to PV, in Sweden.

3.4 System prices

In the market that has dominated Swedish PV applications, i.e. the off-grid domestic segment, there has been little change in the prices during the past few years. This is most likely due to the fact that this market is quite constant and small in volume. The demand for this type of system is quite inelastic, so that a price drop would not result in a great increase in demand.

With the introduction of the investment subsidy and the increased market for grid-connected systems it becomes easier to observe price trends. Previously most projects were one-off installations made for learning or demonstration purposes. This meant that no price trends could be discerned, but with a larger number of projects in 2006 it is possible to see price trends for a couple of typical applications. The price for a system of standard modules retro-fitted to a roof or a façade is typically 50 – 60 SEK/W. For building integrated systems the variation between the installed systems is so large that it is impossible to give a typical price per watt.

Table 5: Turnkey Prices of Typical Applications

Category/Size	Typical applications in your country and brief details	Current prices per W (to one decimal point)
OFF-GRID Up to 1 kW	Remote electrification, domestic or professional	100
OFF-GRID >1 kW	-	n/a
GRID-CONNECTED Specific case	Case: Fjärås Primary Health Care Centre	56
GRID-CONNECTED Up to 10 kW	Typical roof-mounted system	55
GRID-CONNECTED >10 kW	The largest type of PV system in Sweden	50

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

YEAR	2000	2001	2002	2003	2004	2005	2006
Price (SEK/W)	110–150	100–140	100–130	90–110	90–110	90–110	90–110

3.5 Labour places

The number of labour places in the PV business in Sweden has increased steadily during the past few years, mostly due to the increased module production in the industry. In parallel with this, the number of people employed in development has also increased with the establishment of the companies Solibro AB, Midsummer AB and Arontis Solar Concentrator AB. There has also been an increase in the downstream business, much because of the investment subsidy.

In 2006 approximately 33 people were employed in R&D, while 350 were employed in the manufacturing industry. Furthermore, some 22 people are employed in other parts of the Swedish PV community, for instance with policy, installing, consulting and retail. All in all roughly 400 people were employed in the PV sector in Sweden.

3.6 Business value

The PV industry in Sweden is heavily dominated by the module manufacture part of the value chain. Cells are imported and modules are exported, while relatively little is installed in the country. This industry has expanded quite rapidly from volumes of a few MW in 2003 to a total production volume in excess of 50 MW in 2006. Most modules are exported to the German and southern European markets. A little increase in activities in the downstream part of the value chain has been seen in conjunction with the introduction of the investment subsidy scheme.

The overall business value of the PV industry in Sweden is estimated in Table 7. N.B. This is only an estimate, as a complete calculation of added value would require information that is considered sensitive by the industry stakeholders, and thus not released.

Table 6: Value of PV business

Sub-market	Capacity installed in 2006 (kW)	Price per W (SEK/kW)	Value (MSEK)	Totals (MSEK)
Off-grid domestic	280	100	28	
Off-grid non-domestic	32	100	3,2	
Grid-connected distributed	-	-	-	
Grid-connected centralized	301	55	16,6	
				47,8
Export of PV products				1 653e
Change in stocks held				n/a
Import of PV products				1 187
Value of PV business				**514**

4 Framework for deployment (Non-technical factors)

4.1 New initiatives

The only significant Swedish support measure, as far as PV is concerned, is the investment subsidy that was introduced as a tax rebate in May 2005. At the start, 100 MSEK was allocated to support for PV installations in buildings for public use. In the projects eligible for support 70% of the total project cost, including external project management costs, is covered by the investment subsidy. Initially the time frame was from May 2005 to the end of 2007. However, in the 2006 spring economic bill the total cap was raised to 150 MSEK and

the time frame was extended through the end of 2008. Furthermore, in the 2006 autumn economic bill the nature of the support was changed from being a tax reduction to a direct capital support. This was mostly a budget technicality and does not change the effect of the legislation.

Table 7: PV support measures

	National / Regional (State) / Local
Enhanced feed-in tariffs	-
Direct capital subsidies	-
Green electricity schemes	-
PV-specific green electricity schemes	-
Renewable portfolio standards (RPS)	National
PV requirement in RPS	-
Investment funds for PV	National
Tax credits	-
Net metering	-
Net billing	-
Commercial bank activities	-
Electricity utility activities	-
Sustainable building requirements	-

4.1.1 Utility and public perception of PV

Solar energy, thermal and PV, have enjoyed wide public support with roughly three quarters of the population wanting more support for solar energy projects. In light of the recent discussions on global climate change, the support for solar energy has increased even further during 2006. The public support for wind, hydro and bioenergy has also increased, while people are becoming more critical to fossil fuel energy. A common misconception is that a lack of insolation in Sweden makes it less favorable to use solar energy here, compared to continental Europe. However, the yield of a PV system over a year is more or less the same in southern Sweden as in large parts of western and central Europe.

The Swedish utilities have widely different perceptions of and attitudes towards renewable energy. Some have a distinct renewable energy profile while others show little interest in accommodating new renewable energy generation. Some utilities and electric companies are directly or indirectly involved in PV R,D&D. Within the framework of SolEl 03-07, a group of scientists from the University of Lund together with the largest Swedish electricity company, Vattenfall AB, have compiled a report on the benefits of PV for energy producers and utility companies. The result was that the possibilities for PV to compete with other forms of electric energy generation in Sweden before 2050, without support measures, are rather slim. However, the report also showed that there are ample possibilities for house owners to utilize PV in a cost effective way.

4.2 Indirect policy issues

Recent studies on grid-connection in Sweden have highlighted the issue with legislation for grid-connection of small production units, like home PV systems. Although the Swedish electricity market is deregulated, the utility market still consists of local monopolies, with network tariffs regulated by the *Energy Markets Inspectorate*. According to the electricity act (2002:121) the utility should, for connection of small production units (up to 1 500 kW), charge only the cost for measurement and reporting in addition to a connection fee. These charges are monitored in retrospect by the Energy Markets Inspectorate, and presently the typical yearly charge for an installation of a few kW is approximately 4 000 SEK. This is prohibitively expensive for such a small system, which may produce only a few thousand kWh per year.

4.2.1 Electricity certificates

The primary control measure for increased renewable electric energy production in Sweden is the electricity certificate system that has been in place since 2003. The system is based around a supply–demand dynamics, with tradable certificates and an increasing quota that has to be filled by every electricity consumer. One certificate is awarded per MWh electric energy produced by wind, solar, geothermal and wave power. Some hydro power and biomass applications as well as peat-fuelled combined heat and power are also eligible for certificates. The demand for certificates is created by forcing electricity consumers to buy a number of certificates in relation to consumption. In 2006 the mandatory quota was 12,6 %, meaning that for every MWh electricity used 0,126 certificates have to be bought. This quota is increased every year in order to raise the demand for renewable electric energy. Energy intensive industry, with an electricity consumption per company turnover of more than 40 MWh/MSEK, are partly exempt from the mandatory quota.

The electricity certificate system has had little impact on the PV market in Sweden, since the income from certificate sales is only approximately 0,20 SEK/kWh. At the end of 2006, only three PV systems with a total power of 35 kW were registered in the certificate system. This is partly because of the high price for grid-connection and partly because most grid-connected systems have lower power than what is used on-site and therefore feed no energy into the grid.

4.2.2 Taxes

There are a number of taxes on energy used as control measures to foster reduced energy consumption. In 2006, the energy tax levied on electricity was 0,261 SEK/kWh, with reductions for some municipalities in the north of Sweden. This tax was increased by 70 % between 1999 and 2005. In the same time the energy tax on oil has decreased, while the CO_2 tax on oil has more than doubled. For oil there is also a tax on sulfur content. Certain parts of the industry has had exemptions from energy and CO_2 tax, but this is considered illegitimate support by the European Union, and thus the taxation is being adapted in order to conform with the E.U. rules for government support.

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

The Swedish International Development Cooperation Agency (SIDA) are involved in two project where PV is the key technology. One is for rural electrification in Zambia, where

small energy companies are set up in order to install and maintain solar home systems. This project is carried out in cooperation with *Stockholm Environment Institute*. In the second one SIDA is providing guarantees for investments into PV powered mobile phone technology, so that modern communications is made readily available to more people, especially in rural areas. The project is managed by the *South Africa Mobile Telephone Company* (MTN).

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 60 364*. According to a report from the SolEl 03-07 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 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 previously 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.

However, with the introduction of the support and the increase in size of grid-connected projects, more interest has been directed towards the grid-connection issue. A committee is looking into these issues in order to facilitate export of electric energy to the grid from small production units.

4.4 Building permits

A few projects in the investment subsidy programme have run into problems with obtaining permission from the local authorities, in some cases because of the heritage value of the

building. This has led to the projects being reworked with the PV put in less conspicuous positions.

There are few general rules for building permits required for PV installations.

5 Highlights and prospects

5.1 Highlights

The two most important highlights of PV deployment in Sweden, 2006, was that the subsidy system led to as much grid connected as off-grid PV power being installed, and that the production of modules was increased, especially by REC ScanModule.

The grid-connected PV market has previously consisted of one-off projects for learning and demonstration purposes with several projects one year and no projects the next. With the introduction of the investment subsidy in 2005 the grid-connected market has been launched into a slightly different mode, with >10 projects being realized in 2006. This has led to more stakeholders becoming involved in the market, with a couple of more installers and new project commissioners. Previously the larger projects were typically commissioned by energy and building companies with specific interests in learning PV technology. With the support scheme other commissioners, with general interest in renewable energy, are entering the market.

The manufacturing industry, i.e. the module manufacturing companies, have expanded and is employing more people. This applies chiefly to the company REC ScanModule AB, which has more than doubled its yearly production to become the largest PV module producer in Sweden in 2006. The smaller companies have not been able to expand in the same manner, due to constrictions in cell supply. However, a fifth module production plant was set up, indicating that the business will continue to increase in the coming years. One important development was that PV Enterprise AB became the first Swedish PV company to perform an IPO and to become listed on a public stock exchange, First North. This and other developments have increased the press coverage, raising the general awareness about the PV business.

5.2 Prospects

The effect of the investment subsidy will most likely lead to a market increase in 2007 as well, but there is a risk that some projects that have received preliminary acceptance will never be realized. Two thirds of the allocated funds for the investment subsidy were claimed at the end of 2006, and it is highly likely that the cap will be reached in 2007. During 2007 there will be several evaluations of the support system, and probably a recommendation on whether there will be a continuation of the system after 2008. There will probably not be any decision on this before the spring economic bill of 2008. The risk of the support system ending in December 2008, means that it is difficult for stakeholders to invest more long term in the Swedish market, and a stop to the support will certainly cause the market for larger installations to collapse.

As far as the module manufacture companies are concerned, they all have plans for expansion and the bottleneck that may restrict their growth is the possibility to obtain cells.

REC ScanModule have very ambitious plans of adding 55MW of capacity to their 45MW of capacity in 2007. This makes it the most aggressive company in the module business in Sweden. The other manufacturers have more moderate expansion plans, which in some cases are controlled by the supply of cells. 2007 may also see the first commercial production of thin-film PV in Sweden, if the plans of Midsummer AB are realized.

Annex A Method and accuracy of data

The primary method used to gather data for this report is direct surveys, with e-mail or phone questionnaires to the companies in the PV business. Since Sweden has a quite limited market for PV, the number of companies that need to be surveyed is reasonably small, and most of them answer the surveys. The grid-connected installations are also tallied against a systems follow-up service provided by the SolEl 03-07 programme. The accuracy in the collected data is deemed to be around 10 %. Some companies have not answered the questions in the survey, and their sales volume had to be estimated from the overall market change and historic data. The overall accuracy is therefore estimated to 15 %.

Data is also collected from a multitude of sources readily available on the Internet, e.g. economic reports from companies, research reports and media.

Annex B Country information

i) The retail price for electricity for a typical household customer, with a yearly consumption of 5 000 kWh, was 1,4 SEK/kWh during 2006. For a house with direct electric heating, with a consumption of 20 000 kWh, the average price was 1,2 SEK/kWh. This includes electric energy price, distribution fees, energy tax, electricity certificates and value added tax. (From the report *Energiläget 2006* from the Swedish Energy Agency) For industrial customers, the average retail price during 2006 was approximately 0,40 to 0,60 SEK/kWh, including electricity price, distribution fees and energy tax, but without 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 kWh/year. For a detached house with direct electric heating, which is very common in Sweden, the typical yearly consumption is 20 000 kWh. The electricity consumption per capita is roughly 16 500 kWh, which is high in an international comparison, due to high penetration of electric heating combined with a cold climate, 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. By then all meters must be read once per month, and this will probably lead to billing based on real instead of projected consumption. The tariff typically consists of electricity cost, distribution fees, energy tax, fees for electricity certificates and VAT. N.B. the VAT is levied on top of the energy tax. For industrial customers, time-of-use tariffs are common.

iv) The average household income is 395 000 SEK, while the median household income is 316 000 SEK (from Statistics Sweden)

v) The typical mortgage interest rate for private customers, with a solid security like real estate property, is 3,5 % (adjustable-rate mortgage). The fixed-rate mortgages, with similar securities, vary roughly from 4 % (1 year) to 5 % (10 years).

vi) The nominal voltage for household electricity is 230 V. For long distance transmission lines the voltage is typically 200 kV or 400 kV, while in regional networks the voltage varies between 20 kV and 130 kV. The local area distribution network voltage is typically 10 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. Since the deregulation of the electricity market, the business areas of generation, retail and transmission have been separated. However, some companies operate in all three fields. 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 10,7 SEK/l, of which roughly 5,90 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.)