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national survey report of PV power applications in Sweden 2007

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Task 1
Exchange and dissemination of information on PV power systems

National Survey Report of PV Power Applications in Sweden 2007

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List of Abbreviations

BIPV	building integrated PV
BOS	balance-of-system components
CIGS	Cu(In,Ga)Se_2
CMD	Center of Molecular Devices
COE	Center of Organic Electronics
GPV	Gällivare PhotoVoltaic AB
IEA	The International Energy Agency
IEA-PVPS	The IEA Photovoltaic Power Systems Programme
IPO	initial public offering
MISTRA	The Foundation for Strategic Environmental Research
OECD	The Organisation for Economic Co-operation and Development
PV	photovolatic
PV/T	photovoltaic/thermal
REC	Renewable Energy Corporation
RPS	Renewable portfolio standards
SEK	Swedish krona
SIDA	The Swedish International Development Agency
SSF	The Swedish Foundation for Strategic Research
VR	The Swedish Research Council

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 Tasks (research projects/activity areas) is the responsibility of Operating Agents. Information about the active and completed tasks can be found on the IEA-PVPS website www.iea-pvps.org.

ii Introduction

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 2007, 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

Tack vare det stödsystem som inrättades i maj 2005 för solceller på offentliga byggnader ökade mängden installerade solceller kraftigt från 2006 (600 kW/år) till 2007 (1 400 kW/år). Den skarpa ökningen kommer att plana ut under 2008, med ungefär samma mängd installerad effekt. Detta styrs helt av stödsystemet som i princip slog i taket i slutet av 2007. Även om taket lyftes i mars 2008 så måste projekten slutföras under 2008 för att erhålla stöd. Ett 50-tal projekt som hade godkänts men inte genomförts under 2007 kommer troligtvis att byggas under 2008, tillsammans med en del nya projekt. Framtiden för den nätanslutna marknaden är mycket oviss, eftersom det inte finns någon information om en eventuell fortsättning av stödsystemet efter 2008.

De icke-nätanslutna marknaderna är relativt stabila med ungefär 300 kW installerat varje år. Dessa segment existerar på marknadsvillkor utan stöd, och innefattar system för platser där det inte finns möjlighet till nätanslutning, i såväl privata som kommersiella sammanhang.

Priser

Priserna på PV-system och -komponenter i Sverige beror mycket på världsmarknadspriserna. För icke-nätanslutna system är priselasticiteten låg, eftersom det finns få substitut för sommarstugor och kommunikationsutrustning utan tillgång till elnätet. Den nätanslutna marknaden domineras av stödsystemet för offentliga byggnader, men där saknas en mekanism för att pressa ned priser. När fler system installeras går dock priset ned något eftersom projektlednings- och lärkostnader minskas vartefter. Fler projekt med tydligt fokus på låg kostnad utförs också.

Tillverkning

De fem modultillverkarna i Sverige har alla ambitiösa utvidgningsmål. De två som kämpat med svårigheter att få tag på celler till produktionen förutspår bättre möjligheter på det området. De företag som är vertikalt integrerade har haft god tillgång på celler och har kunnat expandera produktionsvolymerna under 2007. Den nya aktören, n67 Solar AB, expanderar sin produktionskapacitet från 10 till 20 MW, redan ett år efter starten.

PV Enterprise AB listades på börsen First North i slutet av 2006 och under 2007 har aktien stigit kraftigt även om företaget har haft problem med att få tag på celler till sin produktion. I slutet av 2007 slöts ett avtal mellan tyska SolarWorld, moderbolag till modultillverkaren GPV, och det svenska investmentbolaget Borevind AB om försäljning av 65 % av aktierna i GPV. Även efter att Borevind tagit över bolaget kommer GPV att köpa celler från det tidigare moderbolaget. I början av 2008 offentliggjorde GPV planer på egen celltillverkning på fem års sikt.

Allmänna medel till solcellsverksamhet

Tidigare har majoriteten av de allmänna medel till solceller gått till forskning och utveckling, med mycket liten del till marknadsstöd och demonstrationsprojekt. Detta har ändrats drastiskt i och med stödsystemet för allmänna byggnader. Under 2007 utbetalades nära 50 MSEK till fastighetsägare inom systemet. Nivån på stödet till forskning och utveckling har inte ändrats speciellt mycket jämfört med tidigare år. Nya mottagare av stöd för forskning är bl.a. företaget Midsummer AB.

1 Executive summary

1.1 Installed PV-power

With the impact of the direct capital subsidy for PV in public buildings, the installed PV power increased drastically from 2006 to 2007, more than doubling to 1 400 kW/year. This sharp increase of market size will flatten out in 2008, with roughly the same amount of installed capacity. This is completely governed by the support system that more or less reached its cap in late 2007. Although the cap was lifted in March 2008 projects still have to be finished before the end of December 2008 to be eligible for support. Some 50 projects that had been approved but not yet executed will most likely be finished in 2008, along with new projects applying for support. The future of the grid-connected market is very unclear, since there is no information on a possible continuation of the support after 2008.

The off-grid markets are quite stable, with roughly 300 kW being installed each year. They are self-sustained on market terms and cater for electrification in remote locations. In domestic as well as non-domestic applications.

1.2 Costs & prices

The prices of PV systems and components in Sweden are mostly dictated by World market prices. In the off-grid markets, the price elasticity is low, since there are few substitute technologies for summer homes or telecommunication systems. In the grid connected market, the direct capital subsidy system does not have a mechanism to promote cost decreases. However, with more projects being carried out the project management costs will most likely come down, and more cost-aware projects are seen.

1.3 PV production

The five PV module manufacturers in Sweden all have ambitious expansion targets. The two companies that have struggled with restricted cell supply see a more positive future with more large contracts for input materials. The vertically integrated companies have been able to source material and increase production volumes during 2007. The new player in the module manufacturing business, n67 Solar AB, is expanding capacity from 10 to 20 MW per year after the first year of operations.

The company PV Enterprise was publicly listed on the stock exchange in late 2006, and during 2007 the share price has risen sharply although the company has had problems with supply of solar cells. In late 2007 it was agreed that the German owner of module producer GPV, Solar World AG, would sell 65 % of the company to a Swedish investment company Borevind AB. The sale was accompanied by supply and sales contracts between the former majority owner and GPV. Plans to start cell production was also announced by GPV in early 2008.

1.4 Budgets for PV

Previously the public funds for PV have mostly been directed at research, development and demonstration, with no money for market support. This has, like the overall market, changed drastically with the support scheme for public buildings. In 2007, close to 50 MSEK was paid out to property managers within this scheme. The level of support for research was not changed significantly, although some new beneficiaries have emerged such as the company Midsummer AB.

Figure 1: Earlier, 80 to 90 % of the PV power was installed in the domestic off-grid sector. Most of these systems are installed in summer cottages where grid-connection is not a feasible option. Electric power for boats is also a common application.

2 The implementation of PV systems

In this report a PV power system consists of modules, inverters, batteries and all installation and control components for modules, inverters and batteries. The market is defined as the amount of all applications with a rated peak power of 40 W or more.

2.1 Applications for photovoltaics

During the past few years, since the introduction of a support measure for PV systems in public buildings, the Swedish PV market has gone through a rapid expansion. From being characterized by the steady, unsupported off-grid market, the grid-connected market surpassed the off-grid one for the first time in 2007.

Off-grid applications Traditionally, the largest markets for PV in Sweden have been found in the off-grid sectors, mostly catering for summer homes, boats and equipment like navigational aids and for communications. These market segments have been reasonably stable over time, with little growth, and no public funding. Between 80 and 90 % of the PV market could previously be found in the domestic off-grid sector, most prominently represented by a summer home without grid access, where a single or a few modules is used to provide power for e.g. lighting, radio and refrigeration. These systems, being off-grid, use batteries to store energy. Two examples of this kind of application are shown in Figure 1.

Another market segment that has been constant and self-sustained is the non-domestic off-grid one. This market typically comprises solutions for stand-alone applications like

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

Year	Sub-market/application				
	Off-grid domestic [kW]	Off-grid non-domestic [kW]	Grid-connected distributed [kW]	Grid-connected centralized [kW]	Total [kW]
2007	248	23	1121	-	1392

parking meters, navigational aids, telecommunications equipment etcetera. This market is small, approximately 10 % of the total off-grid market.

Grid-connected applications Before the introduction of the investment subsidy for PV systems in public buildings, grid-connected systems were few and far between. They were most often erected as demonstration projects, with the express purpose to increase the know-how of PV. Most of these systems have received some type of public funding for demonstrating PV technology. With the introduction of the support system the grid-connected market has gone through a drastic change, rapidly becoming more diverse.

The fact that there is a general subsidy has brought new types of projects and new players to the PV market. Previously, most projects were carried out by energy companies, building companies or other stakeholders that were interested in the technology for learning or demonstration purposes. However, with the subsidy system, projects have been commissioned by a variety of customers ranging from cooperative associations to operators of sports arenas and the Swedish church.

2.2 Total photovoltaic power installed

Off-grid markets There was little change in the off-grid markets, both domestic and non-domestic, as these are not influenced much by the support system. There was 248 kW installed in the off-grid domestic segment during 2007, which is more or less the same market volume as in previous years. In the non-domestic market, 23 kW was installed during 2007. This figure also reflects a quite constant market segment.

Grid-connected markets The most eye-catching development on the Swedish PV market during 2007 was that the market for grid-connected systems more than trebled, thanks to the subsidy for PV in public buildings. Adding to the strong increase between 2005 and 2006, the total installed power in 2007 was approximately double the cumulative previously installed power in the grid-connected segment. Of the 1 121 kW installed, nearly all was supported by the subsidy for public buildings, with only a few privately financed projects.

The average size of projects carried out during 2007 was actually somewhat lower than in 2006, owing to the fact that some municipalities and the Swedish church installed several quite small systems in schools, daycare centres and congregational buildings. At the same time the largest systems have become larger.

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

During 2007, more grid-connected projects have been carried out than ever before, in total around 50 separate systems have been installed. Although many projects were only a few kW, there were several projects that were the largest in Sweden when installed, but

Table 2: The cumulative installed power in four sub-markets

Year	Sub-market/application				
	Off-grid domestic [kW]	Off-grid non-domestic [kW]	Grid-connected distributed [kW]	Grid-connected centralized [kW]	Total [kW]
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	-	1 849
1997	1 640	394	93	-	2 127
1998	1 823	433	114	-	2 370
1999	2 012	448	124	-	2 584
2000	2 216	465	124	-	2 805
2001	2 376	507	149	-	3 032
2002	2 595	544	158	-	3 297
2003	2 814	573	194	-	3 581
2004	3 070	602	194	-	3 866
2005	3 350	633	254	-	4 237
2006	3 630	665	555	-	4 850
2007	3 878	688	1 676	-	6 242

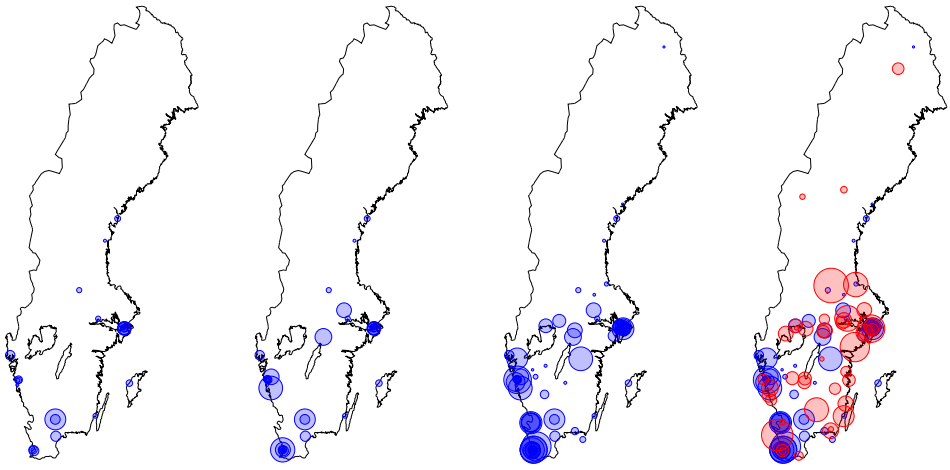
subsequently surpassed. This has been used to create publicity for the projects, and has resulted in a race between property owners to have the largest PV system in Sweden.

The evolution of grid-connected PV systems in Sweden is illustrated in Figure 2, where the few grid-connected systems prior to the start of the subsidy system are displayed in (a). In (b) – (d) the increasing number of systems are shown, with a strong increase between 2006 and 2007. Most of the systems that account for this increase were installed in the larger cities, while the projected systems at the end of 2008 (d) are more evenly distributed.

2.3.1 Investment subsidy for public buildings

The only support for PV installations in Sweden is an investment subsidy that allows for 70 % of project costs to be covered up to a maximum of 5 MSEK per building. The costs covered include material, mounting and external project management costs for projects in buildings that are classified as special buildings or exempt from taxation by the property taxation law (1979:1152). This includes hospitals, churches, sports stadiums, schools, museums and in practice any other building that is designated for public use or in conjunction with activities like public transport.

The support system was previously capped at 150 MSEK of direct capital subsidies, and although this cap was lifted in the spring of 2008, the time frame from May 2005 through the end of 2008 still remains. The estimated amount of installed capacity within the programme is around 3 MW. With an initially quite slow start, the number of applications has increased over time and by the end of 2007 roughly 150 MSEK was allotted to projects, with some tens of support applications waiting to be processed by the regional authorities. Since there was a cap of 150 MSEK the application process was slowed down, but has again increased with the lifting of the cap. Also, several projects approved in 2007 will be realized in 2008, so that the PV market will most likely remain approximately constant from 2007 to 2008. After 2008, the market is at risk of collapsing completely, since it is very unclear whether there will be a continuation of the support system. The vast majority of the PV systems installed within the scheme would not have been carried out without the



(a) 2005-12-31 (b) 2006-12-31 (c) 2007-12-31 (d) 2008-12-31

Figure 2: The grid-connected PV installations in Sweden presented on a map, where the sizes of the discs are proportional to the installation size. For 2008-12-31 the image (d) shows a projection (red discs) based on realized and planned projects in the investment subsidy scheme.

financial support.

The future of market support in Sweden has been widely debated in the PV community, but the key to a continuation of the support system is that an extension be put in place swiftly following the end of the present programme. This is not very likely to happen, since the lead time for preparing this kind of government support often is long. Consequently, there will most certainly be a gap in the support system, which may adversely affect the PV market, especially the PV installers.

The results from the support programme are generally positive, with new stakeholders entering the PV community. Previously, PV has been the concern of stakeholders interested in the technology in itself. With the support programme, property managers, municipalities and other actors have taken an interest in PV as a new method of alleviating their environmental impact. However, for many of these stakeholders the projects carried out are just a first taste of PV technology.

Furthermore some networks have been established, as well within organizations like the City of Malmö, as between different actors in the business. Supplier-buyer networks have been established between consultants, equipment suppliers and electrical installers [2].

2.3.2 Interesting projects, regions and stakeholders

Malmö Malmö city has embraced PV technology as a means to build a more sustainable urban environment, and have carried out quite a few PV projects. The largest project to date in Sweden is called *Sege park* and consists of twin systems, retrofitted to two hospital buildings. The systems are mounted on free-standing structures that also function as shading devices, see Figure 3a.

Another installation where PV is used as solar shading is at the Academy of Music in Malmö, see Figure 3b. Here lamella-type modules are used above the windows.

An association called *Solar City Malmö* has been created in order to promote new projects, not only in the city of Malmö but in the surrounding region. The association was

(a) Sege park

(b) Musikhögskolan, Heleneholm

Figure 3: The largest PV installation in Sweden, with two arrays comprising in total 168 kW, on a hospital building in Malmö.

Figure 4: The installation at Ekologihuset, Lund University, comprises PV in several different positions. Here frame-less modules mounted in front of a south-facing façade.

started as a collaboration between Malmö City, the regional energy agency (*Energikontoret Skåne*) and the University of Lund. The aim of Solar City Malmö is to create a network and a centre of competence in the fields of solar energy, PV and solar thermal.

Ullevi When inaugurated in March 2007, the PV system at the *Ullevi* arena in Gotheburg was the largest PV system in Sweden (later to be surpassed by the Sege park project in Malmö). It is a high-profile installation that covers the roof of the VIP stand, with 86,4 kW clearly visible to a large part of the audience. Its prominent place in the area is designed to attract attention and generate positive publicity.

Stockholm A number of systems have been installed in Stockholm, with the most prominent ones on two sports centres, *Åkeshovshallen* and *Hovet*. Both are rated at roughly 50 kW, and are retrofitted to the flat roofs of the buildings. In the case with Hovet, a technique that has not been used in Sweden before was employed. The system consists of thin-film Si modules integrated into a rubber sheet, which was bonded to the original roof. This was the only feasible technique due to restrictions on the load that could be placed on the flexible roofing material.

Other projects in Stockholm include PV systems on the Stockholm Municipal Theatre (*Stockholms Stadsteater*), on the building of The Swedish International Development Agency (SIDA) at Campus Gärdet, and on a fire station in Vällingby in the western part of Stockholm.

Båstad Another municipality where the public subsidy for PV has been embraced is Båstad, in the south-west of Sweden. An attractive building integrated PV (BIPV) installation has been built with semi-transparent modules used as roof for one of the stands at the

Figure 5: The Swedish Church has installed PV on several congregational buildings; here two examples from Malmö are shown.

Tennis stadium, where an ATP tournament is held each summer. The arena will be self-sustained as far as electricity is concerned during periods of operation. Furthermore the roof of a school has been fitted with PV.

Akademiska hus One of the new stakeholders that has come into the PV market with the subsidy scheme is Akademiska Hus, which owns and manages most university buildings in Sweden. Several large projects have been carried out at university campuses. One example is the building Ekologihuset in Lund, where in total 109 kW is installed in various locations. Frame-less modules are used as solar shading of south-facing windows and adorn the façades, see Figure 4. Although several projects have been carried out by Akademiska hus, they are commissioned by different parts of the company. This means that no central PV competence has been built, yet.

The Swedish Church Like Akademiska Hus, different parts of the Swedish Church has installed PV on several buildings in different locations. This has mainly been initiated on a local level, and not coordinated centrally. For several years there have been plans to put PV on the roof of a church in Fläckebo, but there has been staunch resistance from the Swedish National Heritage Board, claiming that the cultural value of the church would be destroyed. The church has appealed to the highest level in the Swedish judicial system, but was turned down and is contemplating taking the issue to the European court.

Church buildings that have been built more recently have attracted attention since they are not protected by the Swedish National Heritage Board. Furthermore, other congregational buildings have had PV fitted, for instance in four cases in Malmö (see Figure 5). However, also in this case there have been issues with building permits in the case of a mid 20:th century building with particular architectural value.

2.4 Highlights of R & D

Thin-film solar cells The largest research group in Sweden working with thin-film solar cells was previously intimately connected to the spinn-off company *Solibro AB*. Since the launch of a joint venture between Solibro AB and Q-Cells of Germany, the aim of the research group has been reoriented towards more basic research, not directly connected to manufacturing issues. The group primarily works with Cu(In,Ga)Se_2 (CIGS) thin-film solar cell technology.

At Chalmers University in Gothenburg there are also activities on CIGS thin-film solar cell manufacturing in collaboration between the department of microscopy and microanalysis and the company *Midsummer AB* (see section 2.4.1).

Dye-sensitized solar cells Research on dye-sensitized solar cells is conducted within a framework called *Center of Molecular Devices (CMD)*. This centre coordinates researchers at the two universities KTH and Uppsala University, as well as activities involving the corporate research institute *Swerea IVF*. The research areas include understanding of basic mechanisms and material properties as well as device testing and process up-scaling.

Energy & Building Design At the University of Lund, research into systems and integration aspects of PV is conducted within the division of Energy & Building Design. There, BIPV solutions are studied as well as combined solar thermal and PV systems.

Polymer and Organic Solar Cells Research into polymer solar cells is conducted at Linköping and Chalmers universities in collaboration within a framework called *Center of Organic Electronics (COE)*. One of the envisioned applications of these polymer solar cells is to provide energy for polymer electronics embedded in, e.g., packaging products and electronic papers.

Systems research At the division for Environmental Systems Analysis, Chalmers University, policy issues in connection with environmental technology are studied. One example of subjects studied there is the impact of the Swedish subsidy for PV in Public buildings on the technological innovation system.

Energy systems research is also conducted at Uppsala University, where the potential for distributed electricity production from PV in Sweden is studied.

SolEl 03-07 The year 2007 was the final year of the research and development programme SolEl 03-07, which has provided funding for a wide variety of projects, ranging from preliminary studies for BIPV installations to scholarships to graduate students. The research and development has been directed more towards systems and applications than basic device development.

Examples of projects that have been carried out during 2007 are the implementation of SPYCE monitoring on three Swedish PV installations in order to be able to follow energy production, and the writing of a Swedish manual for installation and grid-connection of PV systems. Several research projects on integration of PV in buildings carried out at Lund University was also funded by the SolEl 03-07 programme.

Furthermore, the SolEl 03-07 programme acts as a hub for the PV community in Sweden, organizing seminars and disseminating information to established as well as new groups of PV stakeholders. At the 2007 Swedish National Energy Convention, the SolEl 03-07 programme awarded a prize to the best solar cell installation in terms of aesthetics, efficiency, technological accomplishment and novelty value.

In late 2007 the Swedish Energy Agency approved funding for a continuation of the SolEl-programme. During the beginning of 2008, different stakeholders have been invited to contribute, and a call for new projects was issued in the spring.

2.4.1 Industrial research

Arontis Solar Concentrator AB The small company Arontis Solar Concentrator AB has been developing a low concentrating trough-type combined thermal and PV solar collector based on research previously carried out at several Swedish universities. The product consists of a vertically tracking trough with a geometrical concentration factor of 10, which concentrates the light onto a water-cooled receiver with a PV array. Emphasis has been put on cost efficiency in manufacturing. To date only a small installation has been made for demonstration purpose in Sweden, but the company aims to build its first larger demonstration facility in Spain. In connection to Arontis, a research foundation called *The Foundation for Research on Concentrated Solar Energy*, operates a research laboratory with focus on reflectors and photovoltaic/thermal (PV/T) hybrid systems.

Solibro AB The company *Solibro Research AB* is the result of a joint venture between the company *Solibro AB*, a spinn-off from the CIGS research at Uppsala University, and the solar cell giant *Q-cells*, of Germany. The company will continue developing the CIGS technology, based on co-evaporation on glass substrates, supporting the production facility in Thalheim, Germany. This manufacturing line is starting production with a yearly capacity of approximately 30 MW in mid 2008.

Midsummer AB A second company developing CIGS solar cells have taken a completely different approach, compared to that of Solibro AB, aiming for low production costs using technologies from other thin-film industries. The company, located in Stockholm, will start mass-production of wafer-sized CIGS cells on glass substrates to be used as replacement for Si cells in conventional modules. The smaller scale allows for rational low-cost processing methods, using metal sputtering and selenization processes instead of the more complicated co-evaporation technology.

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

2.5.1 Budgets for PV research

Most of the public budgets for PV research comes from the Swedish Energy Agency, which has the Swedish government's commission to distribute funds to all types of energy related research. Furthermore there are more general research funding bodies that primarily distribute grants to basic research but also to industrially oriented research, like The Swedish Research Council (VR) and The Swedish Foundation for Strategic Research (SSF). One example in this category is the grant of 6 MSEK over two years from The Foundation for Strategic Environmental Research (MISTRA) and SSF to the company Midsummer AB and Chalmers university to development manufacturing technology for CIGS thin-film solar cells.

2.5.2 Budgets for market stimulation

Public funds for market stimulation is channelled through *The National Board of Housing, Building and Planning* (Boverket) and the regional authorities, in the subsidy scheme

for public buildings. Although the scheme was launched in May 2005, few projects were finished in 2005 and 2006, and even fewer grants were paid out. However, in 2007 the number of projects that were finished and actually received their subsidy increased, with 45 MSEK being paid out in total.

2.5.3 Budgets for demonstration/field test programmes

There are no general public budgets for demonstration/field test programmes. However, public budgets have been utilized in some projects to fund the remaining 30 % in projects that have received the subsidy for PV in public buildings. These are not included in Table 3.

Table 3: Public budgets (in MSEK) for R&D, demonstration/field test programmes and market incentives

	R & D [MSEK]	Demo/field test [MSEK]	Market [MSEK]
National	23,3	-	45
Regional	-	-	-
Total	23,3	-	45

3 Industry and growth

3.1 Production of feedstocks and wafers

There is no production of feed-stock or wafers in Sweden, and there are no capacity-building activities in this field at present.

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 the company Midsummer AB plans to start production of thin-film CIGS cells in 2008 (se section 2.4.1). The company intends to sell wafer-sized CIGS cells on glass substrates to conventional module producers, as replacement for Si wafer cells.

Furthermore, with the announcement that Borevind AB is buying the module manufacturer GPV, plans to start cell manufacture in the coming five years were unveiled. This is part of a long term strategy to secure future cell supply.

3.2.1 Gällivare PhotoVoltaic AB

The first solar cell module manufacturer in Sweden was *Gällivare PhotoVoltaic AB (GPV)*, which held the position as largest module manufacturer in Scandinavia up until 2006 when it was surpassed by REC ScanModule AB. GPV was acquired by the German PV company *SolarWorld* in 1999, but in early 2008 a majority of the shares were sold to the Swedish renewable energy investment company *Borevind AB*. However, in view of the scarce cell supply experienced by independent module manufacturers, GPV has signed a supply agreement with its previous majority owner until 2013, when the company aims to

Table 5: Production and production capacity information for the year for each manufacturer

		Total production (MW)*			Maximum capacity (MW)		
Manufacturer	Technology	Cell	Module	Conc.	Cell	Module	Conc.
GPV	mc-Si	-	20	-	-	30	-
ArcticSolar	mc-Si	-	4	-	-	20	-
ScanModule	mc-Si	-	42	-	-	100	-
PV Enterprise	mc-Si	-	4	-	-	30	-
n67 Solar	mc-Si	-	n/a	-	-	10	-
Total		-	70	-	-	190	-

*The number for real production is difficult to obtain, as it is regarded a sensitive issue by some companies

have its own cell production in place. This is the first Si wafer-based cell manufacturing operation that has been announced in Sweden. In parallel with this, an expansion to a production capacity of 60 MW per year is envisaged.

Although the great majority of the produced modules are exported, some is sold domestically through the installer *SwitchPower*, which has ownership links to GPV since Borevind acquired a majority stake in the company. A large part of the production will be sold to the previous owner, Solarworld, also in the years to come.

3.2.2 ArcticSolar AB

ArcticSolar AB is, like GPV, located in Gällivare in the north of Sweden. A majority of the shares are owned by the PV companies NAPS (of Finland) and AlfaSolar (of Germany) in equal proportions. The modules the company produces for its owners are sold under their respective brand names. As an independent producer, without ownership links to cell producers, the company has had problems sourcing enough cells for the modules. Plans for 2008 include an expansion of the real production to 10 MW.

3.2.3 REC ScanModule AB

Since its start in 2003, *REC Scanmodule* has moved on to become one of the largest module production plants in Europe, and one of the fastest growing. It is part of the Norwegian *Renewable Energy Corporation (REC)*, which produces solar grade silicon, wafers and cells and thus secures the supply of material to the REC ScanModule production. This steady supply is the key to the company's ability to grow over the past few years. The growth is set to continue, with a projected capacity increase from 100 to 150 MW per year being ramped up during 2008. This will make the factory, located in Glava Värmland, the second largest module manufacturing plant in Europe.

3.2.4 PV Enterprise Sweden AB

PV Enterprise is the only PV company in Sweden that is publicly listed on a stock exchange, in this case the First North market. An initial public offering (IPO) was performed in late 2006 and during 2007 PV Enterprise was one of the strongest performing stocks on the Swedish stock markets with an increase of 147 %. However, the year was not without difficulties as sales were slow in early 2007, mostly due to a delayed certification process that made sales in Germany difficult. Orders increased towards the end of the year, production was geared up to meet the demand and new personnel were hired. In the first

Table 6a: Typical module prices
(SEK/W, excl. VAT) for a number of years

	Year					
Module prices	2002	2003	2004	2005	2006	2007
Large orders	30	26	26	32	30	28,5
Single modules	75	70	70	70	65	63

quarter of 2008, more modules were shipped than in the whole of 2007. The main production takes place in Vilshult, in the south east of Sweden. There is an additional production site in Tarnow, Poland, which is operated by the subsidiary *Area-51*.

3.2.5 n67 Solar AB

The latest addition to the module production industry in Sweden is *n67 Solar*, which is part of a Danish group of companies, Latitud Solar AS. It is located in the north of Sweden – the name alludes to the latitude of the production location in Porjus, at 67° north. The company has, like the other module manufacturers, undergone rapid expansion and is currently extending the capacity to 20 MW per annum.

3.2.6 General trends

Most of the Swedish module manufacturers are in strong expansion, or have plans for expansion. This is quite unsurprising, in view of the strong international market increase of approximately 40 % per year. Although some of the manufacturers actively try to sell to the domestic market, the great bulk of the production is exported. In this light the Swedish module production companies can be viewed as somewhat separated from the rest of the Swedish PV market.

The key success factor for the manufacturers have been the ability to source enough raw materials, i.e. solar cells, for the production. The companies without ties to upstream production resources have been restricted in their expansion during the past few years of silicon cell shortage. The vertically integrated companies, on the other hand, have been able to expand production without this restriction.

3.3 Manufacturers and suppliers of other components

There are no companies producing inverters, switchgear etc. specifically directed towards the PV market. However, ABB is manufacturing components for these kinds of devices (used by e.g. Xantrex and SMA) and is regarding PV as an emerging business. Although it is difficult to separate component sales to PV specific applications, ABB's sales of switches to the PV industry is on the order of 10 MSEK per year and rapidly increasing.

3.4 System prices

In general the prices of PV in Sweden can be separated into off-grid and grid-connected systems, where the off-grid systems often are sold in a retail context. For these systems, the prices are typically influenced by the European market prices of modules and balance-of-system components (BOS). The prices are quite stable from year to year.

In the grid-connected market, prices have been difficult to follow as most projects executed have been one-off installations where learning costs have been high. With the

Table 7: Turnkey Prices of Typical Applications

Category/range	Typical application	SEK/W
Off-grid Up to 1 kW	Remote electrification, domestic or professional	95
Off-grid (>1 kW)	-	n/a
Grid-connected specific case	Case: Tre Vapen (SIDA) 25 kW rooftop installation	48
Grid-connected (≤10 kW)	Typical roof-mounted system	60
Grid-connected (≥10 kW)	The largest type of BIPV system in Sweden	60

Table 7a: National trends in system prices (SEK/W) for off-grid applications (small systems)

YEAR	2000	2001	2002	2003	2004	2005	2006	2007
Price [SEK/W]	110–150	100–140	100–130	90–110	90–110	90–110	90–110	85–110

subsidy system for PV in public buildings the prices have become more homogeneous, with several installers tendering for projects in public procurements. It is, however, difficult to discern any clear trends in prices. Since all of these systems are installed on buildings, a varying degree of adaptation to the carrying building has been necessary, meaning that prices per watt vary widely.

3.5 Labour places

The number of labour places in the Swedish PV community has grown steadily during the past few years, mostly due to the strong expansion of the module manufacturing industry. Other parts of the PV community has also expanded, with some additional research and new installers entering the market with the subsidy system for public buildings. In total roughly 500 people were employed in Sweden with PV during 2007. This is dominated by the manufacturing industry, where some 445 people were employed, including company R & D.

In total, approximately 50 people were employed in public PV R&D, out of which a majority worked in the thin-film group at Uppsala university and the CMD. In remaining parts of the PV community, with installers, electricity companies, retailers and so on, some 15 people were employed chiefly with PV. In this category it is difficult to estimate the number of labour places, due to the fact that the installers use a number of subcontractors for mounting and electrical work. Furthermore, there are retail companies where PV is only a small part of the activities and where it is difficult to discern how many people are working with PV.

3.6 Business value

The PV value chain in Sweden is, as far as turnover is concerned, heavily concentrated to the module producing part. These companies make up roughly 80 % of the turn-over of the PV business in Sweden. Some activity is seen in the upstream part of the chain, with

Table 8: Value of PV business

Sub-market	Capacity installed in 2007 [kW]	Price [SEK/W]	Value [MSEK]
Off-grid domestic	248	95	24
Off-grid non-domestic	23	95	2,2
Grid-connected	1 121	80	89,7
		Totals	116
Export of PV products			1 995
Change in stocks held			n/a
Import of PV products			1 564
		Value of PV business	547

Table 9: PV Support Measures

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

the cell manufacturing plans of Midsummer and GPV but these operations do not impact the value of business yet. Downstream, the market for installed system is small compared to the module manufacture activities, although the market has increased stronlgy over the past few years. In this downstream part of the value chain, a few new companies have started PV operations following the introduction of the subsidy system for public buildings.

N.B. The numbers on business value in Table 8 provide only a rough estimate of the value added in the Swedish PV business. It should not be compared directly to the PV business value of other countries, as data collection may vary widely.

4 Framework for deployment (Non-technical factors)

4.1 Support measures and new initiatives

With the investment subsidy for PV in public buildings nearly reaching its cap in late 2007, representatives of the PV business started to work for a continuation of the support scheme in order to avoid a gap that may harm the market structures built up in the wake of the support system. Although the cap was lifted in the spring of 2008, the programme will only continue through December 2008. A continuation is in the end a political issue, and is reported to be under consideration by the government.

4.2 Indirect policy issues

4.2.1 Grid-connection Legislation

Presently feeding in electric energy into the grid is allowed in Sweden, but the cost for this is in many cases too high for PV to be viable for a small system, e.g. a typical roof-top system of a few kW. This is due to legislation that stipulates that electric energy delivered into the grid has to be measured, and the data must be stored, with a temporal resolution of 1 h. The utility company, which has a local monopoly, is allowed to charge a certain rate for this service and in most cases this charge equates to more than 1 SEK/kWh for a 3 kW system in the south of Sweden.

During 2007 a commission of inquiry has been working with a proposal for revision of this law, resulting in a recommendation to waive the demand to measure energy delivered by the hour for systems with an output of up to 63 A. Furthermore, the commission suggests that net-billing on a monthly basis should be implemented.

A study [4] was conducted on the consequences of these propositions to the usage of residential scale PV systems in Sweden. From this, it is evident that the proposed legislation would be beneficial to PV system owners, compared to the present situation with high fixed charges for metering. One specific result from allowing net-metering is that a larger system can be installed without having to sell electricity on the market. With electricity demand and PV production not coinciding over the year, the largest PV system that could be used without net-metering corresponds to the minimum load of the house, i.e. on a fine summer's day. The length of the net-billing period would directly influence the maximum size of a PV system under the condition that there should be no net production over a reporting period. Selling electricity externally will most likely not be feasible for a small producer, unless it is possible to sell at a price considerably above market price for conventionally generated electricity.

4.2.2 Electricity certificates

Since 2003, there has been a market based incentive system to promote an increase in renewable electric energy production with the electricity certificate scheme. This system stipulates that all electricity customers are obliged to buy a certain number of electricity certificates per energy used; in 2007 this amounted to 0,151 certificates per MWh electric energy. Producers of renewable electric energy receives one certificate per MWh produced, and the obligation for customers to buy certificates is increased from year to year, creating an increased demand for renewable electric energy. The overall goal of the system is to increase the renewable electric energy production by 17 TWh per year, during the period from 2002 to 2016.

The implications of the certificate system for PV are quite marginal, with the premium from selling certificates at approximately 0,20 SEK/kWh. This is far from enough to warrant the high costs of PV, which is clearly shown in the statistics for issued certificates in 2007. 13 256 082 certificates were issued in total, out of which 19 can be attributed to PV power production. 75 % of the certificates were issued to bio fuelled power (mostly in quite large combined heat and power stations), while small-scale hydro account for 17 % and wind 8 %.

For a small producer, like the case with the owner of a typical domestic PV system, there is little incentive to even enter the certificate system as this would incur extra costs for measuring electricity and to handle certificates.

4.2.3 Taxes

There are a number of taxes that are used to control energy usage, most prominently energy tax and carbon dioxide tax. While the carbon dioxide tax is levied on fuels like oil and coal, the energy tax is levied on fuels and electricity. For industrial activities the energy tax is low, 0,005 SEK/kWh, while it is substantially higher for other activities, 0,27 SEK/kWh with a rebate of roughly 0,10 SEK/kWh for some parts of the country. VAT is levied on top of the energy tax. These taxes do not significantly influence the deployment of PV, since the economic incentives are not nearly enough to offset the premium cost of PV electricity.

4.3 Standards and codes

There are no specific standards and codes that govern the installation of PV systems, but there are parts of several different standards that touch upon the subject. First of all, the general standards for high current installations, ELSÄK-FS 2004:1, should be followed when installing a PV system. Then there is an instruction (AMP) from *Swedenergy*, a non-profit industry organization representing the Swedish energy companies. This instruction deals with the connection of small production units to the grid. Furthermore, there are rules for electrical installations (e.g. SS 436 40 00) that have special sections on PV or that apply in general. Guidelines for PV installations, with references to applicable standards, were compiled in a report, *Installationsguide, Nätanslutna solcellsanläggningar*, published by the SoEl 03-07 research and development programme in 2007 [1].

4.3.1 Building permits

Building permits may be needed for the erection of a PV system, especially if it is mounted on a free-standing structure. Also, for building integrated PV a building permit may be needed depending on how the design looks. One case where the building permits caused a problem was that of a congregational building belonging to the Swedish Church in Malmö. The church was advised that no building permits would be needed to install PV as permanent sunscreens over the windows. However, since the sunscreens protruded 60 cm from the façade, a building permit was in fact required . In this particular case a post factum application to the building and planning office was rejected with reference to the architectural value of the building.

4.3.2 Public procurement act

With the subsidy for PV in public buildings, most of the stakeholders installing PV in their buildings are required to use an open tender system according to the public procurement act (depending on the size of the project). This has led to some problems since they are not able to discuss different solutions with the system suppliers, but must invite to tender with quite specific system requirements. In these public procurement procedures reference projects are requested from the tendering installers, which has made it difficult for new actors on the market.

5 Highlights and prospects

The two most important developments in the PV business in Sweden during 2007 were the substantial increase in installed PV power, and the continuing development of the module manufacturing business. While the module manufacturing companies are set to continue their expansion, the installation of PV power will most likely not increase at the same rate since the end of the investment subsidy is coming closer and projects have to be finished before the end of December 2008.

5.1 Highlights

In 2007, the installed amount of PV increased by 130 % compared to 2006, which is a record high increase. Around 80 % of the power was installed in the grid-connected sector. With few exceptions, these projects were carried out with support from the investment subsidy for public buildings.

The module manufacturing industry is growing, with companies like PV Enterprise starting to increase production following problems with bottle-necks in the supply chain. The largest module company REC ScanModule is forging ahead with its expansion plans that will make its Glava plant the second largest in Europe.

5.2 Prospects

The prospects for the PV market are very much undecided, since a continuation of the support scheme is needed to maintain the development of the market. The political process of establishing a new support measure is reported to be at work [3], but the uncertainties are substantial. If a new subsidy system is put in place there will most likely be a gap that may be harmful to the market structure.

The module manufacturing companies all have expansion plans for the years to come, and several of them have long term contracts with buyers. The independent manufacturers also see a more ample supply of cells, and here as well they have signed advance contracts in order to secure supply of material. REC ScanModule, one of the largest module producers in Europe, are also expanding forcefully with their sister company, REC ScanCell AS, supplying cells.

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Annex

A Methods and accuracy of data

Information to this report was taken from a multitude of sources, including research reports, media, interviews, questionnaires and more. Most numbers collected come from questionnaires to and interviews with the different stakeholders, as well as published reports. Although answers were acquired from a majority of the stakeholders concerned, there were some that did not provide answers. For them, numbers have been extrapolated from previous years answers and other sources of information. The estimated overall accuracy of the numbers on installed PV power is on the order of $\pm 15\,\%$.

For the installed power in the grid-connected market segment, most systems are specified in the applications made to the authorities for support within the subsidy for PV in public buildings. These applications are used as a basis to estimate the amount of installed grid-connected power. Furthermore, there is a follow-up programme on grid-connected systems within the SolEl 03-07 programme. This information is also used to validate the numbers in the grid-connected sector.

B Country information

i) The retail price for electricity for a typical household customer, with a yearly consumption of 5 000 kWh, was 1,7 SEK/kWh during 2006. For a house with direct electric heating, with a consumption of 20 000 kWh, the average price was 1,4 SEK/kWh. This includes electric energy price, distribution fees, energy tax, electricity certificates and value added tax. (From the report *Energiläget 2007* from the Swedish Energy Agency)

For industrial customers, the average retail price during 2006 was approximately 0,50 to 0,80 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 importantly, 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 417 000 SEK, while the median household income is 330 000 SEK (from *Statistics Sweden*)

v) The typical mortgage interest rate for private customers, with a solid security like real estate property, were around 4,5 % (adjustable-rate mortgage) in 2007. The fixed-rate mortgages, with similar securities, typically varied from 5 % (1 year) to 5,5 % (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 during 2007 was typically 12,50 SEK/l, of which roughly 7,75 SEK is made up of taxes (energy tax, carbon dioxide tax and VAT).

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.)