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 2012

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Definitions, Symbols and Abbreviations

For the purposes of this and all IEA PVPS National Survey Reports, the following definitions apply:

PV power system market: The market for all nationally installed (terrestrial) PV applications with a PV power capacity of 40 W or more.

Installed PV power: Power delivered by a PV module or a PV array under standard test conditions (STC) – irradiance of 1 000 W/m^2, cell junction temperature of 25°C, AM 1,5 solar spectrum – (also see 'Rated power').

Rated power: Amount of power produced by a PV module or array under STC, written as W_p.

PV system: Set of interconnected elements such as PV modules, inverters that convert d.c. current of the modules into a.c. current, storage batteries and all installation and control components with a PV power capacity of 40 W or more.

CPV: Concentrating PV

Hybrid system: A system combining PV generation with another generation source, such as diesel, hydro, wind.

Module manufacturer: An organisation carrying out the encapsulation in the process of the production of PV modules.

Off-grid domestic PV power system: System installed to provide power mainly to a household or village not connected to the (main) utility grid(s). Often a means to store electricity is used (most commonly lead-acid batteries). Also referred to as 'stand-alone PV power system'. Can also provide power to domestic and community users (plus some other applications) via a 'mini-grid', often as a hybrid with another source of power.

Off-grid non-domestic PV power system: System used for a variety of industrial and agricultural applications such as water pumping, remote communications, telecommunication relays, safety and protection devices, etc. that are not connected to the utility grid. Usually a means to store electricity is used. Also referred to as 'stand-alone PV power system'.

Grid-connected distributed PV power system: System installed to provide power to a grid-connected customer or directly to the electricity grid (specifically where that part of the electricity grid is configured to supply power to a number of customers rather than to provide a bulk transport function). Such systems may be on or integrated into the customer's premises often on the demand side of the electricity meter, on public and commercial buildings, or simply in the built environment on motorway sound barriers etc. They may be specifically designed for support of the utility distribution grid. Size is not a determining feature – while a 1 MW_p PV system on a rooftop may be large by PV standards, this is not the case for other forms of distributed generation.

Grid-connected centralized PV power system: Power production system performing the function of a centralized power station. The power supplied by such a system is not associated with a particular electricity customer, and the system is not located to specifically perform functions on the electricity grid other than the supply of bulk power. Typically ground mounted and functioning independently of any nearby development.

Turnkey price: Price of an installed PV system excluding VAT/TVA/sales taxes, operation and maintenance costs but including installation costs. For an off-grid PV system, the prices associated with storage battery maintenance/replacement are excluded. If additional costs are incurred for reasons not directly related to the PV system, these should be excluded. (E.g. If extra costs are incurred fitting PV modules to a factory roof because special precautions are required to avoid disrupting production, these extra costs should not be included. Equally the additional transport costs of installing a telecommunication system in a remote area are excluded).

Field Test Programme: A programme to test the performance of PV systems/components in real conditions.

Demonstration Programme: A programme to demonstrate the operation of PV systems and their application to potential users/owners.

Market deployment initiative: Initiatives to encourage the market deployment of PV through the use of market instruments such as green pricing, rate based incentives etc. These may be implemented by government, the finance industry, electricity utility businesses etc.

Final annual yield: Total PV energy delivered to the load during the year per kW of power installed.

Performance ratio: Ratio of the final annual (monthly, daily) yield to the reference annual (monthly, daily) yield, where the reference annual (monthly, daily) yield is the theoretical annual (monthly, daily) available energy per kW of installed PV power.

Currency: The currency unit used throughout this report is Swedish kronor (SEK).

PV support measures:

Feed-in tariff	an explicit monetary reward is provided for producing PV electricity; paid (usually by the electricity utility business) at a rate per kWh that may be higher or lower than the retail electricity rates being paid by the customer
Capital subsidies	direct financial subsidies aimed at tackling the up-front cost barrier, either for specific equipment or total installed PV system cost
Green electricity schemes	allows customers to purchase green electricity based on renewable energy from the electricity utility business, usually at a premium price
PV-specific green electricity schemes	allows customers to purchase green electricity based on PV electricity from the electricity utility business, usually at a premium price
Renewable portfolio standards (RPS)	a mandated requirement that the electricity utility business (often the electricity retailer) source a portion of their electricity supplies from renewable energies
PV requirement in RPS	a mandated requirement that a portion of the RPS be met by PV electricity supplies (often called a set-aside)

Investment funds for PV	share offerings in private PV investment funds plus other schemes that focus on wealth creation and business success using PV as a vehicle to achieve these ends
Income tax credits	allows some or all expenses associated with PV installation to be deducted from taxable income streams
Net metering	allows PV customers to incur a zero charge when their electricity consumption is exactly balanced by their PV generation, while being charged the applicable retail tariff when their consumption exceeds generation and receiving some remuneration for excess electricity exported to the grid
Net billing	the electricity taken from the grid and the electricity fed into the grid are tracked separately, and the electricity account is reconciled over a billing cycle
Commercial bank activities	includes activities such as preferential home mortgage terms for houses including PV systems and preferential green loans for the installation of PV systems
Activities of electricity utility businesses	includes ‘green power’ schemes allowing customers to purchase green electricity, operation of large-scale (utility-scale) PV plants, various PV ownership and financing options with select customers and PV electricity power purchase models
Sustainable building requirements	includes requirements on new building developments (residential and commercial) and also in some cases on properties for sale, where the PV may be included as one option for reducing the building’s energy foot print or may be specifically mandated as an inclusion in the building development

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 23 participating countries are Australia (AUS), Austria (AUT), Belgium (BEL), Canada (CAN), China (CHN), Denmark (DNK), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Malaysia (MYS), Mexico (MEX), the Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), Turkey (TUR), the United Kingdom (GBR) and the United States of America (USA). The European Commission, the European Photovoltaic Industry Association, the US Solar Electric Power Association and the US Solar Energy Industries Association are also members. Both Thailand and the International Copper Association are pending members.

The overall programme is headed by an Executive Committee composed of one representative from each participating country or organization, 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

Introduction

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of photovoltaic power systems. An important deliverable of Task 1 is the annual Trends in photovoltaic applications report. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the Swedish National Survey Report for the year 2012. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

The PVPS website www.iea-pvps.org also plays an important role in disseminating information arising from the programme, including national information.

1 EXECUTIVE SUMMARY

1.1 Installed PV power

The PV power installation rate in Sweden continued to increase in 2012 and a total of 8.4 MW_p was installed, which is almost twice as much as the 4.4 MW_p that was installed in 2011. The off-grid market grew slightly, from 0.7 MW_p in 2011 to 0.8 MW_p in 2012. As in 2011, the large increase of installed systems occurred within the submarket of grid-connected systems. Around 7.6 MW_p was installed in 2012 which is 3.9 MW_p more than the 3.7 MW_p that was installed in 2011. The strong growth in the Swedish PV market is mainly due to lower module prices, a growing interest in PV and the direct capital subsidy that was in place in 2012.

1.2 Costs and prices

The prices for both modules and complete turnkey systems have decreased rapidly the last couple of years in Sweden and typical prices in 2012 were at about half of those of similar systems only two years ago. The price for a typical roof mounted system on a private house decreased from 32 SEK/W_p in 2011 to about 22 SEK/W_p at the end of 2012. The major reason for the large system price reduction in Sweden is the influence of the international market, where prices for modules have continued to decrease. Furthermore, several new installation companies have entered the marked in 2012, adding to the competition in the Swedish market and thereby pushing the prices down.

1.3 PV Production

In 2011 there were five silicon module producers in Sweden. The world production capacity outgrew the world demand in 2011 with a high price reduction on modules as a result. This situation continued in 2012 and many big international module producers have under this period gone bankrupt. The same also applies for the Swedish module production industry. At the end of 2012 only one module producer remained in Sweden. The rest has gone bankrupt in 2011 and 2012. As a result the total module production in Sweden has dropped from 180.8 MW_p in 2010 to 35 MW_p in 2012. However, one should note that Sweden as a country still is a net exporter of PV modules.

1.4 Budgets for PV

The total public budget for PV was approximately 134 million SEK in 2012. Of this, 57.5 million SEK belongs to the direct capital subsidy. 76.5 million SEK went to research and development, which is approximately 15 million SEK more than in 2011.

2 THE IMPLEMENTATION OF PV SYSTEMS

The PV power system market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W or more. A PV system consists of modules, inverters, batteries and all installation and control components for modules, inverters and batteries.

For the purposes of this report, **PV installations are included in the 2012 statistics if the PV modules were installed between 1 January and 31 December 2012, although commissioning may have taken place at a later date**.

2.1 Applications for photovoltaics

Historically, the Swedish PV market has almost only consisted of a small but stable off-grid market where systems for recreational cottages, marine applications and caravans have constituted the majority. This domestic off-grid market is still stable and is growing slightly. However, in the last five years more grid-connected capacity than off-grid capacity has been installed and Sweden now has almost three times more grid-connected PV capacity than off-grid capacity. The grid-connected market is almost exclusively made up by roof mounted systems installed by private persons or companies. So far only a couple of relative small systems can be seen as centralized systems.

2.2 Total photovoltaic power installed

In 2012 another 8.4 MW_p of PV power was installed in Sweden which caused the installation rate to grow by 90 % compared with 2011. Grid-connected system accounted for most of the installed capacity and the largest increase, but the off-grid market also grew slightly. Although the installation rate increased in 2012, the Swedish PV market is still very small and represents only a tiny fraction of Swedens total electricity production.

2.2.1 Methods and accuracy of data

Almost all of the gathered data used in this report comes directly from company representatives. It is usually not a problem to acquire data from the industry but the quality and exactness of the data acquired from different companies varies. Most companies provided very accurate data while a few only provided estimations. Furthermore, some unrecorded installation has probably been carried out that fall outside this report. The accuracy of the data for annual installed power is therefore estimated to be within ± 5 %.

The numbers for the cumulative installed capacity in Sweden are more uncertain. It is impossible to know how many of all off-grid systems that still were in use in 2012. The situation for grid-connected system is slightly better, and a number of systems that have been reported to be taken out of operation have been withdrawn from the figures. To be correct, the numbers of the cumulative installed PV capacity should more be seen as the total PV power installed over the years rather than the total PV capacity in place and running today. However, since a PV system typically has a lifetime of 25 years it is likely that most of the reported cumulative capacity is still up and running.

2.2.2 Installers and retailers of PV modules and systems

The list below contains all of the companies, that were known to the author at the time of writing, that either sells and/or installs PV modules and/or systems in Sweden and that have contributed with data and information to this report. For this report only one company have refused to contribute with data and is thereby not included in this list. There is a broad range of reported capacity between the different companies, from only a few kW_p as solar cells for charging of electronics to several hundreds of kW_p for grid connected large PV systems. If the reader knows of any other active company, please contact the author at: johan.lindahl@angstrom.uu.se

24 Volt	AddCleantech	Arsite AB
Awimex International AB	Axson Svenska AB Energisystem	Billesol AB
Celltech AB	Clas Olsson	Delta Energy Systems AB
Deson AB	Direct Energy Sweden AB	Ecoklimat Norden AB
Ecologisk Kraft Eskilstuna AB	Effecta AB	Egen El AB
Ekologisk Energi Vollsjö	El B-man	Elfa AB
Elkatalogen i Norden AB	Elmco AB	Energi-Center Nordic AB
EnergiEngagemang Sverige AB	Energiförbättring i väst AB	Energikonsulterna i Sverige AB
Energy Solutions	ETV Energy Group	European Sun Products
Exo Tech	Fasadglas Bäcklin AB	Gaia Solar A/S
Gari EcoPower AB	Glacell AB	Glen Dimplex Nordic AB
Gridcon AB	Hallands Energiutveckling	Hjertmans båttillbehör
Innosund AB	Järbo Elcenter AB	KAMA Fritid
Kjell & Company	Kraftpojkarna	Kretsloppsenergi
Lego elektronik	Miljö & Energi Ansvar AB	Modern Energi Sverige AB
Monier Roofing AB	NAPS Sweden	Ninac Energi
Norden Solar	Nordic Solar Sweden AB	Nordic Sunpower
Nossebro Energi	Nuenergi AB	Nyedal Solenergi
OnGrid AB	Orust Engineering	Perpetuum Automobile
Plug in Electric Europe AB	Polygress Solution AB	PVIR
Schueco	Skånevind och Sol	Sol & Energiteknik SE AB
Sol Eye	Sol-El Konsulterna	Solar Lab Sweden
Solar Supply Sweden AB	Solarit AB	SolarOne
Solect Power AB	SolEL Dalby	Solelia Greentech AB
Solenergi & Teknik i Åmål AB	Solfångaren i Viby	Solitek
Solkraft TE	Sunwind Exergon	Svesol värmesystem AB
Ultra Energi	Upplands Energi AB	Vancos
Warm-Ec Skandinavia AB	Westpro Scandinavia	Windforce Aibuzz Holding AB
Windon AB	Åkerby Solenergi	

Table 1: PV power installed during calendar year 2012 in 4 sub-markets.

Sub-market/ application	off-grid domestic	off-grid non-domestic	grid-connected distributed	grid-connected centralized	Total
PV power installed in 2011 (MW_p)	0.81	0.01	6.88	0.74	8.44
Amount of CPV in the above (MW_p)	0	0	0	0	0
Amount of PV in hybrid systems (MW_p)	0	0	0.10[1]	0	0

[1] Low concentrating combined PV and solar thermal power generation systems.

Table 2: PV power and the broader national energy market.

Total national PV as a % of total national electricity generation capacity	New PV capacity as a % of new electricity generation capacity in 2012	Total PV electricity production as a % of total electricity consumption
0.06 %	0.76 %	0.01 %

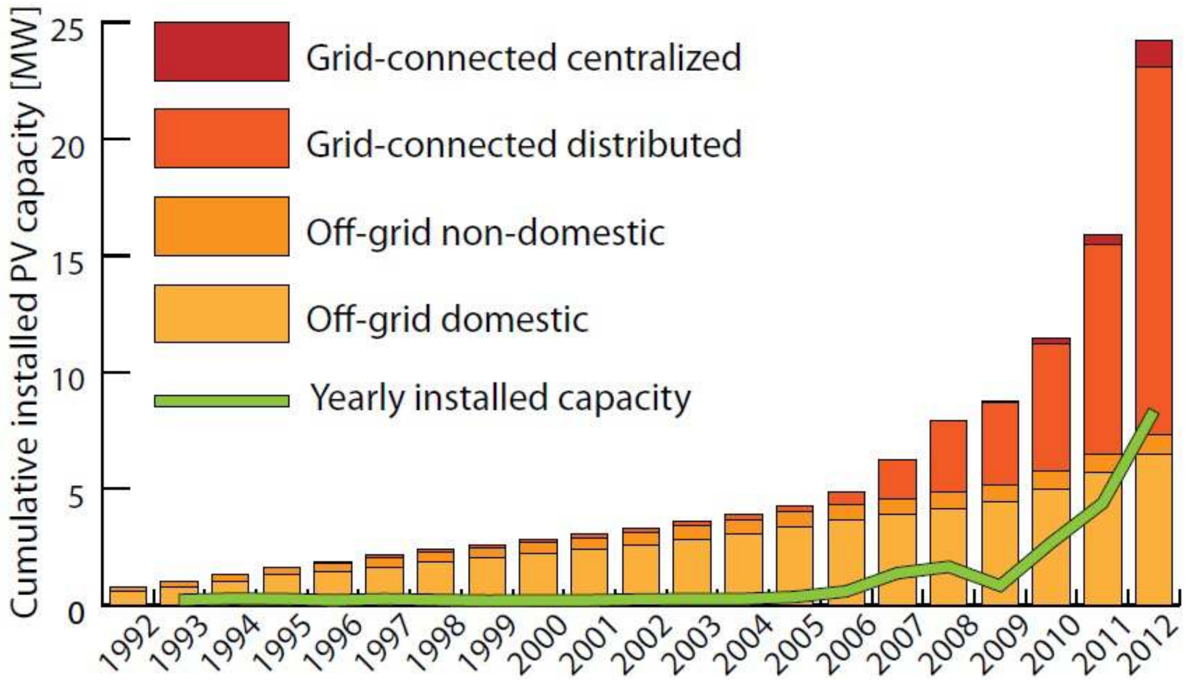

Figure 1. The cumulative installed PV power and yearly installed capacity trends in Sweden.

A summary of the cumulative installed PV Power, from 1992-2011, broken down into four sub-markets is shown in table 3.

Table 3: The cumulative installed PV power in 4 sub-markets.

Cumulative installed capacity as at 31 December					
Year	Off-grid domestic (MW_p)	Off-grid non-domestic (MW_p)	Grid-connected distributed (MW_p)	Grid-connected centralized (MW_p)	Total (MW_p)
1992	0.59	0.21	0.01	-	0.80
1993	0.76	0.27	0.02	-	1.04
1994	1.02	0.29	0.02	-	1.34
1995	1.29	0.30	0.03	-	1.62
1996	1.45	0.36	0.03	-	1.85
1997	1.64	0.39	0.09	-	2.13
1998	1.82	0.43	0.11	-	2.37
1999	2.01	0.45	0.12	-	2.58
2000	2.22	0.47	0.12	-	2.81
2001	2.38	0.51	0.15	-	3.03
2002	2.60	0.54	0.16	-	3.30
2003	2.81	0.57	0.19	-	3.58
2004	3.07	0.60	0.19	-	3.87
2005	3.35	0.63	0.25	-	4.24
2006	3.63	0.67	0.56	-	4.85
2007	3.88	0.69	1.68	-	6.24
2008	4.13	0.70	3.08	-	7.91
2009	4.45	0.72	3.54	0.06	8.76
2010	4.95	0.80	5.43	0.29	11.47
2011	5.66	0.82	8.99	0.40	15.87
2012	6.47	0.83	15.87	1.14	24.31

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

Glava Energy Center

South east of Arvika in Värmland lies Glava Energy Center, which is a test center for renewable energy solutions. Glava Energy Center has three PV parks, one off-grid and two grid-connected. The off-grid park consists of five separate systems of various sizes totaling 2.3 kW. Under 2012 and until mid-2013, the goal of the off-grid park is to develop an export product consisting of freestanding solar panels connected to a battery system for cost-effective short-term energy storage. The first grid-connected park consists of four systems, totaling 134.6 kW. The second park consist of two systems, totaling 73.6 kW, one which is fully owned by Fortum and one owned by Glava Energy Center. Fortum and Bixia buys all the electricity that the two grid-connected parks produce. The main purposes of the grid-connected parks are to test various concepts of modules, mounting stands and inverters.

All interested parties that wish to use the park for different tests are welcome to do this if they either become a member of the center or contribute with free equipment. Currently Glava Energy Center has about 40 members. Glava Energy Center is besides from the members funded through the Interreg/EU, Region Värmland and some municipalities.

Figure 2. Egen Els production and demonstration facility Kullen. (Courtesy Johan Ehrenberg)

Kullen

On a hill close to Katrineholm lies the company Egen Els production and demonstration facility Kullen. The hill is littered with several small PV systems and wind turbines and work both as a power plant that sells electricity and as a place where people can come and have a look at different kinds of small-scale renewable electricity systems, suitable for private customers. Several guided tours and information days are arranged each year for the interested public. The park also offers individuals and companies that do not own land or a suitable property a place where they can set up their own PV systems or rent space on existing ones and thereby contribute to renewable electricity production. The park is growing each year and had a capacity of 240 kW_p at the end of 2012.

Solel i Sala & Heby ekonomiska förening

In 2009 the first FiT agreement in Sweden was established between the local power utility company Sala-Heby Energi AB and a small PV community. The power utility company has agreed to buy all the electricity that the PV community produces to a price of 3.21 SEK/kWh, compared to the average system spot price of 0.28 SEK/kWh. In 2012 a fourth system was installed and the community now has a total production capacity of 199 kWp. Each of the 205 members in the community has bought at least one share for a price of 10 000 SEK. The initial profits for the community will be spent on increasing the production capacity but after five years from the start a part of the profit will be distributed to members according to number of shares. The community is slowly expanding with more members from all over the country and is planning for a fifth system that will be installed in 2013.

2.4 Highlights of R&D

2.4.1 Academic research

Center for Molecular Devices

The research constellation, Center for Molecular Devices (CMD), is one of the world leading scientific centers for research and development of dye-sensitized and nanostructured solar cells. CMD is a collaboration between Uppsala University, the Royal Institute of Technology (KTH) in Stockholm and the industrial research institute Swerea IVF in Mölndal. About 35 people worked within the CMD collaboration in 2012. The center activities include basic physical chemical research for fundamental understanding of components, interfaces and devices, synthetic chemistry for design and preparation of the different components, and engineering research for up-scaling and process development. Immaterial property rights generated by the center are handled in the company Dyenamo AB. The breakthrough of CMD in 2010 by replacing the iodide redox couple with a 1-electron transfer redox system such as Co-complexes has created a very intense research direction worldwide during the last year. New possibilities for solid-state solar cells using organic hole conductors instead of liquid redox electrolytes and replacing dyes with inorganic perovskite layers have also been intensively investigated in the CMD during the last year.

Chalmers

At Chalmers University of Technology Foundation research in many different PV associated areas is carried out, such as design of polymer, organic and hybrid solar cells, plasmons for enhanced light absorption in solar cells, electrolytes and quantum dots for dye-sensitized solar cells, lifecycle analysis and BIPV.

One of the larger projects is Sunflower, which is a collaborative research project of 17 partner institutions from science and industry. Its goal is the development of highly efficient, long-lasting, cheap and environmentally friendly printed organic photovoltaics.

Another big project is PRIMA: Plasmon Resonance for Improving the Absorption of solar cells. This project aims to enhance the performance and reduce cost of different solar cell technologies, including crystalline Si, organic and dye-sensitized solar cells, by use of metal nanostructures that enhance the optical absorption.

Furthermore, during 2012 a new collaborative project was initiated, called Photon fusion and photon fission, which is aiming at add-on technology for existing PV technology involving both physical science research and life cycle analysis.

In addition, a team from Chalmers will participate in a Solar Decathlon competition in China 2013, where universities from all over the world are going to design and build a self-sufficient home with solar as the only energy source.

Högskolan Dalarna

The Solar Energy Research Center (SERC) at Dalarna University carries out research on PV and PV hybrid systems. The group is doing both simulations and practical testing of systems and has several demonstration systems along with a lab where off-grid, grid connected and micro grid systems can be tested. The group is also involved in international PV projects financed by the EU Commission and SIDA. Part of the work is done in multidisciplinary projects where also social, cultural and economic aspects of PV are studied.

Karlstad University

The Materials Physics group at Karlstad University has been running research projects on polymer-based photovoltaics since 2002. The active layer in this type of solution-processed solar cell is a thin film consisting of an electron-donating conjugated polymer and an electron-accepting fullerene-type molecule. The research work is focused on morphological studies of the active layer, using microscopy, depth profiling, and photoelectron spectroscopy techniques, and its influence on the device performance of bulk-heterojunction solar cells. The group collaborates with the Polymer Chemistry group at Chalmers University of Technology.

KTH

At the Royal Institute of Tehcnology, KTH, both the Organic Chemistry group and the Inorganic Chemistry group are involved in PV research within the Center of Molecular Devices collaboration (see above).

Linköping University

Development of polymer based organic photovoltaics (OPV) in the collaboration between Linköping and Chalmers University has extended the family of thiophene-quinoxaline alternating copolymers to include many side chain modifications.

Alternative device architectures for OPV now include semitransparent cells including cathodes based on a surface modification of ITO with a high bandgap amphiphilic polymer, and with transparent polymer anode. Light transmitted by this device can be converted in a second cell. By adding several devices on top of each other, higher photocurrent and efficiency can be obtained than what is found in a standard OPV cell, proving that electrode losses are considerable in standard geometry cells with metal cathodes. Even higher photocurrents can be obtained by using specially designed light traps after the device, improving the incoupling of photons.

Lund University

At University of Lund the division of Energy & Building Design is studying energy-efficient buildings and how to integrate PV and solar thermal into such buildings. The group participated in the international work within IEA SHC Task 41; “Solar energy and architecture” that was finalized in 2012. The task included integration issues for both PV and solar thermal systems, good examples of building integration, and methods and tools used by architects for solar design at early design stages. A new IEA SHC project, Task 51 Solar energy in urban planning, was developed in 2012. This 4-year project will officially start in May 2013, with Swedish leadership by Maria Wall from the group.

At the departments of Chemistry and Physics research on light induced processes in novel types of solar cell materials and solar cells, dye-sensitized solar cells, plastic solar cells and solar cells based on semiconductor nanowires are conducted. The aim of the research is to understand light induced processes like energy transport, charge generation, charge separation and transport, as well as how these processes are related to material properties and morphology. An overall aim is to obtain new knowledge that can lead to better and more efficient solar cells. Research is also conducted to understand the processes that are the basis of artificial photosynthesis for generation of so called solar fuel. A powerful novel approach in this research is to use time resolved ultra-fast x-ray spectroscopy and scattering for exploring reaction mechanisms in these materials.

Mälardalens Högskola

Mälardalens Högskola is conducting research in projects regarding development of the energy system with a high fraction of solar electricity for energy effective buildings. The projects are about PV plus district heating and PV plus heat pumps, which enable buildings to be an active component in the future energy system, and increase the consumer influence on the Nordic Energy market. The group is also involved in projects financed by SIDA (Styrelsen för Internationellt Utvecklingssamarbete), see section 4.2.5.

SolEl programmet

The SolEl-program is a national R&D program for PV systems that is financed by the Swedish Energy Agency (Energimyndigheten), utilities, the real estate industry and companies with an interest in photovoltaic applications. The program has been running in various stages for over 15 years and an extensive network has been built around the program. The program has become an important platform for dialogue between the building and property sector, the government, industry, utilities and solar energy companies.

2011 was the final year for one phase of the program and no activities were carried out within the program in 2012. The planning for next phase, 2013-2015, is now ongoing. The plan is to continue with topics such as PV in the future smart grids and sustainable cities and building related PV-questions.

Umeå University

The Organic Photonics & Electronics Group at Umeå University develops photonic and electronic devices based on novel organic compounds. The group has in 2012 initiated research on organic solar cells by acquiring the necessary equipment and plan to have their first research result published 2013.

Uppsala University

Energy is a strategic focus area at Uppsala University and the solar cell activities are important parts of this research. At the Ångström Laboratory research is pursued within several different aspects of solar cells.

There are two established technologies for fabrication of absorber layers for thin film solar cells at the Ångström Solar Center (ÅSC). The first is co-evaporation of $Cu(In,Ga)Se_2$, CIGS, thin films and the second is a two-step process, consisting of sputtering and selenization/sulphurization where the final outcome is a thin film of $Cu_2ZnSn(S,Se)_4$, CZTS. As the name suggests these thin films are used as light absorbing layers in thin film solar cells. In order to obtain high quality thin film solar cells, optical and electrical properties of all layers in the solar cell need to be co-optimized. There is a high degree of interdependence between the different layers, therefore both single layers, but also complete solar cells and modules are fabricated and characterized. Best efficiencies for CIGS are 18.6 % for a solar cell and 16.8 % for a submodule. The best results for the newcomer CZTSSe is around 8 % efficiency after three years of research. In addition to research on the solar cells and modules also system aspects are studied, such as field testing. Climatic data and module power output data are collected for the most common solar cell technologies at the test site on the roof of the Ångström Laboratory are used as basis for evaluation of e.g. energy yield.

In the Built Environment Energy Systems Group (BEESG) at Solid State Physics, integration of new energy technologies into the built environment is studied from a system perspective. Major research topics related to PV are solar energy potential in the built environment, integration of distributed PV into the power system, utilization of on-site PV generation in buildings and design of net-zero energy solar buildings.

Furthermore, the Physical Chemistry group and the Interface Science group at Uppsala University are involved in the research platform Center of Molecular Devices (see above).

2.4.2 R&D companies

Dyenamo

Dyenamo is the commercial platform of the Center for Molecular Devices and offers various services concerning dye-sensitized solar cells, like patent evaluations and device characterization and analysis. The company also provides materials for dye-sensitized solar cells such as organic dyes and cobalt-complexes for electrolytes.

Exeger Sweden AB

Dye-Sensitized solar cells have the potential to achieve a low cost per W, but have so far lacked conversion efficiency on an industrial scale. The company, which was known under the former name of NLAB solar in 2012, has addressed this problem and has been working on a transparent dye-sensitized solar cell suitable for mass production. In 2012 the company invented a new kind of nontransparent solar cell, similar to the DSC, but based on new materials. The new materials are cheaper than those used in the DSC and the company claims that there is a potential to reach higher efficiencies with these compared to the DSC. In 2012 NLAB managed to raise 135 million SEK in financing for the new cell and will continue to develop it alongside with the transparent DSC. The plan of a 20 MW_p capacity DSC pilot line still remains and the company will in 2013 hire about 25 new employees and develop the production methods needed for full scale production.

Ferroamp Elektronik AB

Ferroamp was founded in 2010 and is currently developing a product that they call an "energy hub". The product is a two way inverter with three ports, one that can be connected to a PV system, one to the grid and one to a battery. This enables the electricity from the PV system to be temporarily stored in the battery before it enters the grid. The production is planned to be in Sweden and the company intend to start selling their product in 2014.

Global Sun Engineering Sweden AB

A Swedish company that has developed a technique for low concentrating combined PV and solar thermal power generation is Global Sun Engineering. Their product use several flat mirrors forming a facet disc that focus the sunlight on solar panels made up of solar cells and heat exchangers that generate heat by circulating water that absorbs heat radiation from the sun. The system has a 2-axis tracking function which allows it to follow the sun. Global Sun Engineering plan to launch their commercial unit in the second quarter of 2012 was delayed and they now intend to have it ready for the market in 2013.

Optistring Technologies AB

Optistring Technologies AB is developing a power inverter system for grid connected PV systems which includes electronics on each module. The system can thereby optimize the power output from each module and makes the entire system independent of external site conditions such as for instance different mounting angles or partial shading. The company was founded in 2011 and is a spin-off company from KTH.

Solarus AB

Solarus is a solar energy company with three different solar panel product lines: one thermal, one combined PV and solar thermal and one PV only. Their systems use modules that in part receive direct sunlight and in part receive focused light from a reflective trough mounted underneath the module. The energy from the sunlight is collected by water pipes and/or solar cells on the backside and on top of the modules. An advantage of using both concentrated and non-concentrated sunlight is that the system performs better under diffuse light conditions. The ramp up of the company's production facility in Älvkarleby in 2012 was delayed and the plan is now to have it up and running in early 2013.

Solibro Research AB

The CIGS thin film solar cell company Solibro started as a spin-off company from Uppsala University and there is still a close collaboration between the company and the university. Solibro was in September 2012 acquired by Hanergy, a Chinese group focused on power production (hydro-, wind as well as solar power) and sales of PV systems based on thin film modules produced within the group. This change in ownership was due to the bankruptcy of the former owner of Solibro, QCells SE. Solibros structure remains with the R&D activities mainly performed in Solibro Research AB in Uppsala, Sweden, and other company activities carried through by Solibro GmbH in Germany. Solibro Research AB is still 100% owned by Solibro GmbH.

Sol Voltaics AB

The nanotechnology company Sol Voltaics AB is producing a nanowire PV material which is designed to be used by existing solar cell producers, both thin film and silicon, to enhance performance. The spin-off company from the Nanometer Structure Consortium of Lund University is using a production method based on guided self-assembly of nanowires in gas phase called Aerotaxy. Nanowire solar cells may have the potential to reach a high efficiency since they are not limited by the same physics as regular planar solar cells and to be cheap since they use less material then other technologies.

Eltek Valare AB

Swedish Eltek Valare AB is part of the global corporation Eltek Group that provides products and solutions within power electronics and energy conversion. The company has R&D divisions in Sweden and Norway that develop and construct inverters for both grid connected and off-grid systems, which are then manufactured in China. Very few inverters from the company are sold in the small Swedish market.

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

2.5.1 Budgets for PV research

The majority of the Swedish Government's funds to PV research are distributed by the Swedish Energy Agency (Energimyndigheten), which is responsible for energy related issues in Sweden. Other organizations that can dispense governmental money to PV related research are The Swedish Research Council (VR), The Swedish Governmental Agency for Innovation Systems (VINNOVA) and The Swedish Foundation for Strategic Research (SSF).

The Energy Development Committee (Energiutvecklingsnämnden) decided in June 2012 to set aside 91 million SEK to the research program "El och bränsle från solen". The program is planned to be in place between 2013 and 2016 and has been established to gather research financed by the Swedish Energy Agency (Energimyndigheten) in the areas of PV, solar thermal and solar fuels. The program's vision is to provide technology that enables an increased use of solar energy in both the Swedish and the global energy system and thereby contributing to a sustainable energy system. The program will include projects of various kinds, from research and development projects carried out by various research institutions to experimental development and demonstration in companies.

2.5.2 Budgets for market stimulation

The budget for the direct capital subsidy program distributed by the Country Administrative board (Länsstyrelsen) was 57.5 million SEK in 2012. In 2012 78.4 million SEK was granted to different PV systems and 78.4 million was also disbursed, which is partly capital from previous year's budgets.

Table 4: Public budgets for R&D, demonstration/field test programmes and market incentives.

	R & D	Demo/Field test	Market incentives
National/federal	76.5 million SEK	-	57.5 million SEK

3 INDUSTRY AND GROWTH

3.1 Production of feedstocks, ingots and wafers

Sweden did not produce any feedstock or wafers in 2012 and there are currently no plans for this kind of production in the future.

3.2 Production of photovoltaic cells and modules

In the beginning of 2012 there were five module producers in Sweden that fabricated modules from imported silicon solar cells. The acceleration of PV module price reductions on the world market in 2011 and 2012 comes from a huge imbalance between the demand and a higher world production capacity. The Swedish module manufactures struggled along with the rest of the module production industry in the world in this harsh market and at the end of 2012 only one of the Swedish companies, SweModule AB, remained in business. The other four had under the year went bankrupt or been closed down. The overall production in 2012 was 35.0 MW, which is considerably lower than the 180.9 MW that was produced in 2010 and the lowest number since 2004.

Table 2: Production and production capacity information for 2012

Module manufacturer	Technology	Total Production (MW_p)		Maximum production capacity (MW_p/ yr)	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
Eco Supplies Solar*	Mono/Poly-Si	-	0.1	-	48.0
Arctic Solar*	Poly-Si	-	1.8	-	34.0
Latitude*	Poly-Si	-	-	-	40.0
SweModule	Mono/Poly-Si	-	33.0	-	100.0
Solar Design*	BIPV	-	-	-	-
Low-concentrating combined PV and solar power generation manufactures					
Absolicon		-	0.1 electrical (0.5 thermal)	-	0.5 electrical (2.5 thermal)
TOTALS		**-**	**35.0**	**-**	**222.5**

* Have closed down their production in 2012.

3.2.1 Production companies

SweModule AB

SweModule AB was the only module production company in Sweden that survived throughout the whole year. The company was formed in 2011, after the closure of the REC ScanModule AB factory, and took over most of ScanModule's facilities and equipment in Glava. SweModule AB produces multi crystalline silicon modules with solar cells from the company's major shareholder Norwegian Innotech Solar. The company increased their workforce in 2012, from about 35 employees in 2011 to about 100 in 2012. The production also went up, from 13 MW_p to 33 MW_p. The primary markets for the company was the traditional markets of Germany and Italy and the Scandinavian countries, primarily Denmark and Sweden.

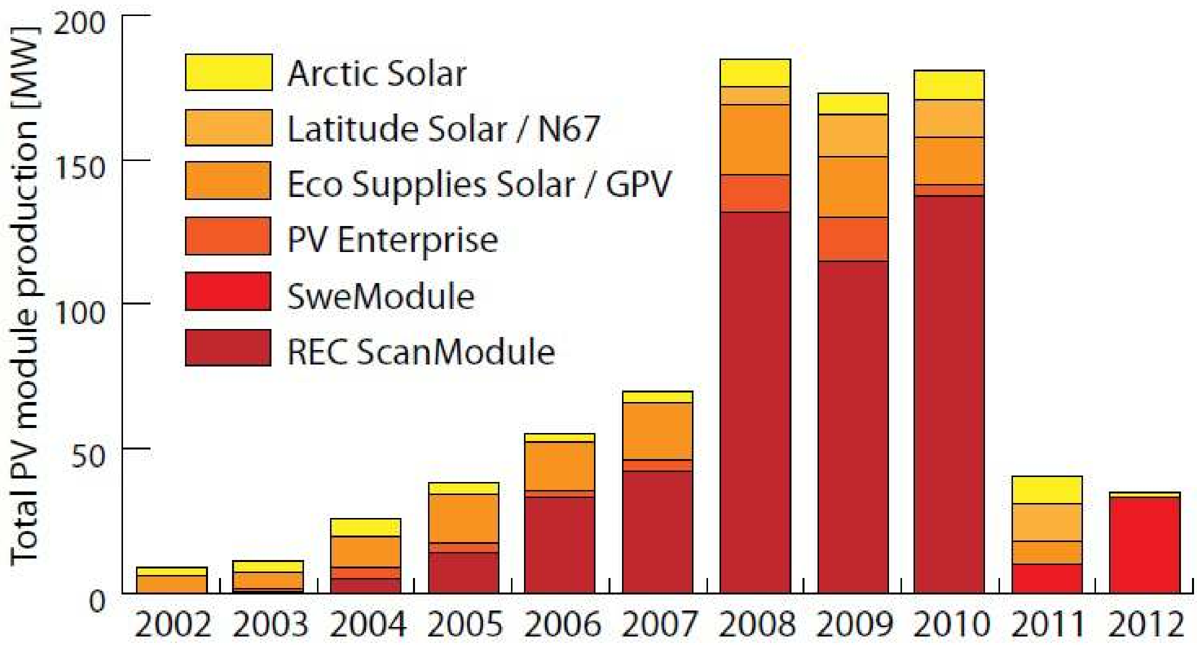

Figure 3. PV module production in Sweden over the years.

Eco Supplies Solar AB

The company former known as Gällivare Photovoltaic AB was reconstructed in 2010 and got a new owner in form of Eco Supplies Europe AB. In this process the company changed their name into Eco Supplies Solar AB. However, in 2012 the company went bankrupt and the production equipment was bought by a new company called Jowa Energy Vision.

Arctic Solar AB

The former multi crystalline silicon module producer Arctic Solar AB produced 1.8 MW_p of PV modules in 2012 before the board decided for a controlled closing of the business. as there was too few orders for profitable production. Most of the employees found new jobs in the mining industry and other business.

Solar Design AB

The specialized building integrated photovoltaic module producer Solar Design went bankrupt in 2012 due to lack of financing. The production equipment, previously owned by PV Enterprise Sweden AB, was sold to Iraq and no further business is planned in Sweden.

Latitude Solar AB

As many other solar module producers Latitude Solar was affected by the current price pressure on the module market and went bankrupt the 27th November 2012.

Jowa Energy Vision

Jowa Energy Vision is a new company that will produce BIPV modules. The company bought the production equipment from the former producer Artic Solar AB and constructed in 2012 a new factory in Allingsås. The production is planned to start in 2013 and the targeted market for the modules is Sweden and the rest of the Nordic countries.

Figure 4. Absolicons installation at Stödehuset is Sweden's largest hybrid installation with 400 m² of concentrating solar collectors. The plant produces 40 kW of electricity and heat to the adjacent sports hall and swimming pool. (Courtesy Joakim Byström)

Absolicon Solar Concentrator AB

Absolicon's combined low-concentrating PV and solar thermal power generation system consists of a cylinder-parabolic reflector that concentrates the light of the sun ten times onto the receiver where the solar cells are mounted. It is equipped with a solar tracking system so that the sunlight always is focused onto the cells. Their system yields about five times as much heat power as electrical power. In 2012 the company sold and installed systems with a total electric power of 130 kW_p in Sweden. The company had in 2012 far-reaching plans for construction of a fully automatic factory with location in Härnösand. But in the beginning of 2013 the company was forced into bankruptcy. However, plans for a restart of the company exist and it will probably be operational in 2013.

3.3 Module prices

The module prices in Sweden followed the world market trend with falling prices in 2012. Typical single module prices are now below 20 SEK/W_p which is below half of what it was in 2009.

Table 3: Typical module prices (SEK/W_p, excl. VAT) for a number of years.

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Typical standard single module prices	70	70	70	65	63	61	50	27	19	16
Best price	26	26	32	30	28,5	25,5	18	20	12	9

3.4 Manufacturers and suppliers of other components

ABB

ABB, with origin in Sweden, is a global company group specialized in power and automation technologies that operate in around 100 countries. At an international level ABB produces and provides a wide range of products for all types of solar systems, from small domestic installations to large power plants. Products for the solar industry include inverters for photovoltaic systems, components for trackers, low voltage components and accessories. ABB also offers products and solutions for the manufacture of solar modules and solar cells, equipment for connection to the medium or high voltage grid and delivers global turnkey photovoltaic system with unit sizes of 1 MW_p. In Sweden ABB manufactures breakers, contactors, electricity meters, enclosures, miniature circuit breakers, pilot devices, power supply relays, residual current devices, surge suppressors, switch disconnectors, and terminal blocks, which all can be used in photovoltaic systems.

MAPAB

MAPAB (Mullsjö Aluminiumprodukter AB) manufactures aluminium structures for the assembly of PV modules. The company provides solutions for mounting on roofs, facades or the ground. Previously, most of the production went on export to the European market, but in 2012 MAPAB started to deliver more of their products to the Swedish market.

Midsummer AB

Midsummer continued with its business model to make equipment for CIGS thin film solar cells on 6 inches large stainless steel substrates using a proprietary all sputtering process in 2012. After having developed the DUO production tool, that has been sold to China as well as being used for R&D and production for special applications at their headquarter in Sweden, Midsummer has spent 2012 adapting to a changing business environment. With the rapid price decline of PV products, Midsummer has developed a niche with flexible modules that weigh about 25% of a corresponding crystalline Silicon module. Midsummer also developed in 2012 a generic research tool that they aim to sell to universities and institutes interested in depositing a large number of thin films in an unbroken vacuum chain. The UNO R&D tool can be supplied with both CIGS and CZTS process, but is not limited to PV only. In parallel to these activities there has been continuous research and improvement in cell efficiency, with over 15% active area achieved on full 6 inch solar cells in 2012.

SolarWave AB

SolarWave AB provides solar driven water purification systems and desalination systems. The target market is mainly developing countries in Africa where the company’s stand-alone system is sold by authorized distributors.

Swedish Electroforming Technology AB

Sweltech is a machine manufacturing company that in 2012 worked with a Vinnova financed project that involved wet chemical fabrication of solar energy materials. The project resulted in development of a process and machine for electro deposition of the grid for silicon solar cells, and contact with a big European solar cell manufacturing company has been established.

3.5 System prices

In Sweden the prices for grid-connected systems are depending on two factors, the global market for modules and balance-of-system components and the size of the Swedish market. In 2012 the demand for grid-connected systems in Sweden was relatively high, due to the direct capital subsidy, and at the same time the global prices for systems continued to decrease. This led to that the cost for complete turnkey PV systems decreased remarkably under 2012. The turnkey prices presented in table 7 are prices typical at the end of 2012 and do not represent the overall pricing during 2012.

Table 4: Turnkey Prices of Typical Applications (SEK/W$_p$, excl. VAT)

Category/Size	Typical applications	Price in 2011
OFF-GRID Up to 1 kW	Roof mounted system for a vacation house	26
OFF-GRID > 1 kW	Roof mounted system for a vacation house	26
ON-GRID up to 5 kW	Roof mounted system on a private house	22
ON-GRID up to 10 kW	Roof mounted system for a commercial building	20
ON-GRID > 10 kW	Roof mounted system for a commercial building	16
ON-GRID > 10 kW	Utility-scale plant	-

Table 8: National trends in system prices (SEK/W$_p$, excl. VAT) for small off-grid and big on-grid applications.

YEAR	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
OFF-GRID Up to 1 kW	165	100	100	100	100	95	90	80	70	45	26
ON-GRID up to 5 kW on a private house	-	-	-	-	-	-	-	-	60	32	22
ON-GRID > 10 kW	-	200	-	60	60	60	67	47	35	25	16

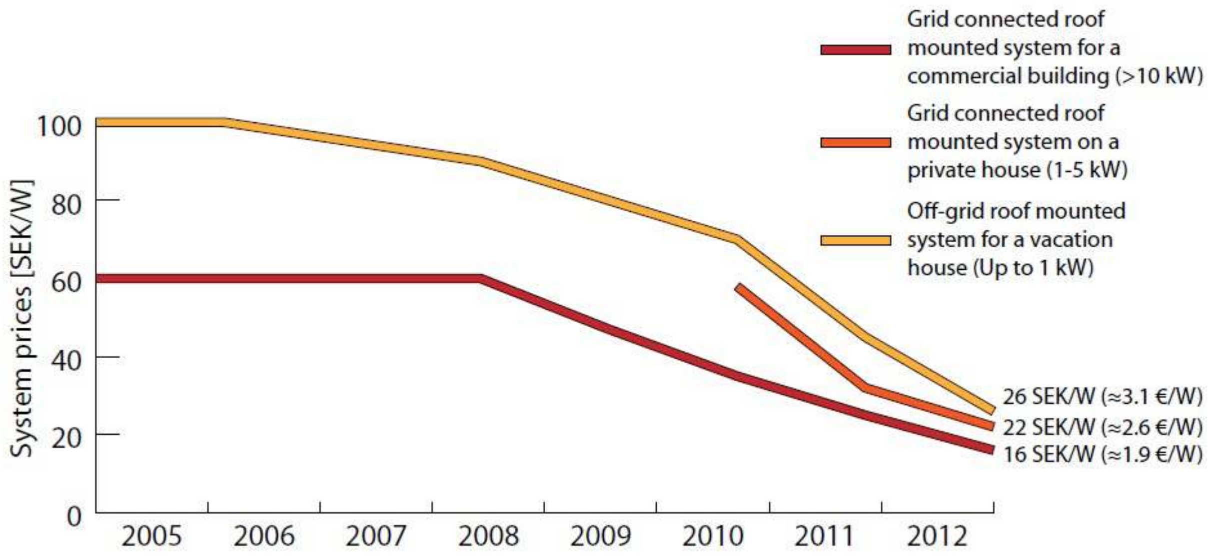

Figure 5. The Swedish price trend for typical turnkey photovoltaic systems (excluding VAT) reported by Swedish installation companies.

3.6 Labour places

The number of jobs in the Swedish PV module production industry has in recent years gone down due to the bankruptcy of several companies. However, the numbers of researchers in the PV field increases and more and more people are involved in installation of PV systems. The number of people with a job related to the PV market in Sweden increased with some 120 persons in 2012 and is now approximately 615 persons. Some utility companies now have people working full time with PV, and that is the reason why the sector called "other" is increasing.

Table 9: Estimated PV-related labour places in 2012

Category	Number of labour places
PV module manufacturers	160
Manufacturers and suppliers of other components	47
R&D companies	78
Installer and retailers of PV modules and systems	161
Academic research	149
Other	20
Total	**615**

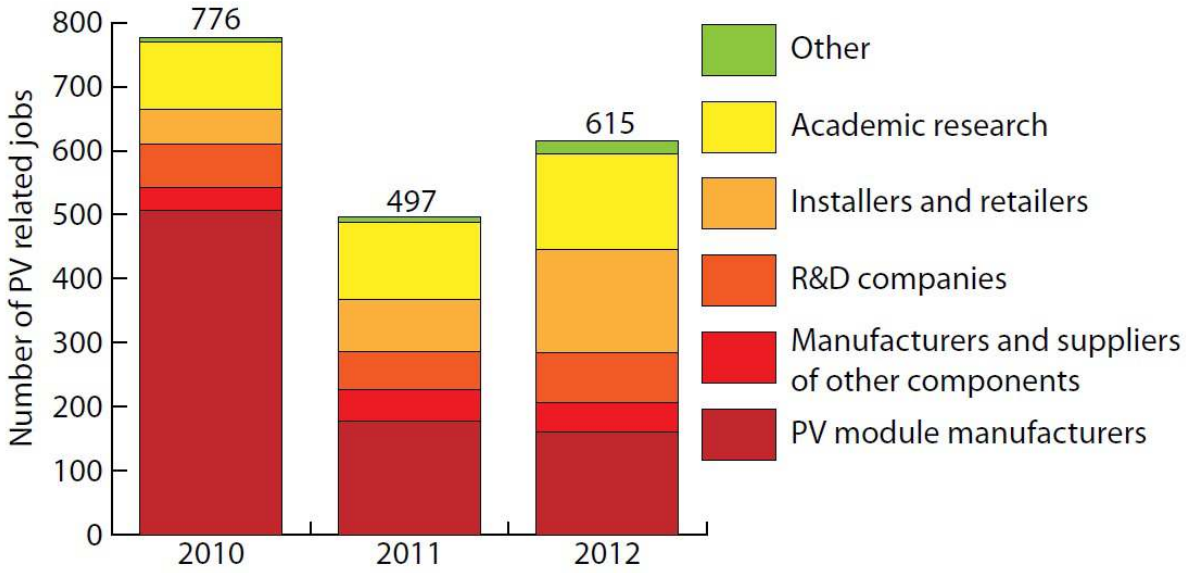

Figure 6. The number of PV related labour places in Sweden the last three years.

3.7 Business value

In table 10 some very rough numbers of the value of the Swedish PV business can be found. The PV business value in Sweden was in 2012 dominated by the module production due to the fact that 35 MW_p was produced, but only 8.4 MW_p was installed.

Table 10: Value of PV business

Sub-market	Capacity installed in 2012 (MW_p)	System Price (SEK/ W_p)	Value	Totals
Off-grid domestic	0.81	26	0.81 x 26	~ 21.1 Million SEK
Off-grid non-domestic	0.01	26	0.01 x 26	~ 0.3 Million SEK
Grid-connected distributed	6.88	20	6.88 x 20	~ 137.6 Million SEK
Grid-connected centralized	0.74	16	0.74 x 16	~ 11.8 Million SEK
Value of PV market				170.8 Million SEK
	Module production in 2012 (MW_p)	**Module price (SEK/ W_p)**	**Value**	
Exports of PV modules	35	9	35 x 9	315 Million SEK
Value of PV business				**485.8 Million SEK**

4 FRAMEWORK FOR DEPLOYMENT (NON-TECHNICAL FACTORS)

4.1.1 The national direct capital subsidy for PV program

A direct capital subsidy for installation of grid connected PV systems (ordinance 2009:689) has been active in Sweden since 2009. This subsidy was planned to end by the 31st of December 2011 but was first prolonged for 2012 and in December 2012 the government announced that it will be extended until 2016 with a budget of 210 million SEK for the years 2013-2016. Since the start in 2009 the program had at the end of 2012 assigned 296.5 million SEK in total.

Under 2011 the subsidy covered 60% (55% for big companies) of the installation cost of PV systems, including both material and labor costs. For 2012 this was lowered to 45% to follow the decreasing system prices in Sweden and was further decreased in the new 2013-2016 ordinance to 35%. The subsidy in 2011 had an upper limit in cost at 2 million SEK per PV system and the system could cost a maximum of 75 000 SEK plus VAT per installed kW_p. These numbers were decreased in the 2012 regulations to 1.5 million SEK per PV system and a maximum of 40 000 SEK plus VAT/kW_p and in the 2013-2016 ordinance, funds can only be applied for if the system cost less than 1.2 million SEK in total and a less than 37 000 SEK plus VAT/kW_p. Solar power/heat hybrid systems are allowed to cost up to SEK 90 000 plus VAT/kW_p.

Under 2012 there was some uncertainty about the future of the Swedish PV market since no one knew if there would be a subsidy in place for 2013. The announcement from the government for a prolongation to 2016 at the end of 2012 was therefore welcome. One upside of the new ordinance is that it now will extend over several years, which will enable installation companies to plan further ahead than they could when the subsidy was prolonged for one year at the time. A downside of the subsidy is that there are much more applications than funding for 2013. The waiting time for the investment subsidy decision is thereby in general 1-2 years in average, but varies between the 21 county administrations (Länsstyrlesen). The effect of the long waiting times and the fact that there are more applications than the current budget renders that the program does not solely work as a stimulation, but also as an upper cap, of the Swedish PV market.

4.1.2 Net-metering

There is strong support among stakeholders for net metering, and the government has started an investigation (the third) on this matter. The investigation is performed by the Ministry of Enterprise, Energy and Communications (Näringsdepartementet) who will present their results in June 2013. A net-metering scheme can thus be in place at the earliest in 2014. Awaiting progress in this question, several utility companies have launched various schemes for buying any surplus electricity generated by their customers PV systems. Some of these schemes work in practice as net metering schemes (See utility business interests).

4.1.3 The green electricity certificate system

In 2003, a tradable green electricity certificate system was introduced in Sweden to increase the use of renewable electricity. The electricity certificate system is estimated to have generated 13 TWh of renewable electricity generation between 2002 and 2011 in Sweden. The basic principle of the system is that producers of renewable electricity receive certificates from the government for each MWh produced. Meanwhile, electricity supplier companies are obliged to purchase green certificates representing a share of the electricity they sell, the so-called quota obligations. The sale of certificates gives producers an extra benefit in addition to revenues from electricity sales. The energy sources that are entitled to receive certificates are wind power, some hydro, some biofuels, solar, geothermal, wave and peat in power generation. In 2012, the quota obligation for Electricity supplier companies was 0.179 or 17.9 %.

From January 2012, Sweden and Norway now have a joint certificate market. The objective of the certificate system is to increase the production of electricity from renewable sources by 26.4 TWh between 2012 and 2020 in Sweden and Norway combined. The common market makes it possible to deal with both Swedish and Norwegian electricity certificates for meeting quotas. Although the market is shared, respective national legislation is governing the electricity certificate system in each country.

In 2012 the average price for a certificate was 181.3 SEK/MWh.

The electricity certificates can in the present shape give some economical contribution to existing solar installations. However, at the time of the writing of this report only 123 PV systems had applied for certificates, which are only about 1/10 of all of the PV systems in Sweden. This indicates that the certificate system of today does not provide any significant support for PV installations in Sweden. There are two reasons why it has been difficult for PV to take advantage of the certificate system. Firstly, it is difficult for small producers to reach a production of 1 MWh of electricity. Secondly, the meters that register the electricity produced at a building are often placed at the interface between the building and the grid. This means that it is only the surplus electricity of a PV system that can generate certificates and the electricity produced and used internally in the building is never included if not the extra cost for an internal meter is paid.

4.1.4 Guarantees of origin

Guarantees of origin are electronic documents that guarantee the origin of the electricity and are intendant to provide energy customers the ability to choose electricity suppliers from an environmental aspect. The law on guarantees of origin was introduced in December 2010 and affects the electricity producers and suppliers. Electricity producers receive a guarantee from the state for each MWh of electricity produced, which can then be sold on the open market. The guarantee of origin shows the type of energy that the electricity comes from. Guarantees of origin are issued for all types of power generation.

The Swedish Energy Markets Inspectorate (Energimarknadsinspektionen) announced in October 2011 new directions on how guarantees of origin should be handled. However, the new regulations do not take full effect until 2013 and it is still very unclear how much a PV-system owner can benefit from this system.

Table 51: PV support measures

	On-going measures	Measures that commenced during 2012
Enhanced feed-in tariffs	Offered by some utilities	
Capital subsidies for equipment or total cost	National	
Green electricity schemes		
PV-specific green electricity schemes		
Renewable portfolio standards (RPS)	National	
PV requirement in RPS		
Investment funds for PV		
Income tax credits		
Net metering	Offered by some utilities	
Net billing		
Commercial bank activities e.g. green mortgages promoting PV		
Activities of electricity utility businesses	Various offers to micro producers of electricity	
Sustainable building requirements		

4.2 Indirect policy issues

The Swedish government has decided that the goal of the Swedish emissions of greenhouse gases from activities that are not part of the system of emissions trading will be reduced by 40 % by 2020 compared with 1990. Besides emission of greenhouse gases by 2020, the government have the following goals:

- Half of Sweden's energy consumption in 2020 will come from renewable energy sources.
- Sweden will in 2030 to have a vehicle fleet that is independent of fossil energy.
- Sweden's net greenhouse gas emissions should be zero by 2050.
- 20 % more efficient energy use in 2020.
- 10 % renewable energy in transport sector by 2020.

4.2.1 Grid-connection legislation

For grid-connected PV systems the Distribution System Operators (DSO's) are required to install a meter with associated collection equipment at the point where the electricity producer's electricity is fed into the national electricity grid. As a general rule, the producer pays for the cost of metering equipment and installation. Small systems that are not able to deliver more than 1 500 kW_p are however excluded from paying the cost of meters and installation. The producer also needs to pay a grid tariff that is decided by the DSO's. However, new regulations that were set in 2010 make exceptions for small systems. A producer that has a fuse at a maximum of 63 A and is producing electricity with a power of maximum 43.5 kW_p will no longer need to pay for the grid tariff as long as the producer during one calendar year draw more electricity from the national grid than the producer feeds in.

4.2.2 Taxes

In Sweden, taxes and fees are charged at both the production of electricity and at the consumption of electricity. Taxes that are associated with production of electricity are property taxes, taxes on fuels, taxes on emissions to the atmosphere and tax on nuclear power. The total property tax on electricity generation plants in 2012 is estimated at around 4 billion SEK (equivalent to about 0.055 SEK/kWh on average for hydropower, 0.004 SEK/kWh for wind and 0.003 SEK/kWh for nuclear power. In addition, utilities pay the state income tax (28 % corporate tax on profit before tax) as all other companies do.

For consumption it is mainly the energy tax on electricity and the related VAT, but there are also charges to fund agencies. The industry paid in 2012 0.005 SEK/kWh in energy tax and the rate for residential customers was 0.29 SEK/kWh (excluding VAT), with the exception of some municipalities in northern Sweden where the energy tax was 0.192 SEK/kWh (excluding VAT). Additionally, VAT (25%) is applied on top of the energy tax.

Altogether, roughly 45 % of the total consumer electricity price was taxes, VAT's and certificates in 2012.

4.2.3 The bidding areas

The Swedish electricity market is from the first of November 2011 divided into four bidding areas by decision of Svenska Kraftnät. The reason for this is that northern Sweden has a surplus of electricity production compared with demand while there is more demand than production in southern Sweden. That has resulted in transmission capacity problems and the borders between the bidding areas have been drawn where there are congestions in the national grid. The idea of the four bidding areas are to make it clear where in Sweden the national grid for electricity needs to be expanded and where in the country increased

electricity production is required in order to better meet consumption in that area and thus reduce the need to transport electricity long distances.
The average Nord Pool spot prices in 2012 for the different areas was 0.277 SEK/kWh in area 1 (Luleå), 0.277 SEK/kWh in area 2 (Sundsvall), 0.282 SEK/kWh in area 3 (Stockholm) and 0.298 SEK/kWh in area 4 (Malmö). The very small difference between the areas does probably not influence the distribution of PV systems over the country.

4.2.4 Emissions trading

The EU system for emission trading began on the first of January 2005. Emission trading is one of the so-called flexible mechanisms defined in the Kyoto Protocol. The purpose of the trade is to cost-effectively reduce greenhouse gas emissions in the EU. Countries and companies are able to choose between implementing measures to reduce emissions in their own country / company or to buy allowances which generate reductions in emissions elsewhere. This will lead to the least expensive measures being implemented first, so that the total cost of meeting the Kyoto Protocol is as low as possible. In Sweden, the carbon dioxide tax has already led to that many of the least expensive measures have been implemented and there are only more expensive measures left.

The first trading period ran from 2005 to 2007. The next trading period ran from 2008-2012, the same as the Kyoto Protocol commitment period. The current trading period started in 2013 and will expire in 2020. For each trading period the total emissions cap in the system is lowered. So far, the emission allowances have been handed out free of charge to operators, but as from 2013, allowances to all electricity production facilities shall be auctioned instead. In the energy sector, all individual plants with a capacity greater than 20 MW_p or district heating systems, where plants together have a greater effect than 20 MW_p are covered by the system. There are about 700 of these plants in Sweden.

The price in 2012 went down from about 10 €/tonne in the beginning of the year to about 8 €/tonne. An applicable rule of thumb is that a price of 10 €/tonne results in a spot price of almost 0.08 SEK/kWh at the Nordic Electricity Retailing market (Nord Pool).

4.2.5 International spread of environmental technologies

The Swedish Energy Agency is managing the Clean Development Mechanism (CMD) and Joint Implementation (JI) Programme of the Swedish Government. The programmes supports international climate projects by purchasing emission reduction units that have been created under the flexible mechanisms of the Kyoto Protocol. The financial support to climate change projects from the Swedish CDM and JI Programme is conducted through bilateral agreements directly with the project developers and via multilateral CDM and JI funds. The Swedish Energy Agency supports a number of PV projects in China, India and Thailand, by participating in the two CDM funds administered by the Asian Development Bank (the Asia Pacific Carbon Fund and the Future Carbon Fund). Two of the projects in China are PV power plants, both with an installed capacity of about 10 MW_p. The other projects in China are building integrated solar photovoltaic (BIPV) projects at different locations with installed capacity ranging from about 2 MW_p up to 6,5 MW_p. The project in Thailand is a PV power plant with an installed capacity of about 55 MW_p and the project in India involves the construction and operation of a 125 MW capacity concentrated solar power (CSP) plant. Through both CDM funds, the agency is also supporting two small-scale solar cooker projects in Gansu in China.

Furthermore, SIDA is financing several projects in developing countries that involve PV. For example Högskolan Dalarna is involved in a project about PV-diesel hybrid systems in Tanzania and Mälardalens Högskola is involved in the following projects, developments of mini grids for rural areas in Africa, development of concentrating PV/Thermal system for Mozambique, and development of PV-supported irrigation system for China.

4.3 Interest from electricity utility businesses

Several utility companies started to market in 2012 small turnkey PV systems suited for roofs of residential houses. Systems sizes vary between the companies but are all between 1.5 kW_p to 7.5 kW_p. The utility companies that at the moment of writing now offer these kinds of turkey PV systems are **Bixia, Din El, E.ON, Fortum, Höörs Energi, KREAB Energi, Lunds Energi, MälarEnergi, Ringsjö Energi, Vattenfall and Öresundskraft**. In common is that all of the utility companies are collaborating with local Swedish installation companies that provide the actual system and perform the installation.

Adjacent to **PiteEnergi**'s office is a solar park which is run in collaboration with the Norwegian research institute Norut in Narvik. Individually monitored PV modules from five different vendors are mounted on two different two-axis tracking systems and both the modules' performance in northern climates and the tracking systems are evaluated.

Several utility companies started in 2011 to introduce compensation schemes for buying surplus electricity produced by small-scale PV systems. In 2012 this trend continued and more and more utility companies now have various offers for micro producers of electricity. Below is a list of a number of these compensation schemes. When the term micro-producer is used in the following section it means that the client is a net consumer of electricity in a year and that the system and the fuse do not exceed 43.5 kW_p and 63 A respectively.

If the reader is aware of other utility companies that offer compensation for surplus electricity production from PV systems, feel free to contact the author at johan.lindahl@angstrom.uu.se

4.3.1 Net metering offers

DinEl started in 2011 to offer net metering on an annual basis and this offer continued throughout 2012. In their solution the client has a fixed kWh price settlement with DinEl where the surplus production is balanced with the consumption. The requirements are that the client is an annual net consumer and the system may not exceed 6 kW_p.

The DSO part of **Kungälv Energi** offers net metering on a yearly basis for micro-producers. One requirement for the net metering offer is that the client has a contract with their electricity supplier for net metering and the electricity trading part of Kungälv Energi does that.

Nacka Energi practice net metering on a monthly basis for a few micro-producers.

Mälarenergi is a DSO company that introduced a monthly net metering scheme in 2011 for micro-producers within the company's grid network. The client does not have to buy the electricity from Mälarenergi. No compensation is given for the surplus electricity if the client produces more than the demand in a month.

The DSO company **Tekniska verken** are currently testing a net metering scheme for micro-producers within the company's grid network. The difference between the client's production and consumption is reported to the company that provides the electricity and the client's electricity bill is based on this value. If production is equal to or greater than the consumption, Tekniska verken reports no consumption to the electricity provider company. On an annual basis, Tekniska verken compiles any monthly net production and compensates the client corresponding to Tekniska verken's cost of purchasing electricity for transmission losses.

Umeå Energi introduced a net metering scheme in 2012 for micro-producers within the company's grid network. If the total production of electricity in a month is greater than the electricity consumption, the balance is saved to the next month.

4.3.2 Feed-in tariff offers

Affärsverken in Karlskrona buys surplus electricity at a price of 0.8 SEK/kWh from micro-producers as long as the client has an electricity supply contract with Affärsverken. If the client also belong to the Affärsverkens grid 0.1 SEK/kWh is added to the compensation.

Bixia improved in 2012 their offer for micro-producers, from the Nord Pool spot price, which was what they offered in 2011, to 1 SEK/kWh. This offer applies to clients who in a calendar year buy more electricity than they produce.

Bixia also offers hourly off-setting for clients where the site of the PV system is physically separated with a large distance from the actual consumption site.

The DSO company **Växjö Energi** started in 2012, in collaboration with Bixia, to offer their customers who want to sell electricity 1 SEK/kWh in compensation.

EgenEl and **Falkenberg Energi** are collaborating and purchase surplus electricity from micro-producers with PV systems at a price of 1 SEK/kWh.

Höörs Energi, KREAB Energi, Lunds Energi, Nynäshamn Energi and **Ringsjö Energi** purchase surplus electricity at a price of 1 SEK/kWh if the client is a net consumer on a yearly basis and if the system does not exceed 10 kW.

Sala-Heby Energi offers micro-producers 0.8 SEK/kWh as long as the client has an electricity supply contract and is connected Sala-Heby Energi's grid.

Skånska Energi offers micro-producers 1 SEK/kWh as long as the client has an electricity supply contract with Skånska Energi. If the client is connected Skånska Energi's grid 0.06 SEK/kWh is added to the compensation.

Telge Energi is offering their existing micro-producer clients with PV systems 1.5 SEK/kWh, including VAT, green electricity certificates and guarantees of origin, for their electricity. However, they are not accepting any new clients until the ongoing investigation for net metering is finished.

Furthermore, as a client of Telge Energi one can add solar power to the electricity contract. Solar power can be bought in the form of a large or small package. The small package costs 25 SEK/month (incl. VAT) and guarantees the client 10 kWh of solar power per month. The large package costs 50 SEK / month (incl. VAT) and gives the client 20 kWh solar power per month.

Öresundskraft started in 2011 to buy surplus electricity at a price of 1 SEK/kWh from micro-producers as long as the client is connected to the grid of Öresundskraft and has an electricity supply contract with Öresundskraft.

The DSO companies in Dalarna; **Dala Energi Elnät**, **Borlänge Energi Elnät**, **Falu Elnät**, **Hedemora Energi**, **Malungs Elnät**, **Smedjebacken Energi Nät** and **Envikens Elnät** purchase surplus electricity at a price of 1 SEK/kWh from micro-producers that belong to their grids.

4.3.3 Nord Pool spot price offers

E.ON offers the Nord Pool spot price minus 0.04 SEK per kWh. E.ON does not require that the client belongs to the grid or have E.ON as their electricity supplier. If the client is a micro-producer and is connected to one of E.ON's low voltage grids the company offers compensation for reduced costs of losses in the transmission of electricity due to the production from the PV system. The compensation is 0.029 SEK/kWh if the client belongs to the "Nord" or "Kramfors" grids and 0.056 SEK/kWh if the client belongs to the "Syd" or "Stockholm" grids.

Eskilstuna Energi och Miljö Försäljning AB buy surplus electricity at the Nord Pool spot price minus 0.03 SEK/kWh from micro-producers. If the client also belongs to Eskilstuna Energi och Miljö Elnät AB's grid 0.05 SEK/kWh is added to the compensation.

Fortum Distribution, the DSO part of the large utility company pays the Nord Pool spot price minus 0.002 SEK per kWh from all kind of clients, both private micro-producers and larger companies as long as the client has Fortum as their electricity supplier.

GodEL buys surplus electricity at the Nord Pool spot price, without deduction, from micro-producers.

Gotlands Elförsäljning AB buys surplus electricity at the Nord Pool spot price minus 0.04 SEK per kWh from micro-producers.

Vattenfall started to buy surplus electricity from micro-producers in October 2011. The government-owned energy company pays the Nord Pool spot price minus 0.04 SEK per kWh for the surplus electricity as long as client has an electricity supply contract with Vattenfall. The client can belong to any grid area in Sweden as long as the client has a valid feed-in subscription with the grid company in question.

4.4 Interest from municipalities and local governments

Several municipalities have started some smaller projects within PV, often in cooperation with local utility and construction companies. The largest project is probably the association Solar Region Skåne which started in 2007 as a collaboration between the municipality of Malmö, Energikontoret Skåne and Lund University. Solar Region Skåne is a network and knowledge center for solar energy activity in the Skåne province. The aim of the association is to in a neutral and objective way disseminate knowledge and information about solar technologies, thus increasing the interest and skills of various stakeholders in the solar industry and among the public.

4.5 Standards and codes

4.5.1 Grid connection rules

A PV production facility connected to an existing electrical installation must meet certain requirements to be safe and not affect other equipment in a detrimental way. The requirements are stated by the ELSÄK-FS 2000:1 and ELSÄK-FS 2007:1 legislation. These refer to technical product standards in agree with European directives. A manufacturer of a product to contained in a power generation facility must also CE mark the product for it to be allowed to be used on the market. The National Electrical Safety Boards (Elsäkerhetsverket) regulations also set that a permanent installation of a production facility shall be performed by a qualified electrician.

Connecting a production facility to an existing electrical installation means that the production facility also is connected to the grid. In the electrical legislation, Ellag (1997:857), it is stated that the transfer of electricity must be of good quality. In order to determine what good quality is, European standards and industry practices are used. Regulations which further specify good quality for the transmission of electricity are currently under formulation by the Swedish Energy Agency (Energimyndigheten).

There are furthermore two important PV specific standards that apply for grid-connected PV system. Swedish Standard SS-EN 61727, Solar power plant - Connection to grid and Swedish Standard SS-EN 61173, Solar power plant - instructions to protect against overvoltage. There are also more general electrical guidelines such as the electrical installation standard SS 436 40 00, the connection of low voltage circuits to the grid standard SS 437 01 40 and the National Electrical Safety Board (Elsäkerhetsverket) directions on how electrical installations shall be executed, ELSÄK-FS 2004:1 that should be followed. A summary of all important standards and guidelines for PV system installation and maintenance has been released in a compilation by the SolEl-program.

Figure 7. Väla Gård, winner of Svensk Solenergi's price "The system of the year". (Courtesy of Skanska Sverige AB)

4.5.2 Building permits

Installation of PV systems on roofs does normally not require building permits, but it can differ between different municipalities. However, if the installation change the external appearance of a building significantly a building permit is required. Some restrictions on roofing materials and roof angles may apply, particular in culture-sensitive environments and buildings.

4.5.3 Public procurement act

For a procurement of a PV system for a public building the stakeholder planning the system must use an open tender system according to the public procurement act. This unfortunately means that the stakeholder cannot ask a supplier for advice or assistance in the proposition making process. In addition, when it comes to public procurement procedures reference projects are often requested from the installers, which makes it harder for new actors to enter the market.

5 HIGHLIGHTS AND PROSPECTS

5.1 Highlights

The prices for turnkey PV-system continued to decreased significantly under 2012 and at the end of the year the prices for complete systems where about half of what the prices were only two years ago. The price drop helped to increase PV installations in Sweden. 8.4 MW_p was installed in 2012, which is almost twice as much as the 4.4 MW_p that was installed in 2011.

5.2 Prospects

The installation rate in 2013 is expected to increase. There is a growing interest for PV in Sweden and general public is very positive to the technology. In a survey done in the beginning of the year almost 80 % participants thought that Sweden should invest more in PV. In 2012 the direct capital subsidy was prolonged until 2016, which will guarantee a stable PV market in the years to come. However, one problem is that the budget for the direct capital subsidy is too small and therefore both functions as a market stimulation and a capacity cap. In June 2013 the government's investigation about net-metering will be finished. An introduction of a net-metering law in Sweden could result in a faster growing PV market in Sweden than today.

ANNEX A: COUNTRY INFORMATION

This information is simply to give the reader some background about the national environment in which PV is being deployed. It is not guaranteed to be 100 % accurate nor intended for analysis, and the reader should do their own research if they require more detailed data.

1) The typical retail electricity price in 2012 was for an apartment ~1.8 SEK/kWh, a house without electricity warming ~1.7 SEK/kWh and for a house with electricity warming ~1.3 SEK/kWh. The industry paid in 2011 about 1 SEK/kWh.

2) The average Swedish household electricity consumption is 4.5 MWh per year.

4) The average disposable income per capita was in 2012 188 600 SEK.

5) Typical mortgage interest rates for 3 month fixation loans started in 2012 at ~4.5 % and slowly decreased under the year to ~3.1 % at the turn of the year.

6) Electricity is transported from the major power stations to the regional electricity grids (40-130 kV) via the national grid (220 kV and 400 kV). From the regional grids, electricity is transported via local grids (40 kV or less) to electricity consumers. The voltage in the wall sockets in Swedish homes is 230 V.

7) The backbone of the electrical grid, the national grid, is owned by the government and managed by Svenska Kraftnät, whereas power utility companies own the regional and local grids. The base price of the electricity is daily set by the Nordic electricity retailing market, Nord Pool. Electricity supplier companies then use this price as basis for their pricing in the competition for customers.

   The Swedish market is dominated by three companies; Vattenfall AB, Fortum and E.ON that are all active in all of three sub markets; generation, retailing and transmission, and therefore have a big influence on the overall electricity market.

8) The average pump price of diesel at a manned station was ~14.8 SEK/l under 2012, including taxes.

9) A typical value of energy production per installed PV power unit in Sweden is 900 kWh/kW_p but differs for different systems and locations in the country.