National Survey Report of PV Power Applications in Sweden 2004

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

International Energy Agency

CO-OPERATIVE PROGRAMME ON PHOTOVOLTAIC POWER SYSTEMS

Task 1

Exchange and dissemination of information on PV power systems

National Survey Report of PV Power Applications in Sweden

2004

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Table of Contents

i Foreword

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

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

The nineteen participating countries are Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), The Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), The United Kingdom (GBR) and The United States of America (USA). The European Commission is also a member.

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

The objective of Task 1 is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of photovoltaic power systems.

ii Introduction

This National Survey Report of photovolatic (PV) power systems reflects the status of the PV market, the industry and policy that influences PV applications in Sweden. One of the purposes of this report is to be part of the basis for the IEA report “Trends in Photovoltaic Applications”, which is jointly written by the members of the IEA-PVPS Task 1. This international report reflects PV power applications in the participating countries, which make up a majority of the PV producing countries in the world. 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 stakeholders that have an interest in PV. The report sets out to describe the PV applications, markets, stakeholder and policies in Sweden 2004, in a comprehensive way. The report also provides important statistics on how much PV is installed in Sweden, as well as the amount of PV modules produced in the Swedish PV industry.

iii Definitions, symbols and abbreviations

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

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

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

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

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

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

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

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

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

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

required to avoid disrupting production, these extra costs should not be included. Equally the additional transport costs of installing a telecommunication systems in a remote area are excluded).

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

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

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

NC: National Currency

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

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

Sammanfattning på Svenska (Summary in Swedish)

Den viktigaste utvecklingen som ägt rum i Sverige under 2004 var riksdagsbeslutet om att inrätta ROT-bidrag för energieffektivisering i byggnader som används för offentlig verksamhet. Paketet med ROT-bidrag innefattar en större mängd åtgärder som stöds med en skatterabatt på 30 % av kostnaden för installationen, medan solcellsprojekt erhåller 70 % av kostnaden. Detta program kommer att löpa från den 15 maj 2005 till den 31 december 2007. Totalt har det satts ett tak på 100 MSEK till solcellsinstallationer, med maximalt 5 MSEK per byggnad. Om programmet utnyttjas fullt ut kommer den totala installerade effekten från solceller i Sverige att öka drastiskt under de kommande åren från ca 4 MW till över 6,5 MW.

Installerad effekt

Eftersom ROT-bidragsprogrammet som beskrivs i föregående stycke inte implementerats förrän 2005, påverkar det inte den installerade solcellseffekten i Sverige under 2004. Den övriga solcellsmarknaden har under de senaste dryga tio åren som IEA-PVPS fört statistik legat konstant på en nivå kring 250 kW per år, varav merparten installerats vid stugor utan elanslutning, eller på båtar och husvagnar.

Under 2004 installerades 285 kW, varav 256 kW faller inom sektorn ”icke nätanslutet för privat bruk”, det vill säga marknaden för fritidshus, båtar, m.m. Resten kan klassificeras som ”icke nätanslutet för professionellt bruk”, t.ex. till telekomutrustning och fyrar som saknar nätanslutning.

Inga nätanslutna system levererades under 2004, även om ett par projekt driftsattes tidigt på året. Denna sektor har varit något intermittent i Sverige, med enstaka projekt vissa år och inga alls andra år. Det är denna sektor som står för de stora volymerna i de ledande länderna Tyskland och Japan.

Priser

En liten minskning kan ses på priserna för solcellsystem i Sverige, men denna minskning ligger inom felmarginalen. Generellt är marknaden inte tillräckligt stor för att det ska bli konkurrens och pressade priser. Detta skulle kunna ändras i och med det nyligen sjösatta stödsystemet.

Tillverkning

Den svenska tillverkningsindustrin, som består av företag som tillverkar moduler från importerade celler, har ökat sin produktion och produktionskapacitet under 2004. Totalt tillverkade de fyra svenska modulföretagen 26 MW. Det största företaget, GPV, stod för 11 MW, medan de tre mindre, ArcticSolar, ScanModule och PV Enterprise, producerade 4 till 6 MW vardera.

Allmänna medel till solcellsverksamhet

Sedan länge har majoriteten av allmänna medel till solcellsverksamhet gått till forskning och utveckling. Detta främst genom Ångström Solar Center vid Uppsala universitet, och SolEl 03-07. Under 2004 gick 23 MSEK till forskning och utveckling, medan ca 1 MSEK gick till demonstrationsprojekt genom programmet PV Nord.

1 Executive summary

The most important development in Sweden, as far as PV is concerned, in 2004 is the conception of a market deployment initiative. The initiative was launched as part of a scheme to subsidize refurbishments for increased energy efficiency in buildings used for public activities, such as schools, libraries, museums and community centres. For PV installations the subsidies in this programme amount to 70 % of the total costs, up to 5 MSEK per building, with a total cap on the PV subsidies of 100 MSEK during the period from 15 May 2005 to 31 December 2007. If fully subscribed to the programme will rapidly increase the cumulative installed PV power in Sweden from approximately 4 MW, today, to more than 6,5 MW at the end of 2007.

Installed PV power

Since the market deployment initiative described above was conceived, but not implemented, in 2004 it did not affect the installed power that year. The PV market in Sweden has been quite constant for the past ten years, with approximately 250 kW installed per year. It has been dominated by the off-grid domestic sector, where most of the PV systems sold are installed to cater for electricity needs in remote cabins, boats and camper vans.

In 2004, 285 kW of PV was installed in Sweden, which reinforces the picture of a small but stable off-grid market. The total amount of installed capacity in 2004 was nearly exactly the same as the year before, but with no installed power in the grid-connected sector. This market segment, grid-connected distributed, has been somewhat intermittent, with one-off demonstration projects increasing the installed power substantially certain years, while no projects are carried out during other years.

Costs & prices

The decrease in prices that has been seen is within the margin of error, and the cost and price structure can be characterized as stable, like the market in general. There is not enough competition, and not large enough market base for the prices to be pressed down. This could very well be changed with a larger market opening up in the wake of the newly launched deployment initiative.

PV Production

The PV production in Sweden, which solely consists of module manufacturing, has increased substantially in 2004 with all four producers extending their capacity and hiring more personnel. The leading PV manufacturer, GPV doubled its production from 5,5 to 11 MW while the second largest manufacturer, ArcticSolar increased from 3,75 to 6 MW. The two newer factories, Scanmodule and PV Enterprise, also increased their production to 5 MW and 4 MW, respectively. PV Enterprise also established production capacity in Poland.

Budgets for PV

Almost all public funds for PV, in Sweden, goes to R & D, with only modest contribution to demonstration projects. In 2004, 23 MSEK were allocated to R & D, mainly Ångström Solar Center, while approximately 1 MSEK went to the PV Nord project, which included funding for demonstration projects.

2 The implementation of PV systems

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

2.1 Applications for photovoltaics

The Swedish PV power applications have been dominated, since the first PV systems emerged on the market, by the *off-grid domestic* market, where most of the systems are used to power remote vacation homes, which have no connection to the main grid. The use of PV on boats and camper vans is also frequent.

There are also larger off-grid systems for domestic use for permanent dwellings in remote areas where there is no possibility to access the main grid. During the past five years special grants have been given to projects for rural electrification in the few places, predominantly in the north of Sweden, previously without electricity. These systems are often hybrids with PV combined with a diesel generator that starts when the charge level of the batteries goes below a certain level.

The second largest application for PV in Sweden is in the *off-grid non-domestic* sector, where the systems are used to power telecommunications equipment, navigation buoys, etcetera, where there is no grid connection. This market segment is considerably smaller than the off-grid domestic sector, but clearly larger than the grid-connected sectors.

The market for larger systems, *grid-connected* ones, has been quite small with only a few installations each year. These have been mostly demonstration projects, commissioned by electricity companies or building companies in order to create competence in the PV sector for future market development.

The number of larger, grid-connected, projects will most likely increase, during the years 2005 through 2007, since the Swedish Parliament passed a bill in late 2004 allowing a tax credit of 70 % of the system costs for PV installed in public buildings, as part of an energy efficiency refurbishment plan.

2.2 Total photovoltaic power installed

As mentioned in the previous section, the majority of installed PV in Sweden consists of small systems on remote cabins, boats and such applications. This market has been remarkably stable since the beginning of the 1990-ies when IEA-PVPS begun surveying the PV market. Typically, 250 kW of photovoltaics is installed in Sweden each year, making the growth of the cumulative amount of PV power installed linear, reaching at the end of 2004 a total of 3866 kW.

The general trend experienced through the past decade continues in 2004, with a total installed power of 285 kW. Of this, 256 kW can be categorized as off-grid domestic, while the remaining 29 kW belongs to the off-grid non-domestic sector. No PV systems for grid-connected use were shipped during 2004. The projects described in section 2.3 were taken into use in 2004, but the systems were installed during 2003.

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

Sub-market/ application ##	31 Dec. 1992 kW	31 Dec. 1993 kW	31 Dec. 1994 kW	31 Dec. 1995 kW	31 Dec. 1996 kW	31 Dec. 1997 kW	31 Dec. 1998 kW	31 Dec. 1999 kW	31 Dec. 2000 kW	31 Dec. 2001 kW	31 Dec. 2002 kW	31 Dec. 2003 kW	31 Dec 2004 kW
off-grid domestic	590	760	1 020	1 285	1 452	1 640	1 823	2 012	2 216	2 376	2 595	2 814	3070
off-grid non-domestic	205	265	293	304	364	394	433	448	465	507	544	573	602
grid-connected distributed	5	15	24	31	33	93	114	124	124	149	158	194	194
grid-connected centralized	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	800	1 040	1 337	1 620	1 849	2 127	2 370	2 584	2 805	3 032	3 297	3 581	3866

The mostly linear trend with an increase of the cumulative installed power by approximately 250 kW per year is the most defining feature of the small but stable Swedish market, in the absence of market deployment initiatives. This may very well be changed drastically when the deployment initiative described in section 4.1 is launched, in May 2005.

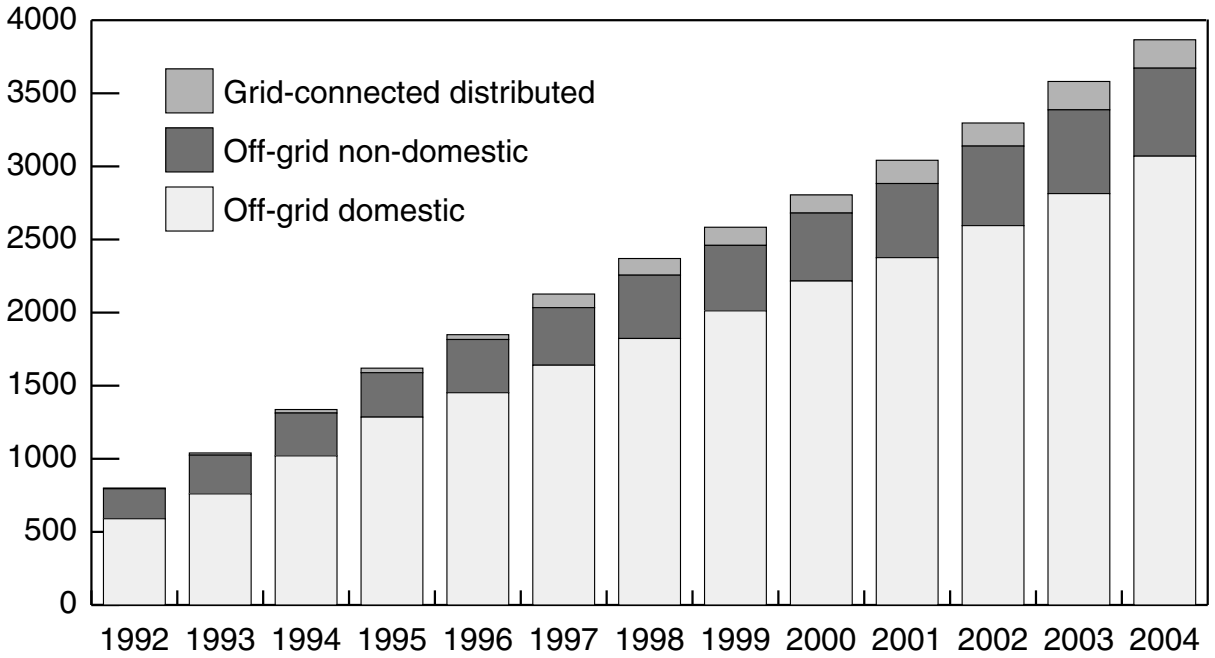

Figure 1: The cumulative installed capacity development in three market segments in Sweden.

2.3 Major projects, demonstration and field test programmes

Hammarby Sjöstad

The major PV projects that have been realized in the past few years have been dominated by the projects in Hammarby Sjöstad. This is a housing area in Stockholm that has been developed with a strong environmental profile. When the area is finished there will be 9 000 flats and 20 000 inhabitants living in an environmentally sustainable part of the Swedish capital. When planning the area, a holistic approach to building technology has been taken, in the sense that most aspects of sustainable development have been considered. Compared to the standard housing areas in Sweden, improvements have been implemented in areas like ventilation control, inside and outside lighting, energy efficiency of windows and machinery, logistics, biogas/ethanol/electric vehicles, and PV.

The PV projects here have been commissioned by building companies, in some instances in cooperation with electricity companies, and have been an important part of the environmental focus in the area, while providing important lessons for the companies involved, on how to integrate PV in the building process.

NCC Grynnan is one of the projects that were taken into use during 2004, and comprises 17,1 kW of brown multi-crystalline PV modules. The brown colour was specifically chosen by the architect, in order to blend better with the façade expression. The house, built by the construction company NCC, is the second one in a pair, where the first building was finished, and the PV system taken into use, in 2003. The modules are placed in the façade, in balcony railings and in semi-transparent windows in the top floor flats.

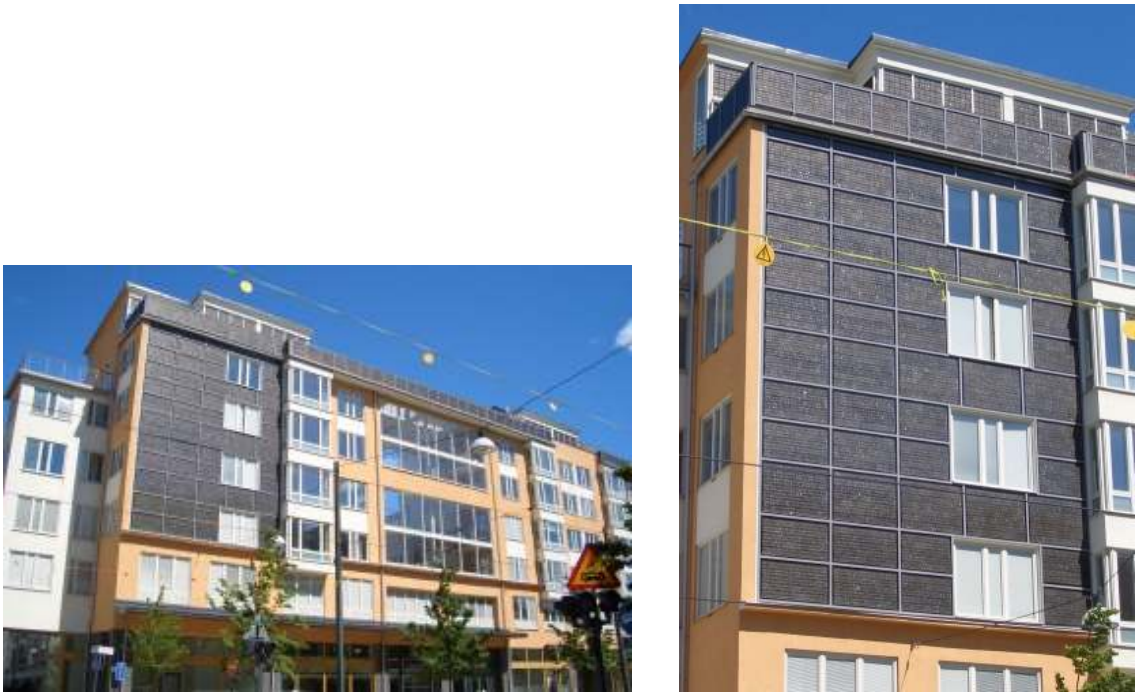

Figure 2: The *Grynnan* building with PV arrays in the façade, balcony railings and semi-transparent windows.

During the first year of operations (from April 2004 through March 2005), the PV arrays delivered 8 492 kWh AC electricity to the grid, which corresponds to a yearly yield of 500 kWh/kW. This is somewhat low compared to the average yield of PV systems in Sweden (typically 600 to 800 kWh/kW). The low number can be explained by the fact that the modules are mounted vertically, which is not optimal from an energy output point of view, and that the façade of the building is not facing the south but southwest (the module azimuth is 205°).

Lysande is a project commissioned by one of the largest real-estate companies in Stockholm, Familjebostäder. The building features two types of modules, in two positions. In front of the façade there are oblong modules, which are used as solar screens for the flats, somewhat like Venetian blinds. These modules, with a total rated peak power of 9,4 kW were designed specifically for this project, and the strings are connected in parallel in order to deal with effects of shading. On the roof, there are 13 kW of standard Gaia PV modules.

The energy yield from the installation has been 630 kWh/kW from February through December 2004 (the system was not operational in January). This discrepancy between this number and the final annual yield is of little importance, since the monthly yield in January in Sweden most often is negligible. The building is oriented so that the façade modules are directed 22° west of south (i.e. the azimuth angle is 202°). These modules are inclined by 45°, close to the optimum for energy production.

The roof-top modules are situated on three sides of the roof, facing east-southeast (102°), south-southwest (202°) and west-northwest (292°). Since the inclination of the roof is only 16°, the energy loss incurred by putting modules on surfaces with less favourable directions (102° and 292°) is not very severe. In this project, the difference in cost between standard modules and made-to-order modules, like the ones at the façade, is highlighted. The standard roof-top modules account for less than one third of the module cost, but supplies about 60 % of the power.

Figure 3: The building *Lysande* in Hammarby Sjöstad, with PV in the solar shading in front of the southern façade, and on three sides of the roof.

Future projects

In light of the recently announced market deployment initiative (see section 4.1), some major projects are anticipated. Preparatory studies for several PV power systems in public buildings have been carried out, with the aim to realize the plans when the deployment initiative is implemented (15 May 2005).

2.4 Highlights of R&D

The dominant PV research initiative in Sweden during the past eight years, Ångström Solar Center at Uppsala University, was terminated during the spring 2005, so that 2004 was its last full year. The research programme consisted of two stages, the first one from 1996 through 1999 and the second one from 2000 to the end of March 2005. Three groups have conducted their research within the framework of this programme, two of which have been working with PV, while the third group has worked with energy efficient windows.

One of the groups, formerly in Ångström Solar Center, is working with thin-film solar cells based on $Cu(In,Ga)Se_2$ (also know as CIGS) with focus on development of the deposition technologies towards production scale. During 2003 and 2004 the company Solibro AB, an off-shoot from the University research group, has started the real scale-up process, aiming at 60 cm by 120 cm modules, in two to three years time. In parallel with the product development work, more basic research has been conducted in order to improve the understanding of the thin-film solar cells. After the end of Ångström Solar Center, the group continues research with renewed focus on understanding of the material and next generation cell and module structures, e.g. Cd-free CIGS-based solar cells.

The second PV group in Ångström Solar Center is also continuing its research on dye sensitized solar cells, but at the Royal Institute of Technology in Stockholm instead of Uppsala University. Even though the group's focus in Ångström Solar Center has been directed towards industrial production, the dye sensitized cell technology is quite young and, therefore, more basic research has also been conducted in order to improve the understanding of the processes that take place in the cells. Research on dye sensitized solar cells has also been carried out at IVF in Gothenburg. These two research groups will work more closely together from the 1 January 2005.

Following the increased interest in PV in Sweden, accompanying the new market deployment initiative, more research institutions have carried out studies within the field. In Gothenburg, at the Chalmers University of Technology, Professor Staffan Jacobsson and co-workers have been evaluating effects of market deployment initiatives in different countries. This work was started when the Swedish government commissioned a report from the Swedish Energy Agency on the feasibility of market support for PV in Sweden, in early 2004.

Systems aspects of PV have been studied at the University of Lund, at the Division of Energy and Building Design, where aspects of integration of PV into the built environment is studied. The Division of Energy and Building Design also teaches a number of courses on PV, for undergraduate students and for stakeholders in the building industry interested in the possibilities of PV in general and the market deployment initiative for public buildings in particular.

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

The greatest part of the public budgets for PV in Sweden has been dedicated to research and development, mainly through the research programme Ångström Solar Center. This was also true for the year 2004, since the market deployment initiative was announced but not implemented during that year.

Budgets for PV research

The general Swedish energy research programme, which is managed by the Swedish Energy Agency, was renewed in a government bill in the autumn of 2004, with substantially reduced funding for the period from 2005 through 2011. The cut, by more than 40 % compared to the previous period, may influence the funding for PV research, as the competition for funding increases.

Through 2004, the majority of the PV research funding has been allocated to the two PV groups at Ångström Solar Center, while some public funding also has been routed through the National PV R & D Programme, SolEl 03-07, which is co-funded by stakeholders in the industry. While the groups at Ångström Solar Center conduct more basic, device oriented research, SolEl 03-07 is oriented towards systems aspects, as well as gathering and disseminating of information.

The research programme Ångström Solar Center, which has been running in two stages since 1996, ended in the beginning of 2005. Future funding to the research groups is not secured in the long term, but in the autumn of 2004 funding for the year 2005 was allocated by the Swedish Energy Agency, as a link between the old Ångström Solar Center programme and future PV research funding.

Public funding has also been awarded the company Solibro AB, which is an offshoot from the thin-film research group at Ångström Solar Center. The company is funded by a number of investors, such as major electricity companies and venture capital funds, while the Swedish Energy Agency contributes to the technological development in the start-up phase of the company.

A number of new projects were launched late in 2004, with focus on industry development. The Swedish Energy Agency has allocated funds for the development of the PV industry in the area of Gällivare, where two of the four module manufacturing companies are located. Funds are also allocated to a project called Ekosol, which aims at developing standards for building integrated PV in small domestic houses, with connection to the grid.

Budgets for market stimulation

Previously, there has been no market deployment initiatives for PV power systems in Sweden, but the small, stable market has been sustained by the off-grid domestic sector. As stated previously, most PV systems in Sweden is utilized to provide electricity in remote areas, especially for summer homes. However, in the spring of 2004 the government and its supporting parties unveiled plans to implement a tax reduction scheme for renewable energy and energy savings initiatives in public buildings. In this comprehensive package there was a

special initiative for PV, for which a 70 % reduction of the investment cost was planned (compared to 30 % for the other measures).

This market deployment initiative was accepted as a part of a government bill in the autumn of 2004, with some alterations. For PV, the most important change was that the time available for the projects considered was extended so that the scheme was set to start 1 January 2005 and the projects would have to be finished by the 31 December 2007. The launch was subsequently delayed until May 2005. In the three years, a maximum of 100 MSEK was allocated specifically for PV. This amount would, if the programme is fully subscribed to, correspond to an increase of the cumulative installed PV capacity in Sweden by more than 70 %.

Budgets for demonstration / field test programmes

The project PV Nord, a programme with the aim to explore the possibilities for grid-connected building integrated PV in northern Europe, was concluded in the end of 2004. The programme, co-financed by the EU and the Swedish Energy Agency with the construction company NCC as co-ordinating partner, was involved in the planning and execution of eight projects in Norway, Sweden, Finland, Denmark and The Netherlands. The two projects described in section 2.3, in Hammarby Sjöstad, were realized within this framework. The key issues studied were: *Aesthetics and PV integration*, *Power and electricity*, *Environment*, *Management and IT*, and *Financing and ownership*.

There have been no major funding allocated from public money directly to demonstration programmes that have been realized in 2004. Some funds, channelled through the national Solar Electricity R & D programme, SolEl 03-07, have been provided for feasibility studies for major projects in the future.

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

	R & D	Demo/Field test	Market
National/federal	23	1	-
State/regional	-	-	-
Total	23	1	-

3 Industry and growth

3.1 Production of feedstocks, ingots and wafers

Following the rapid expansion of the PV market, globally, several module manufacturing companies have been established in Sweden, but there is no production of feedstock, ingots or wafers.

3.2 Production of photovoltaic cells and modules

Gällivare Photovoltaic AB

As mentioned in the previous section, there are several module manufacturing companies in Sweden. One of these companies, *Gällivare Photovoltaic AB* (GPV), has been an established player on the Nordic PV scene since the early 1990-ies.

The company is a fully owned subsidiary of the major German PV company *Solarworld AG*, and is part of Solarworld's vertically integrated structure. The company primarily buys cells from its sister company *Deutsche cell*, and most of the company's produce is also exported to the German market. GPV is situated in Gällivare, in the very north of Sweden, which has become the centre of Swedish PV manufacturing during the past decade. The company has been accredited with ISO 9001 and ISO 14001 certification and the modules are tested and type qualified by *TÜV Rheinland*.

Since 2003, GPV has got a very modern, automated, assembly line, but has retained two manual lines where made-to-order modules can be manufactured. During the year 2004, GPV expanded its operations, increasing the number of employees from 30 in the beginning of the year to 50 at the end. The expansion is set to continue, but scarce supply of cells may inhibit the growth. There has been some difficulties obtaining enough cells during 2004, constricting the production.

ArcticSolar AB

The second PV company in Sweden was established in 2001, also in Gällivare, and is called *Arcticsolar AB*. Owned by *NAPS systems Oy* of Finland, *Alfasolar Vertreibsgesellschaft mbH* of Germany and by the managing director, the company has gone through rapid expansion since the start, and in the summer of 2004 a second production line was introduced and the number of employees was doubled. New machinery was also installed. The expansion is set to continue through 2005, although ArcticSolar, like GPV, have experienced difficulties obtaining cells from the market. Arcticsolar exports all of the modules they produce, and they are sold under the trade names of NAPS and Alfasolar. Some of the modules are re-imported to Sweden through the sales organization of NAPS.

Scanmodule AB

In the past few years, two more module manufacturing plants have been established, one in the region of Värmland, close to the Norwegian border, and the other one in Blekinge, in the southeast. The company in Värmland is called *Scanmodule AB* and is a fully owned subsidiary of the Norwegian *Renewable Energy Corporation AS* (REC).

The company was established in 2003 and is, like *GPV*, part of a vertically integrated corporation. REC owns several companies, whose activities range from manufacturing solar grade silicon (*Solar Grade Silicon LLC*), to module production (Scanmodule) and installation of modules (*SolEnergy*).

The cells in the modules produced at Scanmodule are primarily sourced from the sister company *Scancell* in Norway, and all of the finished modules are exported, predominantly to the German market. The processes are highly automated, and during 2004 investments were

made with the aim to increase the production capacity. These investments are planned to continue in 2005.

PV Enterprise Sweden AB

The second quite recently established company is called *PV Enterprise Sweden AB*, and was started by a veteran in the Swedish PV business, Peter Johnson, who started GPV in 1992. The company is located in the southeast region of Blekinge, and has, like the other PV module manufacturers, expanded rapidly during the past few years, catering primarily for the European market. During 2004, PV Enterprise has extended its production facilities to include operations in Poland.

General trends

The most striking trend in the module manufacturing business in Sweden is that several manufacturers report that they have some trouble sourcing enough cells for the modules they potentially could produce. This is not a specific Swedish problem, but the industry in the rest of the World has also been influenced by this dilemma.

Other trends that have been reported on are that the cells are becoming larger and thinner, and that the modules are also becoming larger, while the prices are continuously decreased. The quantities produced by the Swedish module manufacturers, and their maximum production capacity, are given in Table 4.

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

Cell/Module manufacturer	Technology (sc-Si, mc-Si, a-Si, CdTe)	Total Production (MW)			Maximum production capacity (MW/yr)		
		Cell	Module	Concentrators	Cell	Module	Concentrators
1 GPV	mc-Si	***0***	***8,7***	***0***	***0***	***12***	***0***
2 GPV	sc-Si	***0***	***2,2***	***0***	***0***	***12***	***0***
3 Arcticsolar	mc-Si	***0***	***6***	***0***	***0***	***15***	***0***
4 Scamodule	mc-Si	***0***	***5***	***0***	***0***	***5***	***0***
5 PV Enterprise	mc-Si	***0***	***4***	***0***	***0***	***8***	***0***
TOTALS		**0**	**25,9**	**0**	**0**	***52***	**0**

In Table 4a, the trends in module prices for modules produced in Sweden are given. The price given for large orders represents a price that could be negotiated when buying large volumes, while the 'Single modules' price is what a typical Swedish customer pays for the modules in a small off-grid system.

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

Year		2002	2003	2004
Module prices:	Large orders	30	26	26
	Single modules	75	70	70

3.3 Manufacturers and suppliers of other components

Today, there are no manufacturers of balance-of-system components in Sweden that concentrate specifically on the PV market. However, the company ABB has shown interest in the PV market, and they are planning a grid-connected system at their development facility in Västerås, with the aim to study grid-connection issues.

There is a small company called Cellux AB, working with public lighting based on off-grid PV in an innovative way. Their system consists of a lamp with white diodes, for low energy consumption, and with two lighting modes. In the low lighting mode the consumption is only 0,25 W. When a vehicle or a person approaches the lamp, the high lighting mode is activated, and a signal is sent to the next lamp (along a road, for instance), which is also turned on. When no movement is detected, the lamps are returned to low lighting mode, providing only scant illumination.

3.4 System prices

With the limited market in Sweden (i.e. the off-grid domestic market), the reduction of system prices has not been as forceful as in some parts of the world, notably Japan and Germany. However, the prices have gone down, due to the global decrease in prices. In the grid-connected market, there is really no trend in prices, as the market consists of one-off projects. Rather, it is a row of specific examples. The prices during 2004 for some typical applications / specific cases are given in Table 5.

Table 5: Turnkey Prices of Typical Applications

Category/Size	Typical applications	Current prices SEK/W
OFF-GRID Up to 1 kW	Remote electrification, domestic or professional	90 - 100
OFF-GRID >1 kW	n/a	n/a
GRID-CONNECTED Specific case	Case: Roof installation at *Lysande* in *Hammarby Sjöstad* (*not including installation*)	40
GRID-CONNECTED Up to 10 kW	Typical roof-mounted system (*not including installation*)	55
GRID-CONNECTED >10 kW	n/a	n/a

In Table 5a, the trend in prices for the largest market segment (off-grid non-domestic) is given. These prices are given as intervals for the typical price that year.

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

YEAR	2000	2001	2002	2003	2004
Price /W:	**110-150**	**100-140**	**100-130**	**90-110**	**90-110**

3.5 Labour places

In line with the expansion of the PV module manufacturing industry in Sweden, during the past few years, the numbers of employees in the PV industry has increased substantially. At

Arcticsolar the number of staff doubled when an extra assembly line was introduced in the summer of 2004, while at GPV the number of staff increased by 70 %.

The number of people working with PV in Sweden is dominated by the module manufacturing industry, while the number people employed in R & D and the installation companies is quite constant.

In total 199 people are employed in Sweden with PV activities in 2004, 170 of which were working at the PV module manufacturing companies. 18 people worked with PV research and development, while 11 people fell into the category “others”, which includes installation, utility companies, the government, consultants etcetera.

3.6 Business value

The photovoltaic business in Sweden can be divided into two parts, the manufacture of PV modules, and the retail and installation of modules. For the production of modules, all of the module manufacture companies import cells, in some cases from their sister companies. The cells are assembled into modules, and the modules are laminated. In some cases the modules are exported without a frame, and in other cases the frame is also assembled in the module manufacturing plant. The vast majority of the modules are exported, predominantly in order to cater for the rising demand of the German market, while only a small fraction is actually sold in Sweden.

As for the retail/installation part of the business, the dominant application for PV in Sweden is, as mentioned in earlier sections, small scale off-grid, mostly for domestic use. There are two major companies, NAPS and Sunwind, who import modules and sell them through various agents. A lot of modules are sold at retail outlets, as kits for remote cabins, boats, and so on. There are also a number of small independent retail companies who import their modules directly. Some of the modules manufactured in Sweden are sold through these distribution channels.

The value of business is estimaterd in Table 6. *N.B. in the calculations in Table 6 typical values have been used for cell and module costs, together with information from module manufacturers and retailers/installers. This means that the value of business should be seen as an indicative figure, and not as an absolute truth.*

Table 6: Value of PV business

Sub-market	Capacity installed *in 2004* (kW)	Price per W *(from table 5)*	Value (MSEK)	Totals (MSEK)
Off-grid domestic	*256*	*95*	*24*	
Off-grid non-domestic	*29*	95	*3*	
Grid-connected distributed	-	-	-	
Grid-connected centralized	-	-	-	
				27
Export of PV products				*673*
Change in stocks held				*n/a*
Import of PV products				*532*
Value of PV business				***168***

4 Framework for deployment (Non-technical factors)

4.1 New initiatives

For PV in Sweden, 2004 was a historic year, since it saw the conception of the first market deployment initiative in the business. The initiative is directed towards larger scale projects with PV in public buildings, and is part of a major tax rebate programme for energy efficient refurbishments. In total the budget for the programme is 2 GSEK, while the maximum total budget for the PV part of the programme is 100 MSEK. The general subsidy is 30 % of the refurbishment cost, but for PV the subsidy has been increased to 70 %. With a fully subscribed programme, the initiative will provide a major boost for the PV market, increasing the cumulative installed PV power in Sweden by more than 70 %.

When the initiative was first announced in a government bill in the spring of 2004, it was set to run for eighteen months from the 1 January 2005. Several stakeholders voiced their concern, that the eighteen months time frame would be too short for the programme to be successful, since it may be difficult to increase the pace of the PV market so fast. When the final bill was accepted by the parliament, in the autumn of 2004, an extension had been added, so that the PV installations in the programme has to be finished by the 31 December 2007.

Since the final decision about the initiative came late in the year 2004, the final details were not worked out before the nominal start date, 1 January 2005. This means that the initiative could not be implemented until the spring of 2005. More specifically the initiative will be open for all installations on public buildings commissioned after the 15 May 2005.

In early 2004, the Swedish government commissioned a report on subsidy systems for PV from the Swedish Energy Agency, which was published in June 2004. This report detailed the various subsidy systems around the world, and the possible implications if these were to be

implemented in Sweden. The conclusion of the report was that the best system for Sweden would be a system similar to the German one with feed-in tariffs. In the near term a demonstration programme was also recommended as a complement to the tax reduction scheme detailed above.

Utility and public perception of PV

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

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

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

In a recent survey (J. Dyrkell, *A local model for the expansion of solar cell use in the Gothenburg area*, 2004, Chalmers Technical University) the attitude of customers towards solar electricity as an option in their electricity mix was examined. The conclusions were that the 1000 customers with special environmental interests, who were surveyed, were willing to buy solar electricity corresponding to an installation of 200 kW at a market price. However, in Sweden there is no possibility for a private customer to buy solar electricity yet.

4.2 Indirect policy issues

Electricity certificates

In May 2003, a new scheme for the promotion of renewable energy sources was launched. This scheme is based on a guaranteed market through electricity certificates. For every MWh of renewable electricity energy that an electricity generator produces, the owner receives one certificate. The consumer is then required to buy certificates in proportion to the amount of energy they consume. When a private consumer buys electricity from an electricity company, their certificates are generally handled by the electricity company.

In 2004 the consumers were required to buy certificates amounting to 8,1 % of the consumption, i.e. for every MWh consumed, 0,081 electricity certificates would have to be bought. In the coming years, the mandatory quota will be increased incrementally according to a programme that runs to 2010. In a review of the system during 2004, it was concluded that

the quotas will be raised in the future, compared to the initial plan, in order to increase the impact of the system on renewable energy production.

In the first year of operations, many companies have chosen to pay a fee instead of buying certificates, which leads to less incentives for renewable electric energy production. This fee is set to 150 % of the weighted average of the certificate price over the year. Initially there has been a cap on how high this fee can be, but this cap will be lifted, with the aim to increase the impetus for the companies to buy certificates.

The downside of the certificate scheme, as far as PV is concerned, is that a multitude of renewable energy techniques are treated in the same way. This will most likely lead to an expansion of the cheapest type of renewable energy production, while others are not significantly influenced. So far, only one installation with 8 kW of PV has been accredited in the system, while the majority of the 4,5 MW total power is represented by bio fuels.

There is also an issue with the fairly short horizon of the certificate scheme. As it is, the electricity certificates scheme will run through 2010, which is a quite short period of time considering the level of investments that is required for a producer to start renewable electric energy production. This issue has also been raised in the review of the system during 2004.

Taxes

The energy tax on electricity has been steadily increased since the beginning of the 1980-ies, continuing with a 5 % increase as of the 1 January 2005. There are also several taxes levied on the discharge of hazardous substances, such as carbon dioxide, sulphur and nitrous oxides. The carbon dioxide tax was increased by 20 % in the beginning of 2004 to a level of 0,91 SEK/kg of CO_2. This tax is levied on oil, coal, natural gas, kerosene, LPG and petrol, and the reason for raising it substantially more than the energy tax is to provide incentives for CO_2 emissions reduction. However, fuels used for electricity production, rail road and air traffic as well as shipping is freed from this tax. Agricultural businesses also have a general tax relief.

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

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

Since 1998 the Swedish International Development Cooperation Agency, SIDA, has been working with rural electrification in Zambia. The aim of the project is to provide electricity to parts of the country where there is no electric grid. In these parts the main supply of energy has traditionally come from kerosene and batteries. The result of the project is that a number of so-called ESCOs (Energy Service Companies) have been established. In 2004 over 400 solar home systems had been installed in this programme.

SIDA has also supported a project in Uganda, providing securities for investments in PV powered cellular phones. This project, managed by the South African telephone company MTN and supported by SIDA, has provided thousands of Ugandans with access to telephone service.

4.3 Standards and codes

There are no specific standards or codes for the connection of PV power systems to the national grid, but the general regulations for electric power installations should be followed as far as possible. If the system voltage of the PV array is higher that 120 V d.c. a fence is required around the modules. The Swedish regulations allow the d.c. part of the system to be ungrounded if the system voltage is lower than 250 V. Electricity delivered to the grid has to follow the European standard EN 50.006 (with the Swedish equivalent SS 421 18 11). Other standards that have to be followed include: ELSÄK-FS 2004:1 (electrical health and safety instructions from *The Swedish National Electrical Safety Board*), SS 436 40 00 (electric installation regulations) and SS 437 01 40 (low voltage installation standards).

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

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

In a project carried out by the company ABB with funding from SolEl 03-07, the possibility of connecting a small PV array to the grid in order to sell electric energy was examined. The conclusion was that since this type of installation is very rare in Sweden, there are substantial extra costs. For each installation a fixed fee is paid to the utility company for measurements of and reporting on the production of electric energy. This fee is so high today, that for a 3 kW system the cost per produced kWh is higher than the electricity retail price, making it impossible to profit from a smaller grid-connected system, even if the system price were zero. This problem may be resolved if this type of installation becomes more common, and if the retail price for PV electric energy is increased through a feed-in tariff or a solar exchange.

Building permits

Small PV-arrays for domestic use do not require a building permit, while larger installations do. In general, there have been no problems acquiring building permits for the larger PV systems that have been installed, but on some occasion concerns have been voiced about reflections off of PV arrays disturbing traffic. Some difficulties with the building permit were encountered for one of the PV systems in the Hammarby Sjöstad area, while at the same time, the municipality of Stockholm awarded the building a prize for the inclusion of PV in the design.

5 Highlights and prospects

The most important developments in PV in Sweden 2004 were the increase in module manufacturing and the conception of the market deployment initiative for public buildings. In the four module manufacturing plants in Sweden the number of employees increased by approximately 50 people, which corresponds to a 30 % increase in the number of people employed in the PV business in Sweden. Meanwhile the output from the module manufacturers doubled reaching 26 MW.

The market deployment initiative that was incorporated in the government bill concerning energy efficient refurbishment of public buildings is quite extensive by Swedish standards. If all the funds allocated to PV installations are used (100 MSEK over three years), the cumulative installed power in Sweden would increase by more than 70 %. This is quite an ambitious target, and may play an important role in forming a more active market for PV, nationally.

Furthermore the Swedish Energy Agency recommended, in a report to the Government in June 2004, that a second deployment initiative be implemented, directed at private consumers. In the report, the potential influences of different subsidy systems were evaluated, and a feed-in law, much like the one in Germany, was recommended.

Annex A Method and accuracy of data

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

The numbers on the amount of modules produced in Sweden, are obtained using similar surveying methods, but with the difference that there are only four manufacturers to take into account. These numbers are estimated to be well within a margin of error of ±10 %.

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

Annex B Country information

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

i) The retail price for electricity for a typical household customer, with a yearly consumption of 20 000 kWh, was 1,20 SEK during 2004. This includes energy price, distribution fees, energy tax, electricity certificates and value added tax. (From the report *Energimarknad 2004* from the Swedish Energy Agency)

For industrial customers, the average retail price during 2004 was approximately 0,70 SEK/kWh, including the electricity price, distribution fees and energy tax, but no VAT. The difference between industrial and domestic customers does not lie in the electricity price, but in the energy tax and 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 17 300 kWh, which is high in an international comparison, due to high penetration of electric heating and a large electric-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. The tariff consists of electricity cost, distribution fees, energy tax, fees for electricity certificates and VAT.

For industrial customers, time-of-use tariffs are common.

iv) The average household income is 288 000 SEK, while the median household income is 360 000 SEK (from Statistics Sweden)

v) The typical mortgage interest rate for private customers, with a solid security like real estate property, is 3,6 % (adjustable-rate mortgage). The fixed-rate mortgage rates, with similar securities, vary roughly from 2,80 % (1 year) to 4,60 % (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.

Some companies are vertically integrated, with generation, distribution and retail operations. There are three large companies like this, dominating the market; *Fortum AB*, *Sydkraft AB* and the state-owned *Vattenfall AB*. There are also a number of smaller generation companies with retail operations, some with and some without a distribution network. There is a Nordic electric energy exchange, Nord Pool, where also some actors from Germany and Poland take part.

viii) The diesel fuel price in Sweden is typically 10 SEK/l, of which roughly 5,50 SEK is made up of taxes.

ix) The typical yield from a PV system is 600 to 800 kWh/kW with some examples of yields above 800 kWh/kW. (These numbers were extracted from data on energy production obtained from installations primarily in the Stockholm area.)