IEA INTERNATIONAL ENERGY AGENCY

Swedish Energy Agency

National Survey Report of PV Power Applications in SWEDEN

2014

PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

Prepared by

Johan Lindahl, Uppsala University

TABLE OF CONTENTS

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 member countries

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 participating countries and organisations can be found on the www.iea-pvps.org website.

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 promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation. 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 country National Survey Report for the year 2014. 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 INSTALLATION DATA

The PV power system market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W_p or more. A PV system consists of modules, inverters, batteries and all installation and control components for modules, inverters and batteries. Other applications such as small mobile devices are not considered in this report.

For the purposes of this report, PV installations are included in the 2014 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2014, although commissioning may have taken place at a later date.

1.1 Applications for Photovoltaics

Historically, the Swedish PV market has almost only consisted of a small but stable off-grid market where systems for holiday cottages, marine applications and caravans have constituted the majority. This domestic off-grid market is still stable and is growing slightly. Since 2007 more grid-connected capacity than off-grid capacity has been installed annually and Sweden now has seven 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 relatively small systems of up to 1 MW_p can be seen as centralized systems.

1.2 Total photovoltaic power installed

The installation rate of PV continues to increase in Sweden. A total of 36.2 MW_p were installed under 2014, which is almost twice as much as the 19.1 MW_p installed under 2013. This means that the Swedish PV market doubled for the fourth year in a row. Sweden has a stable off-grid PV market, which goes back many years. Both in 2013 and 2014 1.1 MW_p were sold, and in total 9.5 MW_p of off-grid systems have been sold in Sweden. In recent years, the market for grid-connected PV systems has grown rapidly. Private persons and companies contributed to doubling the overall grid connected PV capacity in Sweden in 2014 when 35.1 MW_p were installed. At the end of 2014 the sold cumulative grid connected capacity was 69.9 MW_p. Summing up the off-grid and grid connected PV capacities one ends up at a total of 79.4 MW_p of PV that has been sold in Sweden until the end of 2014. This capacity is annually producing an estimated 75 GWh per year, which represents roughly 0.06 % of Sweden's total electricity consumption. The strong growth in recent years is mainly due to falling system prices and a growing interest in PV in Sweden.

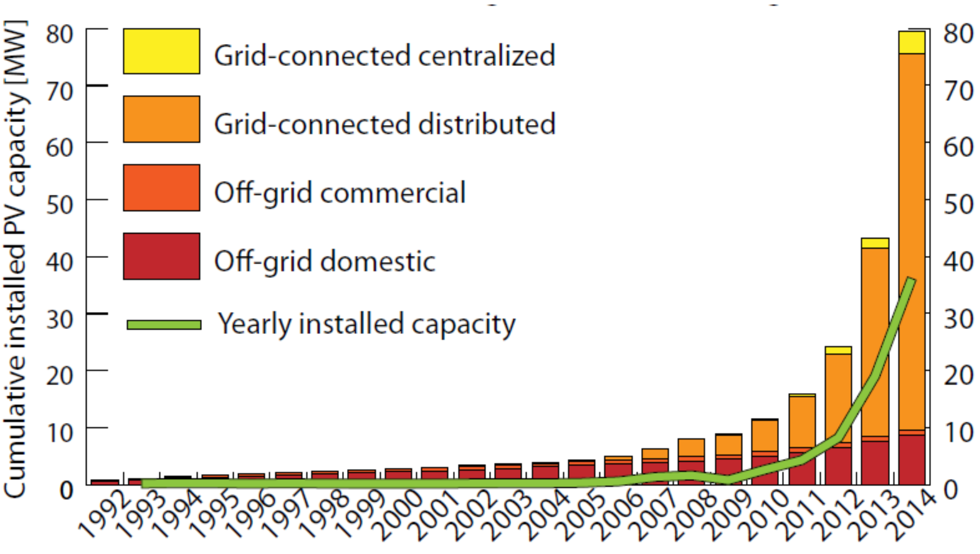

Figure 1: The cumulative installed PV power in Sweden in 4 sub-markets and the yearly installed capacity.

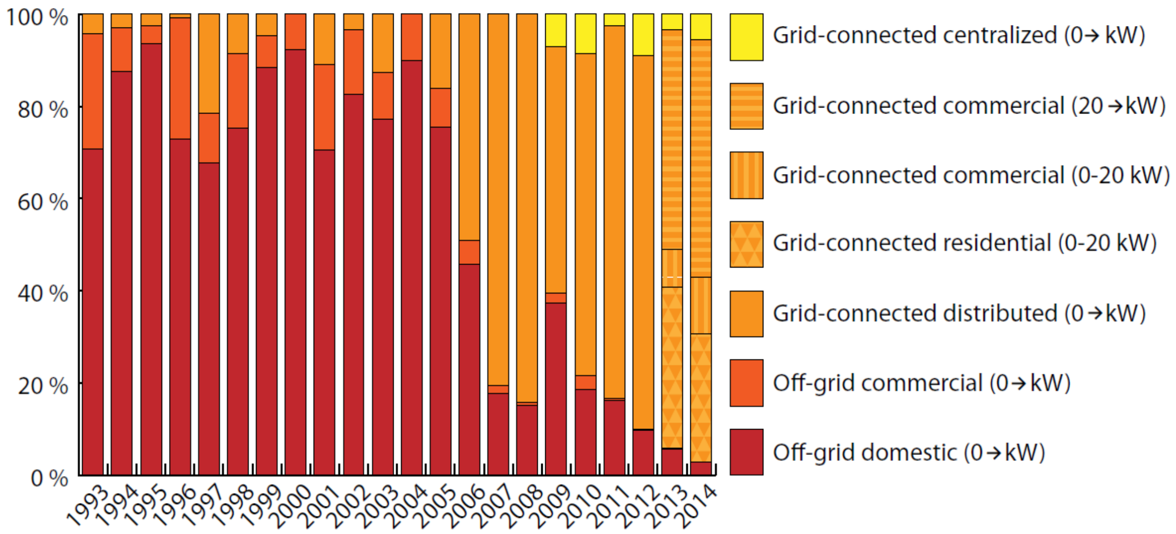

Figure 2: The Swedish PV market divided into market segments

All of the gathered data used in this report comes directly from company representatives, and are sales data. It is usually not a problem to acquire data from the installers and retailers of PV systems, but the quality and exactness of the data from different companies varies. Most companies provided very accurate data while a few only provided estimations. Furthermore, some unrecorded installations have probably been carried out that fall outside this report. The accuracy of the data for annual installed power is therefore estimated by the author to be within ± 10 %.

The numbers for the cumulative installed capacity in Sweden are more uncertain. There are in the current situation, no practical way to estimate how many systems that have been decommissioned. The Swedish PV market is still very young and a majority of the systems have been installed during the last 5 years. Since a PV system typically has a lifetime of at least 25 years, the number of decommissioned systems is probably very low. However, to be correct, the numbers for the cumulative installed PV capacity should be seen as the total PV power installed over the years rather than the total PV capacity in place and running today.

Table 1: PV power installed during calendar year 2014

			MW_p installed in 2014	MW_p installed in 2014	AC or DC
Grid-connected	BAPV	Residential	31.68	9.61	DC
		Commercial		22.07	DC
		Industrial		Included in commercial	DC
	BIPV	Residential	0.72	0.44	DC
		Commercial		0.28	DC
		Industrial		0	DC
	Ground-mounted	cSi and TF	2.75	2.75	DC
		CPV		0	DC
Off-grid		Residential	1.07	1.04	DC
		Other		0.03	DC
		Hybrid systems		unkown	DC
		Total	36.22		DC

Table 2: Data collection process.

If data are reported in AC, please mention a conversion coefficient to estimate DC installations.	Data is reported in DC
Is the collection process done by an official body or a private company/Association?	It is done by the author on behalf of the Swedish Energy Agency
Link to official statistics (if this exists)	This report
The accuracy estimated by the author	within ± 10 %

The electricity production in Sweden is dominated by hydropower, 42.5 % of total electricity generation in Sweden in 2014, and nuclear power, 41.1 %. Wind turbines have been built at an accelerated rate in recent years and electricity from wind power accounted for 7.6 % of the total electricity generation in Sweden in 2013. The rest, 8.8 %, is CHP. The total electricity generation in Sweden was 151.2 TWh in 2014 of which 135.6 TWh was consumed in Sweden[1].

[1] Elåret 2014, Svensk Energi

Table 3: PV power and the broader national energy market[2]

	2014 Numbers	2013 Numbers
Total power generation capacities (all technologies)	39 549 MW_p	38 273 MW_p
Total power generation capacities (renewables including hydropower)	25 155 MW_p	24 107 MW_p
Total electricity demand (consumption)	135.6 TWh	139.2 TWh
New power generation capacities installed during the year (all technologies)	1 470 MW_p	1 034 MW_p
New power generation capacities installed during the year (renewables including hydropower)	1 048 MW_p*	753 MW_p*
Total PV electricity production in GWh-TWh	~66 GWh	~38 GWh
Total PV electricity production as a % of total electricity consumption	0.06 %	0.03 %

*Net increase of renewable power generation capacities.

Table 4: Other information

	2014 Numbers
Number of PV systems in operation in your country	Unknown
Capacity of decommissioned PV systems during the year in MW_p	Unknown
Total capacity connected to the low voltage distribution grid in MW_p	Unknown
Total capacity connected to the medium voltage distribution grid in MW_p	Unknown
Total capacity connected to the high voltage transmission grid in MW_p	Unknown

[2] Elåret 2014, Svensk Energi.

Table 5: The cumulative installed PV power in 4 sub-markets

Year	Off-grid domestic	Off-grid non-domestic	Grid-connected distributed	Grid-connected centralized	Total
1992	0.59	0.21	0.01	0	0.80
1993	0.76	0.27	0.02	0	1.04
1994	1.02	0.29	0.02	0	1.34
1995	1.29	0.30	0.03	0	1.62
1996	1.45	0.36	0.03	0	1.85
1997	1.64	0.39	0.09	0	2.13
1998	1.82	0.43	0.11	0	2.37
1999	2.01	0.45	0.12	0	2.58
2000	2.22	0.47	0.12	0	2.81
2001	2.38	0.51	0.15	0	3.03
2002	2.60	0.54	0.16	0	3.30
2003	2.81	0.57	0.19	0	3.58
2004	3.07	0.60	0.19	0	3.87
2005	3.35	0.63	0.25	0	4.24
2006	3.63	0.67	0.56	0	4.85
2007	3.88	0.69	1.68	0	6.24
2008	4.13	0.70	3.08	0	7.91
2009	4.45	0.72	3.54	0.06	8.76
2010	4.95	0.80	5.41	0.29	11.45
2011	5.66	0.82	8.93	0.40	15.80
2012	6.47	0.83	15.65	1.14	24.08
2013	7.54	0.86	32.99	1.79	43.18
2014	8.58	0.89	66.14	3.79	79.40

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

The domestic production of modules was 34 MW_p in 2014, but only about 2 MW_p of these went to the Swedish market. So the majority of the production is exported and a majority of the installations are done with imported modules, mainly from China and Germany. Module prices in Sweden are therefore heavily dependent on the international module market and actions. Actions such as the European Commission's anti-dumping duties on Chinese PV imports also affect the module prices in Sweden. Sweden has seen a very fast price decline on PV modules the last years due to a growing domestic market, which has allowed retailers to import larger quantities, and due to the overall price decline of modules on the international market.

Table 6: Typical module prices for a number of years – SEK/W_p

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Standard module prices:	70	70	70	65	63	61	50	27	19	14.2	9.7	8.15
Best price		-	-	-	-	-	-	-	-	-	-	-
PV module price for concentration		-	-	-	-	-	-	-	-	-	-	-

2.2 System prices

The prices for both individual modules and complete turnkey systems went down by about 1 SEK/W_p in 2014. Installation companies reported that typical prices for a turnkey residential systems has declined from an average of approximately 17 SEK/W_p (excluding VAT) in late 2013, to just over SEK 15/W_p by the end of 2014. For large commercial systems over 20 kW_p the average price was about 13 SEK/W_p at the end of 2014.

The biggest reason for that system prices in Sweden have gone down is that the prices for modules and balance of system (BoS) equipment has dropped in the international market. Another reason is that the Swedish market is growing, providing the installation firms a steadier flow of orders and an opportunity to streamline the installation process, thus reduce both labor and the cost margins. Competition in the market has also increased. In 2010 the author of this report was aware of 37 active companies that sold modules or photovoltaic systems in Sweden. In late 2014 the corresponding figure had gone up to 126.

The turnkey prices presented in table 7 and figure 3 are an average of what different installers considered to be their typical price at the end of 2014, and do not represent the overall pricing during 2014.

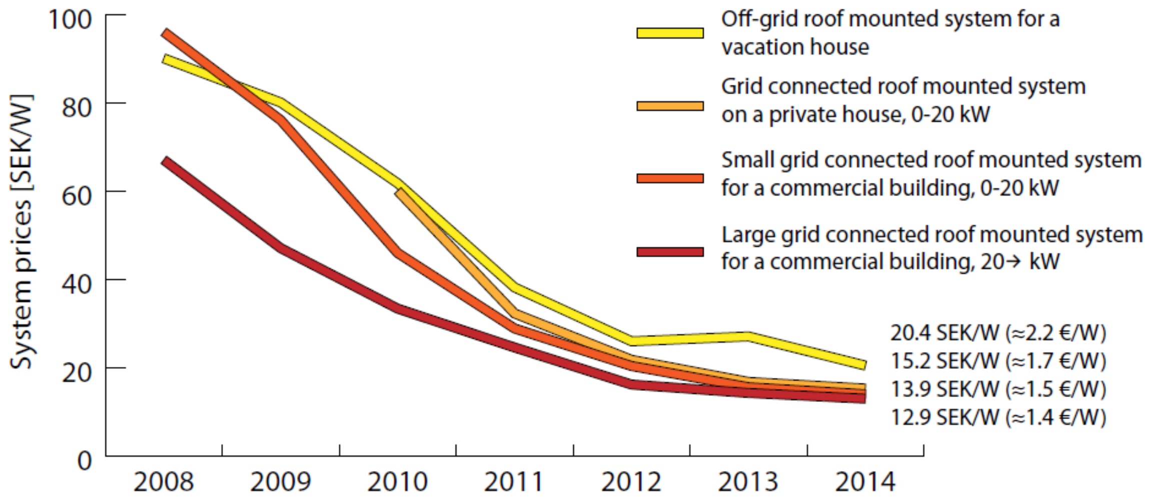

Figure 3: Average typical prices for turnkey photovoltaic systems (excluding VAT) reported by Swedish installation companies.

Table 7: Turnkey Prices of typical applications (excluding VAT) – SEK/W$_p$

Category/Size	Typical applications and brief details	Current prices
Off-grid, up to 1 kW$_p$	A stand-alone PV system is a system that is installed to generate electricity to a device or a household that is not connected to the power grid. Typically modules or systems for small cottages, caravans or boats.	25.0 SEK/W$_p$
Off-grid, >1 kW$_p$	A stand-alone PV system is a system that is installed to generate electricity to a device or a household that is not connected to the public grid. Typically systems in combination with batteries for small cottages and vacation houses.	20.4 SEK/W$_p$
Grid-connected, roof mounted, up to 20 kW$_p$ (residential)	Systems installed to produce electricity to grid-connected households. Typically roof mounted systems on villas and single-family homes.	15.2 SEK/W$_p$
Grid-connected, roof mounted, up to 20 kW$_p$ (commercial)	Systems installed to produce electricity to grid-connected commercial buildings, such as public buildings, agriculture barns, grocery stores etc.	13.9 SEK/W$_p$
Grid-connected, roof mounted, above 20 kW$_p$ (commercial)	Systems installed to produce electricity to grid-connected industrial buildings.	12.9 SEK/W$_p$
Grid-connected, ground-mounted above 1 MW$_p$	Power-generating PV systems that work as central power station. The electricity generated in this type of facility is not tied to a particular customer and the purpose is to produce electricity for sale.	13.7 SEK/W$_p$*
Other category existing in your country		N/A

*Only two parks of 1 MW$_p$ each has been built in Sweden, and this is the price for one of them.

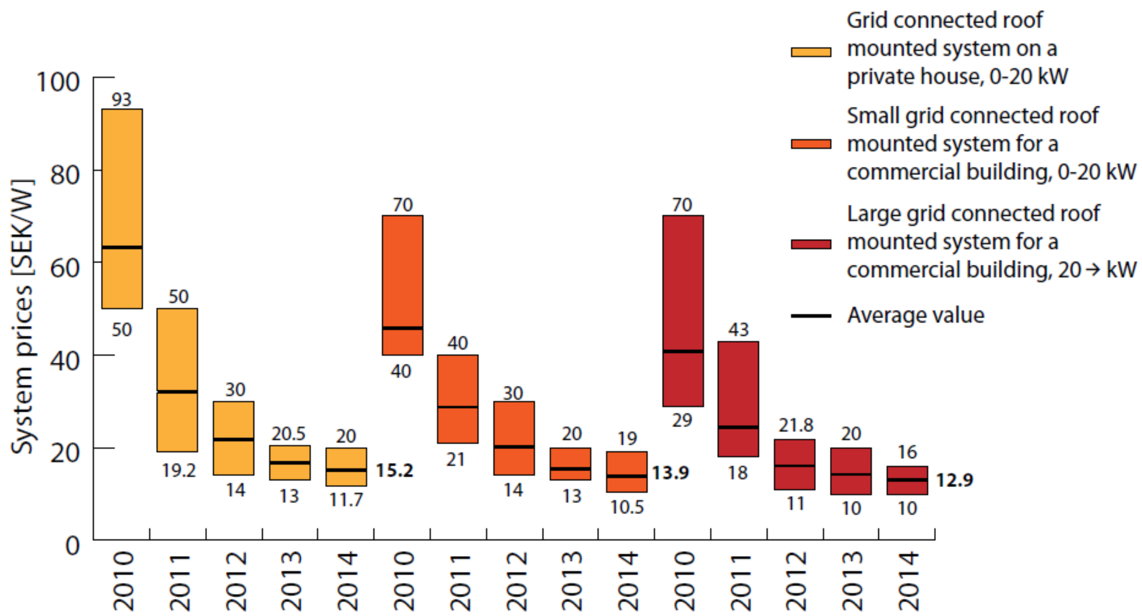

Figure 4: The price difference for typical turnkey PV systems between different Swedish installation companies (excluding VAT). Note that this is the prices that the companies regard as typical for them, and that the graph does not show the highest and lowest prices in Sweden.

Table 8: National trends in system prices for different applications (excluding VAT) – SEK/W$_p$

	2006	2007	2008	2009	2010	2011	2012	2013	2014
Off-grid, 0-1 kW$_p$	100	95	90	80	61.7	38.1	25.9	27	20.4
Residential PV systems < 10 kW$_p$	-	-	-	-	60	32.2	21.7	16.7	15.2
Commercial and industrial	60	60	67	47	33.3	24.5	16.1	14.2	12.9
Centralized Ground-mounted	-	-	-	-	-	-	-	-	13.9*

*Only two parks of 1 MW$_p$ each has been built in Sweden, and this is the price for one of them.

2.3 Cost breakdown of PV installations

The “average” category in table 9, which is summarized in figure 5, represents the average cost for each cost category and is the average of the typical cost structure reported by twelve Swedish installation companies. The average cost is taking the whole system in to account and summarizes the average end price to customer. The “low” and “high” categories are the lowest and highest cost that any of the companies reported that they could achieve within this segment. These costs should be seen as individual posts, i.e. summarizing these cost do not give an accurate system price.

The cost structure presented below is from the customer’s point of view. I.e. it does not reflect the installer companies overall costs and revenues.

On the question “In which segments do you expect the most likely cost reductions over the next five years?” nine companies expected cost reductions for hardware, mainly modules and inverters, two didn’t expect any major cost reductions at all and one company predicted the major cost reductions to occur in installation work.

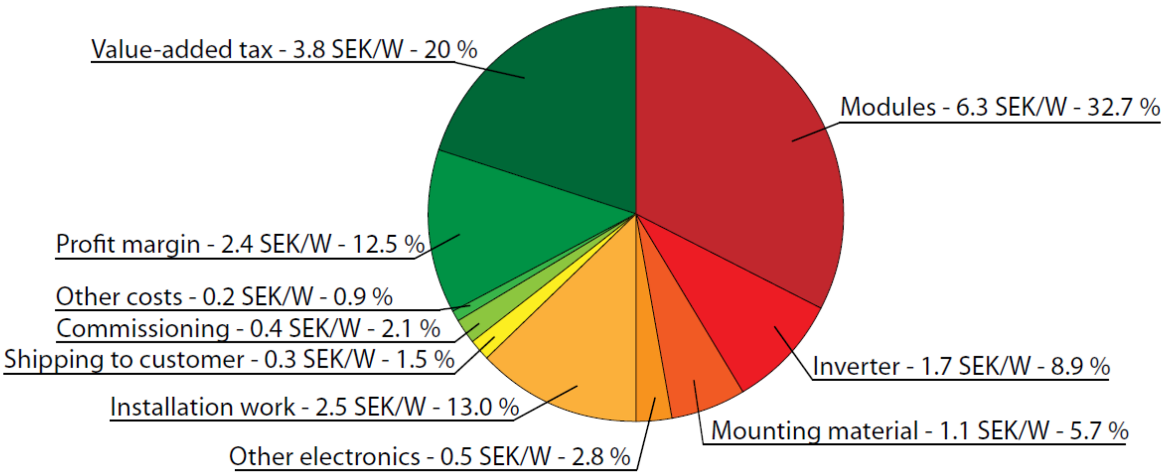

Figure 5: Average of twelve Swedish installation companies cost structures for a typical turnkey grid-connected roof-mounted residential PV system <10 kW$_p$ to the end costumer in the end of 2014.

Table 9: Cost breakdown for a residential PV system < 10 kW$_p$ – SEK/W

Cost category	Average (SEK/W$_p$)	Low (SEK/W$_p$)	High (SEK/W$_p$)
Hardware			
Module	6.26	4.90	14.00
Inverter	1.72	1.00	4.00
Mounting material	1.11	0.29	3.20
Other electronics (cables, etc.)	0.54	0.04	3.00
Subtotal Hardware	9.63		
Soft costs			
Installation work	2.48	1.00	6.40
Shipping and travel expenses to customer	0.29	0.00	1.83
Permits and commissioning (i.e. cost for electrician, etc.)	0.39	0.00	3.60
Other costs	0.17	0.00	1.00
Profit margin	2.42	0.30	6.74
Subtotal Soft costs	5.75		
Total (excluding VAT)	**15.38**		
Average VAT	3.85		
Total (including VAT)	**19.23**		

2.4 Financial Parameters and programs

The Swedish PV market is still quite small and there is therefore currently no standard way on calculating the return on a PV investment.

Table 10: PV financing paramters

Average cost of capital for a PV system	5-7 % companies 2-4 % private persons

2.4.1 Third-party-ownership and leasing schemes

In 2014 there was no company offering PV leasing contracts. However, in the beginning of 2015, the company Eneo Solution AB has secured financing and entered a cooperation agreement with the utility company Umeå Energi, which will now be able to offer solar leasing contracts to tenants, owners of commercial and public buildings.

2.4.2 PV financed by cooperatives

One interesting PV financing scheme that exists in Sweden is PV cooperatives. The high upfront cost of a PV system can be difficult to finance for a private person, and one way to get around this is to get together and form a cooperative.

In 2009 the first FiT agreement in Sweden was established between the local power utility company Sala-Heby Energi AB and a small PV cooperative, Solel i Sala & Heby ekonomiska förening. The power utility company agreed to buy all the electricity that the PV cooperative produced the first years at a price of 3.21 SEK/kWh. From 2014 this has changed and they now receive the Nord Pool spot price, which was 0.341 SEK/kWh in average in 2014. In 2014 the PV cooperative had in total six systems with a total production capacity of 599 kW_p. Each of the 226 members in the PV cooperative has bought at least one share for a price of 5 000 SEK. The initial profits for the PV cooperative 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 PV cooperative is slowly expanding with more members from all over the country.

Two more PV cooperatives were started in 2013, Åsbro Solel and Solel i Lindesberg ekonomisk förening. Åsbro Solel now has about 20 members and Solel i Lindesberg ekonomisk förening has 80 members. The shares cost is 5000 SEK each in both of the PV cooperatives, and both are planning to build their first system in the 2015.

2.5 Additional Country information

Sweden is a country in northern Europe. With an area of 447,435 km², Sweden is the fifth largest country in Europe and has a population of about 9.8 million people. The population density of Sweden is therefore low with about 22 inhabitants per km², but with a much higher density in the southern half of the country. About 85 percent of the population lives in urban areas, and that proportion is expected to increase.

2.5.1 Demand and electricity prices

In Sweden the physical electricity trading takes place on the Nordic electricity retailing market, Nord Pool Spot market. Historically, electricity prices in Sweden have primarily been dependent on the rainfall and snow melting. The availability of cheap hydro power in the north determines how much more expensive production that is needed to meet demand.

Continued global economic recession, stable production of nuclear power and the lack of longer periods of intense cold resulted in small differences in the monthly average electricity prices in 2014. The Nord pool spot prices decreased in 2014, mainly due to a temperature driven electricity consumption reduction, from 139 TWh in 2013 to 136 TWh in 2014. The average price on the entire

Nord Pool Spot market was 0.269 SEK/kWh in 2014, which is an 18 % decrease from the average price of 0.329 SEK/kWh in 2013. The highest spot price in Sweden in 2014 was 0.954 SEK/kWh and the lowest 0.005 SEK/kWh [3].

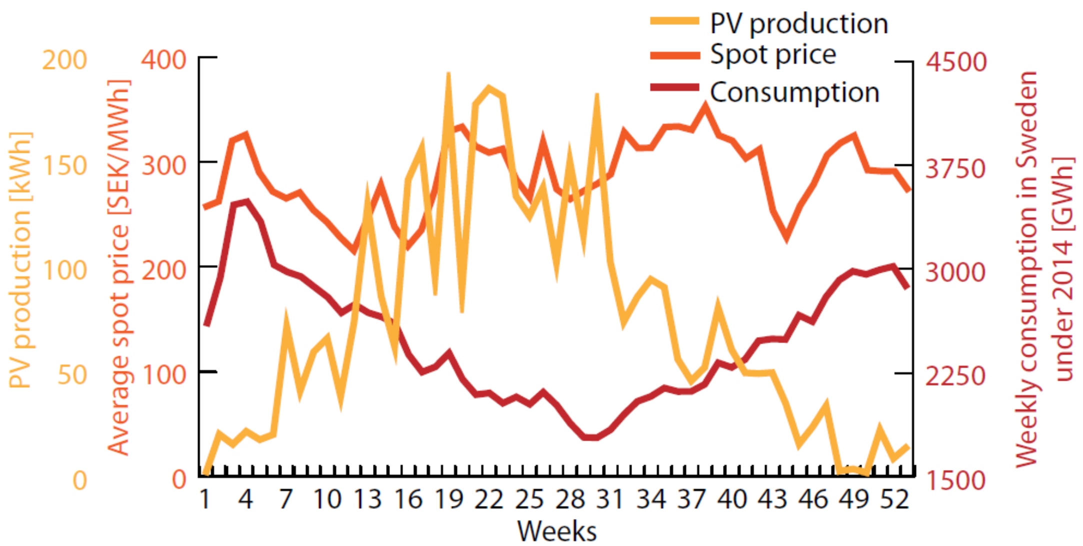

Figure 6: Weekly price on the Nord Pool spot market in electricity area SE3 in 2014[4], weekly electricity consumption in Sweden in 2014[5] and actual production from a 4 kW$_p$ PV system in 2013. The curve of the PV production would be smoother if all PV production in the whole country would be summarized. However, such statistics currently don't exist.

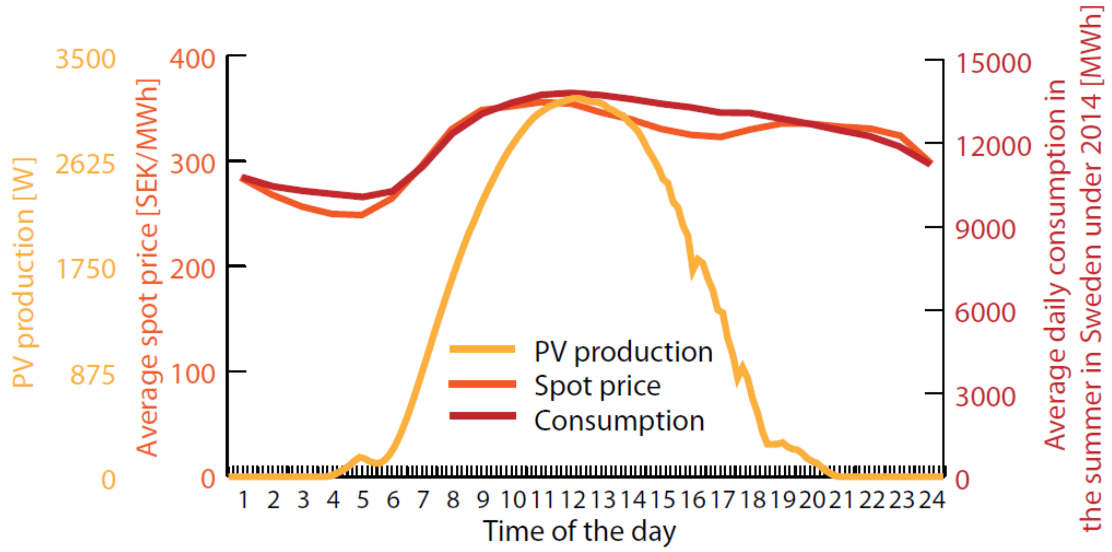

Figure 7: Average daily spot price between 1/6 and 31/8 on the Nord Pool spot market SE3 [4], average daily electricity consumption in Sweden between 1/6 and 31/18 [5] and real production from a 4 kW$_p$ system a sunny day in June.

In Sweden the electricity demand varies between seasons and the greatest demand is during the winter. So there is a seasonal mismatch between PV production and the highest electricity demand, as figure 6 illustrates. However, on a daily basis there is a good match between PV production,

[3] Elåret 2014, Svensk Energi
[4] Market data, Nord Pool Spot homepage
[5] Statistik elmarknad, Svenska Kraftnät's homepage

electricity demand and spot prices since both demand and spot prices are higher in the middle of the day, also in the summer, as figure 7 illustrates.

The Swedish electricity market is from the first of November 2011 divided into four bidding areas by decision of the Swedish National Grid (Svenska Kraftnät). The reason is that northern Sweden has a surplus of electricity production compared to the demand, while there is a higher 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 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 2014 for the different areas were 0.286 SEK/kWh in area 1 (Luleå), 0.286 SEK/kWh in area 2 (Sundsvall), 0.288 SEK/kWh in area 3 (Stockholm) and 0.290 SEK/kWh in area 4 (Malmö). The very small difference between the areas does not influence the distribution of PV systems over the country in the same extent as the population distribution and the global solar radiation does (see section 2.5.1.1).

The consumer price of electricity varies between different categories of clients, between urban and rural areas and depends on the variable distribution costs, differences in taxation, subsidies, government regulation and electricity market structure. Household electricity costs consist of several components. The base is the Nord Pool Spot price of electricity. On top of that, energy tax, the cost of green electricity certificate, the variable grid charge, the fixed grid charge, VAT and sometimes an electricity surcharge and fixed trading fee are added. Figure 8 illustrates the end consumer price and shows the evolution of the lowest variable electricity price deals offered by different utilities for a base case, which is a typical house with district heating in the Stockholm bidding area that has a consumption of 10 000 kWh/year and has Vattenfall as the grid owner. The figure also shows the variable part of the electricity price, which is what can be saved if the micro-producer replaces purchased electricity with self-generated PV electricity. Furthermore, the value of the surplus electricity is shown for two base cases with the Nord pool spot price as a base compensation offered by electricity trading utility companies (see section 7.2), energy compensation from the grid owner (see section 3.2.1.1), the newly introduced tax reduction system (see section 3.1.7.1) and with and without the green electricity certificate, since few PV owners is using the green electricity certificate system (see section 3.1.1.2). Note that the electricity price in figure 8 is the lowest achievable, and that most clients pay more. It is also worth noting that some utility companies offer higher compensations than the Nord Pool spot price, so with all current possible revenue streams, the surplus electricity can have a higher value than the self-consumed electricity.

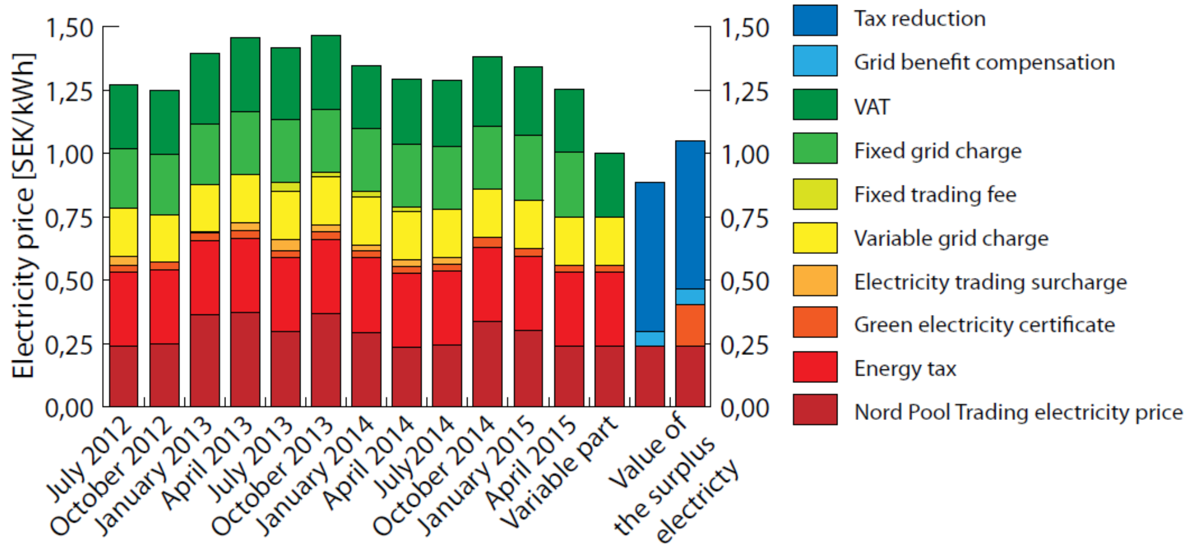

Figure 8: Evolution of the lowest variable electricity price offers for a typical house with district heating in Stockholm that has an annual electricity consumption of 10 000 kWh/year, a 16 ampere fuse and Vattenfall as the grid owner.

Table 11: Country information.

Retail electricity prices for a household	1.0-1.8 SEK/ kW_p (including grid charges and taxes)			
Retail electricity prices for a commercial company	1.0-1.5 SEK/ kW_p (including grid charges and taxes)			
Retail electricity prices for an industrial company	0.55-1.0 SEK/ kW_p (including grid charges and taxes)			
Population at the end of 2014	9 767 357			
Country size (km^2)	447 435 km^2			
Average PV yield	800 – 1 100 kWh/kW_p			
Name and market share of major electric utilities		Electricity production (2014)[6]	Share of grid Subscribers (2013)[7]	Number of retail customers (2013)[8]
	Vattenfall	43 %	35 %	18 %
	E.ON	17 %	19 %	13 %
	Fortum	17 %	17 %	12 %

[6] Elåret 2014, Svensk Energi
[7] Statistics from The Swedish Energy Markets Inspectorates homepage
[8] Data from Energimarknaden, a part of Svenska Nyhetsbrev 2014

2.5.2 Global solar radiation

The total amount of solar radiation that hits a horizontal surface is called the global radiation. The global solar radiation thus consists of the direct radiation from the sun and the diffuse radiation from the rest of the sky and the ground. The solar radiation therefore depends on the weather, on the position on the globe and the season of the year. Sweden has a lower solar radiation than in many countries farther to the south, since the maximum insolation angle is only 58 degrees in the far south. In the long-term variation of global radiation in Sweden a slight upward trend of +0.3 % per year has been noted and the average solar radiation has increased with about 8 % from the mid-1980s until now, from about 900 kWh/m^2 in 1985 to about 1000 kWh/m² in 2014. 2014 was a little bit less sunny year in Sweden compared with the record year of 2013, but still received 980 kWh/m^2.

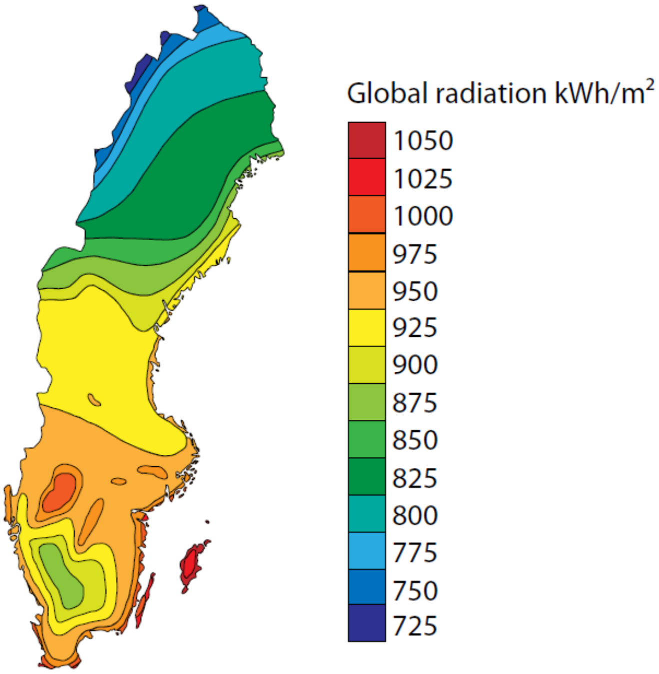

Figure 9: Global solar radiation in Sweden in one year.

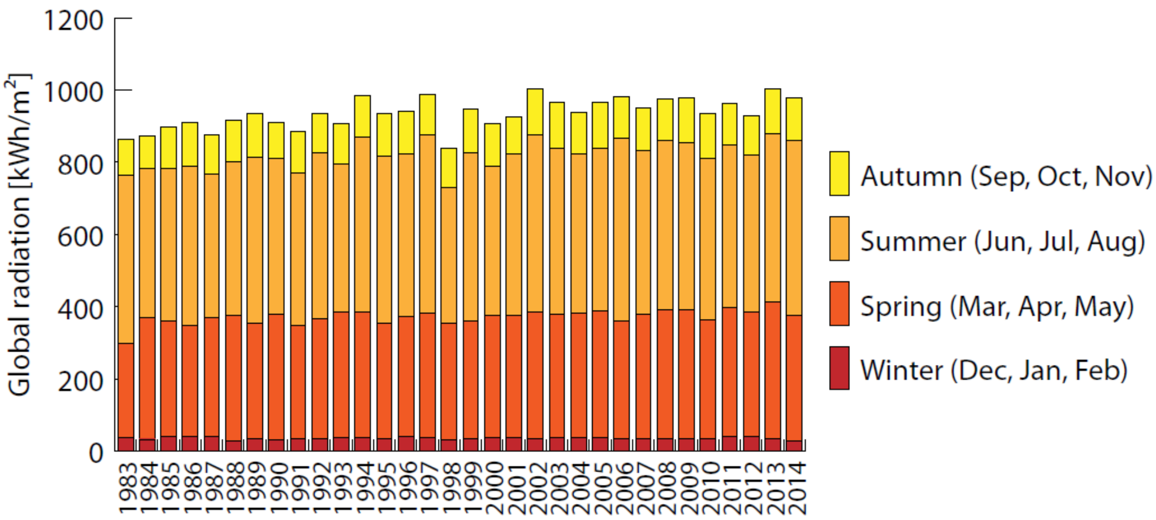

Figure 10: The development of global solar radiation in Sweden from eight weather stations.

2.6 Levelized cost of electricity

When including the Swedish VAT of 25 % the investment cost was about 19.2 SEK/W for a typical residential installation at the end of 2014 (see section 2.3). To calculate the levelized cost of electricity (LCOE) the following equation can be used[9];

$$LCOE = \frac{Initial\ investment + (Annual\ costs * n) - Residual\ value}{\sum_{i=1}^{i=n} \frac{First\ year\ yield * (1 - System\ degradation\ rate)^{i-1}}{(1 + Interest\ rate)^{i}}}$$

where *i* is years and *n* is the lifte time of the system. Using the commonly used assumptions for a small residential PV system in table 12, a LCOE of 1.25 SEK/kWh is obtained. This value is as dicussed in section 2.5.1 in parity with the varibale part of the end consumer electricty price in Sweden. One should note that LCOE values hevialy depend on the made assumptions and should be seen as indications. If for example an interest rate of 0 % is instead assumed, one ends up at 0.88 SEK/kWh. And if the system owner on top of that receives 20 % of the investment cost form the direct capital subsidy program (see section 3.1.1.1), the LCOE drops to 0.73 SEK/kWh.

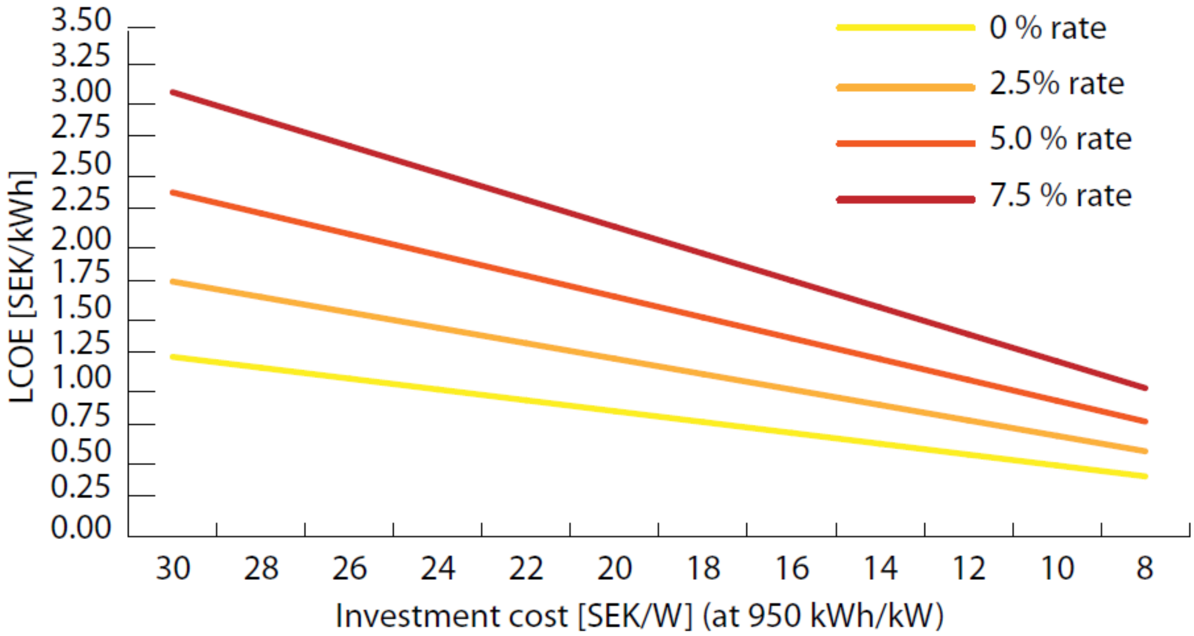

Figure 11: LCOE dependence on investment cost and interest rate.

[9] B. Stridh, S. Yard, D. Larsson, B. Karlsson, Production Cost of PV Electricity in Sweden, 28th European Photovoltaic Solar Energy Conference and Exhibition

Table 12: PV system performance assumptions

Parameter	Value	Comment
Life time [years]	30	A PV module usually has a warranty of 25 years, but the life time is probably longer.
Initial investment [SEK/ kW_p]	19 200	See section 2.3.
Annual cost [SEK/year and kW_p]	100	Replacement of inverter after 15 years.
Residual value [SEK/kW_p]	0	The value of a 30 year system is currently unknown.
First year yield [kWh/kW_p and year]	900	Based on existing PV systems in Sweden.
System degradation rate [%]	0.5	Compilation of several international degradation studies.[10]
Interest rate [%]	2.5	Average mortgage rate in 2014.

[10]Jordan, D.C. et al. Outdoor PV Degradation Comparison. NREL/CP-5200-47704. February 2011

3 POLICY FRAMEWORK

This chapter describes the support policies aiming directly or indirectly to drive the development of PV. Direct support policies have a direct influence on PV development by incentivizing or simplifying or defining adequate policies. Indirect support policies change the regulatory environment in a way that can push PV development.

3.1 Direct Support measures

Table 13: PV support measures

	On-going measures	Measures that commenced during 2014
Feed-in tariffs		National
Capital subsidies for equipment or total cost	National	
Green electricity schemes	National	
PV-specific green electricity schemes		
Renewable portfolio standards (RPS)	National	
PV requirement in RPS		
Investment funds for PV		
Income tax credits		
Prosumers' incentives (self-consumption, net-metering, net-billing…)	Offered by some utilities	
Commercial bank activities e.g. green mortgages promoting PV		
Activities of electricity utility businesses	Yes	
Sustainable building requirements		

3.1.1 Support measures existing in 2014

3.1.1.1 The national direct capital subsidy for PV program

In 2006 a direct capital subsidy program was introduced to stimulate investments in energy efficiency and conversion to renewable energy sources for public buildings. In this program PV system could get 70 % of the installations cost covered if they were built on a public building, and this program got the grid connected PV market started in Sweden. This version of the program ended the last of December in 2008. In the beginning of 2009 there was a gap with no direct support to grid connected PV and the installation rate went down in 2009, as can be seen in figure 1. However, a new subsidy program was introduced in mid-2009, now open for all actors[11]. This subsidy program 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. These funds ran out already in 2014, so at the end of 2014 the government decided to add another 50 million SEK for 2015. Since the start of the new

[11] Förordning (2009:689) om statligt stöd till solceller. Ministry of Enterprise, Energy and Communications

program in 2009, 448.4 million SEK had been assigned and 341.5 million SEK had been disbursed at the end of 2014[12].

Until 2011 the new version of 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 lowered in 2013 to 35 %. For 2015 the level has been decreased to maximum 30 % for companies and 20 % for others. Funds can now only be applied for if the system costs are less than 37 000 SEK excluding VAT/kW_p. Solar power/heat hybrid systems are allowed to cost up to SEK 90 000 plus VAT/kW_p. If the total system costs exceed 1.2 million SEK, capital support is only granted for the part of the system cost that is less than this value.

The direct capital subsidy program got the grid connected PV market kick started when it was introduced. However, the Swedish PV market has now outgrown the program since there are many more applications than available funding. From 2009 and to the end of 2014 about 8 197 applications have been received by the county administrative boards (Länsstyrelser), of which about 3020 have been supported. The waiting time for the investment subsidy decision can therefore in some cases be longer than 2 years, but varies between the 21 county administrations. The effect of the long waiting times and the fact that there are more applications than the current budget leads to that the program not solely stimulates, but also constitutes an upper cap of the Swedish PV market. The shortcomings of the program have been identified as a critical issue for further PV development in Sweden[13].

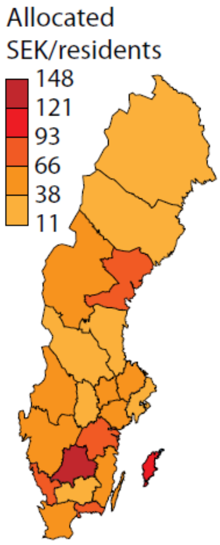

Figure 12: The map shows the amount granted per capita for each county from the grant starting even[12].

[12] Support for installation of solar cells - Monthly Report December 2014, The Swedish Energy Agency

[13] A. Palm, An emerging innovation system for deployment of building-sited solar photovoltaics in Sweden, Environmental Innovation and Societal Transitions (2014) 15 pp 140-157

Table 14: The Swedish direct capital subsidy program

	2006-2008 ordinance	2009-2011 ordinance	2012 ordinance	2013-2014 ordinance	2015 ordinance
Maximum coverage of the installation costs	70 % Only for public buildings	55 % Companies 60 % Others	45 %	35 %	30 % Companies 20 % Others
Upper cost limit per PV system	5 000 000 SEK	2 000 000 SEK	1 500 000 SEK	1 300 000 SEK	1 200 000 SEK
Maximum system cost per W (excluding VAT)	-	75 SEK/W	40 SEK/W	37 SEK/W	37 SEK/W
Budget	150 000 000 SEK	212 000 000 SEK	60 000 000 SEK	210 000 000 SEK	50 000 000 SEK
Disbursed funds	142 531 152 SEK (end of 2008)	114 301 404 SEK (end of 2011)	192 647 605 SEK (end of 2012)	341 565 853 SEK (end of 2014)	-

3.1.1.2 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 original goal of the certificate system was at that time to increase the annual electricity production from renewable energy sources by 17 TWh 2016 compared with the levels of 2002. The basic principle of the system is that producers of renewable electricity receive one certificate from the government for each MWh produced. Meanwhile, electricity suppliers are obliged to purchase certificates representing a specific share of the electricity they sell, the so-called quota obligations. The sale of certificates gives producers an extra income in addition to the revenues from electricity sales. Ultimately it is the electricity consumers that pay for the expansion of renewable electricity production as the cost of the certificates is a part of the final end consumer electricity price. The energy sources that are entitled to receive certificates are wind power, some small hydro, some biofuels, solar, geothermal, wave and peat in power generation. In 2014, the quota obligation for electricity supplier companies was 14.2 %[14].

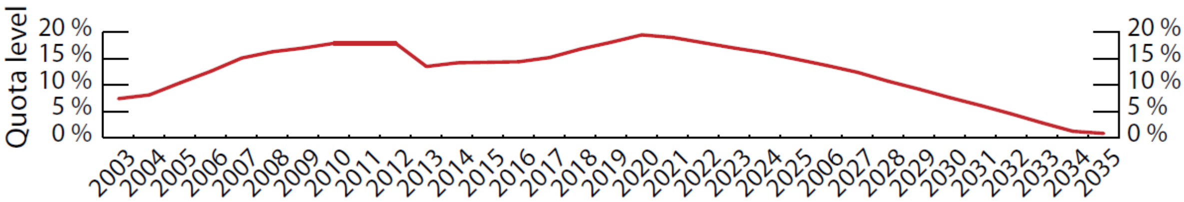

Figure 13: The quota level in the green electricity certificate system.

As from January 2012, Sweden and Norway have a joint certificate market. The objective of the certificate system is now 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 certificates for meeting quotas. Although the market is shared, respective national legislation is governing the green electricity certificate system in each country. The system is estimated to have generated 13.3 TWh of renewable electricity between 2002 and 2012 in Sweden, and the joint Norwegian-Swedish system another 6.2 TWh of renewable electricity since 2012.

[14] Elåret 2014, Svensk Energi

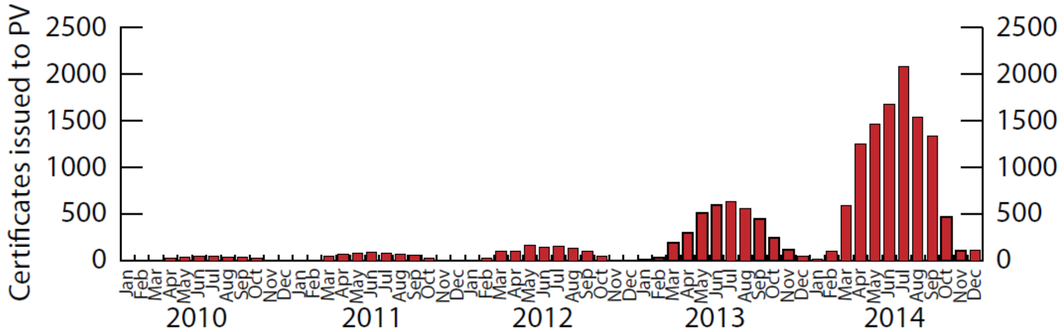

Figure 14: Green electricity certificates issued to PV produced electricity[16].

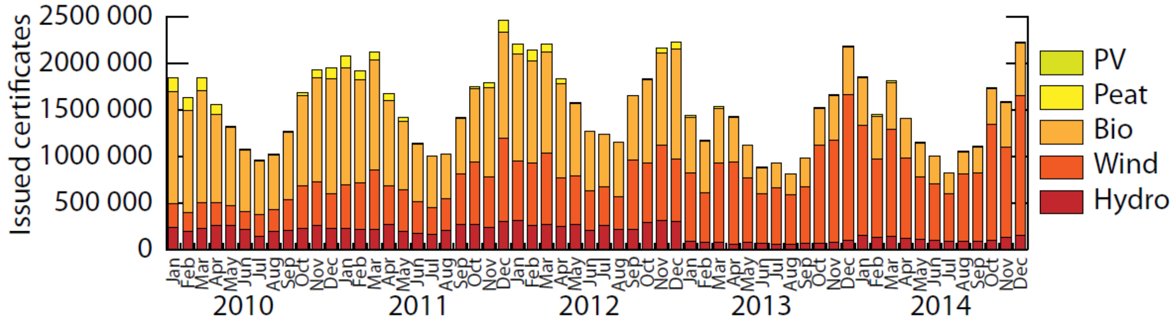

Figure 15: The allocation of green electricity certificates to different technologies in Sweden[15].

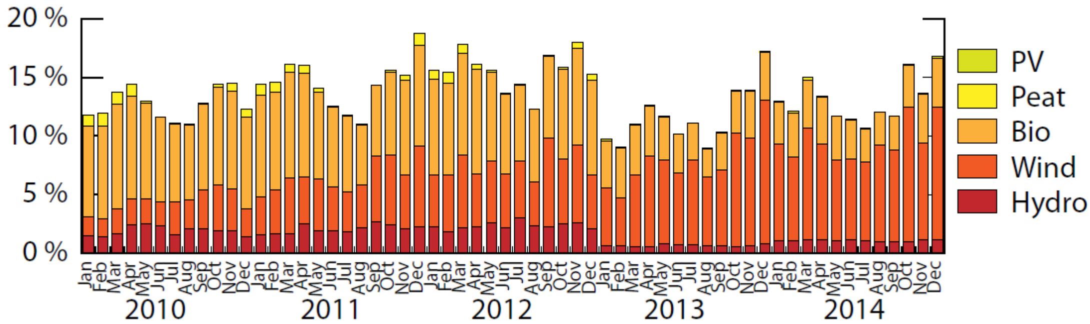

Figure 16: The share of certificate entitled electricity as of total electricity consumption in Sweden[16].

The average price for a certificate was 196.5 SEK/MWh in 2014, which resulted in an average additional price of 0.027 SEK/kWh for the end consumers.

As can be seen in figure 15, a major part of the certificates goes to wind and bio mass power, which produces more in the winter months. Even after taking into account the electricity consumption in Sweden, which is higher in the winter, the allocation of certificates are higher in the winter months, as shown in figure 16. Introducing more PV into the green electricity certificate system would even out these seasonal differences. However, only 19.7 MW_p of PV power were at the end of 2014 accepted in the certificate system, making it only one third of the total installed PV capacity obtained from the sales statistics. 10 770 certificates were issued to PV in 2014, which corresponds to 10 770 MWh of PV electricity production. This can be compared to an estimated production of 69.9 MW_p × 900 kWh/kW_p ≈ 62 910 MWh from all grid-connected PV systems in Sweden. So only about a fifth of the PV produced electricity receives certificates. The reader should note that the

[15] Statistics of certificates from Cesar, the Swedish National Grid system for account management of certificates and guarantees of origin

calculation above is very simplified since not the whole cumulative grid connected PV power at the end of 2014 was up and running throughout the whole year. So the share of PV produced electricity that received certificates is higher than stated in table 14, but are still very low.

Table 15: PV in the green electricity certificate system

	2012	2013	2014
Grid connected PV power according to sales statistics	16.8 MW_p	34.8 MW_p	69.9 MW_p
Accepted PV systems in the certificate system[16]	5.2 MW_p	13.2 MW_p	19.7 MW_p
Issued certificates[17]	1 029 MWh	3 705 MWh	10 770 MWh
Rough estimation (on the high side) of total PV production	15 120 MWh	31 320 MWh	62 910 MWh
Share of total installed PV power in the certificate system	30.9 %	37.9 %	28.2 %
Rough estimation (on the low side) of the share of PV produced electricity that obtained a certificate	6.8 %	11.8 %	17.1 %

There are several reasons why it has been difficult for PV to take advantage of the green electricity certificate system. One is that many owners of small PV systems don't think the small income that green electricity certificates offers is worth the extra administrative burden. It has also been hard to find a buyer for just a few certificates. This is slowly about to change as more and more utilities offer to buy certificates from micro-producers (see section 7.2). One other reason is that the meters that register the electricity produced at a building often are 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 will not receive a certificate, if not the extra cost for an internal meter and an extra yearly measurement fee is paid. For residential PV systems the extra cost for the meter and the yearly measurement fee is higher than the income from the extra certificates from the electricity used in the building. Therefore, many PV system owners do not get certificates for all of their electricity production, which explains why the share of estimated PV produced electricity that obtained a certificate is lower than the share of total installed PV power in the certificate system. The trend with an increasing share of PV electricity that receives certificates is probably due to that some larger parks have been built the last years that receive certificates for all of their production.

To summarize, the green electricity certificate system in the present shape is being used by some larger PV systems and parks but does not provide a significant support to increase PV installations in Sweden in general.

[16] The Swedish National Grid's system for account management of certificates and guarantees of origin

3.1.1.3 Guarantees of origin

Guarantees of origin (GO's) are electronic documents that guarantee the origin of the electricity and are intended 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 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 GO's shows the type of energy that the electricity comes from. GO's are issued for all types of power generation. Applying for guarantees of origin is still voluntary.

7 944 GO's from PV were issued in 2014[17]. Some utility companies have attempted to get the trade going by, e.g. buying PV GO's to a quite high price (see section 7.2), but the volumes are still too small for a working trading market. So the real value of GO's from PV is still uncertain.

3.1.2 Prosumers' development measures

Self-consumption of PV electricity is allowed in Sweden, but no national net-metering system exists. However, several utilities offer various agreements, including net-metering, for the surplus electricity of a micro-producer (see section 7.2). In the wake of the government's proposal for a tax credit for self-generated renewable electricity (see section 3.1.7.1) a debate started in the spring of 2014 about what tax rules that apply to micro-producers. It was for a while unclear what regulations to follow, but in June 2014 the Swedish Tax Agency (Skatteverket) came out with a percept and clarified the following[18]:

3.1.2.1 Income tax

Owning a PV system is not regarded as a business from a legal point of view. The revenues will be taxed as capital income from a private residence. In many cases there will be no income tax because of the standard deduction of 40 000 SEK, which can be subtracted from the total income of each residence.

3.1.2.2 Energy tax

The assessment that owning a PV system not is regarded as a business activity is also relevant concerning the energy tax. Electricity from a PV system is excluded from energy tax and the producer of PV electricity does not have to pay the energy tax neither for the self-consumed nor for the delivered electricity. This applies provided that:

- The producer does not have other electricity production facilities that together have an installed capacity of 100 kW_p or more.
- The producer does not professionally deliver any other electricity to other consumers.
- The compensation for the surplus electricity does not exceed 30 000 SEK in a calendar year.

3.1.2.3 Registration for VAT

Even if owning a PV system not is regarded legally as a business activity, a special assessment must be made as to the obligation to register for and pay VAT.

The judgment C-219/12, Fuchs, in the European Court concluded that the sale of electricity from a PV system located on, or adjacent to, a private residence is an economic activity when the electricity

[17] The Swedish National Grid's system for account management of certificates and guarantees of origin

[18] The Swedish Tax Agenct's percept "Beskattningskonsekvenser för den som har en solcellsanläggning på sin villa eller fritidshus som är privatbostad"

produced continuously is supplied into the grid for remuneration. The PV system is therefore obliged to register for, and pay VAT, regardless of the amount of electricity that is sold.

3.1.2.4 Deduction of the VAT for the PV system

Sweden has a non-deductible VAT for permanent residence. The possibility to deduct the input VAT for a PV system therefore depends on whether all produced electricity is sold, or if a portion of the generated electricity is consumed directly for housing and only the surplus electricity is sold to an electricity supplier.

If only the surplus electricity is sold to an electricity supplier and the PV system also serves the private facility, then deduction of the VAT for the PV system is not allowed.

If all generated electricity is delivered to an electricity supplier, then the PV system is used exclusively in economic activity and deduction of the VAT for the PV system is allowed.

3.1.3 BIPV development measures

There were no measures for BIPV development in 2014 in Sweden.

3.1.4 Rural electrification measures

Sweden has a well-developed power grid and practically all permanent housing is connected to the grid. However, there are some recreational cottages in the remote country side that lack electricity and the market for off-grid PV for these houses is relative large in Sweden. However, this market is economically competitive and does not need any subsidies. So, currently there exist no PV specific measures for electrification of rural areas.

3.1.5 Decentralized storage and demand response measures

There are currently no national measures for decentralized storage or demand response in Sweden. However, development of smart grids is ongoing.

The biggest smart grid project is on the Swedish island Gotland called Smart Grid Gotland. This is a development project that will show how it is possible to modernize an existing power gird to be able connect larger amounts of renewable energy, while maintaining or improving power quality. The project also aims to give the customers the opportunity to actively participate in the energy market through demand response. One sub project is a market test, where electricity prices are based on the current wind power generation. Electricity consumers in the market test will receive price signals that indicate when electricity prices are low or high, and through a smart energy box installed at their house, the consumers will be able to regulate the consumption of electricity. The project started in 2012 and is expected to continue to the end of 2016.

3.1.6 Support measures phased out in 2014

No PV support measures were phased out in 2014 in Sweden, but the level of the direct capital has as of the start of 2015 been lowered (see section 3.1.1.1).

3.1.7 New support measures implemented in 2014

3.1.7.1 Tax credit for micro-producers of renewable electricity

No new PV support measures were implemented in 2014, but as of the 1 of January 2015 a tax credit for micro-producers of renewable electricity, an amendment to the Income Tax Act has been introduced[19]. The tax credit is 0.60 SEK/kWh for renewable electricity fed into the grid. The right to receive the tax credit applies to both physical and legal persons. To be entitled to receive the tax credit the PV system owner must:

- feed in the surplus electricity to the grid at the same connection point as where the electricity is received,
- not have a fuse that exceed 100 ampères at the connection point,
- notify the grid owner that renewable electricity is produced at the connection point.

The basis for the tax reduction is the number of kWh that is fed into the grid at the connection point under a calendar year. However, the maximum number of kWh for which a system owner can receive the tax credit may not exceed the number of kWh bought within the same year. In addition one is only obliged to a maximum of 30 000 kWh per year. The grid owner will file the measurement on how much electricity that has been fed into and out of the connection point in one year and the data will be sent to the Swedish Tax Agency (Skatteverket). The tax reduction will then be included in the income tax return information, which should be submitted to the Swedish Tax Agency in May the next year.

The tax credit of 0.60 SEK/kWh is received on top of other compensations for the surplus electricity, such as compensation offered by electricity retailer utility companies (see section 7.2), the grid benefit compensation (see section 3.2.1.1) and green electricity certificates (see section 3.1.1.2). The tax credit system can be seen as a FiT for the surplus electricity. However, unlike the FiT systems of e.g. Germany, the Swedish tax credit system does not offer a guaranteed purchase agreement over long periods. This means that the extra income a micro-producer receives from the tax credit system when feeding electricity to the grid can be withdrawn quickly. The Swedish Government intends to evaluate the system when it has been applied for at least two calendar years.

3.1.8 Measures currently discussed but not implemented yet

In March 2015 the government presented a new tax proposal concerning the energy tax exemption rule that certain owners of renewable energy sources have. The background to the proposal is that the Swedish government wants to increase the national ambitions in the green electricity certificate system. In the new agreement with Norway, Norway has demanded that Sweden should remove the existing exemptions for energy tax such as “wind power that is not delivered professionally and for other electricity from renewable energy sources that are not delivered professionally”. The reason for this is that e.g. a municipality can own a big wind power park, use the grid to transport the electricity to their facilities and use the electricity there without having to pay the energy tax, while the electricity from the same kind of wind power park owned by a utility is taxed with the energy tax. In striving to meet Norway's requirements, the Finance Ministry (Finansdepartementet) came up with a proposal[20] that would have the consequence that all the electricity produced from one large system, or many smaller systems owned by an organization, exceeding 144 kW_p in total, would be subjected to the energy tax of 0.293 SEK/kWh on all of the production. I.e. not only the electricity actually supplied to the grid, but also on the electricity that is produced solely for self-consumption

[19] The Swedish Tax Agency homepage

[20] Vissa punktskattefrågor inför budgetpropositionen för 2016, Finansdepartementet, Skatte- och tullavdelningen

within a building. This would increase the LCOE of the self-produced and consumed PV electricity for large commercial roof mounted PV system substantially, making many of them non-profitable.

Currently about 10 % of the PV capacity in the green electricity certificate system would be affected by the proposed tax laws if they are implemented. The effect of the tax laws could have a larger impact on future PV installations in Sweden, since there are several large PV systems that currently are in the planning or construction phase. The tax laws would probably also lead to that organisations that have built a few PV systems would stop when they are close to the 144 kW_p limit, since the systems owned by one organisation needs to be summed up. It would mean that the Swedish PV market continuously will lose the experienced customers and always relay on new unexperienced customers that needs to be educated.

However, the tax proposal received a lot of criticism under the spring and the government withdraw the first version of the proposal. The energy tax proposal is at the time of writing this report under revision.

3.1.9 Financing and cost of support measures

In the first version of the direct capital subsidy program 142 531 152 SEK were disbursed and in the second version a total of 341 565 853 SEK[21] has been disbursed from 2009 to the end of 2014. This system is financed by government money, which is distributed by the 21 county administrations.

Furthermore, PV systems have benefited from the green electricity certificate system and have since the start received 16733 certificates to a value of 3 033 383 SEK[22]. The green electricity certificate system is financed by electricity consumers, with the exception of electricity-intensive industries that have certificate costs only for the electricity that is not used in the manufacturing process.

Altogether the Swedish PV market has received 487 130 388 SEK in subsidies, which corresponds to roughly 50 SEK/capita.

[21] Support for installation of solar cells - Monthly Report December 2014, The Swedish Energy Agency

[22] The Swedish National Grid’s system for account management of certificates and guarantees of origin

3.2 Indirect policy issues

3.2.1 National policies affecting the use of PV Power Systems

3.2.1.1 Grid benefit compensation

A micro-producer is entitled to reimbursement from the grid owner for the electricity that is fed into the grid. The compensation shall correspond to the value of the energy losses reduction in the grid that the surplus electricity entails[23].

How this should be calculated is still rather unclear and the legislative text actually states that the government should issue more detailed regulations on the calculation of this compensation. Meanwhile, the compensation varies between different grid owners and grid areas and is typically between 0.02-0.07 SEK/kWh.

3.2.1.2 ROT tax deduction

The ROT-program is an incentive program for the construction industry in Sweden in the form of tax credits. ROT is a collective term for measures to renovate and upgrade existing buildings, mainly residential properties. Repair and maintenance as well as conversions and extensions are counted as ROT work and are therefore tax deductible, provided that such work is carried out in close connection with a residence that the client owns and in which he or she lives, or if it is a second home, like a recreational summer house.

The ROT-tax deduction is 50 % of the labor cost and of maximum 50 000 for the installation of a PV system. The requirements are that the house is older than five years and that the client has not received the direct capital subsidy for PV. Installation or replacement of solar panels is entitled ROT, while services of solar panels are not.

The Swedish Tax Agency (Skatteverket) did in 2014 accept a request from the Swedish Solar Energy Association (Svensk Solenergi) about using a standard deduction in the calculation of labor costs for the installation of PV systems, with reference to the equivalent standard for the installation of solar heat systems[24]. According to the Swedish Tax Agency labor costs are estimated at 30 % of the total cost, including VAT. Since the ROT tax deduction amounts to half of the labour costs, the total deduction for the whole systems becomes 15 %, which is only 5 % lower than the direct capital subsidy for private person's level of 20 % (see section 3.1.1.1). The up-side of the ROT-tax deduction scheme is that there is no queue and that the client can be sure of receiving this subsidy.

3.2.1.3 Deduction for interest expenses

If one borrows money to buy a PV system one can utilize the general interest rate deduction of 30 % of loan rates. If the deficit of capital exceeds 100 000 SEK, the tax credit is 21 % for the excess amount.

3.2.2 International policies affecting the use of PV Power Systems

3.2.2.1 Emission trading

The EU system for emission trading began 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

[23] The Swedish Electricity Act, 3rd chapter, paragraph 15

[24] The Swedish Solar Energy Associations homepage

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 Swedish carbon dioxide tax (see section 3.2.5.1) 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 and smaller combustion plants connected to district heating with a total capacity greater than 20 MW_p are included in the system. There are about 760 of these plants in Sweden[25].

The price of emission allowances was at a low level under 2014. At times the spot price was below for 4 euros/tonne. The recession is a major contributing factor to the low prices. An applicable rule of thumb is that a price of 10 euros/tonne results in a spot price of roughly 0.08 SEK/kWh at the Nord Pool spot market.

3.2.2.1 EU building directive

In 2010 EU adopted a directive that requires all new buildings in the EU to be zero-energy-buildings by 2020. This directive could play an important role in promoting PV installation in the built environment. In Sweden the current building codes do not allow internally produced electricity to contribute to fulfilling the energy efficiency standards, unless it is used for heating. Therefore, the building directive has so far played a negligible role for the Swedish PV market. However, this might change as the National Board of Housing, Building and Planning (Boverket) proposes to include "free flowing energy" inside the building system boundary. I.e. it should be possible to use local renewable electricity production to reduce a building’s energy consumption to achieve the zero-energy-building level[26].

3.2.3 The introduction of any favourable environmental regulations

No new environmental regulations that strongly affect PV were implemented in Sweden in 2014.

3.2.4 Policies relating to externalities of conventional energy

3.2.4.1 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 taxes associated with electricity consumption are mainly the energy tax on electricity and the related VAT, but there are also charges to fund agencies. The industry paid 0.005 SEK/kWh in energy tax in 2014 and the rate for residential customers was 0.293 SEK/kWh (excluding VAT), with the exception of some municipalities in northern Sweden where the energy tax was 0.194 SEK/kWh

[25] From the Swedish Environmental Protection Agency homepage about emission trading

[26] Förslag till svensk tillämpning av nära-nollenergibyggnader, the National Board of Housing, Building and Planning

(excluding VAT). Additionally, a VAT of 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 2014[27].

Power generation facilities in Sweden are charged with a general industrial property tax. The assess value for hydropower was increased in 2013 and by this increase the tax revenues from property tax on hydropower increased from about 4 billion SEK per year to 6 billion SEK per year. Furthermore, the assess value for nuclear power and CHP was increased in 2013 by about 100 % and 75 %, respectively. The total property tax on electricity generation plants in 2015 is estimated at around 6.4 billion SEK[28].

Electricity produced in nuclear power plants has been taxed since 1984 and was initially a production tax. In 2000 it was transformed into a power tax. This means that the tax is based on the reactor thermal power, and thus is independent of the amount of electricity produced. The power tax amounts from 1 January 2008 to 12 648 SEK/MW per month, equivalent to an average of about 0.055 SEK/kWh. Furthermore, in order to finance the future costs of disposal of spent nuclear fuel and decommissioning of nuclear power plants, a fee is implemented, which is individual for each nuclear power plant. As a weighted average this fee is 0.022 SEK/kWh in Sweden. As from 2015, this fee for waste fund was raised and the weighted average is expected to about 0.04 SEK/kWh from now on.

Including VAT the total tax and fee's from the power sector is expected to be 42 billion SEK in 2015, corresponding to about above 5 % of the government's revenues.

3.2.5 Taxes on pollution

3.2.5.1 Carbon tax

According to the law on tax on energy, no tax deduction is allowed on fuels used for the production of electricity. Full carbon tax amounts from the 1 January 2015 to around 1.15 SEK/kg of carbon dioxide. Biofuels and peat are not taxed[27].

3.2.5.2 Sulphur tax

Sulphur tax is paid at 30 SEK/kg on emissions of sulfur dioxide from combustion of solid fossil fuels and peat. For liquid fuels, the tax is 27 SEK/cubic meter for each tenth of a weight percent sulfur in fuels that exceeds 0.05 weight percent[27].

3.2.5.3 Nitrogen oxide fee

The fee for emitting nitrogen oxide (NO_2) is 50 SEK/kg in the use of boilers and gas turbines with a utilized energy supply that is greater than 25 GWh/year. Most of the fees paid are refunded to the payers of the fee in proportion to their share of the useful energy. The Swedish Environmental Protection Agency (Naturvårdsverket) has during 2014 conducted an investigation on behalf of the government which proposes that only about half of the fees should be refunded[27].

[27] Elåret 2014, Svensk Energi

[28] Elåret 2014, Svensk Energi

4 HIGHLIGHTS OF R&D

4.1 Highlights of R&D

The Swedish solar cell related research consists largely of fundamental research in new types of solar cells and photovoltaic materials. Several of the research groups in this category are at the forefront and are highly regarded internationally. Before 2013, no research on the world-dominant silicon technology has been conducted, but now Karlstad University has initiated activities within this topic. Furthermore, there are some smaller groups that focus on PV systems and PV in the energy system oriented research.

4.1.1 Commercial R&D

4.1.1.1 SolEl programmet

The SolEl-program is a national R&D program for PV systems, which 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 been an important platform for dialogue between the building and property sector, the government, industry, utilities and solar energy companies. The program is focused on PV in the future smart grids, sustainable cities and building related PV questions.

During 2013 a new phase of the program started. A first call for projects was announced and new projects started in 2014. One study was finalized in 2014, which evaluated larger building integrated and building applied photovoltaic installations.

4.1.1.2 SP Technical Research Institute of Sweden

SP Technical Research Institute of Sweden is an international research institute, which conducts various PV research, testing and evaluation activities. In 2014, SP was involved in, among other things, a study on PV systems in agriculture, comparative testing of small grid-connected solar PV systems and certification of PV system installers. SP is also active in IEA-PVPS task 13 “performance and reliability of photovoltaic systems” and is taking part in the planning of the new task 15 “Building integrated PV”. SP coordinates the national project ”Testbed for new solar energy solutions”, which together with Glava Energy Center, Chalmers, Dalarna University and ten other partners aims at developing the innovation infrastructure for products, services and processes in the solar field. SP is also engaged in PV standardization through SEK TK 82, which is the Swedish mirror committee for IEC TC 82. In late 2014 SP together with Chalmers and Solkompaniet was awarded the project “A Swedish strategic innovation agenda for solar electricity” which runs in the first half of 2015.

4.1.1.3 The Glass Research Institute

The Glass Research Institute (Glafo), situated Växsjö, is an internationally working research institute, which conducts research**,** development, education and technical support on glass. Since April 2014 Glafo is coordinating the Solar-ERA.NET EU project LIMES, which aims to exploit the development of 1 mm toughened glass as an encapsulant to produce light weight, low cost PV modules with enhanced efficiency. LIMES is a three year project with a total funding of 1.3 Million Euros. Additionally, Glafo has studied the impact of colored encapsulant glass on the overall efficiency of monocrystalline, polycrystalline and CIGS solar cells. Glafo has as well been engaged in integrating solar cells in building-related products.

4.1.1.4 Swedish Institute of Agricultural and Environmental Engineering

JTI – Swedish Institute of Agricultural and Environmental Engineering are leading a project connected to solar electricity in agricultural areas. The project was started in late 2013 and will run to mid-2015. Involved partners are JTI, Uppsala University, Herrljunga Elektriska AB, Energikontoret Mälardalen, The Federation of Swedish Farmers LRF, SP Technical Research Institute of Sweden and Solkompaniet AB. This project aims at identifying the realizable potential of solar electricity and examining quality and safety issues, as well as developing business models and financing PV solutions adapted to agriculture. The project will also investigate the possibilities for load management and accumulation to increase the internal use of the produced electricity.

4.1.2 Academic research

4.1.2.1 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 2014. The center activities include fundamental research in physical chemistry for understanding of components, interfaces and devices, synthetic chemistry for design and preparation of the different components, as well as engineering research for up-scaling and process development. Immaterial property rights generated by the center are handled in the company Dyenamo AB (see section 5.6.1.2). 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 years. New possibilities for solid-state dye-sensitized solar cells using organic or metal complex 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 years.

4.1.2.2 Chalmers

At Chalmers University of Technology Foundation research in many different PV associated areas is carried out, such as design of polymers, organic and hybrid solar cells, plasmons for enhanced light absorption in solar cells, electrolytes and quantum dots for dye-sensitized solar cells, photon up- and down-conversion, lifecycle analysis, optical thermal metasurfaces; windows able to convert solar illumination into heat, and BIPV.

One of the larger projects is PhotoNVoltaics, which is a collaborative research project of partner institutions from science and industry in Sweden, France and Belgium. The ambition of PhotoNvoltaics is to enable the development of a new and disruptive solar cell generation resulting from the marriage of thin-film crystalline-silicon photovoltaics (c-Si PV) with advanced light-trapping schemes from the field of nanophotonics.

Another big project is the photon fusion photon fission project that was initiated during 2012, which is aiming at add-on technology for existing PV technology involving both physical science research and life cycle analysis.

Under 2014 the "Energy on campus"-initiative was launched, which, among other activities, will look at how the campus can be used both for implementation of PV-technology and PV-research.

4.1.2.3 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

Swedish International Development Cooperation Agency (SIDA). Parts of the work are done in multidisciplinary projects where also social, cultural and economic aspects of PV are studied.

4.1.2.4 Karlstad University

The Materials Physics group at Karlstad University has been running research projects on organic and polymer-based photovoltaics since 2002. The active layer in polymer solar cells is a solution-processed thin film that consists of an electron-donating conjugated polymer and an electron-accepting fullerene-type molecule. The research is focused on morphological studies of this active layer and its influence on the electrical performance of the solar cell. For the morphology studies microscopy, depth profiling and various synchrotron-based photoelectron spectroscopy techniques are used. These methods are also applied in studies of thin films of vacuum-deposited molecular semiconductors. Research projects related to photo degradation in air and alternative electrode materials are also ongoing, with the purpose of increasing the stability and lifetime of organic solar cells.

Karlstad University also has a silicon solar cell research group. The group was recently started, and the initial time was spent on setting up laboratory equipment for the characterization of solar cells and solar cell materials. The present research focuses on crystalline silicon, especially ingot cast silicon, which is the worlds most used material for solar cells. Apart from material research, further activities are planned in the field of improved and specialized solar modules together with the local industry and European partners. In 2014, one ongoing research collaboration with Massachusetts Institute of Technology, Boston, was focusing on measurements of the recombination strength of dislocations and the detection of impurities in multi-crystalline silicon solar cells based on synchrotron techniques. Furthermore, within a European project, the group also carried out crystallization experiments at facilities of SINTEF, Trondheim and started new research on copper related light induced degradation of solar cells.

4.1.2.5 Linköping University

Semi-transparent solar cells can be used for building stacked tandem solar cells with different band gaps. In 2014 the Biomolecular and Organic Electronics group at Linköping University started to print semi-transparent organic solar cells on large areas with a dedicated roll to roll printing machine. By sequential deposition of three organic layers on top of a flexible plastic substrate, devices can be produced in semi-infinite geometries at printing speeds of meters per minute. Two of these layers are transparent polymer electrodes sandwiching an active absorber layer generating photocurrent and voltage. Transmitted light can be reinjected with the help of light scattering layers, or be used in a second semi-transparent organic solar cell. In this way, tandems are constructed.

New materials are also studied at Biorgel at LiU, like polymer/polymer blends as well as small molecule donor/polymeric acceptor, which give decent efficiencies in devices. Both have the advantage of stronger optical absorption, as the weakly absorbing acceptor fullerene is substituted with a strongly absorbing polymeric acceptor. More fundamental physics studies highlight the situation that the charge carriers in disordered donor/acceptor blends do not reach equilibrium before extraction.

4.1.2.6 KTH Royal Institute of Technology

The division of Applied Physical Chemistry at the Royal Institute of Technology is involved in the CMD group (See above). In addition to the research of dye-sensitized solar cells another project at KTH seeks to understand how PV systems on multi-family housing technically and economically can be integrated into the residential cooperative's energy system. A primary objective is to determine the most cost-effective PV systems under relevant policy scenarios and effectively relay the results to the boards of directors of cooperatives across Sweden.

4.1.2.7 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. The last deliverable in Task 41 was a website with a Case Study Collection with buildings integrating solar strategies. The 50 examples from 11 countries were selected out of 250 proposals based on their integration quality and solar energy concept. A new IEA SHC project, Task 51, Solar Energy in Urban Planning, was officially started in May 2013, with Swedish leadership by Maria Wall from the group. This task is going on until April 2017.

At the departments of Chemistry and Physics conduct 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. The group works in close collaboration with the Nanometer Structure Consortium at Lunds University in several topics. A new research area, which started in 2013, is organic perovskites, which is a promising solar cell material. The aim of the group’s 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. In 2014 the group started the work which will lead to the capability to process complete working solar cells of the perovskite material.

4.1.2.8 Mälardalens Högskola

Mälardalens Högskola is conducting research in projects regarding development of the energy system with a high fraction of solar electricity for energy efficient 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.

4.1.2.9 Umeå University

The Organic Photonics & Electronics Group at Umeå University develops photonic and electronic devices based on novel organic compounds and the research is divided into three main topics; organic light-emitting electrochemical cells, organic transistors and organic photovoltaics. In 2013, the group performed a number of studies on organic solar cells, using novel device configurations and in-house synthesized materials, and the first results were published in 2014.

4.1.2.10 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.

Ångström Solar Center at Uppsala University was created in 1996. Within this center, activities devoted to research on thin film solar cells based on $Cu(In,Ga)Se_2$ (CIGS) were carried out. Since then the activities have grown and expanded to also include solar cells based on $Cu_2ZnSn(S,Se)_4$, or CZTS. The research includes both synthesis and characterization of these two important types of solar cells as well as applications of thin film solar cells in solar driven water splitting. As research in thin film solar cells to a large extent is based on high quality material research, the group has a large devoted lab facility in the clean room of the Ångström Laboratory. Thin film processes employed to produce high efficiency solar cells are: sputtering, thermal co-evaporation, atomic layer deposition, chemical vapor deposition, electron beam evaporation and chemical bath deposition. In addition, the group has its own measurement lab for electro-optical characterization. Best efficiencies are slightly below 20 % for CIGS-based solar cells and around 8 % for solar cells based on CZTS. In a test site at the roof of the Ångström laboratory, an array of solar cell modules made using different technologies are monitored together with data on irradiance and temperature.

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, variability assessment of solar irradiance, integration of distributed PV into the power system and self-consumption of on-site PV generation in 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).

4.2 Public budgets for R&D and demonstration/field test programmes

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, and the Swedish Research Council (Vetenskapsrådet). Other organizations that can dispense governmental money to PV related research are 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 start the research program "El och bränsle från solen". The program has a budget of 123 million, which will be spread over four years. The program started in January 2013 and will run until December 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 technologies that enable 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 includes projects of various kinds, from research and development projects carried out by various research institutions to experimental development and demonstration in companies.

The Swedish Energy Agency has in addition to the public funding for R&D presented in figure 17 in 2014 also paid almost 68 million SEK in conditional loans for PV related technological and business development.

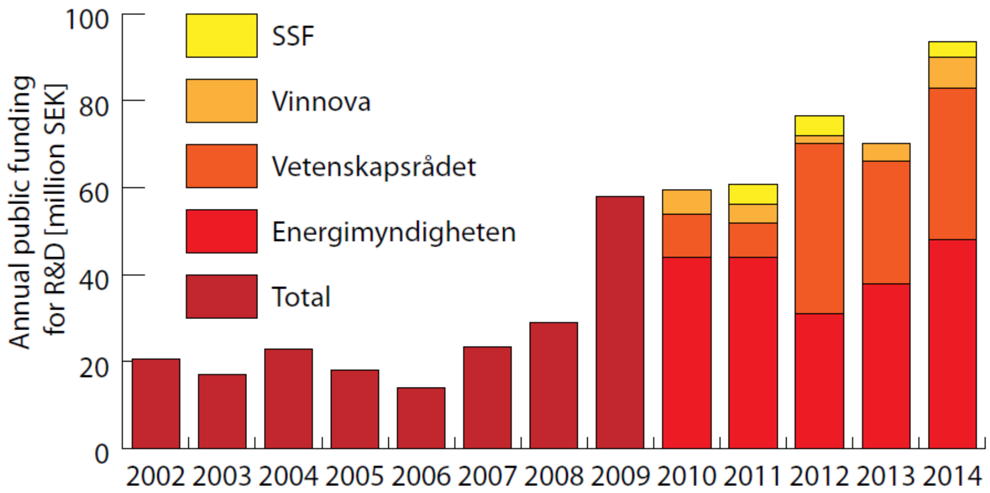

Figure 17: Annual public funding for PV related R&D in Sweden.

Table 16: Public budgets for R&D, demonstration/field test programmes and market incentives

	R & D	Demo/Field test
National/federal	93.6 million SEK	68 million SEK
State/regional	N/A	N/A
Total	93.6 million SEK	

4.2.1 Demonstration and field test sites

4.2.1.1 Kullen

On a hill close to Katrineholm lies the company Egen El's production and demonstration facility Kullen. The hill is littered with several small PV systems and wind turbines. It works 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 persons. 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 has now a capacity of 500 kW_p, of which 450 kW_p is PV.

4.2.1.2 Glava Energy Center

Located 35 km south east of Arvika in Värmland is 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_p. The first grid-connected park consists of four systems, totalling 134.6 kW_p. The second park consist of two systems, totaling 73.6 kW_p, one of which is fully owned by Fortum and one owned by Glava Energy Center. Fortum and Bixia buy all the electricity that the two grid connected parks produce. In 2013 a test bed was developed in cooperation with SP Technical Research Institute of Sweden, and with support from Vinnova. The main purpose of this test bed is to test various concepts of modules, mounting stands and inverters in the Nordic climate. Glava Energy Center also has a well-equipped Science Center where school classes comes and visit on a regular base in order to carry out experiments related to renewable energy.

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 equipment, which can be used by the center. Currently Glava Energy Center has about 30 members. Glava Energy Center is besides from the members funded through the Interreg/EU, Region Värmland and the city of Arvika.

5 INDUSTRY

5.1.1.1 Svensk Solenergi

Svensk Solenergi (SSE) is a trade association which, with more than one hundred professional members and represents both the Swedish solar energy industry as well as the research institutions active in the solar energy field. Since the Swedish PV market still is rather small, the association's resources have so far been rather limited. However, the organisation is growing and the activity is increasing.

5.2 Production of feedstock, ingots and wafers

Sweden did not produce any feedstock or wafers in 2014 and there are currently no plans for this kind of production in the future.

Table 17: Production information for the year for silicon feedstock, ingot and wafer producers

Manufacturers	Process & technology	Total Production	Product destination	Price
N/A	Silicon feedstock	tonnes	N/A	N/A
N/A	sc-Si ingots.	tonnes	N/A	N/A
N/A	mc-Si ingots	tonnes	N/A	N/A
N/A	sc-Si wafers	MW_p	N/A	N/A
N/A	mc-Si wafers	MW_p	N/A	N/A

5.3 Production of photovoltaic cells and modules

Module manufacturing is defined as the industry where the process of the production of PV modules (the encapsulation) is done. A company may also be involved in the production of ingots, wafers or the processing of cells, in addition to fabricating the modules with frames, junction boxes etc. The manufacturing of modules may only be counted to a country if the encapsulation takes place in that country.

The overall module production in Sweden in 2014 was 34.0 MW_p, exclusively produced by SweModule AB. In the beginning of 2011 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 partly came from a huge imbalance between the demand and the much higher production capacity in the world at that time. The Swedish module manufacturers struggled along with the rest of the module production industry and at the end of 2012 only SweModule AB of the Swedish companies remained in business.

5.3.1.1 SweModule AB

SweModule AB was the only active module producer in Sweden in 2014. 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. Over 2.500.000 multi crystalline silicon modules, corresponding to 0.5 GW, have been produced at the site since 2003. Since 2011 solar cells from the company's owner Norwegian Innotech Solar have been used. The company produced 34 MW_p of modules in 2014, of which about 2.0 MW_p was sold on the Swedish market. Modules were distributed to a total of 21 countries around the world in 2014, but the primary markets for the company were England, Italy and France. In 2014 SweModule continued to develop their modules by integration of smart technology and developed its co-operation with Glava Energy Center and other European research centers.

5.3.1.2 Jowa Energy Vision

Jowa Energy Vision bought in 2012 the production equipment from the former Swedish producer Artic Solar AB and has assembled the equipment in a factory in Alingsås. The plan is to produce modules for building integrated systems with focus on roof applications, but the company will also be able to accommodate orders from architects with special requests. The targeted markets for the modules are the Nordic countries. Some modules have been produced as proof of concept. However, the plan to produce larger quantities was put on hold in 2014.

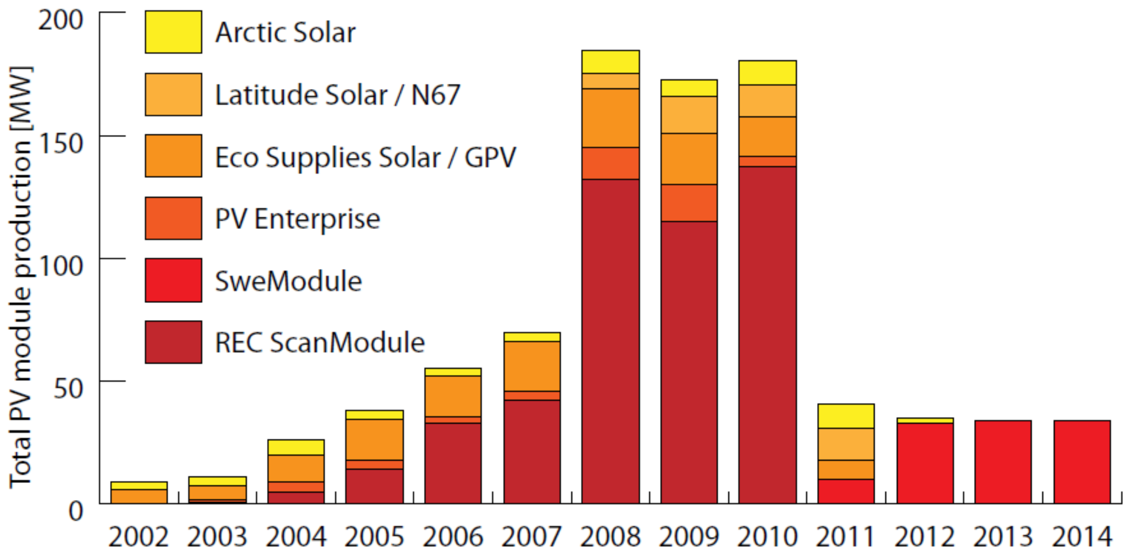

Figure 18: PV module production in Sweden over the years.

Table 18: Production and production capacity information for 2014

Cell/Module manufacturer	Technology	Total Production (MW_p)		Maximum production capacity (MW_p /year)	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
SweModule	Mono/Poly-Si	-	34	-	100
Thin film manufacturers					
Midsummer AB	CIGS	-	0.1	-	N/A
Cells for concentration manufactures					
N/A		-	-	-	-
Combined solar power and heat manufactures					
Absolicon Solar Collector AB	low-concentrating solar tracking	-	0.01	-	N/A
Solarus Sunpower Sweden AB	partly direct and partly focused light	-	0.03	-	N/A
TOTALS		0	34.1	0	100

5.4 Manufacturers and suppliers of other components

5.4.1.1 ABB

ABB, with origin in Sweden, is a global company group specialized in power and automation technologies. Based in Zurich, Switzerland, the company employs 145 000 people and operates in approximately 100 countries. ABB employs 9 000 people in Sweden and has operations in 30 different locations. At an international level, ABB produces and provides a wide portfolio of products, systems and solutions along the solar PV value chain that enable the generation, transmission and distribution of solar power for both grid connected and micro-grid applications. ABB's offering include inverters, low-voltage and grid connection, stabilization and integration products, complete electrical balance of plant solutions as well as a wide range of services including operations and maintenance, and remote monitoring. 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 PV systems.

5.4.1.2 Ferroamp Elektronik AB

Ferroamp was founded in 2010 and is currently developing a product that they call an EnergyHub. 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. In the end of 2014 Ferroamp reached a milestone as they started their first production with a pre-series of the EnergyHub, hence going from a solely R&D company to also being a production company. The production take place in Sweden and the company have plans for a larger production series in 2015. Another important event for Ferroamp in 2014 was the start of a project together with Fortum, which aims at developing virtual power plants by connecting PV systems. A virtual power plant is a cluster of distributed generation installations which collectively are run by a central control entity, and therefore work as one large power plant.

5.4.1.3 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 was exported to the European market, but in 2012 MAPAB started to deliver more of their products to the growing Swedish PV market and in 2014 98 % of their products were sold in Sweden.

5.4.1.4 Midsummer AB

Midsummer is a supplier of equipment for manufacturing of CIGS thin film flexible solar cells. However, the company also has a small production of modules, mainly for demonstration purposes. Founded in 2004 by people with a background from the optical disc manufacturing equipment and the photo mask industry, Midsummer has its head office in Stockholm, Sweden. Midsummer’s compact turnkey manufacturing lines produces 6 inch wafer-like CIGS thin film solar cells deposited on stainless steel substrates using a proprietary all sputtering process. 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’s customers are thin film solar cell manufacturers all over the world. Midsummer has also developed a generic research tool called UNO 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 processes, but is not limited to PV only. In parallel to these activities there has been continuous research and improvements in the lab and the company has been able to increase the efficiency for 156×156 mm cells from 15.8 % in 2013 to 16.7 % in 2014. With a new type of grading of the CIGS layer, they have also been able reduce the thickness of the CIGS layer to 800 nm. Normally the thickness of the CIGS layer is 2000 nm.

5.4.1.5 Netpower Labs AB

PV modules produces DC current that usually in traditional systems is transformed via inverters to AC current, which is distributed on the grid and in many cases later transformed back to DC to run different application. In each transformation step losses occur. Netpower Labs is a company that develops DC-based backup power systems for data centers and tele/data-com systems. They have developed hardware and a concept with DC-UPS systems with integrated PV regulators for running i.e. server rooms and lightning systems directly on DC current without the transformation steps, and thereby reducing the losses significantly. The fabrication of the components takes place in Sweden, (Töreboda, Söderhamn). Netpower Labs installed in 2014 three DC systems with integrated PV regulators, two for running lightning systems and one for running a server hall.

5.4.1.6 Nilar International AB

The battery producer Nilar was founded in 2000 and has two R&D departments, one in the USA and one in Sweden, which develop the company's bi-polar NiMH battery technology. The batteries are produced at the company's factory in Sweden. Nilar uses a modular design, with building blocks of either 12 V or 24 V, which allows batteries to be coupled in parallel and series to battery-packs that can deliver the desired power and capacity. Nilar started in 2014 to develop an electronic solution which would enable their NiMH batteries to replace regular lead acid batteries. This would allow their batteries to be used for storage of variable electricity production from e.g. PV or wind and the company plan to introduce this solution to the market in 2015.

5.4.1.7 SolarWave AB

The main business of Gävle based SolarWave AB is to provide solar driven water stand-alone purification systems and desalination systems. Solar cells with a total power of 0.5 kW_p drives a water purification unit, which cleans water using an ultra violet disinfectant technology. The process is chemical free and eliminates bacteria, virus and protozoa. In 2014 SolarWaves product was approved by the United Nation and some systems where delivered to the organization. Furthermore, some systems where sold to the Swedish Civil Contingencies Agency (Myndigheten för samhällsskydd och beredskap), who used them in e.g. Sudan and the Philippines. However, the target market is mainly developing countries in Africa and the company has subsidiaries in Uganda, Tanzania and authorized distributors in Nigeria, Ethiopia and Cameroun. The company has sold around 75 systems from the start, of which 20-25 systems were sold in 2014.

5.4.1.8 Swedish Electroforming Technology AB

Sweltech is a machine manufacturing company that has two projects related to PV. One is the development of a machine and a process for electro-deposition of the grid for silicon solar cells. The second project, which started in 2014, is a collaboration with Solibro Research AB where Sweltech is a subcontractor and supplier for a lithography machine.

5.4.1.9 Weland Stål AB

Weland Stål AB in Ulricehamn manufactures a range of roof safety products. In the last years the company has experienced a growing interest in their products from the growing Swedish PV market. In the wake of this Weland Stål developed a new line of attachment parts for mounting solar panels on roofs in 2014. The production is situated in Ulricehamn and the products have so far only been sold at the Swedish market.

5.5 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 the writing) that either sold and/or installed PV modules and/or systems in Sweden in 2014 and that have contributed with data and information to this report. 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 a few MW_p for grid connected PV systems. If the reader knows of any other active company, please contact the author at: johan.lindahl@angstrom.uu.se

24 Volt	Absolicon	Agera Energi AB
Air By Solar Sweden AB	Ale Energi	Alfa SolVind I Skåne AB
Apptek Teknik och Applikationer AB	Attemptare AB	Awimex International AB
Baltic Suntech AB	BestEl	Bevego Byggplåt & Ventilation AB
Billesol AB	Bråvalla Solteknik AB	Celltech AB
Clas Olsson	Co2kompensera	Co2Pro AB
Comne Work AB	Dala Värmesystem AB	Deson AB
Ecologisk Kraft Eskilstuna AB	Effecta AB	Egen El
Egen Sol och Vind	Ekologisk Energi Vollsjö	El & EnergiCenter
El B-man	Electronic Technic LS AB	Electrotec Energy
Elfa AB	Elkatalogen i Norden AB	Elmco
Elproduktion i Stockholm AB	Energi-Center Nordic AB	EnergiEngagemang
Energiförbättring i väst AB	Energihuset i Vimmerby AB	Etab energi AB
ETV Energy Group	Euronom AB	European Sun Products
EWF ECO AB	Futura Energi	Gaia Solar A/S
Gari EcoPower	GermanSolar Sweden AB + PVIR	GFSol AB
Glacell	Global Sun Engineering	Gridcon
Hallands Energiutveckling	Helio Solutions AB	Herrljunga Elektriska AB
HESAB	Hjertmans båttillbehör	Innosund AB
JN Solar AB	KAMA Fritid	Kinnan AB
Kjell & Company	Kraftpojkarna AB	Kretsloppsenergi i Kummelnäs AB
Lego elektronik	Lightenergy AB	MeraSol AB
Miljö & Energi Ansvar AB	Naps Solel AB	Ninac Energi
Norden Solar	Nordh Energy	Nordic Solar
Nordic Sunpower	Nordisk System Teknik AB	Nyedal Solenergi
Orust Engineering	Per Martin Hellström AB	Perpetuum Automobile
Plug in Electric Europe AB	Polygress Solution AB	Prolekta Gotland AB
Rexel Sverige AB	Sapa Building System AB	Sol & Energiteknik AB
Sol Eye	Solar Supply Sweden AB	Solarenergy Scandinavia AB
Solarit	Solarlab Sweden	SolarOne
Solcellsbyggarna Boxholm AB	Solcellsproffsen AB	Solect Power AB
Solelia Greentech AB	Solenergi & Teknik i Åmål AB	Solenergi i Undrom
Solens Energi	Solfångaren i Viby	Solkompaniet Sverige AB
Solkraft TE	Solkungen AB	Solorder AB
Solortus AB	SolTech Energy Sweden AB	Stures Rörinstallationer AB
Suncell House AB	Sundaya Nordic AB/Hybrid Energy AB	Sunwind Exergon
Susen AB	SVEA Renewable Solar AB	Svesol värmesystem AB
Teknikhamstern	Ten Star Solar AB	Uppland Energi
UPS-teknik i väst AB	Vallacom	Vancos
Warm-ec Skandinavia AB	Veosol Teknik AB	Victor Energy ApS
Viessmann Värmeteknik AB	Villavind AB	Windforce Airbuzz Holding AB
Windon AB	VäxthusEffekten AB	Yokk Solar Ltd
Yorvik Solar	Åkerby Solenergi	

5.6 R&D companies and companies with R&D divisions in Sweden

5.6.1.1 Absolicon Solar Collector AB

Former Absolicon Solar Concentrator AB underwent a reconstruction in 2013 and changed its name in this process to Absolicon Solar Collector AB. Absolicon has been producing and installing its combined low-concentrating solar tracking PV and solar thermal power generation system, which consists of a cylinder-parabolic reflector that concentrates the light of the sun ten times onto the receiver, where the solar cells are mounted. The system yields about five times as much heat power as electrical power. In the wake of the bankruptcy and the reconstruction, the company devoted the work in 2013 and 2014 almost solely to product development and research projects. In 2014 the company installed a 10 kW_p system in Greece. This system boils an organic fluid in the receiver that runs a turbine and the system therefore yields electricity from both the solar cells and the turbine. Absolicon also received an order for a solely thermal system in Spain. The company has plans for construction of two fully automatic factories, one with location in Härnösand in Sweden and one in the US.

5.6.1.2 Dyenamo AB

Dyenamo AB offers chemical components and characterization equipment for research and production of dye-sensitized solar cells, perovskite solar cells and solar fuels. In addition, the Dyenamo business includes a set of services, such as custom characterization of devices and components, process development, patent evaluations and technology evaluations.

5.6.1.3 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.

5.6.1.4 Emulsionen Ekonomiska Förening

Emulsionen has together with their partner EgenEl developed equipment and IT systems for measurement of the PV production from micro-producers for the green electricity certificate system (see section 3.1.1.2). It sits directly by the solar or wind power inverter and reports the gross production for allocation of certificates, instead of in the normal case for micro-producers where only the surplus production is registered.

5.6.1.5 Exeger Sweden AB

Dye-Sensitized solar cells (DSC) have the potential to achieve a low cost per W, but have so far lacked conversion efficiency on an industrial scale. Exeger Sweden AB has addressed this problem and has been working on a transparent dye-sensitized solar cell suitable for mass production. The company is developing both transparent and non-transparent cells and is one of the companies in the world that has made most progress in commercializing the DSC technology. In the end of 2013 Exeger received the machines and equipment for their planned DSC pilot line in Stockholm, with a capacity of about 20 MW_p. 2014 was devoted to installation and development of all the equipment and the company plan to produce their first commercial test series in 2015.

5.6.1.6 Global Sun Engineering Sweden AB

Global Sun Engineering is developing a technique for low concentrating combined PV and solar thermal power generation. Their product uses several flat mirrors forming a facet disc that focuses 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. The small Luleå based company is now searching for capital to be able to introduce their product to the market.

5.6.1.7 Optistring Technologies AB

Optistring Technologies is commercializing a power inverter system for grid connected PV systems which includes electronics attached to each module. The module level electronics 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, and makes it safer at the same time. Optistring was founded in 2011 and is a spin-off from KTH research. The team is right now focusing their efforts on the inverter system and work together with global electronic manufacturing partners on the supply side. On the customer side the focus is on global panel manufacturers and system integrators to bring the technology to the market. The company finalized the 3rd generation of their products in 2014, and is now deploying pilot installations in both Sweden and abroad together with their customers and partners.

5.6.1.8 Solarus AB

Solarus is a solar energy company with two different solar panel product lines: one thermal, one combined PV and solar thermal. 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. Solarus moved to new facilities in Gävle in the beginning of 2014 and in the manual production line the company produced about 150 solar panels in 2014, mostly the combined PV and thermal type. Each module produces 230 W of electricity and 1200 W heat under peak conditions. The modules where used in different installations in Sweden, Denmark, the Netherlands and South Africa. Solarus is now building a larger production facility in the Netherlands, with plans of a production of 10 000-20 000 modules per year, and the facility in Gävle will in the future be used for product development.

5.6.1.9 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. Since September 2013 Solibro Research AB, situated in Uppsala, is owned by Hanergy Thin Film Power Group Ltd, a company listed on the Hong Kong stock exchange. In 2014 Hanergy started to build a new factory in Nanjing, China which will use the Solibro technology and have a production capacity of 300 MW_p. Solibro Research AB task is to further develop the Solibro technology and in 2014 the company achieved a new world record for thin film solar cell world record of 21.0 %, which later in the year was surpassed by the Center for Solar Energy and Hydrogen Research (ZSW), which achieved 21.7 % for a CIGS cell. Furthermore, in 2014 Solibro Research AB also developed a new utility field mounting system as well as a new BIPV mounting system for their CIGS modules and has built an outdoor test facility for modules.

5.6.1.10 SolTech Energy Sweden AB

Stockholm based SolTech Energy Sweden AB, has developed a building integrated solar energy system that use glass tiles instead of traditional roof tiles made of concrete or clay. Underneath the glass tiles, proprietary thermal or thin film PV modules for heating/hot water and electricity generation are installed. The tiles are manufactured of highly transparent glass and have a double bend, which enables the glass tiles to be installed together with traditional concrete tiles and various complementary products made for such traditional tiles. Product development is carried out by SolTech in Sweden, with production being subcontracted/outsourced to producers in Europe.

5.6.1.11 Sol Voltaics AB

The nanotechnology company Sol Voltaics AB is developing both nanowire solar cells and 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 due to advanced materials and nanophotonics compared to regular planar solar cells and to be cheap since they use less material then other technologies. 2014 was dedicated to R&D activities and Sol Voltaics managed to improve the efficiency of the nanowire cells and the potential of the nanowire film. A step towards commercialization was also made as a new tool for fabrication of nanowires using industrial methods was built.

6 PV IN THE ECONOMY

This chapter aims to provide information on the benefits of PV for the economy.

6.1 Labour places

The number of labour places in the Swedish PV module production industry has in recent years decreased dramatically due to the bankruptcy of several companies. However, the number of people involved in selling and installing PV systems increases as the market grows. The growing Swedish PV market also leads to an increased involvement from the utility companies.

In many companies and research institutes several people only work partly with PV related duties. The number of PV related jobs in this report is an assembly of all the reporting stakeholders' estimations over how many full-time jobs the Swedish PV market employs at their company. The figures are therefore not exact and should be seen as rough estimations.

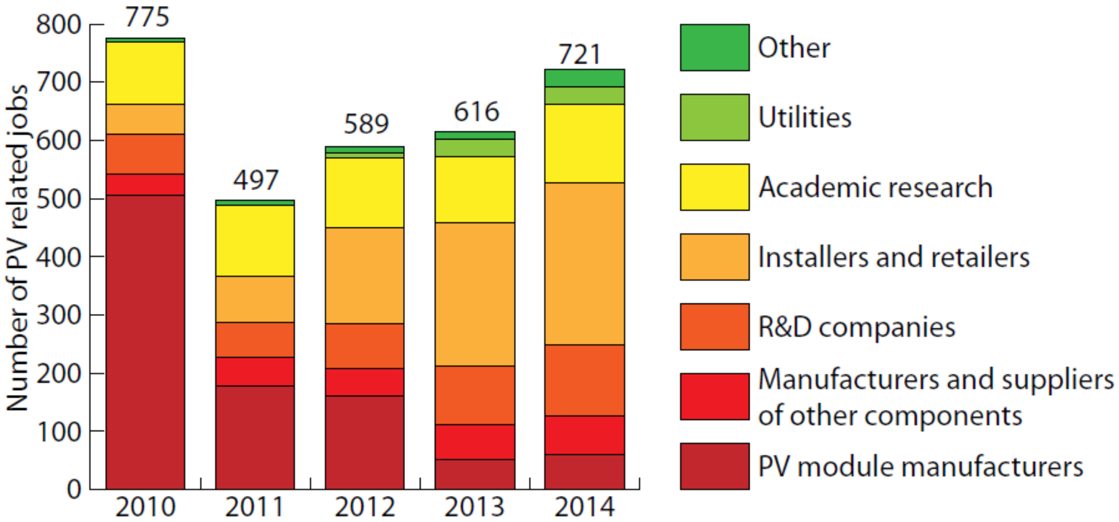

Figure 19: Evolution of the number of PV related labour places in Sweden.

Table 19: Estimated PV-related labour places in 2014

Market category	Number of full time jobs in 2014
PV module manufacturers	61
Manufacturers and suppliers of other components	65
R&D companies	122
System installers and retailers	279
Academic research	134
Electricity utility businesses and government	31
Other	29
Total	721

6.2 Business value

In table 18 some very rough estimations of the value of the Swedish PV business can be found. In Sweden about 2 MW_p of the domestic module production was installed in the country, which means that roughly 32 MW_p was exported and 34 MW_p was imported.

Table 19: Value of PV business

Sub-market	Capacity installed in 2013	Price per W_p	Value	Totals
Off-grid domestic	1.05 MW_p	20.5	21.5 million SEK	
Off-grid non-domestic	0.03 MW_p	25.0	0.75 million SEK	
Grid-connected distributed	33.15 MW_p	14.5	480.7 million SEK	
Grid-connected centralized	2.00 MW_p	13.0	26 million SEK	
Value of PV market				~ 529 million SEK
Export of PV products	~ 32 MW_p of modules exported * 7 SEK/W			~ 224 million SEK
Import of PV products	Included in the value of PV market			N/A
Change in stocks held	Unknown			N/A
Value of PV business				~ 753 million SEK

7 INTEREST FROM ELECTRICITY STAKEHOLDERS

7.1 Structure of the electricity system

In Sweden 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 the electricity consumers. The voltage in the wall sockets in Sweden is 230 V.

The backbone of the electrical grid, the national grid, is owned by the government and managed by the Swedish National Grid (Svenska Kraftnät), whereas power utility companies own the regional and local grids. The Energy Markets Inspectorate (Energimarknadsinspektionen) is the regulatory authority over the electricity market. Since the grid is a monopoly, there is only one network owner in each area that is licensed.

The base price of the electricity is daily set by the Nordic electricity retailing market, Nord Pool. Electricity trading companies then use this price as basis for their pricing in the competition for customers. The Swedish electricity market was deregulated in 1996, which resulted in that the customers could change their electricity supplier more easily.

There are about 120 electricity trading companies and 160 grid owners. However, 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, transmission and retailing, and therefore have a big influence on the overall electricity market.

7.2 Interest from electricity utility businesses

Several utility companies started in 2012 to market 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 15 kW_p. The utility companies that the author is aware of that offered these kinds of turnkey PV systems in 2014 are: Ale Energi, Din El, Elverket Vallentuna, E.ON, Fortum, Gotlands Elförsäljning, Kraftringen, MälarEnergi, Nossebro Energi, Skånska Energi, Telge Energi, Umeå Energi and Vattenfall. These utility companies all have in common that they collaborate with local Swedish installation companies that provide the actual system and execute the installation.

Furthermore, several utility companies started in 2011 to introduce compensation schemes for buying surplus electricity produced by micro-producers. This trend continues and more and more utility companies now have various offers for micro-producers. Below is a list of a number of these compensation schemes for the surplus electricty. The requirement to be defined as a micro-producer is that the system and the fuse do not exceed 43.5 kW_p and 63 A respectively. A micro-producer that is a net consumer of electricity during a year doesn't have to pay for the grid tariff or the cost of meter installation (see section 8.1.1).

There is about 120 electricity trading companies and about 160 grid owners in Sweden, so the compilation below most likely not complete. But it gives examples of the various offers that a micro-producer can find. In the list the compensation is listed in öre, which is 0.01 SEK. The utility companies change their offers from time to time, so the reader should contact the utility company directly to be sure that the offer listed here is still valid. The compilation below was latest updated in June 2015.

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

Utility company	Compensation per kWh*	PV system requirements regarding the maximum power, size of fuse and production	Fixed fees in connection with the contract of selling the surplus electricity	Does the micro-producer need to be connected to the utility company's grid	Does the micro-producer need to be net-consumer on yearly basis	Does the micro-producer need to buy electricity from the utility company	Does the utility company buy green electricity certificates from the micro-producer**	Does the utility company buy quarantees of origin from the micro-producer	The utility company's compensation for guarantees of origin	Comments
Affärsverken	80 öre	100 A	None	Yes	Yes	Yes	Yes	Yes	A package price along with certificates	
	Nord Pool spot price + 5 öre	100 A	None	No	Yes	Yes	Yes	Yes		
Ale Energi	Nord Pool spot price	43.5 kW and 100 A	Fixed monthly fee of 25 SEK (incl. VAT)	No	No	No	Yes	Yes	Unknown	
BestEl	Net metering on monthly basis	6 kW	None	No	Yes	Yes	Yes	Yes	0.2 öre/kWh	The customer receives one invoice for the consumption and one for the production. This is co-billed, which means that the total production is deducted from the total consumption. On top of this the micro-producer can get the tax reduction.
Bixia	Nord Pool spot price	No upper limit	None	No	No	No	Yes	-	0.2 öre/kWh	The guarantees of origin are taken care of by Bixia and therefore included in their remuneration.
Borlänge Energi	40 öre	100 A and max 30 000 kWh/year	None	No	No	Yes	Yes	No		
Dalakraft	48 öre	100 A and 30 000 kWh/year	None	No	No	Yes	Yes	Yes	12 öre/kWh for both certificates and GO's	Locked contract lenght of one year.
	Nord Pool spot price	100 A and 30 000 kWh/year	None	No	No	Yes	Yes	Yes		Locked contract lenght of one month.
Elverket Vallentuna	Nord Pool spot price -1 öre	43.5 kW and 63 A	None	No	Yes	Yes	Yes	Yes		
Enkla Elbolaget	48 öre	100 A and 10 000 kWh/year	None	No	No	Yes	Yes	Yes	12 öre/kWh for both certificates and GO's	
	Nord Pool spot price	100 A and 30 000 kWh/year	None	No	No	Yes	Yes	Yes		
E.ON	Nord Pool spot price - 4 öre	No upper limit	None	No	No	No	Yes	Yes	0.2 öre/kWh	
ETC el	160 öre	63 A	None	No	Yes	Yes	Yes	Yes	Unknown	Only valid for customers who have purchased the PV system from Egen El until 1 June.
	Nord Pool spot price	No upper limit	None	No	Yes	Yes	Yes	Yes	Unknown	
Falkenberg Energi	48 öre	100 A	None	No	Yes	Yes	Soon	Soon	Unknown	
Falu Energi & Vatten	According to the electricity supply contract	43.5 kW and 63 A	None	No	Yes	Yes	Yes	Yes	Unknown	The compensation for the excess electricity mirrors the electricity purchase contract. If the electricity purchase contract is a fixed price contract, the surplus electricity gets the same fixed compensation + VAT (energy tax not included). If electricity contract includes a variable price, the surplus electricity gets a variable compensation + VAT.
	NordPool spot price -1.5 öre	43.5 kW and 63 A	None	No	Yes	No	Yes	Yes	Unknown	
Fortum Markets	Nord Pool spot price	100 A	None	No	Yes	Yes	No	No		
GodEl	Nord Pool spot price	43.5 kW and 63 A, only private persons	None	No	No	Yes	Yes	Yes	20 öre/kWh	
Gotlands Elförsäljning	200 öre	43.5 kW and 63 A	None	Yes	Yes	Yes	Yes	Yes	Unknown	Only valid for customers who have purchased the PV system from Gotlands Energi AB.
	Nord Pool spot price - 4 öre	43.5 kW and 63 A	None	No	Yes	Yes	Yes	Yes	Unknown	
Gävle Energi	Nord Pool spot price	43.5 kW and 63 A	None	No	No	Yes	Yes	Yes	Unknown	
Göteborg Energi Din El	Nord Pool spot price + 5 öre	43.5 kW and 63 A	None	No	Yes	Yes	Yes	Yes	20 öre/kWh	This agreement apply only to private persons.
	Nord Pool spot price -2.9 öre	43.5 kW and 63 A	None	No	No	No	Yes	Yes	2.9 öre/kWh	These agreement apply to both individuals and companies.
Jämtkraft	60 öre	No upper limit	None	No	No	No	Yes	No		Only valid for customers who have purchased the PV system from Jämtkraft.
	Nord Pool spot price -1.5 öre	No upper limit	None	No	No	No	Yes	No		
Kalmar Energi	80 öre	43.5kW and 63A	None	No	Yes	Yes	Yes	No		
Kraftringen	140 öre	<10 kW	None	Yes	Yes	Yes	No	No		
	80 öre	10-20 kW	None	Yes	Yes	Yes	No	No		
	Nord Pool spot price - 2 öre	>20 kW	None	No	Yes	Yes	No	No		
Kungälv Energi	Nord Pool spot price + 25 öre	43.5 kW and 63 A	None	Yes	No	Yes	No	No		
MälarEnergi	Net-metering on yearly basis	100 A	None	No	No	Yes	Yes	Yes	Unknown	The value of each purchased kWh is offset against the value of each sold kWh. If ther exist a surplus in one month, the customer receives this revenue at the next month's bill.
Mölndal Energi	Nord Pool spot price	43.5 kWp and 63 A	None	No	No	No	Yes	Yes	Unknown	
Nossebro Energi	Nord Pool spot price - 3 öre	No upper limit	None	No	No	Yes	Yes	Yes	Unknown	
OX2	Nord Pool spot price - 2 öre	43.5 kW and 63 A	None	No	No	Yes	Yes	No		
Sala-Heby Energi	50 öre	43.5 kW and 63 A	None	No	Yes	Yes	Yes	Yes	0.15 öre/kWh	
SEVAB Strängnäs Energi	Nord Pool spot price - 2 öre	43.5 kW and100 A	None	No	Yes	Yes	Yes	No		
Skellefteå Kraft	48 öre	63 A	None	No	Yes	Yes	No	No		
Skånska energi marknad	Nord Pool spot price	No upper limit	None	Yes	Yes	Yes	No	No		
Sollentuna Energi	Nord Pool spotpris -1.9 öre	43.5 kW och 63 A	None	No	Yes	Yes	Yes	Yes	2 öre/kWh	
Storuman Energi	Nord Pool spot price - 2 öre	No upper limit	None	No	No	Yes	Yes	Yes	1 öre/kWh	The contract combine variable and fixed prices. Variable price is used when the spot price is low and the fixed price is used when the electricity price risks rising. Compensation for the surplus electricty is stored in an account that have 3.5% interest rate.
Sundsvall elnät	43 öre	43.5 kW and 63 A	None	Yes	Yes	No	No	No		
Sölvesborg Energi	80 öre	43.5 kW and100 A	None	No	No	Yes	Yes	Yes	Unknown	
Telge Energi	Nord Pool spot price - (0.3-4.0) öre	No upper limit	A administrative fee of 30 SEK per green electricty certificate	No	No	Yes	Yes	Yes	25 öre/kWh	Variable remuneration in 4 parts (electricity, certificates, guarantees of origin and VAT) which follows price trends in the electricity market. The remuneration policy is to ensure that the value of the electricity sold, including tax credit, shall be equal to or greater than the value of the purchased electricity.
Umeå Energi	80 öre	43.5 kW and100 A	None	No	Yes	Yes	Yes	Yes	2 öre/kWh	
Upplands Energi	Nord Pool spot price- 2 öre	43.5 kW and 63 A	None	No	No	Yes	Soon	Soon		
Vattenfall	Nord Pool spot price + 100 öre	43.5 kW and 63 A	Unknown	No	Yes	Yes	No	No		Only valid for customers who have purchased the PV system from Vattenfall.
	Nord Pool spot price + 40 öre	43.5 kW and 63 A	Unknown	No	Yes	Yes	No	No		The compensation is the Nord Pool spot price + 40 öre per kWh the first year. Thereafter the remuneration is the Nord Pool spot price
Vimmerby Energiförsäljning	Nord Pool spot price + 60 öre	43.5 kW, 63 A and max 10 000 kWh/år	None	No	Yes	Yes	Yes	No		
Öresundskraft	40 öre	No upper limit	None	No	Yes	Yes	Yes	No		

*All compensation per kWh is listed without VAT. In addition to the listed compensation the utilities pay VAT, but the micro producer will then pay the VAT to the tax office.

** The value of green electricty certificates varies and price statistics can be found in the CESAR database.

7.3 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 centre for solar energy activity in the Skåne province. The aim of the association is, in a neutral and objective way, to disseminate knowledge and information about solar technologies, thus increasing the interest and skills of various stakeholders in the solar industry and among the public.

7.3.1 Sun maps

To help potential stakeholders in PV to easier assess the potential for their particular roof, several of Sweden’s largest cities have initiated ”sun maps”. These sun maps illustrates in color scale the incoming solar radiation on all of the roofs in the city, taking into account the tilt of the roof and shadowing effects of nearby buildings or building elements. The cities that have launched or is about to launch a sun map is Stockholm, Göteborg, Lund, Örebro, Eskilstuna, Uppsala, Sollentuna.

8 STANDARDS AND CODES

8.1 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. Some of the regulations and standards related to small-scale PV systems in Sweden are:

- The National Electrical Safety Boards (Elsäkerhetsverket) regulations of certain electrical equipment.
- The National Electrical Safety Boards regulations on electromagnetic compatibility (EMC).
- The National Electrical Safety Boards regulations require that a permanent installation of a production facility shall be performed by a qualified electrician.
- A manufacturer of a product that will be used in a power generation facility must CE mark the product for it to be allowed to be used on the market.
- Section 712 of the Swedish Standard SS 436 40 00, Power systems with photovoltaic solar cells.
- Swedish Standards SS 437 01 40, The connection of low voltage circuits to the grid standard.
- Swedish Standard SS-EN 50438, Requirements for connection of small generators in parallel operation with the general grid.
- Swedish Standard SS-EN 61727, Solar power plant - Power supply.
- Swedish Standard SS-EN 61173, Solar power plant - Instructions for protection against over voltage.
- Product standards EN (IEC) 61215 - Photovoltaics - Design and approval of PV modules of crystalline silicon
- EN (IEC) 61646 - Photovoltaics - Design and approval of photovoltaic thin film technology
- CE marking and EMC Directive (89/336/EEC) for inverters.

More information can be found at www.elsakerhetsverket.se and www.solelprogrammet.se/.

8.1.1 Cost of metering equipment and installation

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. 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 is defined as a micro-producer, and will no longer need to pay for the grid tariff or the cost of meter installation as long as the producer is a net consumer during one calendar year.

8.2 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.

8.3 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 is limited in asking 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 sometimes makes it harder for new actors to enter the market.

9 HIGHLIGHTS AND PROSPECTS

The prices for turnkey PV systems continued to decrease in 2014. In 2010 the price of a typical PV system with a size of 5 kW_p for a villa was about 375 000 SEK, including VAT. With the rapid price reductions in recent years, the price was approximately 95 000 SEK, including VAT, at the end of 2014, and there are indications that the prize decline trend will continue in 2015. The price drop helped to increase PV installations in Sweden. 36.2 MW_p was installed in 2014, which is about twice as much as the 19.1 MW_p that was installed in 2013. This means that the Swedish PV market has doubled four years in a row.

The installation rate in 2015 is expected to increase, but to what extent is unsure. In general there is a growing interest for PV in Sweden and the general public is very positive to the technology. In a survey done in the beginning of 2014, almost one out of five of the Swedish homeowners said that they are considering investing in the production of their own electricity in the next five years in the form of PV or a small wind turbine. The introduction of the tax reduction and the increase of activity from utilities with regards to micro-producers are expected to enhance the growth within the residential sector. However, the quite heavy administrative burden that micro-producers need to go through to benefit from all revenue streams and the long queue in the direct capital subsidy for PV program probably stifles the growth.

For the commercial sector the new energy tax legislation that currently is under revision is a critical issue. It would be a heavy blow for this segment, which is on the brink of being profitable without subsidies, if larger PV system will be obliged to pay energy tax on the self-produced and consumed electricity. Investors are currently awaiting the current revision of the tax legislation, and the installation rate of 2015 could be affected by the time of uncertainty.

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^{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.

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_p 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_p 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

Compensation schemes (self-consumption, net-metering, net-billing…)	These schemes allow consumers to reduce their electricity bill thanks to PV production valuation. The schemes must be detailed in order to better understand if we are facing self-consumption schemes (electricity consumed in real-time is not accounted and not invoiced) or net-billing schemes (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). The compensation for both the electricity self-consumed and injected into the grid should be detailed. Net-metering schemes are specific since they 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 surplus electricity exported to the grid
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

IEA INTERNATIONAL ENERGY AGENCY