IEA INTERNATIONAL ENERGY AGENCY

Swedish Energy Agency

National Survey Report of PV Power Applications in Sweden
2015

PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

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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 Technology Collaboration 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 2015. 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 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 2015 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2015, 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 had at the end of 2015 about eleven 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 1MW_p can be seen as centralized systems.

1.2 Total photovoltaic power installed

1.2.1 Method

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: 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 %

1.2.2 The Swedish PV market

The installation rate of PV continues to increase in Sweden. A total of 47.4 MW_p were installed under 2015, as shown in Figure 1 and Table 2. This means that the Swedish PV market grew with 31 % as compared to the 36.2 MW_p that was installed in 2014. The Swedish PV market therefore didn't manage to continue the trend between 2012 and 2014 where the yearly market doubled each year.

Sweden has a stable off-grid PV market, which goes back many years. In 2015 the off-grid market grew from the 1.1 MW_p sold in 2014 to 1.6 MW_p, a 48 % increase. In total 11.0 MW_p of off-grid systems have been sold in Sweden.

In recent years, the market for grid-connected PV systems has grown rapidly in Sweden. This continued in 2015 and another 45.8 MW_p was installed under the year, a 30 % increase, which means that the cumulative grid-connected capacity was 115.7 MW_p at the end of 2015. Summing up the off-grid and grid connected PV capacities, one ends up at a total of 126.8 MW_p of PV that has been sold in Sweden until the end of 2015, illustrated in Figure 2.

The strong overall growth in recent years is mainly due to the declining system prices (see section 2.2), the introduction of the direct capital subsidy system (see section 3.1.1), and that the PV technology is very popular with the public [1].

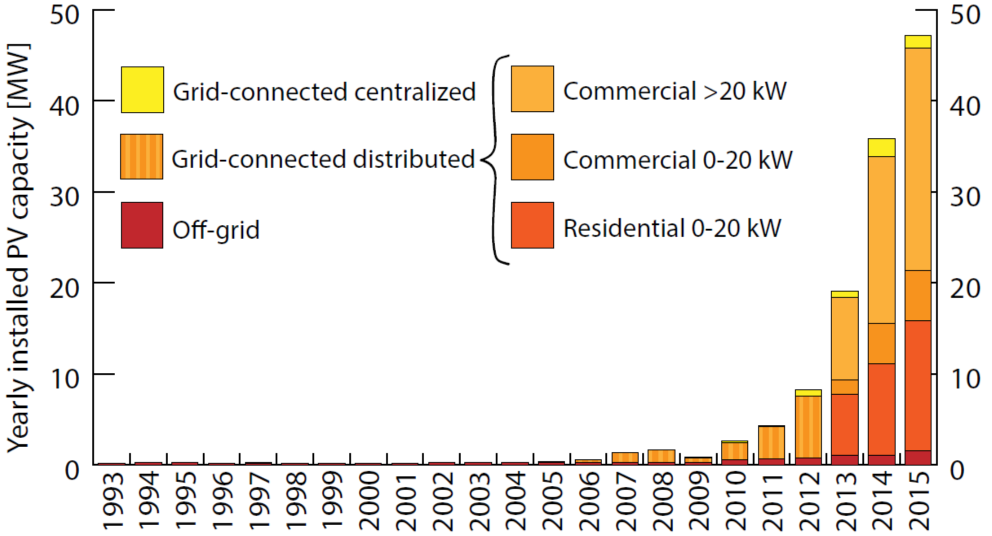


Figure 1: Yearly installed PV capacity in Sweden.

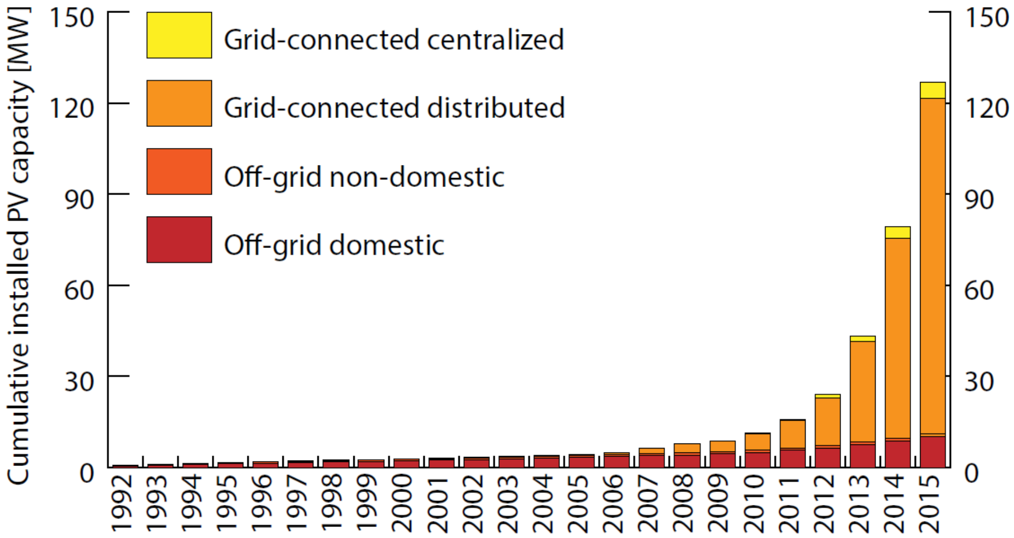


Figure 2: Cumulative installed PV capacity in Sweden.

Table 2: PV power installed during calendar year 2015.

			MWₚ installed in 2015	MWₚ installed in 2015	AC or DC
Grid-connected	BAPV	Residential	43.12	13.89[1]	DC
		Commercial		29.23	DC
		Industrial		Included in commercial	DC
	BIPV	Residential	1.09	0.40	DC
		Commercial		0.32	DC
		Industrial		0.37	DC
	Ground-mounted	cSi and TF	1.60	1.60	DC
		CPV		0	DC
Off-grid		Residential	1.57	1.54	DC
		Other		0.03	DC
		Hybrid systems		Unknown	DC
		Total	47.38		DC

[1] Only includes residential systems below 20 kW_p.

Table 3: Other market information.

	2015 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

Table 4: The cumulative installed PV power in 4 sub-markets (MW_p).

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	5.65	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	66.15	3.79	79.41
2015	10.12	0.92	110.59	5.16	126.79

1.2.3 Swedish PV market segments

In Figure 3 various market segments of the yearly installed PV capacity in Sweden is illustrated. There has been a clear shift from a market dominated by off-grid systems to a market where a majority of the sold systems is grid-connected.

Figure 3 show that very few grid-connected centralized systems (systems that are not linked to a specific consumer) have been installed in Sweden. The reason is that there principally are no support schemes for big PV parks in Sweden, except for the green electricity certificate system (see section 3.1.3), as the direct capital subsidy has a maximum aid limit per system (see section 3.1.1). Big PV parks therefore basically have to compete with the spot prices of the Nord Pool spot market.

The biggest market share in Sweden has grid-connected distributed systems, 94 % of the yearly market in 2015. In the three last years, a breakdown of this market segment have been included in the statistic collection. The grid-connected distributed systems has been divided into residential systems between 0 and 20 kW_p (a typical system in this segment is a roof-mounted system on a villa), small commercial systems between 0-20 kW_p (typical systems in this segments are roof mounted systems installed on barns or small commercial buildings) and large commercial systems >20 kW_p (typical systems in this segments are roof mounted systems on larger residential buildings, commercial buildings or warehouses). This breakdown shows that the market of small residential systems increased from 10.1 MW_p in 2014 up to 14.3 MW_p in 2015 (a 42 % increase) and that small residential systems made up 30 % of all the installed capacity in 2015 (an increase of 2 % as compared to 2014). Furthermore, 5.5 MW_p and 24.4 MW_p were installed within the small and large commercial segment, as compared to the 4.4 MW_p and 18.3 MW_p installed in 2014. These two market segments therefore grew with 17 % and 28 %, respectively, and made up of 12 % and 52 % of the yearly installed capacity in 2015.

The small residential market is therefore the segment that showed most progress in 2015. One possible explanation for the fast growing residential marked could be the introduction of the tax credit for micro producers in the beginning of 2015 (see section 3.1.5), but it is hard to derive the exact underlying mechanisms.

One explanation for the slower market growth of the commercial sector could be the coming introduction of new tax laws. The coming tax laws require that inter alia real estate owners with large, or many, PV systems will have to start paying the Swedish energy tax also on the self-consumed electricity (see section 3.3.3), which will dramatically decrease the profitability of PV systems. It is difficult to determine with certainty, but these new tax laws could have influenced the commercial market segment already in 2015.

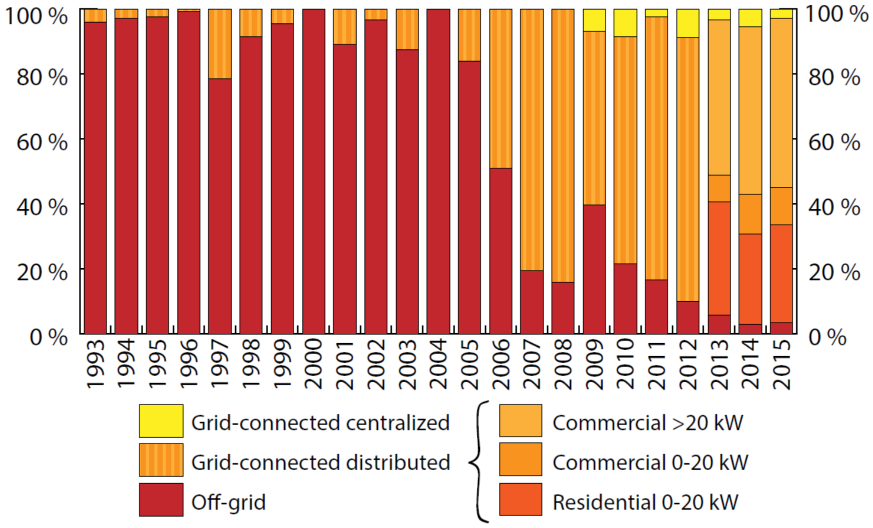
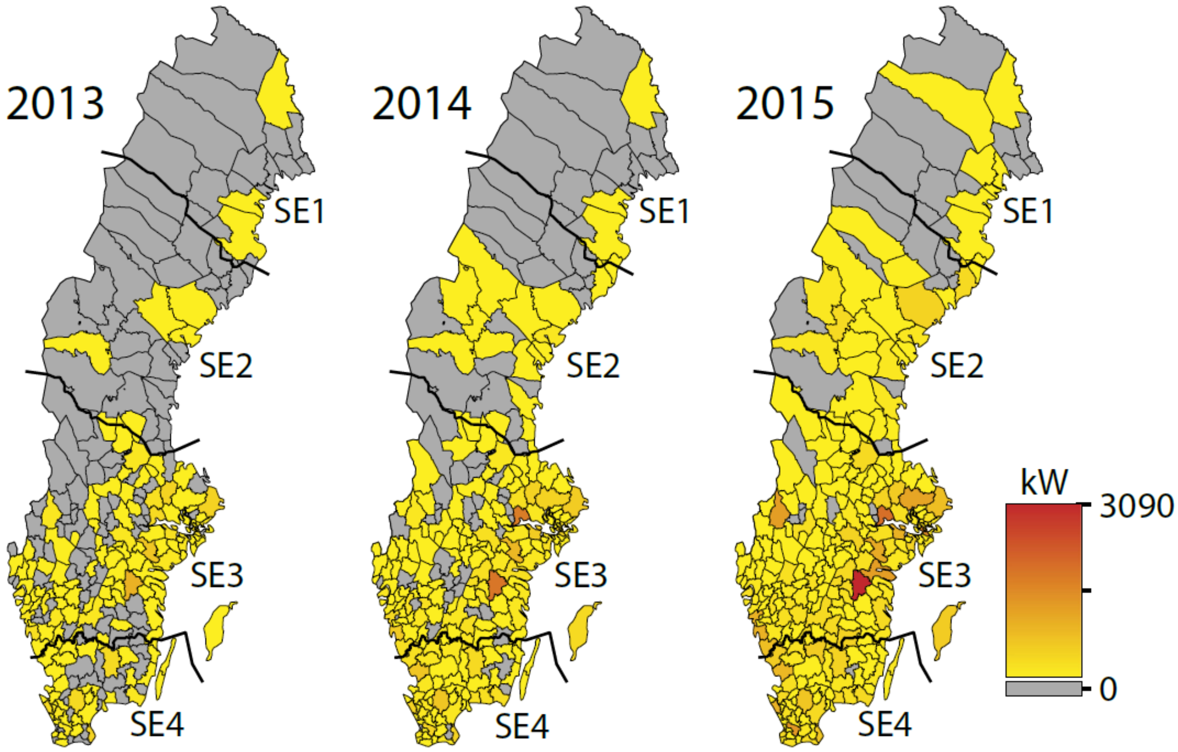


Figure 3: Various market segments share of the yearly installed capacity in Sweden.

1.2.4 The geographical distribution of PV in Sweden

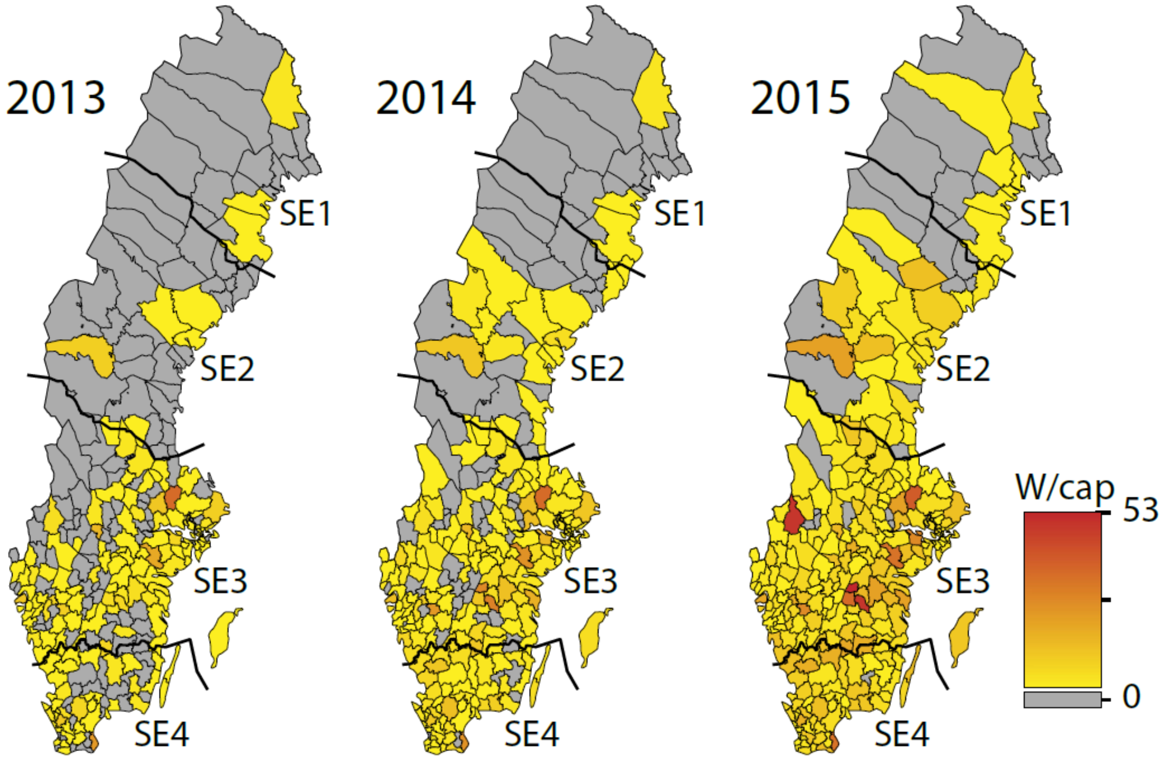
The Swedish Energy Agency (Energimyndigheten) has statistics about approved systems in the green electricity certificate system that can be separated down to municipality-level. This has been done in Figure 4 and Figure 5. These maps do not give a complete picture, but rather an indication of the geographical distribution of PV, since only about 38 % of the installed PV capacity (according to the sales statistics) has been approved for the green electricity certificates (see Section 3.1.3).

Figure 4 and Figure 5 clearly show that the expansion of PV takes place at different speeds in the Sweden's municipalities. When it comes to most installed PV capacity (in terms of total installed solar power authorized in the certificate system) – Linköping municipality, followed by Västerås and Stockholm was in the top at the end of 2015. If the installed PV capacity is divided by capita, Vadstena, Boxholm and Arvika, were instead the top three municipalities in Sweden. It is no coincidence that these municipalities in the forefront, as local incentives have been shown to play an important role in the deployment of PV in Sweden (see section 7.3).



These maps have been produced by Svensk Solenergi and David Lingfors at Uppsala University.

Figure 4: The total power of the approved PV systems in the Swedish green electricity certificate system in each of Sweden's municipalities.



These maps have been produced by Svensk Solenergi and David Lingfors at Uppsala University.

Figure 5: The total power of the approved PV systems in the Swedish green electricity certificate system per capita in each of Sweden's municipalities.

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) [2], marked as SE1, SE2, SE3 and SE4 in Figure 4 and Figure 5. The reason is that northern Sweden has an excess of electricity production, because that is where a lot of the wind power and a majority of the hydropower are situated, while there is more demand than production in southern Sweden. That has resulted in transmission bottlenecks 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 is 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. From this perspective it is good that a majority of the PV capacity is being installed in southern Sweden and mainly in the densely populated municipalities, as Figure 4 shows.

1.2.5 PV in the broader Swedish energy market

The electricity production in Sweden is dominated by hydropower, 46.7 % of total electricity generation in Sweden in 2015, and nuclear power, 34.3 %. Wind turbines have been built at an accelerated rate in recent years and electricity from wind power accounted for 10.5 % of the total electricity generation in Sweden in 2015. The rest is CHP, of which bio stand for approximately 6.5 % [2]. The total electricity generation in Sweden was 158.6 TWh in 2015. The electricity consumption was 135.9 TWh and another 9.4 TWh was lost in the grid. In total Sweden imported 12.6 TWh and exported 35.2 TWh [2].

As can be seen in Figure 6, the Swedish electricity comes from production technologies that have a relatively low CO_2-foot print. This along with the low electricity prices (see section 2.7) are probably the main reasons why the Swedish PV market still is rather small.

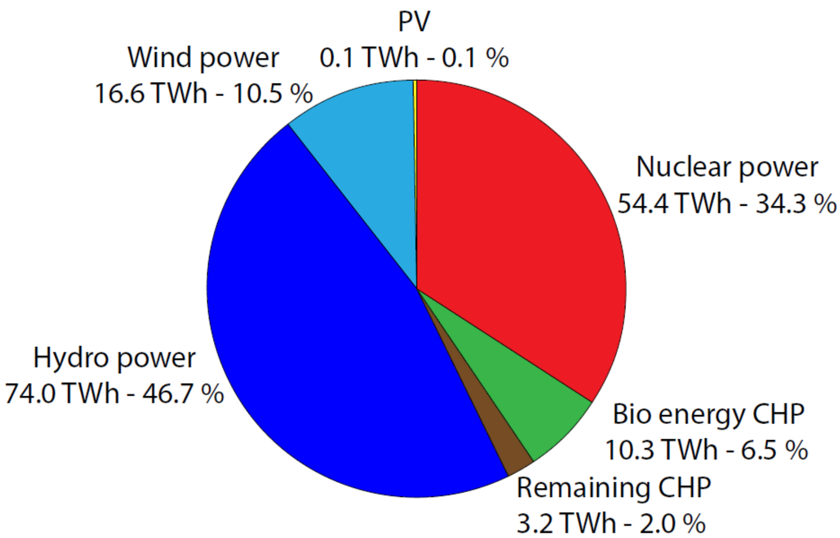


Figure 6: Total electricity production in Sweden in 2015 [2].

Table 5: PV power and the broader national energy market [2].

	2015 Numbers	2014 Numbers
Total power generation capacities (all technologies)	39 951 MW	39 549 MW
Total renewable power generation capacities (including hydropower)	25 736 MW	25 155 MW
Total electricity demand (consumption)[1]	145.3 TWh	144.0 TWh
New power generation capacities installed during the year (all technologies)	992 MW	1 470 MW
New renewable power generation capacities installed during the year (including hydropower)	~783 MW	~1 239 MW
Total PV electricity production in GWh[2]	~120 GWh	~75 GWh
Total PV electricity production as a % of total electricity consumption	0.08 %	0.05 %

[1]Including losses in the grid.
[2]Based on an annual production of 950 kWh/kW_p.

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

Module prices in Sweden are heavily dependent on the international module market. 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. However, a stabilization of the module prices has occurred in the European market the last couple of years [3], which has led to that the prices decline of modules in Sweden has slowed down, as shown in Table 6.

Table 6: Typical module prices for a number of years reported by Swedish installers and retailers – SEK/W$_p$.

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Standard module prices	70	70	70	65	63	61	50	27	19	14.2	8.6	8.2	7.6
Lowest prices	-	-	-	-	-	-	-	31.5	12	9.5	6	6	5.1
Highest prices	-	-	-	-	-	-	-	68	50	40	16	12	10

One of the reasons for the stabilization of module prices in Europe is the of import duties on Chinese PV modules and cells that was introduced in 2013 by the European Commission [4]. In these measures a minimum import price (MIP) was introduced, which means that no silicon solar cells or modules can be imported to the European Union at a price lower than 0.56 €/W$_p$, which corresponds to about 5.2 SEK/W$_p$. In Figure 7 an approximate breakdown of the origin of the modules installed in Sweden in 2015 is presented. As can be seen a majority of the modules was produced in China and was thereby affected by the import duties. The European Commission is evaluating if the import duties should be kept, expanded to more countries or terminated. Whatever the decision, Figure 7 shows that it will affect the future module prices in Sweden.

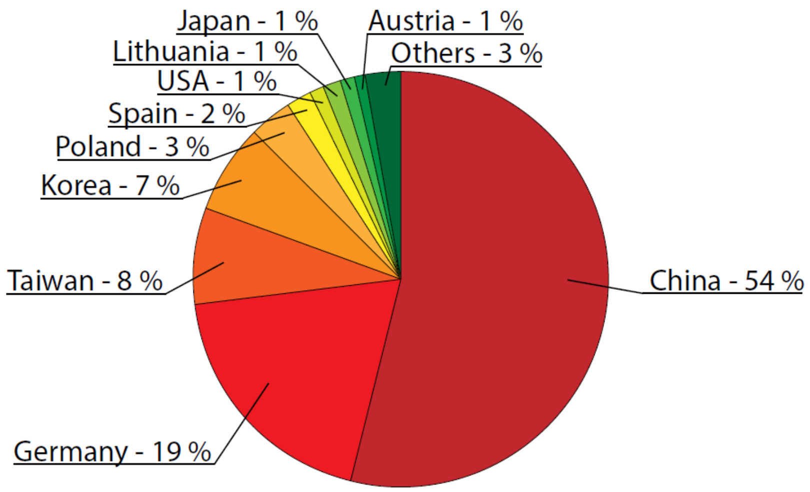


Figure 7: An approximate breakdown of the production country of the modules that was installed in Sweden in 2015, based on information from the Swedish installers and retailers of PV systems.

2.2 System prices

Sweden has experienced a large decrease in PV system prices since 2008, as Figure 8 shows. The major reason for the decline in system prices in Sweden 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 labour and cost margins. Competition in the market has also increased. In 2010 the author of this report was aware of 37 active companies that sold or installed modules or PV systems in Sweden. In late 2015 the corresponding figure had gone up to 154.

However, the very fast decrease in PV system prices in Sweden the last few years has slowed down, as Figure 8 shows. An average of the installation companies reported typical turnkey prices in the market segments, small roof-mounted commercial systems, large roof-mounted commercial systems and centralized ground-mounted PV parks was at the end of 2015 12.7 SEK/W_p, 11.8 SEK/W_p and 10.3 SEK/W_p, respectively. That means that for the prices in all these market segments went down with approximately 1 SEK/W_p in 2015, as Figure 8 and Table 8 shows. In the market segment of small residential systems, the prices stagnated in 2015 and ended up at 15.0 SEK/W_p, which is within the marginal error range of the weighted average price of 14.9 SEK/W_p from 2014.

The slowdown of the price reduction of PV system is matter-of course as it is impossible to continue with such a fast price reduction as was seen a couple of years ago when the Swedish market was catching up the international market prices. The price reduction of 6–8 % that occurred in 2015 in the commercial sector is still a good achievement.

The stagnation of the prices for the residential sector can likely partly be explained by the stagnation of the price development of modules in the European market. The modules stand for one third of the total residential system price, as Figure 10 shows, and almost half of a larger commercial system, as Figure 11 illustrates. The Swedish VAT will always stand for 20 % of the total installation costs for a private person, and since the VAT is dependent on inter alia the hardware costs it becomes difficult for the installation companies to lower the system prices if the hardware is kept at a constant level. So the future development of the module prices in Europe will heavily influence the system price development in Sweden.

Another possible reason for the stagnation of the residential system prices is the long project times for residential systems in Sweden. In a survey made in which 15 Swedish installation company participated revealed that the average of the estimated times from first contact with the customer to the completion of a small residential systems was 127 days. Of this time the customer's decision process takes the most time with an average of the estimated times of 84 days (variation of between 550 to 0 days was reported). Once the customer has decided to install PV, the average time from the signed contract to completed PV system is about 44 days according to the answers in the survey (variations between 90 to 14 days was reported by the different companies).

The overall project total project time from first contact to a completed system was 35 days in Germany in 2013 [5]. The significantly longer project times in Sweden have effects on financing costs for purchased materials, the volume of annual installations and the relative costs to operate an installation company. The major reason for the long times from first contact to signed contracts was in the survey reported to be the long waiting times for a decision about direct capital subsidy (see section 3.1.1).

The turnkey prices presented in Figure 8, Figure 9 and Table 7 are a weighted average of what different installers considered to be their typical price at the end of 2015. The typical price reported from each installer has been weighted by the market share of that specific installer.

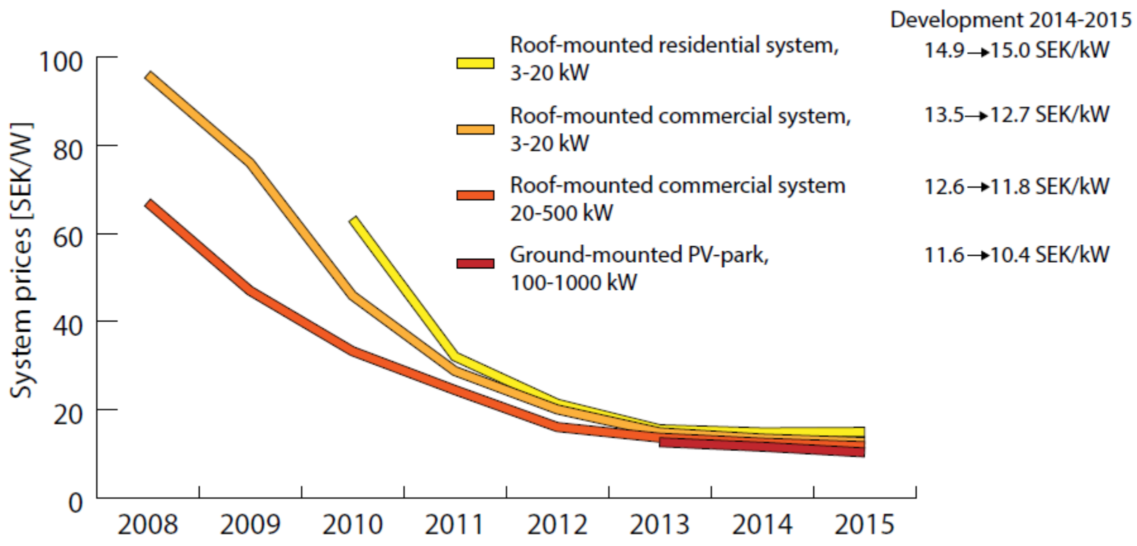


Figure 8: Weighted average prices for turnkey photovoltaic systems (excluding VAT) over the years, reported by Swedish installation companies.

Table 7: Weighted average turnkey prices of typical applications (excluding VAT).

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. The battery ins not included in the price.	20.1 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.	15.0 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.	12.7 SEK/W_p
Grid-connected, roof mounted, above 20 kW_p (commercial)	Systems installed to produce electricity to grid-connected industrial buildings.	11.8 SEK/W_p
Grid-connected, ground-mounted, 100-1000 kW_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.	10.3 SEK/W_p

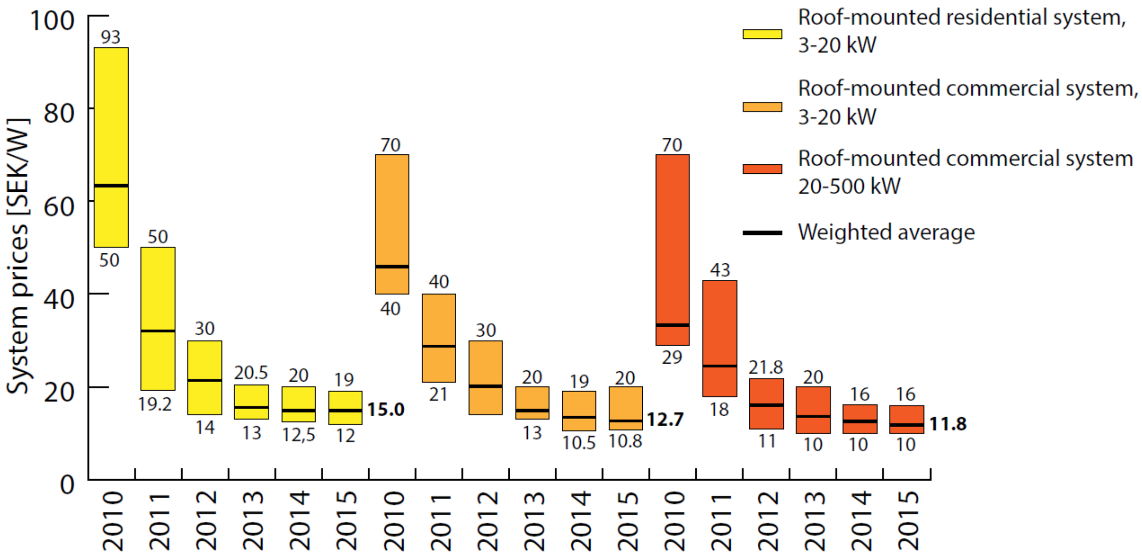


Figure 9: The price difference for typical turnkey PV systems between different Swedish installation companies (excluding VAT). Note that this is the prices that the companies regard as typical for their company, and that the graph therefore <u>does not</u> show the absolute highest and lowest prices in Sweden.

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

	2007	2008	2009	2010	2011	2012	2013	2014	2015
Off-grid PV systems, 1-5 kW_p	95.0	90.0	80.0	61.7	38.1	25.9	27	20.4	20.1
Residential PV systems, 3-20 kW_p	-	-	-	60.0	32.1	21.4	15.6	14.9	15.0
Commercial and industrial PV system, 20-500 kW_p	60.0	67.0	47.0	33.3	24.5	16.1	13.7	12.6	11.8
Centralized Ground-mounted PV system, 100-1000 kW_p	-	-	-	-	-	-	12.7	11.6	10.3

2.3 Cost breakdown of PV installations

The cost breakdown data was collected in a survey where 15 installations companies contributed with estimations on what was their typical cost structure is for a PV system with a size between 4–6 kW_p which is mounted on the roof of a villa. In the survey 5 installations companies also contributed with a similar estimation on what their typical cost structure is for a PV system with a size between 40–60 kW_p that is mounted on the roof of a commercial building.

The "average" category in Table 9 and Table 10, which is summarized in Figure 10 and Figure 11, represents the average cost for each cost category and is the average of the typical cost structure reported by the 15 respective 5 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.

When comparing Figure 10 with Figure 11 some clear differences of the cost structures of a small residential system and a larger commercial system can be distinguished. Most notably is that a private person has to pay VAT when installing a system, which a company usually do not have to do. Secondly, a larger commercial PV system usually need more design and planning work, and such a post has been added in that cost structure.

Overall almost all costs items are lower for the larger commercial system due up-scaling benefits. Most noticeable is the lower costs for inverters, installations work and profit margin.

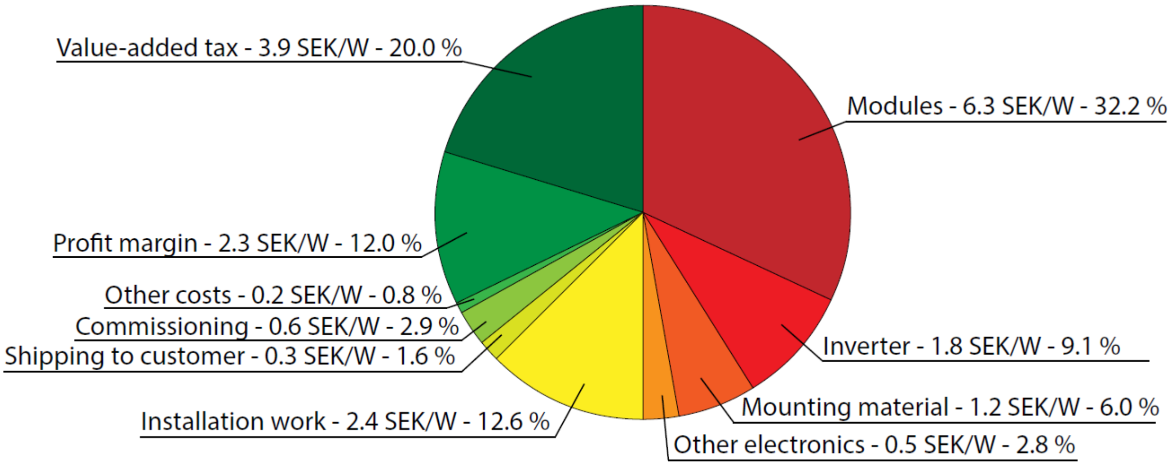


Figure 10: Average of 15 Swedish installation companies cost structures for a typical turnkey grid-connected roof-mounted residential PV system (4–6 kW_p) to the end customer in the end of 2015.

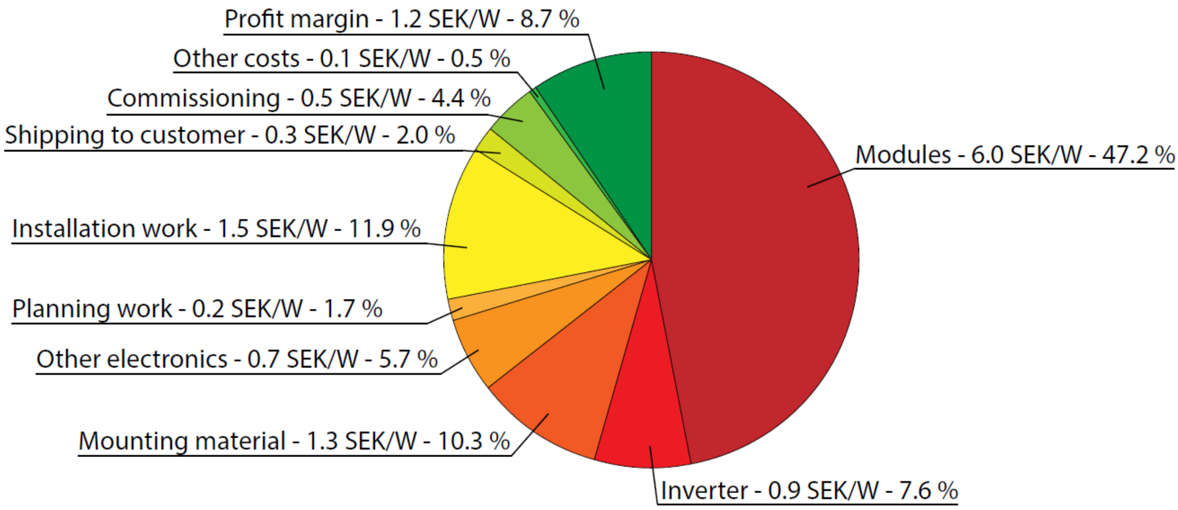


Figure 11: Average of 5 Swedish installation companies cost structures for a typical turnkey grid-connected roof-mounted commercial PV system (40–60 kW_p) to the end customer in the end of 2015.

Table 9: Cost breakdown for a grid-connected roof-mounted residential PV system 4–6 kW$_p$.

Cost category	Average (SEK/W$_p$)	Low (SEK/W$_p$)	High (SEK/W$_p$)
Hardware			
Module	6.26	5.00	14.00
Inverter	1.78	1.00	4.00
Mounting material	1.17	0.29	3.20
Other electronics (cables, etc.)	0.54	0.04	3.00
Subtotal Hardware	**9.75**		
Soft costs			
Installation work	2.43	1.00	6.40
Shipping and travel expenses to customer	0.33	0.00	1.83
Permits and commissioning (i.e. cost for electrician, etc.)	0.55	0.00	2.70
Other costs	0.16	0.00	1.00
Profit margin	2.34	0.30	6.74
Subtotal Soft costs	**5.81**		
Total (excluding VAT)	**15.56**		
Average VAT	3.89		
Total (including VAT)	**19.45**		

Table 10: Cost breakdown for a grid-connected roof-mounted commercial PV system 40–60 kW$_p$.

Cost category	Average (SEK/W$_p$)	Low (SEK/W$_p$)	High (SEK/W$_p$)
Hardware			
Module	5.98	4.89	9.10
Inverter	0.94	0.44	2.00
Mounting material	1.28	0.65	2.90
Other electronics (cables, etc.)	0.74	0.10	2.00
Subtotal Hardware	**8.94**		
Soft costs			
Planning work	0.21	0.10	1.00
Installation work	1.52	0.85	2.30
Shipping and travel expenses to customer	0.26	0.10	0.50
Permits and commissioning (i.e. cost for electrician, etc.)	0.53	0.15	1.00
Other costs	0.07	0.00	0.11
Profit margin	1.17	0.10	2.05
Subtotal Soft costs	**3.76**		
Total	**12.70**		

2.4 Financial parameters

The interest rate (reporäntan) of the central bank of Sweden (Riksbanken) started at -0.0 % in 2015 and was gradually lowered to -0.35 % under the year [6]. Changes in interest rate central bank have a direct impact on the market rates, which therefore has been very low in 2015. The cost of capital for a PV system has consequently been low in 2015.

In Table 11 the average mortage rate under 2015 has been used for residential installations. For commercial installations in Sweden a realistic loan rate has been reported to be the STIBOR rate plus 450 dps. For a large ground-mounted installation the reported internal rate of return for Sweden's largest PV park has been chosen.

Table 11: PV financing information.

Average rate of loans – residential installations [7]	1.8 %
Average rate of loans – commercial installations [8]	4.2 %
Average cost of capital – industrial and ground-mounted installations	6.0 %

2.5 Specific investments programs

In 2014 there was no company offering PV leasing contracts. However, in 2015, the company Eneo Solution AB has started to offer solar leasing contracts to owners of commercial and public buildings. They have also entered a cooperation agreement with the utility company Umeå Energi, which in 2016 will start offering solar leasing contracts to private persons. Another company, Save-by-solar Sweden AB did initiate discussions with financing partners in 2015 and hope to be able to offer leasing contracts in 2016.

Table 12: Summary of existing investment schemes.

Third Party Ownership (no investment)	yes
Renting	
Leasing	yes
Financing through utilities	
Investment in PV plants against free electricity	
Crowd funding (investment in PV plants)	yes
Other (please specify)	

2.6 Additionell country information

Sweden is a country in northern Europe. With an land area of 407 310 km^2 [9], Sweden is the fifth largest country in Europe and has a population of about 9.85 million people [10]. The population density of Sweden is therefore low with about 24 inhabitants per km^2, but with a much higher density in the southern half of the country. About 85 % of the population lives in urban areas, and that proportion is expected to increase.

Table 13: Country information.

Retail Electricity Prices for a household (range)	1.0–1.8 SEK/kW_p (including grid charges and taxes)			
Retail Electricity Prices for a commercial company (range)	1.0–1.5 SEK/kW_p (including grid charges and taxes)			
Retail Electricity Prices for an industrial company (range)	0.55–1.0 SEK kW_p (including grid charges and taxes)			
Population at the end of 2015 [10]	9 851 017			
Country size (km^2) [9]	407 310			
Average PV yield in kWh/kW_p	950 kWh/kW_p - (800–1 100 kWh/kW_p)			
Name and market share of major electric utilities		Electricity production (2015) [2]	Share of grid Subscribers (2014) [11]	Number of retail customers (2013)[2]
	Vattenfall	41 %	16 %	18 %
	E.ON/ Uniper	16 %	19 %	13 %
	Fortum	16 %	-	12 %
	Ellevio[1]	-	17 %	-

[1] Ellevios grid used to belong to Fortum.
[2] Data from Energimarknaden, a part of Svenska Nyhetsbrev 2014.

2.7 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 hydropower in the north determines how much more expensive production that is needed to meet demand.

The average price at the Nord Pool Spot market was approximately 0.20 SEK/kWh in 2015, a decrease of almost 0.07 SEK as compared to 2014. The monthly average spot price varied from 0.08 to 0.29 SEK/kWh in 2015. The maximum hourly rate for the year amounted to just under 0.65 SEK/kWh on November the 23rd at 17–18, while the minimum hourly rate was as low as 0.01 SEK/kWh on December 25th at 02–03 [2].

The decrease in electricity price was due to several factors, like a high water flow for the hydropower and the absence of long periods of extreme cold. Continued globally subdued economic conditions, with low fuel prices as a consequence, further contributed to the lowest average Swedish spot price since 2000 [2].

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 is 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 2015 for the different areas were 0.198 SEK/kWh in area 1 (Luleå), 0.198 SEK/kWh in area 2 (Sundsvall), 0.206 SEK/kWh in area 3 (Stockholm) and 0.214 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 does (see section 1.2.4).

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 12 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.

In Figure 13 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, is illustrated. Furthermore, the value of the excess 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 3.8.1), the newly introduced tax credit system (see section 3.1.5) and with and without the green electricity certificate, since few PV owners is using the green electricity certificate system (see section 3.1.3).

The reader should note that the electricity price in Figure 12 is the lowest achievable, and that most customers 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, both self-consumed electricity and the excess electricity can have a higher value than in Figure 13.

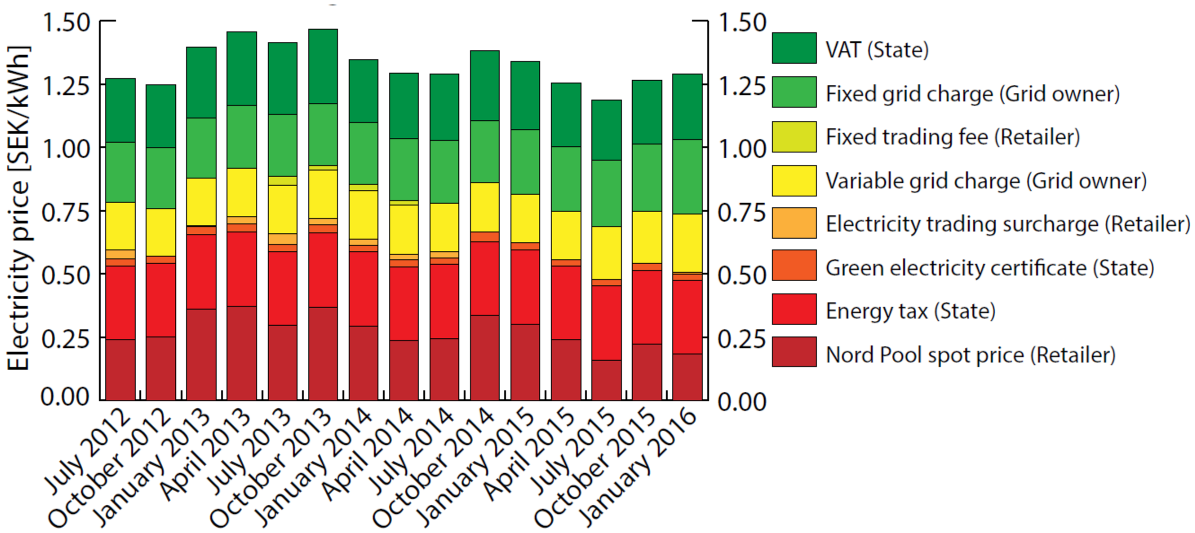


Figure 12: Evolution of the lowest variable electricity price offers for a typical house with district heating in Stockholm that has an annual electricity consumption of 10 000 kWh/year, a 16 ampere fuse and Vattenfall as the grid owner [12].

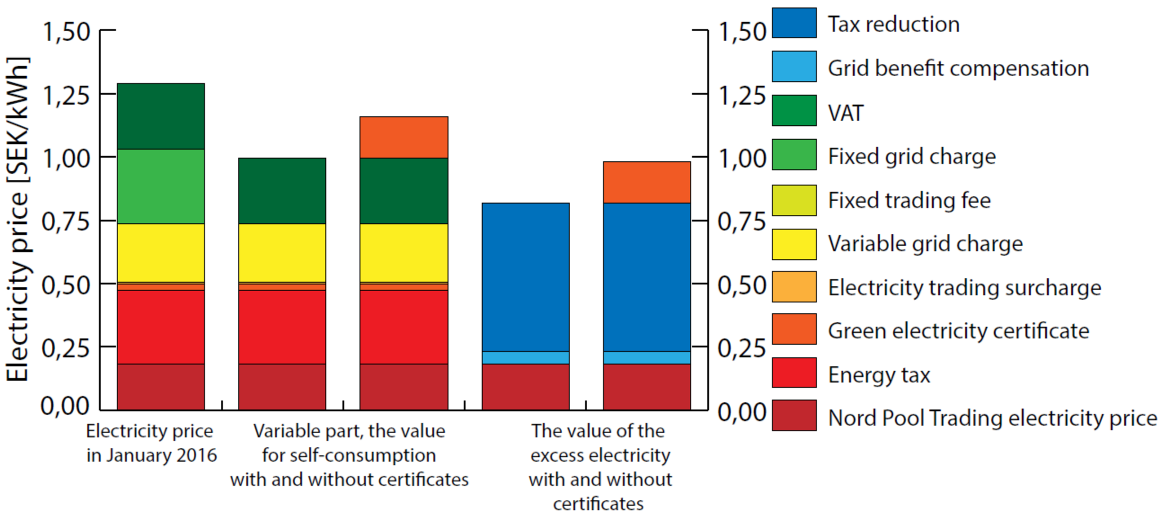


Figure 13: The lowest variable part of the electricity price and the compensation for the excess electricity, with and without the extra remuneration from green electricity certificates.

2.7.1 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 the current level of the recent years, which is about 1000 kWh/m^2. 2015 was a little bit less sunny year in Sweden compared with the record year of 2013, but still received 943 kWh/m^2 [13].

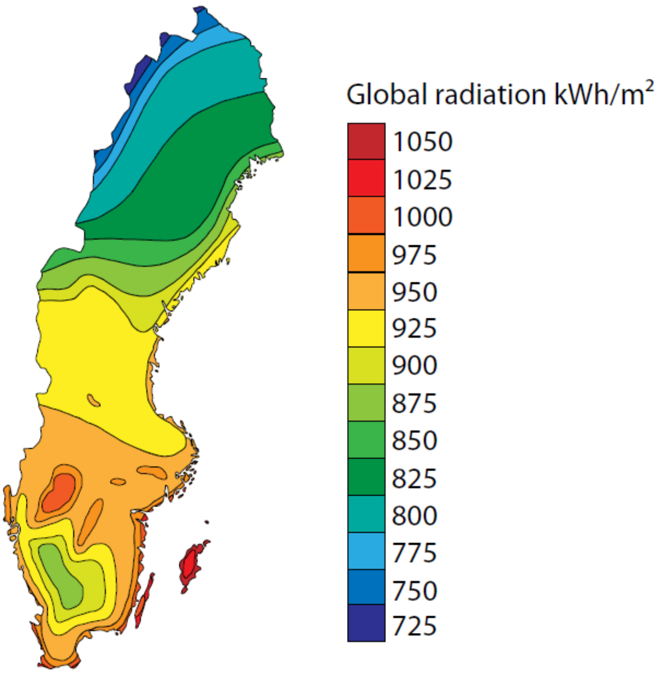


Figure 14: Global solar radiation in Sweden in one year [13].

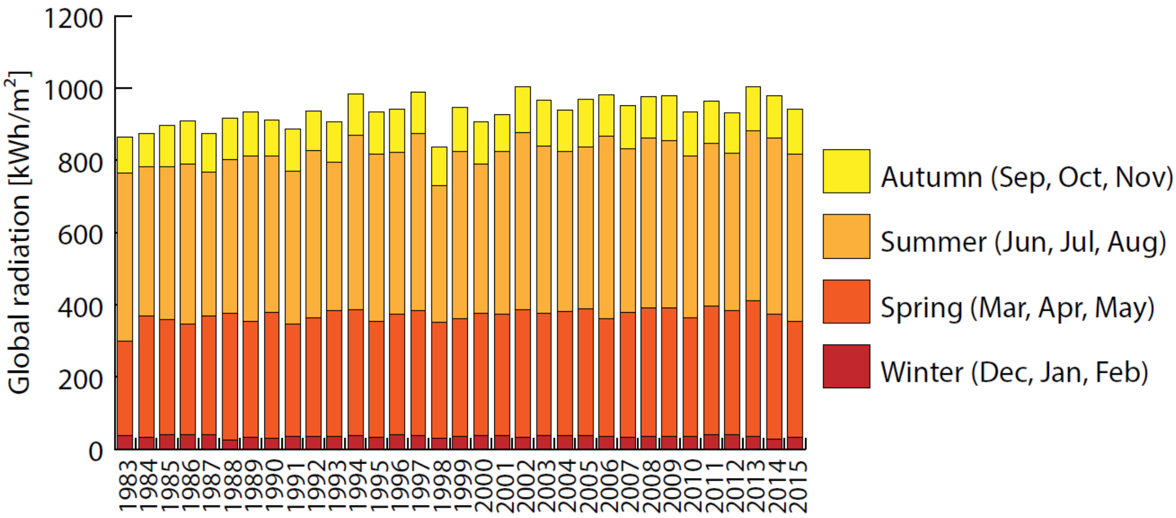


Figure 15: The development of global solar radiation in Sweden from eight weather stations [13].

2.8 Levelized cost of electricity

When including the Swedish VAT of 25 % the investment cost was about 18.75 SEK/W for a typical residential installation at the end of 2015 (se section 2.2). To calculate the levelized cost of electricity (LCOE) the following equation can be used [14];

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

where *i* is years and *n* is the lifetime of the system. Using the commonly used assumptions for a small residential PV system in Table 14, a LCOE of 1.09 SEK/kWh is obtained. This value is in parity with the variable part of the end consumer electricity price and the compensation for the excess electricity in Sweden (see section 2.7).

One should note that LCOE values heavily depend on the made assumptions and should be seen as indications. Right now the interest rates are very low in Sweden, and for private persons the rate is 0 % on saving accounts in almost all Swedish banks. So if for example a person already has the money for a PV investment, and the interest rate therefore is assumed to be 0 %, 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), the LCOE drops to 0.68 SEK/kWh.

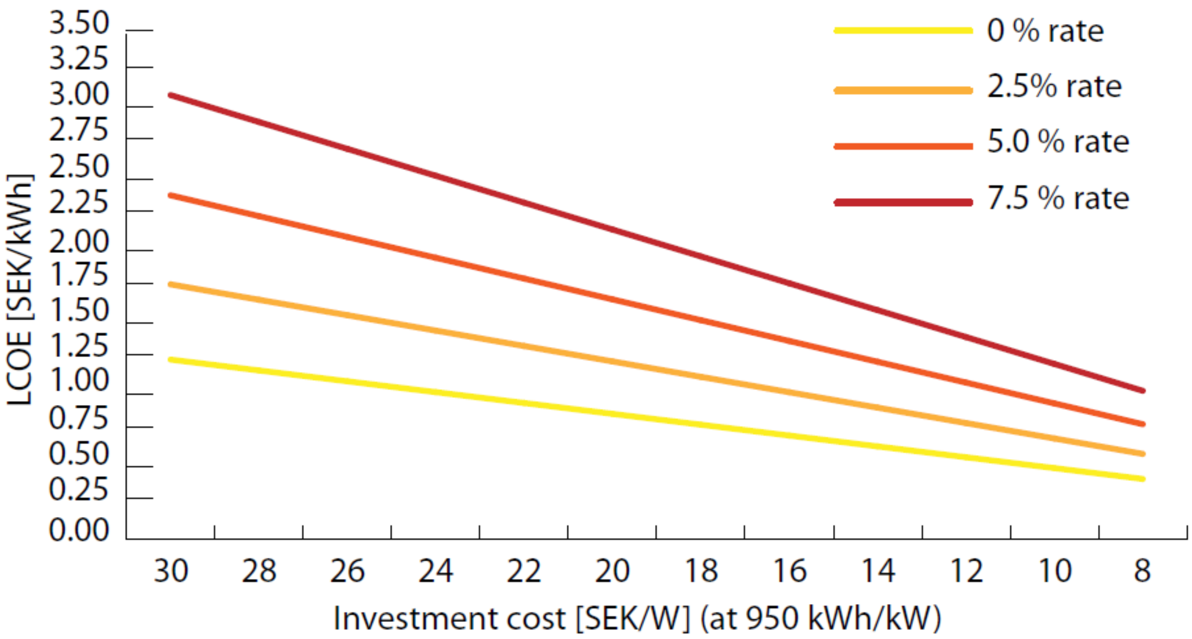


Figure 16: LCOE dependence on investment cost and interest rate.

Table 14: PV system performance assumptions.

Parameter	Value	Comment
Lifetime [years]	30	A PV module usually has a warranty of 25 years, but the lifetime is probably longer.
Initial investment [SEK/ kW_p]	18 750	See section 2.2.
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 old system is currently unknown.
First year yield [kWh/kW_p and year]	950	Based on existing PV systems in Sweden.
System degradation rate [%]	0.5	Compilation of several international degradation studies [15]
Interest rate [%]	2.0	Average mortgage rate in 2015 [7].

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.

Table 15: PV support measures summary table.

	On-going measures – Residential	Measures that commenced during 2015 – Residential	On-going measures – Commercial + industrial	Measures that commenced during 2015 – Commercial + industrial	On-going measures – Ground-mounted	Measures that commenced during 2015 – Ground mounted
Feed-in tariffs	-	-	-	-	-	-
Feed-in premium (above market price)	Yes	Yes	(Yes)[1]	(Yes)[1]	-	-
Capital subsidies	Yes	-	Yes	-	Yes	-
Green certificates	Yes	-	Yes	-	Yes	-
Renewable portfolio standards (RPS)	-	-	-	-	-	-
Income tax credits	Yes[3]	Yes[3]	(Yes)[3]	(Yes)[3]		
Self-consumption	Yes	-	Yes	-	Yes	-
Net-metering	-	-	-	-	-	-
Net-billing	-	-	-	-	-	-
Commercial bank activities e.g. green mortgages promoting PV	-	-	-	-	-	-
Activities of electricity utility businesses	Yes	-	Yes	-	Yes	-
Sustainable building requirements	Yes	-	Yes	-	Yes	-
BIPV incentives	-	-	-	-	-	-

[1] Only small commercial system can benefit from the tax credit system.
[3] The feed in premium is compensated as income tax credits. It is the same system.

3.1 Direct support policies for PV installations

3.1.1 The direct capital subsidy for PV installations 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 [16]. 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 would 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.

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 labour 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 90 000 SEK 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 (see Table 16).

Since the start of the first program in 2006, 653 million SEK had been assigned and 557.6 million SEK had been disbursed at the end of 2015. This capital has supported a total installation of 47.1 MW$_p$, which means that on average subsidy has been 11.8 SEK/W$_p$.

The direct capital subsidy program got the Swedish 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 until the end of 2015 about 10 693 applications have been received by the county administrative boards (Länsstyrelser), of which about 3 772 have been granted support and 3 131 have been disbursed [17]. 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 long waiting times have been identified as a critical issue for further PV development in Sweden [18].

Table 16. Summary of the Swedish direct capital subsidy program. Excerpts from the statistics 2016-01-29.

	2006 – 2008	2009	2010	2011	2012	2013	2014	2015	Total
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 [million SEK]	5	2			1.5	1.3		1.2	
Maximum system cost per W (excluding VAT) [SEK/W]	-	75			40	37		37	
Budget [million SEK]	150	212			60	210		50	**532**
Granted resources [million SEK] [17]	138[1]	28.4	74.1	71.2	58	122.4	67.9	94.7	**653**
Disbursed funds [million SEK] [17]	138[1]	0.05	33.2	81	78.3	73.2	75.6	78.2	**557.6**
Installed capacity based with support from the direct capital subsidy [MW$_p$]	2960[1]	0.18	2.05	3.16	6.41	11.30	14.11	6.96	**47.13**[2]
Yearly installed grid connected PV capacity according to the sales statistics [MW$_p$]	2825[1]	0.52	2.11	3.63	7.46	17.99	35.15	45.81	**115.75**[3]

[1] In total between 2006–2008.
[2] System installed with support from direct capital subsidy between 2006 and 2015.
[3] Cumulative grid connected PV capacity according to sales statistics.

Listed in Table 16 is the annual installed PV capacity that has received support from the direct capital subsidy as compared to the sales statistics that has been collected over the years through the annual Swedish national survey reports. The statistics from direct capital subsidy program correlates well with sales statistics, except for 2009 and from 2013 and onwards. For 2009 it can be explained with a backlog of installations from the older direct capital subsidy program. For the difference in the statistics for from 2013 and onwards, there are three likely contributory reasons. One is that the task of filing and registries statistics for capital subsidy program is lagging behind. A second reason could be that there is margin of errors in the sales statistics. The third explanation is that now a day many complete the installation of their PV system without first being granted the direct capital subsidy. This can be seen in the database of the program where there are several systems that have a registered system completion date that is earlier than the granted support date.

The trend that more and more PV systems is being installed without having been granted direct capital subsidy is an interesting trend. A few possible motives behind this development might be:

• Because of the long waiting times, PV system owners completes their systems earlier and expects to be granted direct capital subsidy afterwards.

• Private PV customers use the ROT tax deduction instead (see section 3.8.2).

• PV system customers find it attractive enough to install photovoltaic solar cell without the direct capital subsidy, and a possible later gratification of the support is seen as a bonus.

In an effort to lower the waiting times for the support the government decided in the autumn of 2015 to greatly increase the annual budget for the years 2016–2019 with 235, 390, 390 and 390 million, respectively [19], as illustrated in Figure 17. This large increase in budget will probably have a positive effect on the Swedish PV market, but to which extent is still uncertain and the impact will partly be decided by which coverage levels the government decides on for the future.

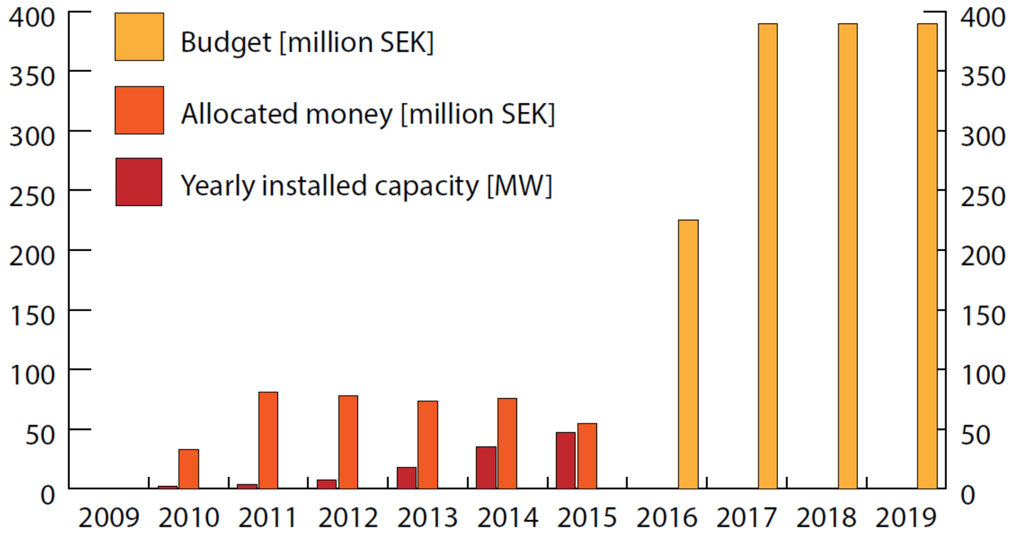


Figure 17: Disbursed capital and the future budget of the direct capital subsidy along with the annual Swedish PV market.

3.1.2 The direct capital subsidy for renewable energy production in the agriculture industry

In 2015 the Swedish Board of Agriculture (Jordbruksverket) introduced a direct capital subsidy for production of renewable energy. The subsidy can be applied for if a company have a business in agriculture, garden- or herding. The subsidy is given to support production renewable energy for both agricultural activities and for sale. This may be in the form of biomass, wind, hydropower, geothermal and PV.

The subsidy is granted for purchase of materials, services purchased from consultants to plan and carry out the investment, but not salary to employees or own work. The level of the direct capital subsidy is 40 % of the total expenses. The maximum amount of aid a company can receive is decided by the respective County Administration (Länsstyrelse) or by the Sami Parliament (Sametinget) [20].

The support level of this direct capital subsidy is higher than in the national direct capital subsidy program for PV installation. This can be motivated by that many agriculture companies pay a lower level of the Swedish energy tax (see section 3.3.1), which makes the value of self-consumed electricity lower than for regular electricity consumers and therefore a PV system less profitable. A higher subsidy level increases the profitability PV installation on barns and other agriculture buildings, which is a market segment with a large potential [21].

3.1.3 The green electricity certificate system

The basic principle of the green electricity certificate system is that producers of renewable electricity receive one certificate from the government for each MWh produced. Meanwhile, certain electricity stakeholders are obliged to purchase certificates representing a specific share of the electricity they sell or use, the so-called quota obligation. 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, and each production facility can receive green electricity certificates for a maximum of 15 years.

The quota-bound stakeholders are; electricity suppliers, electricity consumers who use electricity that they themselves produced if the amount of electricity used is more than 60 MWh per year and if it has been produced in a plant with an installed capacity of more than 50 kW_p, electricity consumers that have used electricity that they have imported or purchased on the Nordic power exchange, and electricity-intensive industries that have been registered by the Swedish Energy Agency (Energimyndigheten) [22].

The system was introduced in Sweden in 2003 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 in 2016 compared with the levels of 2002. In 2012 was Sweden and Norway joined forces and formed a joint certificate market. The objective then was that the electricity certificate system would increase the production of electricity from renewable sources by 26.4 TWh between 2012 and 2020 in Sweden and Norway combined. In the common market there is the opportunity to deal with both Swedish and Norwegian certificates to meet quotas [23]. In March 2015 the Swedish and Norwegian Governments a new agreement which raised the common goal with 2 TWh to 28.4 TWh until 2020. This increase will only be funded by Swedish consumers [24]. The joint Norwegian-Swedish system has since 2012 produced 10.3 TWh of renewable electricity [2].

In 2015, the quota obligation for electricity suppliers was 14.3 %, and with the new agreement the quota obligation was raised to 23.1 % in 2016 [25]. The average price for a certificate was 160.2 SEK/MWh in 2019 [26], which resulted in an average additional price of 0.028 SEK/kWh for the end consumers [2]. The established trend in the level of the quota duties is summarized in Figure 18 and the price trend in Figure 19.

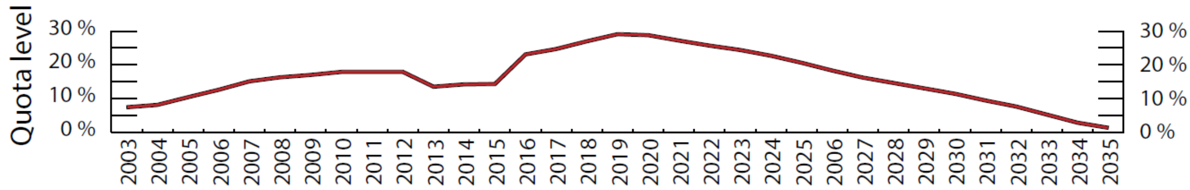


Figure 18: The quota levels in the green electricity certificate system [25].

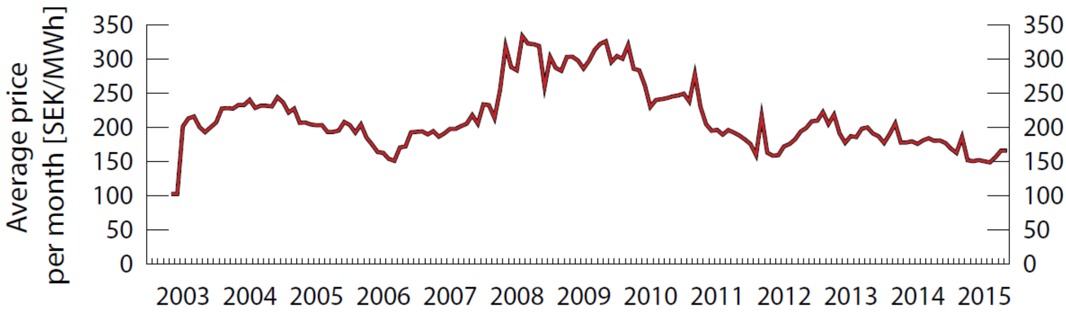


Figure 19: The price development of the green electricity certificates [26].

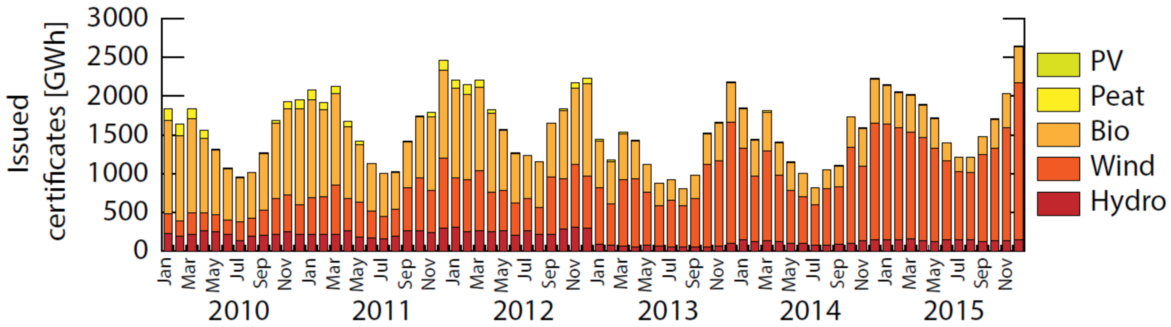


Figure 20: The allocation of green electricity certificates to different technologies in Sweden [26].

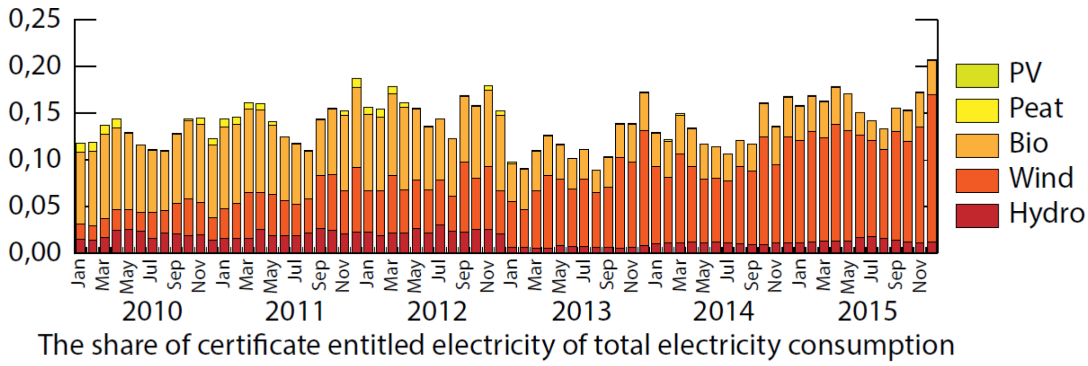


Figure 21: The share of certificate entitled electricity as of total electricity consumption in Sweden [26][27].

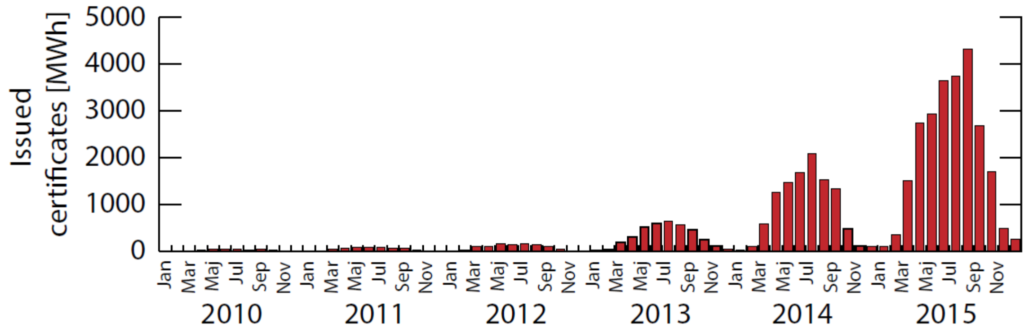


Figure 22: Green electricity certificates issued to PV produced electricity [26].

Until 2006 there were no solar systems in the electricity certificate system. However, as Table 17 and Figure 20 shows, the number of approved PV installations increased over the years and the majority of approved plants in the certificate system are now photovoltaic systems. However, these systems only make up for a very small part of the total installed power and produced certificates. As can be seen in Figure 20, the majority of the certificates go 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 is higher in the winter months, as illustrated in Figure 21.

Only 48.6 MW_p of PV power were at the end of 2015 in the certificate system, making it only 38 % of the total installed PV capacity obtained from the sales statistics. 24 511 certificates were issued to PV in 2015, which corresponds to 24 511 MWh of PV electricity production. This can be compared to the theoretical production of 126.8 $MW_p \times 950$ $kWh/kW_p \approx 120\,460$ 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 calculation above is very simplified since not the whole cumulative grid connected PV power at the end of 2015 was up and running throughout the whole year.

There are several reasons why it has been difficult for PV to take advantage of the electricity certificate system and why solar owners refrain from applying. One is that many owners of small photovoltaic systems do not consider the income that certificates provide is worth the extra administrative burden. The main reason for this is that the meter that registers the electricity produced by a PV system is often placed at the interface between the building and the grid. This has the consequence that it is only excess production from a PV system that generates certificates and the solar electricity that is self-consumed internally in the building is not awarded any certificates. A PV owner can get certificates also for the self-consumed electricity if an internal meter is installed. For smaller PV systems the additional cost of such a meter and the annual metering fee can be higher than the revenue from the additional certificates, which means that many refrain from applying for certificates for the self-consumed electricity. This is the main reason why the number produced certificates eligible kWh per installed power and year is so low in Table 17.

Another reason why it has been difficult for PV to take advantage of the certificate system is that it can be difficult for an individual to find a buyer for only a few certificates. However, this is about to change as more and more utilities have begun offering to purchase certificates from micro-producers (see Section 7.2). This may be the reason for the clear trend in Table 17, where the proportion of approved solar power owned by private persons is increasing.

Table 17: Statistics about PV in the electricity certificate system [26][28].

	Number of approved PV systems in the certificate system at the end of each year	Total approved solar power in the certificate system at the end of each year	Share of the solar power in the certificate system that is owned by private persons	Number produced certificates from solar cells per year	Number produced certificates eligible kWh per installed power and year
2006	2	28 kW_p	0 %	20 MWh	714.3 kWh/kW
2007	3	35 kW_p	0 %	19 MWh	542.9 kWh/kW
2008	8	301 kW_p	0 %	129 MWh	428.6 kWh/kW
2009	10	361 kW_p	0 %	212 MWh	587.3 kWh/kW
2010	19	1 249 kW_p	1 %	278 MWh	222.6 kWh/kW
2011	43	1 635 kW_p	9 %	556 MWh	340.1 kWh/kW
2012	124	3 077 kW_p	26 %	1 029 MWh	334.4 kWh/kW
2013	463	10 536 kW_p	41 %	3 705 MWh	351.7 kWh/kW
2014	1124	23 660 kW_p	48 %	10 770 MWh	455.2 kWh/kW
2015	2550	48 600 kW_p	52 %	24 511 MWh	504.3 kWh/kW

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.

3.1.4 Guarantees of origin

Guarantees of origin (GO's) are electronic documents that guarantee the origin of the electricity. Electricity producers receive a guarantee from the government for each megawatt hour (MWh) of electricity. The electricity producer can then sell GO's on an open market. The buyer is usually a utility company who wants to sell that specific kind of electricity. Utilities buy guarantees of origin corresponding to the amount of electricity they would like sell. GO's are issued for all types of power generation and applying for guarantees of origin is still voluntary.

When the electricity supplier has bought the GO's and sold electricity to a customer, the GO's are nullified. The nullification ensures that the amount of electricity sold from a specific source is equivalent to the amount of electricity produced from that source.

A utility who wants to sell, for example, electricity from PV can do it in two ways. Either by nullify guarantees of origin from its own PV-system, or by purchasing guarantees of origin from a PV-system owner and cancel them when the supplier sells the electricity to the end customer.

In 2015 in Sweden 19 052 GO's from PV were issued, 12 767 were transferred and 7 238 were nullified [26]. 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 in Sweden is still uncertain.

3.1.5 Tax credit for micro-producers of renewable electricity

The 1 of January 2015 a tax credit for micro-producers of renewable electricity, an amendment to the Income Tax Act has been introduced [29]. 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 excess electricity to the grid at the same connection point as where the electricity is received,
- not have a fuse that exceed 100 amperes 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 excess electricity, such as compensation offered by electricity retailer utility companies (see section 7.2), the grid benefit compensation (see section 3.8.1) and revenues for selling green electricity certificates and guarantees of origins (see section 3.1.3 and 3.1.4). The tax credit system can be seen as a FiT for the excess electricity. However, unlike the FiT systems of e.g. Germany, the Swedish tax credit system does not offer a guaranteed purchase agreement over a specific time period. 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.

3.1.6 PV support measures phased out in 2015

No PV support measures were phased out in 2015 in Sweden, but the level of the direct capital has as of the start of 2015 been lowered (see section 3.1.1).

3.1.7 PV support measures introduced in 2015

In 2015 the tax credit for micro-producers (see section 3.1.5) and the direct capital subsidy for renewable energy production in the agriculture industry (see section 3.1.2) were introduced.

3.2 Support for electricity storage and demand response measures

To help increase individual customers the opportunity to store their own produced electricity the Swedish government has allocate funds for a direct capital subsidy for energy storage for households, R&D and innovation procurement. The budget for the storage subsidy program is 25 million SEK in 2016 and 50 million per year from 2017 to 2019 [30]. The levels of the subsidy are currently being discussed.

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.

3.3 Self-consumption measures

3.3.1 General taxes on electricity

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 (see section 3.8.4), taxes on fuels, taxes on emissions to the atmosphere and tax on nuclear power. Including VAT, the total tax and fee's withdrawal from power sector is estimated to be about 42 billion 2016 [2].

The taxes associated with electricity consumption are mainly the energy tax on electricity and the related VAT. The manufacturing and agriculture industry paid 0.005 SEK/kWh in energy tax in 2015. The rate for residential customers was 0.294 SEK/kWh (excluding VAT), with the exception of some municipalities in northern Sweden where the energy tax was 0.194 SEK/kWh (excluding VAT) [2]. 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 2015.

3.3.2 Self-consumption rules in force in 2015

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 excess 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 3.1.5) 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 [31]:

3.3.2.1 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.

3.3.2.2 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 excess electricity does not exceed 30 000 SEK in a calendar year.

3.3.2.3 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 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.

3.3.2.4 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 excess electricity is sold to an electricity supplier.

If only the excess 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.

3.3.3 Future energy tax on self-consumption

The Swedish government wanted in 2015 to increase its national ambition within the green electricity certificate system (see section 3.1.3) to 30 TWh. Norway agreed to that, but with the requirement that the Swedish government removed the current exemption from the energy tax that wind power (and other renewable electricity) that is not delivered professionally were benefiting from. Therefore, new rules will come into force the first of July 2016, which states that [57]:

Exemption from the energy tax will apply to electricity produced:

- in a system of installed generator capacity below 50 kW,
- by a legal person who possesses a total installed generator capacity of less than 50 kW, and
- that has not been transferred to a grid subject to the grid-concession stated in the Electricity Act.

An installed generator power of 50 kW shall correspond to:

- 125 kW for Wind- or wave power,
- 255 kW_p for a photovoltaic system, and
- 50 kW for other energy sources without a generator.

When electric power is produced from various sources, the installed power should be added together.

The Swedish energy tax is a consumption tax, and the tenet of the Swedish Energy Act states that all electrical power that is consumed in Sweden should pay the energy tax. Before, the general consensus was that self-consumed electricity was exempted from the energy tax. But the new rules mean that PV owners, that own more than 255 kW_p in total, will have to start paying the energy tax also on the PV electricity that is produced and self-consumed within the same building.

This new law has received criticism, both during the remittance of the law [30] and afterwards. The criticism is based partly on ideological reasons, as other goods or services produced for one's own use usually are not taxed in Sweden. The other perspective is that if the 255 kW_p limit is exceeded the profitability of a PV system is usually lost as the value of the self-consumed electricity is reduced by the energy tax (see Figure 13), which corresponds to 0.294 SEK/kWh.

The fact that the law will take effect July 1 2016 has already had the consequences that several large real estate owners that have started to install PV systems on their building has announced that they now have cancelled planned future PV expansions, as they already reached the limit of 255 kW_p (or soon will). The power limit of 255 kW_p is not really the biggest problem, as only very few Swedish PV systems exceed this size. The problem is rather that the limit is set per the total power a legal person owns, instead of per each system.

Due to the criticism and the likely negative influence on the distributed commercial market segment, the government has declared that they intend to in 2016 investigate if this new law could be improved [30]. However, the outcome of this investigation is uncertain.

Table 18: Summary of self-consumption rules for small private PV systems in 2015.

PV self-consumption	1	Right to self-consume	Yes
	2	Revenues from self-consumed PV	Savings on the electricity bill
	3	Charges to finance Transmission & Distribution grids	None
Excess PV electricity	4	Revenues from excess PV electricity injected into the grid	Various offers from utilities + 0.6 SEK/kWh + Green certificates
	5	Maximum timeframe for compensation of fluxes	1 year
	6	Geographical compensation	On site only
Other characteristics	7	Regulatory scheme duration	Subject to annual revision
	8	Third party ownership accepted	Yes
	9	Grid codes and/or additional taxes/fees impacting the revenues of the prosumer	Grid codes requirements and requirement for VAT registration
	10	Regulations on enablers of self-consumption (storage, DSM…)	None
	11	PV system size limitations	Below 100 Amp. And maximum 30 MWh/year for the tax credit
	12	Electricity system limitations	None
	13	Additional features	Feed in tariffs from the grid owner

3.4 BIPV development measures

There were no measures for BIPV development in 2015 in Sweden.

3.5 Tenders, auctions & similar schemes

There were no national or regional tenders, auctions or power purchase agreements in 2015 in Sweden.

3.6 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 countryside 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.

3.7 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 419 573 609 SEK has been disbursed from 2009 to the end of 2015 [17]. 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 had at the end on 2015 received 41 244 certificates to a value of 6 844 615 SEK [26]. 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 568 949 376 in subsidies, which corresponds to roughly 58 SEK/capita.

3.8 Indirect policy issues

3.8.1 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 excess electricity entails [32].

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.

3.8.2 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 summerhouse.

The ROT-tax deduction in 2015 was 50 % of the labour cost and of maximum 50 000 for the installation of a PV system. As of the first of January 2016 the tax deduction has been reduced to 30 % of the labour costs [30]. 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 [33].

According to the Swedish Tax Agency labour costs are estimated at 30 % of the total cost, including VAT. The total deduction for the whole PV systems was therefore 15 % in 2015, and will from 2016 instead be 9 %. The up side of the ROT-tax deduction scheme is that there is no queue and that the PV owner can be sure of receiving this subsidy.

3.8.3 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 [34].

3.8.4 Property taxes

Power generation facilities in Sweden are charged with a general industrial property tax. Today the PV technology is not defined as power generation technology in the valuation rules for power production units in the real estate law (Fastighetstaxeringslagen). The tax agency has so far classified the few large PV parks that exist as “other building” and taxed them as an industrial unit. Currently the property tax of an industrial unit represents 0.5 % of the assessed value of the facility [35].

A recent governmental investigation, that at the time of writing is out on remittance, suggest that PV should be introduced as a specific power production type in the real estate law. The investigation also suggest that the tax rate for PV power production facilities should be the same as for wind power, which is 0.2 % of the assessed value of the facility [35].

Furthermore, the investigation suggests that so-called micro-generation of electricity, and another generation of electricity for self-consumption, where a surplus production is sold, does not normally mean that a building is established for commercial production of electric power. Such buildings are consequently not usually a power plant building in the property tax legal sense and should therefore not be taxed as a power production facility [35].

4 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. Furthermore, there are some smaller groups that focus on PV systems and PV in the energy system oriented research.

4.1 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 20 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.

4.1.1.2 SP Technical Research Institute of Sweden

SP Technical Research Institute of Sweden is an internationally present research institute, which conducts various PV research, testing, evaluation and educational activities. In 2015, SP started two new research projects on PV. One (PROOF - Competetive industrialized PV roofing) financed by Swedish Energy Agency in the SOLAR-ERA.NET EU program is developing and demonstrating a prefab PV roof solution, the other (ELSA-Solar shading in a holistic perspective") is a large national project involving a wide range of stakeholders aimed at increasing acceptance and knowledge regarding solar shading with integrated PV. SP is also active in IEA-PVPS task 13 "performance and reliability of photovoltaic systems" and has also joined the new task 15 "Enabling Framework for the Acceleration of BIPV". Furthermore, SP is engaged in PV standardization through SEK TK 82, which is the Swedish mirror committee for IEC TC 82. In 2015 SP worked together with Chalmers and Solkompaniet in a project where "A Swedish strategic innovation agenda for solar electricity" was compiled, which aims at guiding Swedish businesses and policy makers in their work in the near future. SP also contributes with expertise on PV in several national and local programs related to education and information.

4.1.1.3 The Glass Research Institute

The Glass Research Institute (Glafo), situated Växjö, 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 long project with total funding of 1.3 Million Euros. (The Swedish project partners are financed by the Swedish Energy Agency with about 0.6 Million Euros.). Glafo has as well been engaged in another SOLAR-ERA.NET project about integrating solar cells in prefabricated roofs. The project aims at develop a solution that is both cheap and esthetical attractive. A prototype is planned to be installed in one of Skanska's new buildings at the end of the project. Furthermore, Glafo has started to work with organic PV. One project is to study the impact of the laminating process of organic PV between glass sheets. Another project will examine the possibility of manufacturing a tandem cell with a combination of coloured organic PV and CIGS or silicon.

4.1.1.4 *Swedish Institute of Agricultural and Environmental Engineering*

The Swedish Institute of Agricultural and Environmental Engineering (JTI) were in 2015 leading a project that identified the realizable potential of solar electricity in agricultural areas as well as investigated different business models and financing PV solutions form farmers. The project also investigated the possibilities for load management and accumulation to increase the internal use of the produced electricity in different agricultural buildings. The project was started in late 2013 and was finalized in mid-2015.

4.2 Academic research

4.2.1.1 *Center for Molecular Devices*

The research constellation, Center for Molecular Devices (CMD), is one of the world leading scientific centres 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 2015. 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 5.5.1.2). 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.

4.2.1.2 *Chalmers*

At Chalmers University of Technology 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.

Larger projects include PhotoNVoltaics, a collaborative research project of partner institutions from science and industry in Sweden, France and Belgium – The PF2 project – aiming at add-on technology for existing PV technology involving both physical science research and life cycle analysis – and the "Energy on campus"-initiative which was launched in 2014 and that has been gaining momentum during 2015, which, among other activities, will look at how the campus can be used both for implementation of PV-technology and PV-research.

There is also applied research related to feasibility and economics mainly related to self-consumption in municipal buildings (in cooperation with and financed by Göteborg Energi), modelling of electricity grids, including distributed wind and solar PV power (financed by the Swedish Energy Agency), as well as electrification of urban areas in Africa and innovation system research, including PV power.

4.2.1.3 *Högskolan Dalarna*

The Solar Energy Research Center (SERC) at Dalarna University carries out research on PV, PV hybrid and PVT 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, micro-grid systems as well as PVT systems can be tested. The group is also involved in international PV projects financed by the EU Commission, national agencies and foundations such as the 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.

4.2.1.4 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 on going, with the purpose of increasing the stability and lifetime of organic solar cells.

Karlstad University has also a silicon solar cell research group. Their present research focuses on crystalline silicon, especially cast ingot silicon, which is the worlds most used material for solar cells. Since 2015, Professor Markus Rinio of the group leads the European research project “HighCast”, which aims to improve high-performance multicrystalline silicon for solar cells and involves industry and research groups in Germany and the UK. Associated partners are located in Norway, France and at Massachusetts Institute of Technology, USA. The group also works with KTH in Sweden and CENER in Spain on new tandem solar cell devices based on GaInP and silicon. A good collaboration with the local region, mainly through Glava Energy Center, and Norwegian partners is maintained within projects of Region Värmland and the Interreg project “EcoInside”. Together with European industry and institute partners the group investigates light-induced degradation effects in industrial silicon solar cells. Karlstad University has unique characterization equipment for silicon solar cells and small sized modules, such as high-resolution light beam induced current topography (LBIC) and defect density mapping with an advanced automated optical microscope.

4.2.1.5 Linköping University

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 organic layers on top of a flexible plastic substrate, devices can be produced in semi-infinite geometries at printing speeds of meters per minute. Semi-transparent solar cells can be used for building stacked tandem solar cells with different band gaps. Transmitted light can be used in a second semi-transparent organic solar cell and in this way tandems solar cells are constructed. Light can also be reinjected into the semitransparent solar cell with light scattering from white paper layer. The group have developed new imaging methods based on intermodulation methods and Fourier analysis, for rapid photocurrent imaging and recombination current imaging, for solar cells and modules. New materials are continuously being evaluated, now with the focus to reduce the voltage loss in donor-acceptor blends. New acceptors in molecular and polymeric forms are giving attractive improvements of power conversion efficiency. In 2015 the group mounted their organic solar cells inside windows at Linköping University and at Tekniska verken in Linköping.

4.2.1.6 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 investment potential of PV systems considering deregulated electricity market dynamics and relevant policy scenarios. The project concludes in 2016 and will relay the results to the boards of directors of cooperatives across Sweden. The same group started a new project in 2015 considering the combination of PV with ground source heat pumps, where waste heat from the module and excess electricity generation is used for seasonal borehole storage towards technical and economic optimization.

4.2.1.7 Lund University

At University of Lund the division of Chemical 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 and organometal halide perovskites. The division works in close collaboration with nanoLund at Lund University on several topics. Work on the organometal halide perovskites, a new promising solar cell material, which in very short time has reached power conversion exceeding 20 %, was initiated in 2013 and has produced new insights into the function of the materials, which will lead to the design of new better solar cells. The aim of our 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 division started to build expertise and facilities for production and studies of complete working solar cells of the perovskite materials.

In the nanoLund group at Lund University, a group of scientists are working with nanotechnology PV. One project is about improving the efficiency of today's silicon PV technology through integration of nanowires. Ideally this nanotechnology offers to reach efficiencies even up to 50 %. The group is also working with growth of InP or GaAs nanowire PV, where they have set conversion efficiency records of 13.8 % and 15.3 %, respectively.

Furthermore, 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.

4.2.1.8 Mälardalens Högskola

Mälardalens Högskola is conducting research in several subjects regarding PV. On project is to study 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. Another research area is off-grid PV systems for developing countries where one project is about irrigation in China and another is about solar home systems in Africa. Furthermore, research is conducted about the profitability of PV in Sweden and another project aims at developing products, concepts and business models that facilitate a cost-effective and architectural development of solar cells in the built environment.

4.2.1.9 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.

4.2.1.10 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 vapour 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 a new record of 9.7 % for solar cells based on CZTS was set in 2015. 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 and solar power, integration of distributed PV into the power system and self-consumption of on-site PV generation in buildings. The group received funding for three new research projects in 2015 and is growing from the four employees working in the group in 2015.

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).

4.3 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 23 in 2015 also paid 130 million SEK in conditional loans for PV related technological and business development.

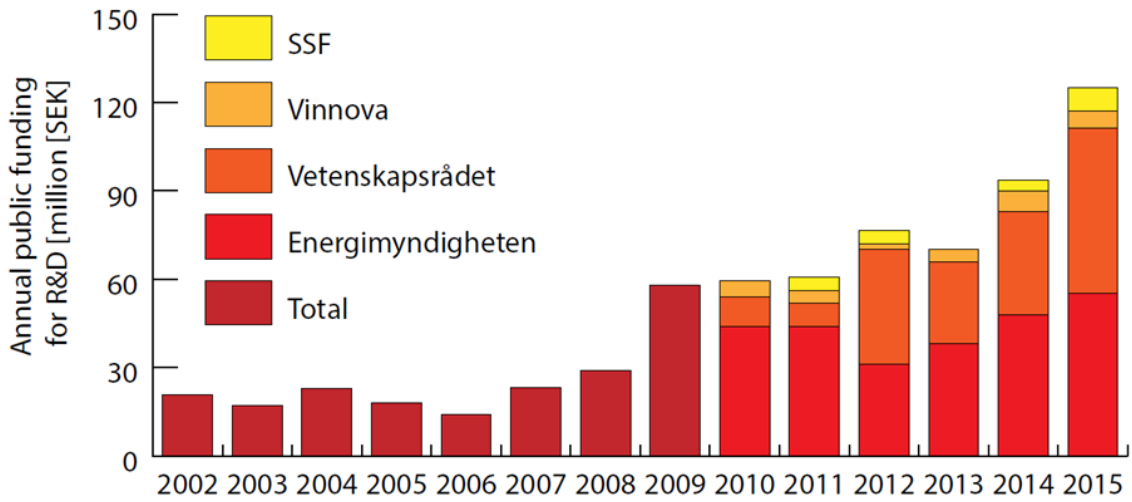


Figure 23: Annual public funding for PV related R&D in Sweden.

Table 19: Public budgets for R&D, demonstration/field test and business development programmes in 2015.

	R & D	Demo/Field test
National/federal	125 million SEK	130 million SEK
State/regional	unknown	unknown
Total	255 million SEK	

4.3.1 Demonstration and field test sites

4.3.1.1 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 had at the end of 2015 a capacity of 500 kW_p, of which 450 kW_p is PV.

4.3.1.2 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 totalling 2.3 kW_p. The first grid-connected park consists of four systems, totalling 135 kW_p. The second park consist of two systems, totalling 74 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 grids connected parks produce. In total there are 30 different PV systems in the test parks and some are combined with 11 different energy storages. 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 that school classes 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 40 members. Glava Energy Center is besides from the members funded through the Interreg/EU, Region Värmland and the city of Arvika.

5 INDUSTRY

The Swedish PV industry mainly contains small to medium size installer and retailers of PV modules or systems. At the writing of this report the author was aware of 154 companies that sold and/or installed PV modules and/or systems in the Swedish market (see section 5.6). There are also 12 companies active in manufacturing of production machines or balance of systems equipment (see section 5.4). Furthermore, there are about 11 R&D companies (see section 5.5). Since the bankruptcy of SweModule Sweden currently do not have any traditional cell or module production, but there are plans for future production in Sweden (see section 5.3).

5.1.1.1 Svensk Solenergi

Svensk Solenergi is a trade association which, with about 140 hundred professional members, represents both the Swedish solar energy industry and market 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 2015 and there are currently no plans for this kind of production in the future.

Table 20: Production information for 2015 for silicon feedstock, ingot and wafer producers.

Manufacturers	Process & technology	Total production	Product destination	Price
None	Silicon feedstock	0 tonnes	-	-
None	sc-Si ingots.	0 tonnes	-	-
None	mc-Si ingots	0 tonnes	-	-
None	sc-Si wafers	0 MW_p	-	-
None	mc-Si wafers	0 MW_p	-	-

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.

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. In 2015 also SweModule was filed for bankruptcy, and there is no longer any large-scale module production in Sweden. The overall module production that actually took place in Sweden in 2015 was therefore only 1.2 MW_p, exclusively produced by SweModule before the bankruptcy. However, the Swedish company Windon produced some modules through OEM contracts in facilities abroad.

5.3.1.1 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 and the company is currently investigating a few strategic partners.

5.3.1.2 SweModule AB

SweModule was the only active module producer in Sweden in the beginning of 2015. 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 12th of March 2015 SweModule went bankrupt. However, the company continued to produce small quantities of PV modules until the 12th of May, and in total 1.2 MW_p of modules was produced in 2015.

5.3.1.3 Windon AB

Windon was started in 2007 after a year of product development of different PV equipment. In 2011 Windon began to OEM produce PV modules with its own brand in SweModules production facility in Glava, Sweden. Since the closer of the production facility in Glava in 2015, the company has moved their O&M production of modules to a factory in Poland. In addition to the module production the company developed their own ground-mounting stand, and in 2014 Windon started to develop inverters within the range of 1–20 kW_p, which will be launched in 2016. The company currently has their production in China, Poland, Germany and Sweden.

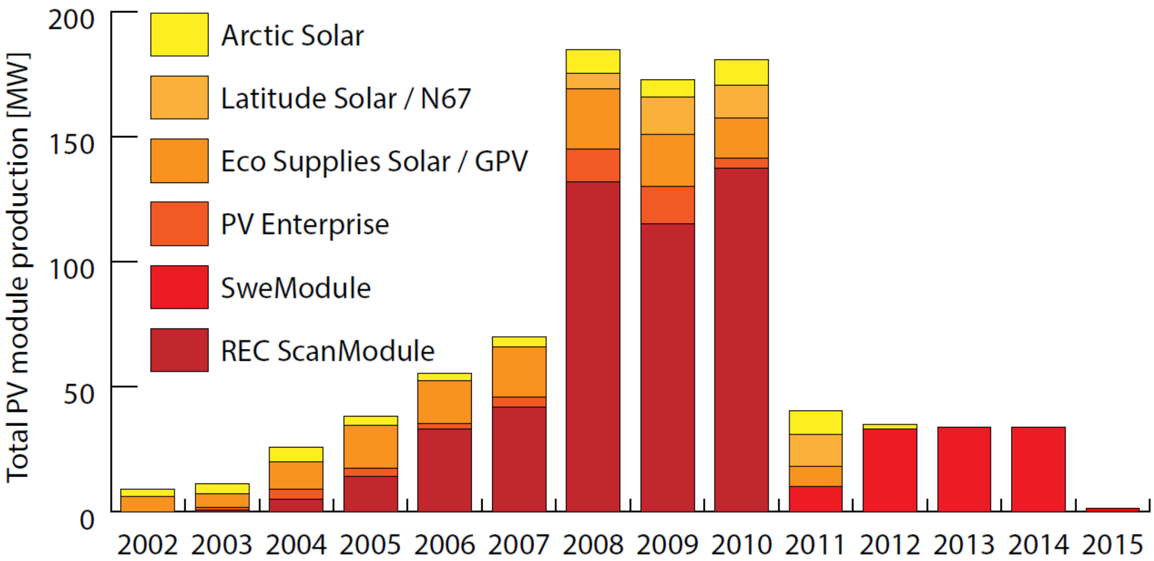


Figure 24: PV module production in Sweden over the years.

Table 21: Production and production capacity of Swedish module producers in 2015.

Cell/Module manufacturer	Technology	Total production (MW_p)		Maximum production capacity (MW_p/year)	
		Cell	Module	Cell	Module
Wafer-based PV					
SweModule	Mono/Poly-Si	-	1.2	-	100
Thin film					
None	CIGS	-	-	-	-
Cells for concentration					
None		-	-	-	-
TOTALS		0	1.2	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 includes 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 Box of Energy AB

Box of Energy is a battery technology provider that has specialized on battery systems for PV and wind production. The lithium-ion batteries are produced in South Korea and the battery system product is assembled in Anderstorp by a partner company. Box of Energy’s battery system includes technology that handles the control and regulation of charging and discharging the battery from PV/wind production along with power control and planning of the energy consumption. Their battery system also has features that allow the system to go into off-grid operation if the power from the grid is lost. The company has installed 4 systems that are monitored for testing and certification, and another 14 systems has been sold and installed at different customers.

5.4.1.3 Emulsionen Ekonomiska Förening

Emulsionen is offering a metering system, which includes equipment and an IT system, to micro-producers so they can receive the green electricity certificate system (see section 3.1.3) also for the self-consumed electricity. The system sits directly by the solar or wind power inverter and reports the gross production for allocation of certificates. The actual meter is manufactured in China, but the company assembles the data logger in Sweden. In 2015 the company sold about 500 of their metering products.

5.4.1.4 Ferroamp Elektronik AB

Ferroamp was founded in 2010 and has developed a product that they call an EnergyHub. The EnergyHub technology offers a new system design that enables a better utilization of renewable energy in buildings by introducing a local DC nanogrid ecosystem with smart power electronics. PV solar production and energy storage is closely integrated on a DC grid, reducing conversion losses as solar energy is stored directly in the batteries without multiple conversion steps as common in traditional system designs. The EnergyHub offers cost effective backup power functionality for selected DC loads such as servers, LED lights and DC fast charging of electric vehicles. Ferroamp has also developed a platform for energy efficiency measurements with a service portal for partners and customers, which extends operation hours to nights and winter months with dynamic power peak management and selective load control.

In 2014 Ferroamp reached a milestone as they started series shipment of the EnergyHub ACE system for energy efficiency, hence going from a solely R&D company to a production company. In the end of 2015 Ferroamp released its PV solar and energy storage solutions. Shipments of scalable PV solar and Energy Storage solutions will start in early 2016. The production takes place in Sweden and the company has plans for a larger production series in 2016. Another important event for Ferroamp was the start of a project together with Fortum, which aims at developing virtual power plants by connecting PV systems with integrated energy storage. 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.

5.4.1.5 MAPAB

MAPAB (Mullsjö Aluminiumprodukter AB) manufactures aluminum 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 2015 98 % of their products were sold in Sweden.

5.4.1.6 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 produce 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 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 to 15.1 % total area efficiency (17.3 % aperture area) during 2015. With cells using this new cell recipe, Midsummer's flexible modules have now passed China's National Energy Bureau's 13 % efficiency threshold for CIGS thin film solar modules (corresponding to 14.3 % aperture area module efficiency), as measured and certified by the certified Japanese independent testing laboratory Chemitox, Inc.

5.4.1.7 Netpower Labs AB

PV modules produces DC current, which in traditional systems is transformed via inverters to AC current. The AC current is 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 centres and tale-/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. In 2015 one solar system running a DC lightening system and a one system for a smaller data room in an office building was installed. The interest for DC current powering data centres, lightening and server rooms are increasing, which probably will mean that interest of using PV in these kind systems will be become more and more attractive.

5.4.1.8 Nilar International AB

The battery producer Nilar was founded in 2000 and has two R&D departments, one in 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 12 V, which allows batteries to be coupled in parallel and series to battery-packs that can deliver the desired power and capacity. In 2014 Nilar started to develop an electronic solution that 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. During 2015 the company worked with two PV related projects. The first is about a development of storage package for telecom and PV solutions. These battery packages are scalable and can be delivered in sizes from 1 kWh storage capacity up to several MWh. In the second project Nilar worked in collaboration with Ferroamp to integrate their batteries in Ferroamp's energy-hub. Currently Nilar's largest markets are England, Holland, Germany and the Nordic countries.

5.4.1.9 SolarWave AB

The main business for SolarWave is to provide solar driven water stand-alone purification systems and desalination systems. The systems include solar cells with a total power of 0.5 kW_p that 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. The systems are assembled in Järfälla in Sweden but the target market is mainly developing countries in Africa. SolarWave's largest market is currently in Uganda, but they have also authorized distributors in Tanzania, Nigeria, Ethiopia and Cameroun. Furthermore, in 2014 SolarWave's product was approved by the United Nation and some systems where delivered to the organization. The company is also selling some systems to the Swedish Civil Contingencies Agency (Myndigheten för samhällsskydd och beredskap) and has lately entered an agreement with UNHCR to deliver systems to them. The company has sold around 135 systems from the start, of which 60 systems were sold in 2015.

5.4.1.10 Sapa Building Systems AB

Sapa has for long been producing aluminum mounting systems for doors, windows, glass roofs and glass facades. Most of the production is located in Sweden. In 2015 the company initiated a collaboration with the BIPV product and installation company SolTech Energy Sweden AB and Sapa is now planning to produce aluminum profiles for BIPV solutions.

5.4.1.11 Swedish Electroforming Technology AB

Sweltech is a machine manufacturing company that in 2015 had 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, which is ongoing but currently with a low activity. The second project was a collaboration with where Sweltech delivered a lithography machine to Solibro Research AB. This project started in 2014 and was finalized in 2015.

5.4.1.12 Weland Stål AB

Weland Stål 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 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 R&D companies and companies with R&D divisions in Sweden

5.5.1.1 Absolicon Solar Collector AB

Former Absolicon Solar Concentrator 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. Currently the company focus on developing pure solar thermal systems and building manufacturing lines for those. But the original product with integrated PV still exists and PV might later be integrated in the production.

5.5.1.2 Dyenamo AB

Dyenamo offers chemical components and characterization equipment for research and production of dye-sensitized solar cells, perovskite solar cells and solar fuels. The company also provides demonstration projects of dye-sensitized solar modules. 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.

5.5.1.3 Eltek Valare AB

Swedish Eltek Valare 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.

5.5.1.4 Epishine

Epishine is a spin-off company from the organic PV research that is being conducted at Linköping University and Chalmers University. The company is trying to commercialize the flexible and semi-transparent organic/plastic solar cells that have been developed at these two Universities. The solar cells are made of organic layers on top of a flexible plastic substrate and therefore free of any metals. The actual active layer of the solar cell consists of polymers, while the base material is PET plastic, which is a cheap plastic that can be recycled. The production process is similar to newspaper printing. All production takes place in a production facility in Norrköping. The organic cells are flexible and light, less than 0.3 kg/m^2, which indicate that the production and transportation costs will be very low. The cells have today a conversion efficiency about 1 % and proves the manufacturing process. In research these types of cells have reached 10 %, which show the future potential. The company is currently looking for investors to be able to accelerate the development and start large-scale production.

5.5.1.5 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 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. The company uses screen-printing and has recently finalized the world’s largest DSC production plant located in Stockholm, Sweden. In this production facility Exeger has the ability to print lightweight flexible and aesthetically solar cells that can be integrated into products such as consumer electronics, automobile integrated photovoltaics, building integrated and building applied photovoltaics. The most probable first product is a self-charging e-reader/tablet cover. The production capacity for the new factory is 10 million units annually of e-reader sized cells.

5.5.1.6 Global Sun Engineering Sweden AB

Global Sun Engineering has developed 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 that allows it to follow the sun. Due to the fast price decline of regular modules, the company put their activities on hold in 2015.

5.5.1.7 Optistring Technologies AB

Optistring Technologies is commercializing a power inverter system for grid connected PV systems that 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, which were deployed in pilot installations in both Sweden and abroad. In 2015 the Optistring developed their 4th generation, which is designed for large-scale production.

5.5.1.8 Solarus AB

Solarus is a solar energy company with their roots I Sweden. The company has two different solar panel product lines: one thermal and 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. The commercial focus lies on the PV/T module, which produces 230 W of electricity and 1 200 W heat under peak conditions. In 2014 Solarus moved to new R&D facilities in Gävle and also started to build a larger production facility in hydrothe Netherlands in the Netherlands. This production facility was ramped up in 2015 and produced around 400 PV/T modules. The plant has a production capacity of 10 000–20 000 modules per year and Solarus plans for a larger production in 2016.

5.5.1.9 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 from Q-cells 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, 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 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 has been surpassed. 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. The BIPV mounting system was in 2015 certified by TÜV. Reference PV plants for both the mounting systems has been constructed by the company and systems are available to customers. The manufacturing of the mounting systems is outsourced.

5.5.1.10 SolTech Energy Sweden AB

Stockholm based SolTech Energy Sweden, 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.

5.5.1.11 Sol Voltaics AB

Sol Voltaics improves the efficiency of solar energy capture, generation and storage through the use of nanomaterials. The company is developing a high-volume production platform for its patented Aerotaxy nanowire thin-film process. The product is a completely new kind of nanowire-film-based solar cell, designed for integration with traditional crystalline solar PV to create high efficiency, low-cost tandem modules. Sol Voltaics' claim that their technology can boost module efficiencies by at least 50 % with only a 5–10 % cost increase. In 2015, Aerotaxy was able to demonstrate first active solar cell nanowires, an important step towards a high efficiency tandem solution. A major break-through in alignment of nanowires was also achieved, with very high yields over 10s of cm^2 areas. In addition, Fraunhofer-ISE confirmed a world-record PV conversion efficiency of 15.3 % for Sol Voltaics' epitaxially grown GaAs nanowire solar cells early in 2015.

5.6 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 2015, 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@svensksolenergi.se

24 Volt	Agera Energi AB	Agronola
Air by Solar Sweden AB	Alfa SolVind i Skåne AB	Apptek Teknik och Applikationer AB
Attemptare AB	Awimex International AB	Baltic Suntech AB
BayWa R.E. solar systems ApS	Bevego Byggplåt & Ventilation AB	Billesol AB
Bråvalla Solteknik AB	Celltech AB	Clas Olsson
Co2kompensera	Co2Pro AB	Comne Work AB
Dala Värmesystem AB	Deson AB	DrivhusEffekten ApS
Ecoklimat Norden AB	Ecologisk Kraft Eskilstuna AB	ECOscience
EDT Service	Effecta AB	Egen El AB
Egen Sol och Vind	Ekologisk Energi Vollsjö	El & EnergiCenter
El B-man	Electronic Technic LS AB	Electrotec Energy
Elfa AB	Elinx Solar Energy	Elkatalogen i Norden AB
Elkontakten i Ale AB	Elmco AB	Elproduktion i Stockholm AB
Elterm i Allingsås AB	Elverket Vallentuna AB	Eneo Solutions AB
Energi Solvind ESV AB	Energi-Center Nordic AB	EnergiEngagemang Sverige AB
Energiförbättring i väst AB	Energihuset i Vimmerby AB	Energiteknik i Kungälv AB
Enersol	Etab energi AB	Euronom AB
EWF ECO AB	EWS GmbH & Co. KG	Fasadautomatik AB
Futura Energi	Gaia Solar A/S	Gari EcoPower AB
Garo Gnosjö	GermanSolar Sverige AB	GFSol AB
Gridcon Solcellsteknik AB	Hallands Energiutveckling AB	Helio Solutions AB
Herrljunga Elektriska AB	HESAB	Highlands International AB
Hilmeko AB	Hjertmans båttillbehör	Holje-El AB
Implementa Hebe AB	Innosund AB	JN Solar AB
KAMA Fritid AB	Kinnan AB	Kraftpojkarna AB
Kretsloppsenergi Kummelnäs AB	Lambertsson Sverige AB	Lego Elektronik AB
Lundgrens el AB	MeraSol AB	Miljö & Energi Ansvar AB
Miljö- VVS- & Energicenter	Naps Solel AB	NIBE Energy Systems
Norden Solar	Nordh Energy	Nordic Solar Sweden AB
Nordic Sunpower	Nordisk System Teknik AB	NTS Group AB
Nyedal Solenergi	Orust Engineering	Plannja AB
Polygress Solution AB	PPAM Solkraft	Prolekta Gotland AB
Rexel Sverige AB	Save-by-Solar Sweden AB	Scandinavian PV Solutions
Sol Eye	Solar Supply Sweden AB	Solarenergy Scandinavia AB
Solarit AB	Solarlab Sweden	SolarOne
Solcellsbyggarna Boxholm AB	Solcellsproffsen AB	Solect Power AB
Solelia Greentech AB	Solenergi & Teknik i Åmål AB	Solenergi Göteborg
Solenergi i Undrom	Solens Energi	Solfångaren i Viby
Solitek	Solkompaniet Sverige AB	Solkraft EMK AB
Solkraft TE	Solkungen AB	Solorder AB
Solortus AB	SolTech Energy Sweden AB	Spindel AB
Sun of Sunne	SUNBEAMsystem Group	Suncell House AB
Sundaya Nordic AB	SunnyFuture AB	Sunwind Exergon AB
Susen AB	Sustainable Energy Nordic AB	SVEA Renewable Solar AB
Svenska Solenergigruppen AB	Svenskt Byggmontage AB	Svesol värmesystem AB
Teknikhamstern	Ten Star Solar AB	Upplands Energi AB
UPS-teknik i väst AB	Vallacom AB	Vancos Munka Ljungby AB
Warm-Ec Skandinavia AB	Veosol Teknik AB	Victor Energy ApS
Viessmann Värmeteknik AB	Wikmans Elektriska	Villavind AB
Windforce Airbuzz Holding AB	Windon AB	VOE Service AB
Yokk Solar Ltd	Yorvik Solar	Åkerby Solenergi
Östgöta Solel AB		

6 PV IN 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, consulting firms and real estate owners.

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.

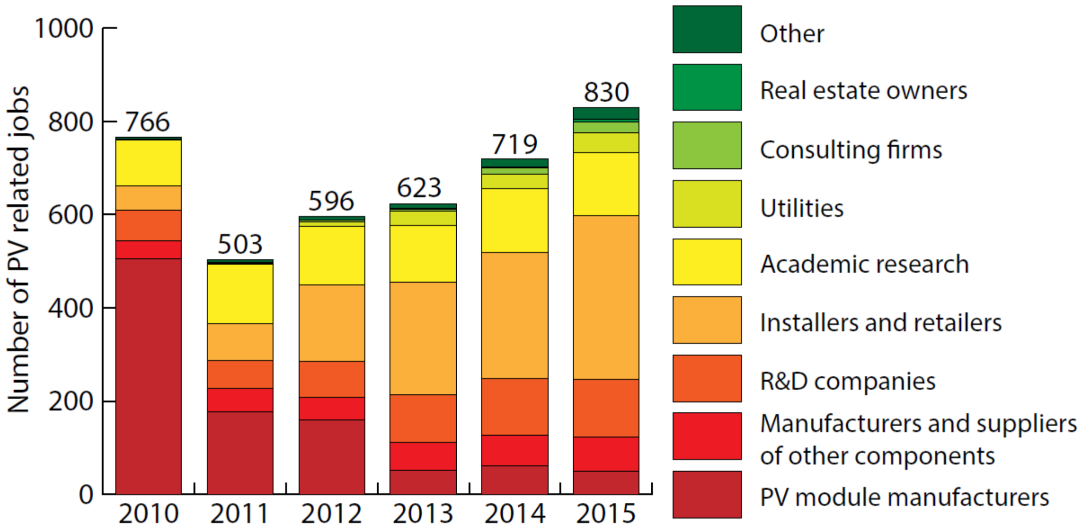


Figure 25: Estimated total full time jobs within the Swedish PV industry.

Table 22: Estimated total full time jobs within the Swedish PV industry in 2015.

Market category	Number of full time jobs in 2015
PV module manufacturers	50
Manufacturers and suppliers of machinery and other components	73
R&D companies	123
PV system installers and retailers	352
Academic research	135
Utilities	42
Consulting firms	23
Real estate owners	6
Government and others	26
Total	830

6.2 Business value

In Table 23 some very rough estimations of the value of the Swedish PV business can be found.

Table 23: Rough estimation of the value of the PV business in 2015 (VAT is excluded).

Sub-market		Capacity installed in 2015 [MW_p]	Average price [SEK/W_p]	Value
Off-grid		1.57	20.1	~ 32 million SEK
Grid-connected distributed	Residential 0–20 kW_p	14.29	15.0	~ 214 million SEK
	Commercial 0–20 kW_p	5.48	12.7	~ 70 million SEK
	Commercial >20 kW_p	24.66	11.8	~ 291 million SEK
Grid-connected centralized		1.37	10.3	~ 14 million SEK
Value of the PV market				**~ 621 million SEK**
Export of PV products[1]		1.2 MW_p of modules exported x 7 SEK/W		~ 8 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				**~ 629 million SEK**

[1] Other PV products have been exported, but the author is not aware of the quantities.

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, 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 2015 are; Ale Energi, BestEl, Dalakraft, E.ON, ETC El, Elverket Vallentuna, Fortum, Gislaved Energi, Gotlands Elförsäljning, Göteborg Energi, Jämtkraft, Kraftringen, MälarEnergi, Nossebro Energi, OX2, Sala-Heby Energi, Skånska Energi, Sollentuna Energi & Miljö, Telge Energi, Umeå Energi, Upplands Energi, Vattenfall, and Varbergs Energi. These utility companies 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 the excess electricity produced by micro-producers. This trend continues and more and more utility companies now have various offers for the micro-producer’s excess electricity, their green electricity certificates and guarantees of origin. The offers and compensation varies between the utilities. Most of them have in common that the demand that the micro-producer is a net consumer of electricity during a year and that they buy their electricity from the utility company. Some buy the GO's and the green electricity certificates, while some don’t. The overall compensation from utilities for the electricity, plus GO's and the green electricity certificates, varies between 0.25 and 0.65 SEK/kWh [36].

7.3 Interest from municipalities and local governments

As can be seen in Figure 4 and Figure 5 there are some municipalities in Sweden that stands out in installed PV in total and by capita. Important factors for the high local PV diffusion rates are in general peer effects and local organisations that promote PV. Research has shown that the influence of local initiatives from different stakeholders has played a major role in the deployment of PV in many of the municipalities with the highest PV penetration in Sweden [37]. In several cases local electric utilities, often owned by the municipality, have successfully taken an active role in supporting PV with action such as purchasing the excess electricity of PV adopters, selling PV systems and dissemination of information (see section 7.2). Other local initiatives that have influenced the adoption of PV are seminars and information meetings arranged by e.g. a utility or County Administration (Länsstyrelse).

Some Swedish municipalities has introduced ambitions goal for PV. One example is the municipality of Uppsala that has set a goal to have approximately 30 MW_p of PV by 2020 and about 100 MW_p by 2030 [38]. Other examples of initiatives from some Swedish municipalities are the introduction of simplified construction and permitting rules for roof-mounted PV system. Furthermore, to help potential stakeholders in PV to easier assess the potential for their particular roof, several municipalities have created ”sun maps”. These sun maps illustrate in colour scale the incoming solar radiation on all of the roofs in the city, sometimes taking into account the tilt of the roof and shadowing effects of nearby buildings or building elements. At the time of writing the municipalities with a sun map in Sweden are; Alingsås, Botkyrka, Eskilstuna, Göteborg, Höganäs, Katrineholm, Kumla, Köping, Landskrona, Linköping, Lund, Motala, Mölndal, Norrköping, Stockholm, Umeå, Uppsala, Varberg, Vellinge, Västerås, Örebro and Österåker.

The largest local PV promoting 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 activities 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.

8 HIGHLIGHTS AND PROSPECTS

8.1 Highlights

The positive PV market development in Sweden continued in 2015 as the annual market grew with 31 % to a yearly installed power of 47.4 MW_p. This means that Sweden passed the 100 MW_p threshold as the cumulative installed capacity at the end of 2015 was 126.8 MW_p. The PV system prices continued to go down for larger system, both ground- and roof-mounted, but stabilized for small residential systems in 2015.

The major policy change in 2015 was the introduction of the tax credit for the excess electricity of micro-producers. This scheme makes it much more attractive for private persons and small companies to invest in PV.

On the industry side Sweden lost its last module producer when SweModule filed for bankruptcy in the spring. However, several Swedish companies focusing on new PV technologies or balance of system components continued to develop in a healthy way. Furthermore, the Swedish PV industry is becoming broader as more and more actors with other core businesses, such as utilities and real estate owners, is taking an increasing interest in the PV technology.

8.2 Prospects

The Swedish PV market is in the short term expected to continue to grow. The introduction of the tax credit for micro-producer and the increase of activity from utilities have made the situation for private persons and small companies quite good. 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. The administrative situation might get better as there exist a current law suggestion which except private person from the need to register for VAT when they want to sell excess electricity. So these two markets segments are expected to continue to expand in 2016.

For larger real estate owners, the new tax laws which means that they have to pay energy tax also on the self-consumed PV electricity, is a major hurdle. These new tax laws will have a negative impact on the market segment of large commercial PV systems. How this market segment develops in the near future is hard to tell, and will probably depend on what conclusion and suggestions to changes in the law the ongoing investigation brings forward.

The off-grid market has shown a stable slow growth for a long time. As off-grid installations are not in need of subsidies, the slow market growth can be explained by the gradually decreasing system prices. A trend that probably will continue.

The market of large centralized PV parks is still marginal occurrence in Sweden. Even if a 2.7 MW_p PV park is being built outside of Varberg in western Sweden [39], this market segment is expected to play a minor role next few years. For this market segment to grew significantly either the electricity spot prices must increase, or the system prices decrease (probably both).

In the long term, the Swedish PV market is in a good position to grow. In general, there is a growing interest for PV in Sweden and the general public is very positive towards the technology. In a survey done in the beginning of 2014 [40], 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 government has also given the Swedish Energy Agency the mission to develop a broad PV strategy for Sweden. This work is ongoing and will be presented the 17th of October 2016 [41].

Furthermore, recently five of the major Swedish parties in the parliament; the Social Democrats (Socialdemokraterna), Green Party (Miljöpartiet), Moderate Coalition Party (Moderaterna), the

Centre Party (Centern) and the Christian Democrats (Kristdemokraterna), reached an agreement that states a goal that Sweden shall have a 100 % renewable power sector by 2040 [42]. This means that the 34 % of the total Swedish electricity production that nuclear stands for must be replaced until 2040.

The agreement is so far only a framework, and it will in 2016 be filled with more concrete measures. However, one thing that is included in the agreement, which will have a concrete impact on the PV market, is that the Swedish green electricity certificate system will be extended. It was planned to end in 2020, but will now be prolonged to 2030. The goal for the extended certificate system is that an additional of 18 TWh of renewable electricity will be built within the certificate system between 2020 and 2030 [42].

Another potential positive thing for PV in the agreement is that it is made clear that the politicians plan to make it easier for small-scale electricity production. The agreement states that the existing regulations should be adapted to new products and services in energy efficiency, energy storage and sale of micro-produced electricity [42].

Nonetheless, the Swedish PV market still depends a lot on subsidies, and if PV should be able to contribute to an appreciable part of the Swedish electricity mix the PV system prices must continue to go down, or the electricity prices to go up.

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