IEA INTERNATIONAL ENERGY AGENCY

Swedish Energy Agency

National Survey Report of PV Power Applications in Sweden

2016

PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

Prepared by

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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 Swedish National Survey Report for the year 2016. 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 and any related installation and control components. 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 2016 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2016, although commissioning may have taken place at a later date.

1.1 Applications for Photovoltaics

Until the early 2000s, the Swedish PV market almost exclusively 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 2016 about fifteen 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 built on self-consumption business models. About 32 % of the installed grid-connected PV power is privately owned systems on small houses and approximately 62 % is built on company, agriculture or public buildings. So far only a couple of relatively small ground-mounted systems are centralized PV parks, 6 % of the grid-connected market. The largest of them was built in 2016 and is 2,7 MW_p.

1.2 Method

1.2.1 Sales statistics

All the gathered data on the installed capacity and prices used in this report come 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 installers report data with the accuracy down to the kW_p-level. However, not all installers have the internal routines or time to do this, and some companies have therefore provided estimates at an accuracy of 100 kW_p-level. These estimates can differ in both directions, although estimates may be more likely to be rounded upwards.

Another uncertainty in the sales statistics is that companies sell and buy modules between each other. This means that there is a risk that in some cases a double count of the same module occurs. To avoid this, all installers report whether the modules they install/sell are bought directly from abroad or if they are bought from another Swedish company. Only modules coming directly from abroad or produced in Sweden are counted for in the total numbers. Nevertheless, there are still probably some errors in the quantities reported to be bought from abroad or from Swedish companies that lead to a certain double counting, and thus to a possible overestimation of the installed PV power.

Another uncertainty is that the author probably is not aware of all installers active on the Swedish market. Their data is therefore not included in the sales statistics, which may lead to an underestimation of the installed effect.

Due to the sources of errors discussed above, the accuracy of the data for annual installed power from the sales statistics are estimated by the author to be within ± 10 %.

The numbers for the cumulative installed capacity in Sweden are more uncertain. There is 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 most of the systems have been installed during the last five 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 % for the yearly numbers Within ± 15 % for the cumulative numbers

1.2.2 Data from the grid owners

Due to the time-consuming manual work with the collection of sales statistics and the many uncertainties in the data quality of this method, the Government gave in 2015 the Swedish Energy Agency an assignment to investigate how the PV statistics could be collected in the future. The Swedish Energy Agency presented their suggestions in a report in 2016 [1]. As it is mandatory to notify the grid owner when a PV system is connected to the grid, the Swedish Energy Agency plans to collect the data of grid-connected PV systems from the Swedish grid owners. In the short term this is done through surveys sent out by Statistics Sweden, SCB, (Statistiska Centralbyrån).

A first national survey was made in 2017 to get the total installed PV capacity at the end of 2016. Through this method, SCB collects the number of grid-connected systems and the total power of these systems within in the segments <20 kW_p, 20–1 000 kW_p and >1 000 kW_p [2]. These statistics also have a geographical resolution, which is at municipality-level. However, several municipalities have been marked as blank in this first version of the official data due to secrecy reasons. The total power within each market segment is however official and is summarized in Table 2.

Table 2. The grid-connected PV at the end of 2016 collected from the grid owners by SCB [2].

	<20 kW_p	20–1 000 kW_p	>1 000 kW_p	Total
Grid-connected PV capacity according to the grid owners collected by SCB	73 703 kW_p	62 442 kW_p	4 718 kW_p	140 862 kW_p

There is a clear divergence between the grid-connected PV capacity that SCB has collected through the grid owners in Sweden, 140.8 MW_p, and the cumulative grid-connected PV capacity (presented in Table 5) that the author and previous Swedish IEA-PVPS representatives has collected through sales statistics from the Swedish installation companies over the years, 192.9 MW_p. This difference of 52 MW_p can partly be explained by the deficiencies and uncertainties in the collection of the sales statistics discussed in section 1.2.1.

But it is also due to some errors in the data from the grid owners. When the data from the grid owners is examined closer, it is obvious that some PV systems are missing. The most obvious example is that the data from SCB states there is 287 kW_p installed in the municipality of Arvika. But Sweden's third biggest PV park, with an installed capacity of 1 040 kW_p, is situated in Arvika. So, in this case the grid owner has missed to report this PV capacity to SCB. The author has also been informed that one of the larger grid operators in Sweden only has information about the number of PV systems, and not the power, installed in their grid over a period due to deficiencies in the registration of the PV installations under that period. So, it seems like several systems can be missing in the SCB statistics due to shortcomings in the routines of different grid owners.

Other uncertainties with the data from the SCB are reports that not all PV system owners have registered their system, and thus failing to comply with the legislation.

How many PV systems and capacity that are missing in the SCB statistics is impossible to quantify, but they are judged not to be negligible. However, as this was the first time data about the Swedish PV market was collected through the grid owners, the quality of this data is expected to be better in the future as the grid owners form better routines to collect and report this information. There is also an ongoing work to evaluate and improve this method by identifying potential sources of error in the data and by improving the survey questionnaire to minimize the risk misunderstandings by SCB, the Swedish Energy Agency and the author.

In the future, this method will probably produce data about the grid-connected PV capacity with a much higher quality, along with better time and geographical resolution, as compared to the sales statistic method. So, for future Swedish NSR reports it is likely that the data will come from the grid owners. However, due to the current errors in this first version of the method, the fact that this method is not yet able to produce annual installation numbers and the advantage of having a historical continuity of the data the author has together with the Swedish Energy Agency decided that it is exclusively the sales statistics that is used in this year's version of the Swedish NSR report.

1.3 Total photovoltaic power installed

The installation rate of PV continues to increase in Sweden. A total of approximately 79.2 MW_p were installed in 2016, as shown in Figure 1 and Table 3. This means that the annual Swedish PV market grew with 63 % as compared to the 48.4 MW_p that was installed in 2015.

Sweden has a stable off-grid PV market. Both in 2015 and 2016 about 1.5 MW_p of off-grid applications were sold. In total 12.6 MW_p of off-grid PV applications have been sold in Sweden since 1993.

In recent years, the market for grid-connected PV systems has grown rapidly in Sweden. This continued in 2016 as another 77.7 MW_p of grid-connected systems were installed under the year, a 65 % increase compared to the 47.0 MW_p installed in 2015. The cumulative grid-connected capacity was at the end of 2016 approximately 192.9 MW_p.

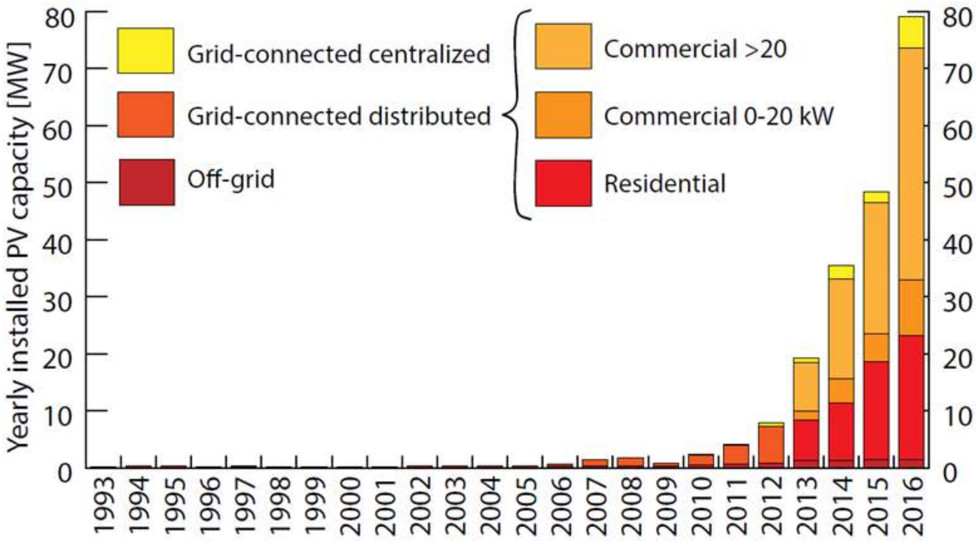

Figure 1: Annual installed PV capacity in Sweden.

Table 3: PV power installed during calendar year 2016.

			MW_p installed in 2016	MW_p installed in 2016	AC or DC
Grid-connected	BAPV	Residential	68.89	21.33[1]	DC
		Commercial		47.56	DC
		Industrial		Included in commercial	DC
	BIPV	Residential	1.81	0.35	DC
		Commercial		1.46	DC
		Industrial		0.0	DC
	Ground-mounted	cSi and TF	6.95	6.95	DC
		CPV		0.0	DC
Off-grid		Residential	1.50	1.44	DC
		Other		0.06	DC
		Hybrid systems		Unknown	DC
		Total	**79.15**		**DC**

[1] Only includes residential systems below 20 kW_p.

Table 4: Other market information.

	2016 Numbers
Number of PV systems in operation in your country[1]	10 027
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

[1] The number of PV systems in Sweden only includes grid-connected PV systems and the data comes from the SCB collection from the grid owners. This data contains some uncertainties, which are discussed in section 1.2.2.

Summing up the off-grid and grid-connected PV capacities, one ends up at a total of 205.5 MW_p of PV that have been sold in Sweden until the end of 2016, illustrated in Figure 2 and summarized in Table 5. The cumulative PV market grew with 63 % under 2016, which is in line with the marked development over the last five years where the cumulative market has grown with 52 %, 83 %, 84 %, 62 % and 63 %, respectively.

The strong overall growth in recent years started with the introduction of the direct capital subsidy system (see section 3.2.1) in 2006, and has then been fuelled by the declining system prices (see section 2.2), high popularity among the public, a growing interest from utilities (see section 7.2) and an ongoing reformation work from the Government to simplify the rules for micro producers (see section 3.4).

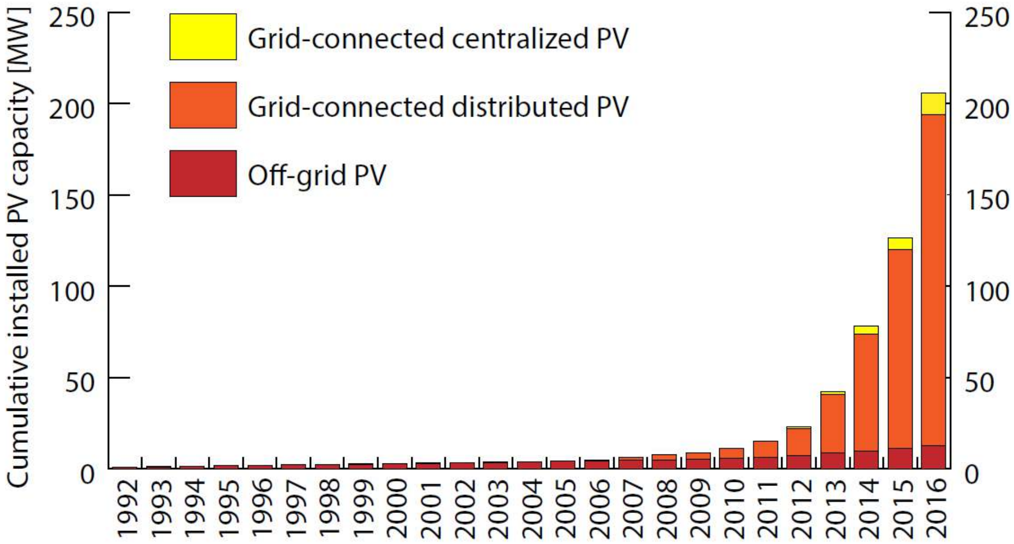

Figure 2: Cumulative installed PV capacity in Sweden.

Table 5: The cumulative installed PV power in four 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	4.94	0.79	5.15	0.20	11.08
2011	5.63	0.80	8.42	0.35	15.20
2012	6.41	0.81	14.82	1.08	23.12
2013	7.59	0.83	32.15	1.83	42.40
2014	8.77	0.86	64.07	4.16	77.86
2015	10.19	0.90	109.11	6.10	126.30
2016	11.63	0.97	181.16	11.69	205.45

1.4 Swedish PV market segments

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

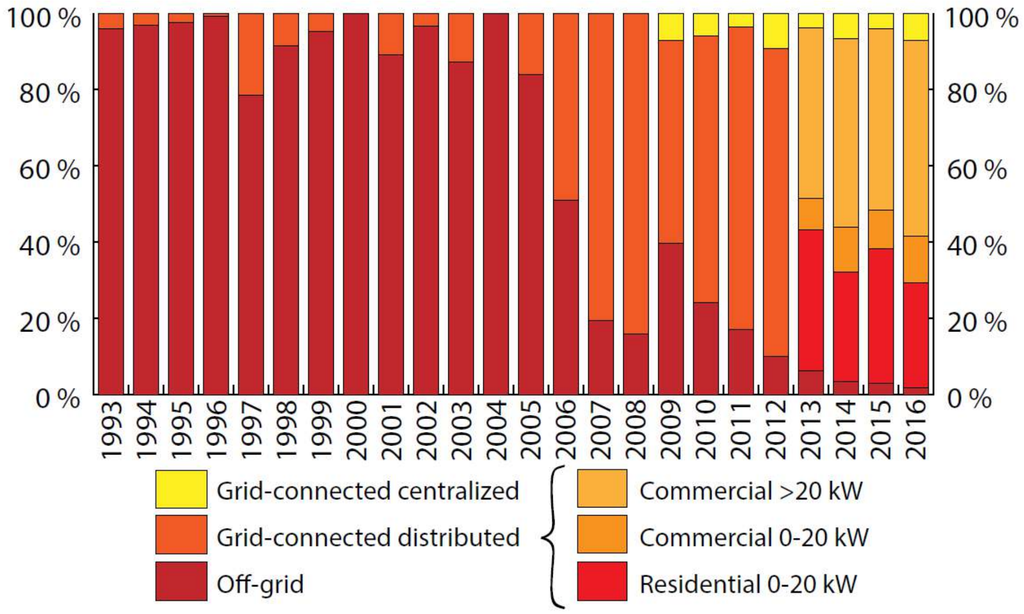

Figure 3: Various market segments' share of the yearly installed capacity in Sweden.

Figure 3 shows 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 3.2.3), as the direct capital subsidy has a maximum aid limit per system of 1.2 million SEK (see section 3.2.1). Big PV parks therefore basically must compete with the spot prices of the Nord Pool spot market. In 2016 5.6 MW_p was installed within this market segment, a 189 % increase compared with the 1.9 MW_p that was installed in 2015.

The biggest market share in Sweden is held by grid-connected distributed systems, 91 % of the yearly market in 2016. For the four most recent years, a breakdown of this market segment has been included in the statistic collection. The grid-connected distributed systems have been divided into residential systems between 0 and 20 kW_p (a typical system in this segment is a roof-mounted system on a detached home), small commercial systems between 0-20 kW_p (typical systems in this segment are roof mounted systems installed on barns or small commercial buildings) and large commercial systems >20 kW_p (typical systems in this segment are roof mounted systems on larger residential buildings, commercial buildings or warehouses). This breakdown shows that the market of small residential systems increased by 27 %, from 17.1 MW_p in 2015 to 21.7 MW_p in 2016 and that small residential systems made up 27 % of all the installed capacity in 2015. Furthermore, 9.7 MW_p and 39.3 MW_p were installed within the small and large commercial segment in 2016, as compared to the 4.9 MW_p and 22.5 MW_p installed in 2015. These two market segments therefore grew with 98 % and 75 %, respectively, and made up of 12 % and 51 % of the yearly installed capacity in 2016.

The grid-connected centralized sector is therefore the segment that showed most percental progress in 2016. One reason is that the biggest PV park in Sweden so far, a 2.7 MW_p park outside of Varberg, came online in 2016. This could make this growth a onetime deviation from the normal market development. On the other hand, the author is aware of about five utility companies that are discussing investments in centralized PV parks in Sweden, so this market segment could continue to grow in the future.

1.5 The geographical distribution of PV in Sweden

The new data from SCB have statistics about the PV power that can be separated down to municipality-level. However, due to missing systems and the fact that several municipalities have been marked as blank in the official data due to secrecy reasons (see section 1.2.2) the data from the Swedish green electricity system (see section 3.2.3) have been used to illustrate the geographical distribution of PV in Sweden in Figure 4 and Figure 5. As only about 49 % of the installed PV capacity (according to the sales statistics) have been approved for the green electricity certificates (see section 3.2.3). These maps do not give a complete picture, but should rather be seen as an indication of the geographical distribution of PV in Sweden.

Figure 4 and Figure 5 clearly show that the expansion of PV takes place at different speeds in 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 Stockholm and Varberg were in the top at the end of 2016 with 4.5, 4.2 and 3.9 MW_p, respectively. If the installed PV capacity is divided by capita, Ödeshög, Varberg and Vadstena were instead the top three municipalities in Sweden with 71.4, 63.4 and 62.7 W_p/capita, respectively. It is no coincidence that these municipalities are 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).

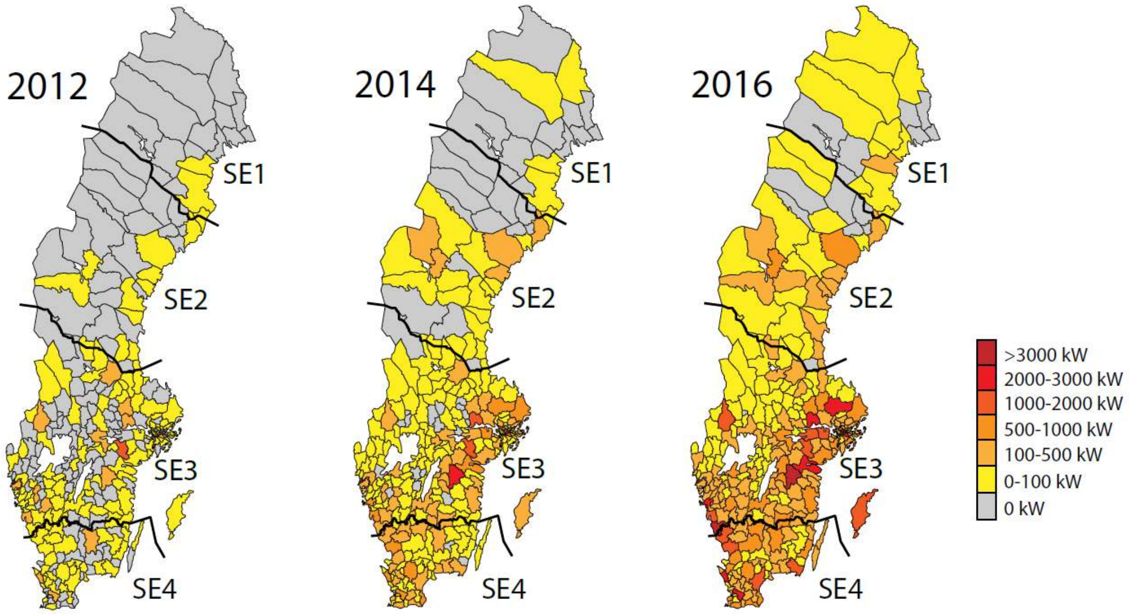

Figure 4: The total power of the approved PV systems in the Swedish green electricity certificate system in each of Sweden's municipalities.

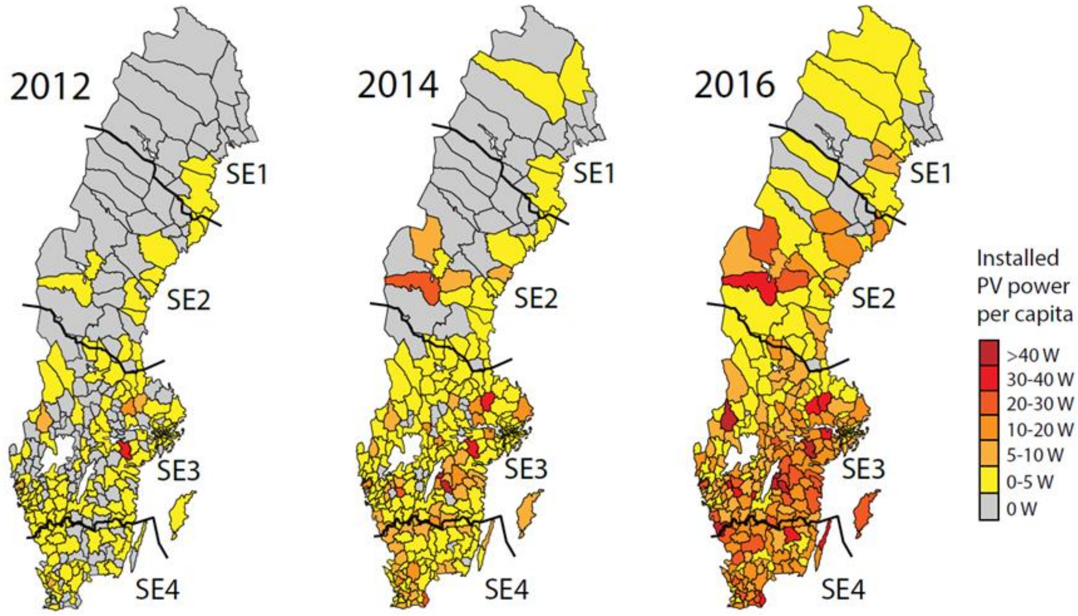

Figure 5: The total power of the approved PV systems in the Swedish green electricity certificate system per capita in each of Sweden's municipalities.

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) [3], 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. This 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 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.

1.6 Installed battery capacity in combination with PV

For the first time the surveys that went out to the installations companies included questions about grid connected battery capacity that had been installed in combination with PV systems. According to the installations companies a total battery capacity of 1 698 kWh was installed in combination with PV systems in 2016, as Table 6 summarizes. The numbers are quite low, but an increase in 2017 is expected since the Government has introduced a direct capital subsidy for batteries (see section 3.3.1)

The reader should be aware that this battery capacity is not the total annual installed grid connected battery capacity in Sweden in 2016. It is only the battery capacity that PV installation companies have installed in connection to distributed PV systems.

Table 6. Annual installed grid connected battery capacity in combination with PV systems.

Year	Private system	Commercial system	Total
2016	233 kWh	1 465 kWh	1 698 kWh

1.7 PV in the broader Swedish energy market

The electricity production in Sweden in 2016 was dominated by hydropower, 40.4 % of total electricity generation, and nuclear power, 39.9 % [4]. Wind turbines have been built at an accelerated rate in recent years and electricity from wind power accounted for 10.2 % of the total electricity generation. The rest is CHP, of which bio stands for approximately 7.3 %. The total electricity generation in Sweden was 151,7 TWh in 2016, a decrease from the 158.6 TWh produced in 2015. The electricity consumption was 140 TWh. In total Sweden imported 14.3 TWh and exported 26.0 TWh [4].

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 2.6.1) is probably the main reason why the Swedish PV market still is rather small.

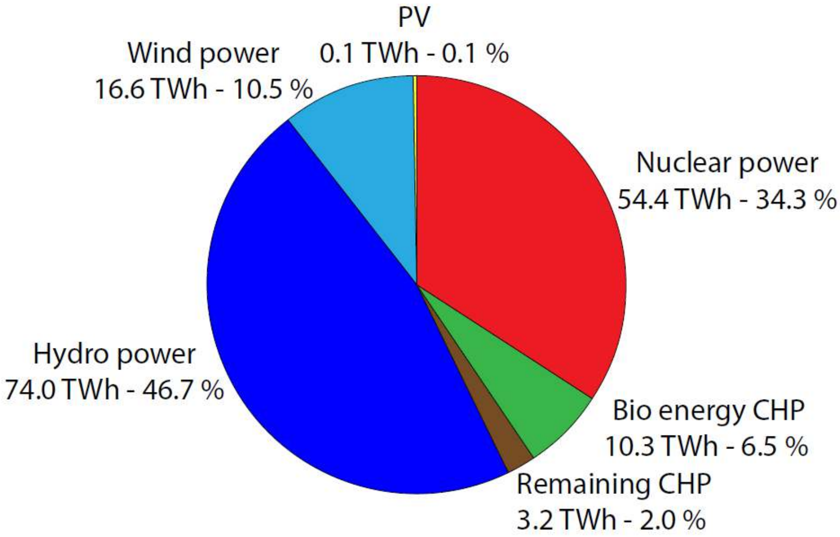

Figure 6: Total electricity production in Sweden in 2016 [4].

Table 7: PV power and the broader national energy market [5].

	2016 Numbers	2015 Numbers
Total power generation capacities (all technologies)	40 004 MW	39 973 MW
Total renewable power generation capacities (including hydropower)	26 485 MW	25 758 MW
Total electricity demand (consumption)[1]	140 TWh	136.8 TWh
New power generation capacities installed during the year (all technologies)	864 MW	992 MW
New renewable power generation capacities installed during the year (including hydropower)	834 MW	783 MW
Total PV electricity production in GWh[2]	~190 GWh	~120 GWh
Total PV electricity production as a % of total electricity consumption	0.13 %	0.08 %

[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 saw a very fast price decline on PV modules between 2008 and 2013 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. Since then the price decline has been more moderate and is following the global markets prices.

Table 8: Typical module prices over the years reported by Swedish installers and retailers – SEK/W$_p$.

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Standard module prices	70	70	65	63	61	50	27	19	14.2	8.6	8.2	7.6	6.5
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 Sweden is the of import duties on Chinese PV modules and cells that was introduced in 2013 by the European Commission [6]. 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 over the years is presented. As can be seen, since 2013 most of the modules have been produced in China and have thereby been 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.

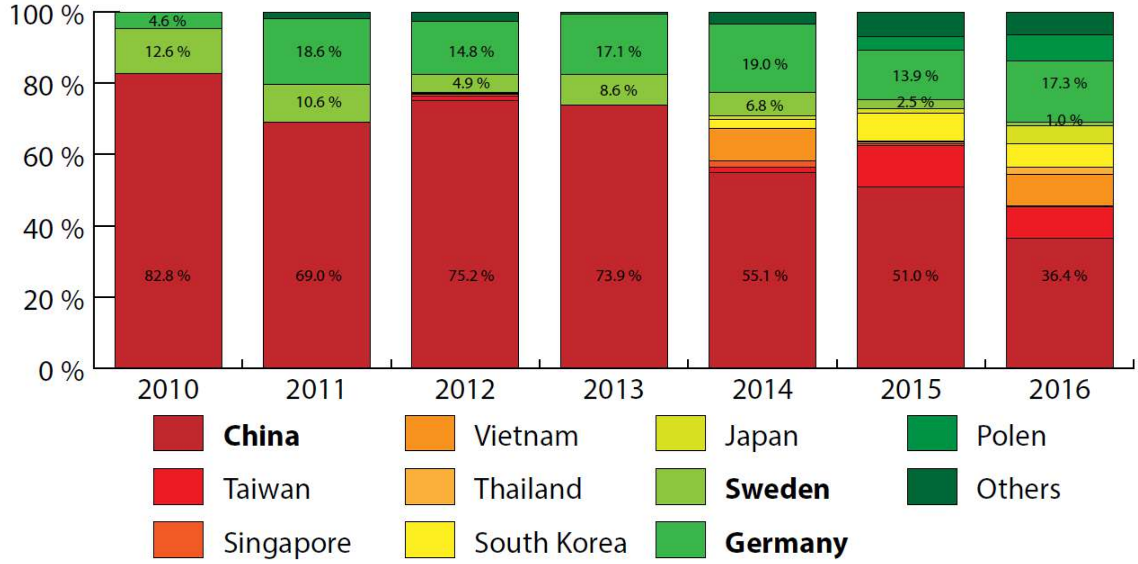

Figure 7: An approximate breakdown of the production country of the PV modules that has been installed in Sweden since 2010, based on information from the Swedish installers and retailers of PV systems. The "Others" category include the countries Estonia, Belgium, The Filipins, France, Greece, The Netherlands, Italy, Lithuania, Malaysia, Slovenia, Spain, South Africa, The Czech Republic, Turkey, US and Austria.

In Figure 7 one can see a clear change of the origins of modules between 2010 and 2016. Historically, China, Sweden and Germany have had the highest market shares. The market share of Swedish produced modules has dropped after 2014, which is due to the closure of the module production factories that happened at the same time (see section 5.3). Overall about 5.9 MW_p of Swedish produced modules has been installed in Sweden since 2010.

The dominant market share of China has also declined over the years, and especially since 2013. This correlates with the import duties on Chinese PV modules and cells that were introduced in 2013. These duties have made it more attractive to buy non-Chinese produced modules, and there is today a much higher diversity of the origin of the PV modules installed in Sweden. One explanation is that several of the big Chinese module producers have started module production in other eastern Asian countries, such as Malaysia, Taiwan, Thailand and Vietnam, to get around the European and American module duties. The share of Chinese modules is probably even lower, and the share from south east Asian countries higher, for 2016 than what is shown in Figure 7, since some installation companies that buy modules from Chinese companies report the origin as from China, while they have been produced elsewhere, due to misunderstanding and unawareness.

2.2 System prices

Sweden has experienced a large decrease in PV system prices since 2010, as Figure 8 shows. The major reason for the decline in system prices in Sweden is that the prices for modules and the balance of system (BoS) equipment have 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 reducing 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 mid-2017 the corresponding figure had gone up to 229.

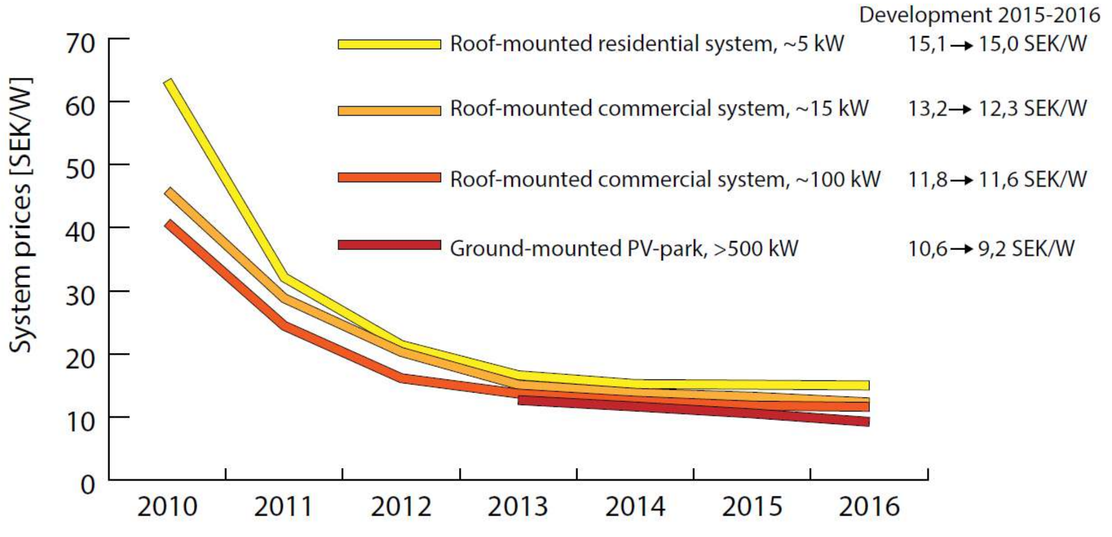

Figure 8: Weighted average prices for turnkey photovoltaic systems (excluding VAT) over the years, reported by Swedish installation companies.

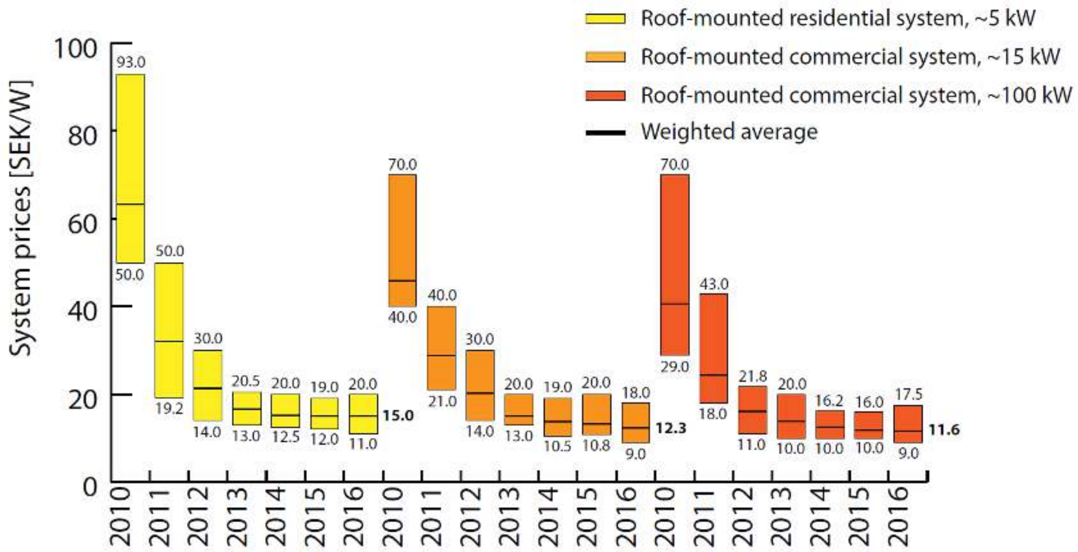

Figure 9: The price difference for typical turnkey PV systems between different Swedish installation companies (excluding VAT). Note that these are the prices that the companies regard as typical for their company, and that the graph therefore does not show the absolute highest and lowest prices in Sweden.

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 2016 12.3 SEK/W_p, 11.6 SEK/W_p and 9.2 SEK/W_p, respectively. That means that the prices in these market segments went down with about 7 %, 2 % and 13 % respectively in 2016, as Figure 8 and

Table 10 shows. In the market segment of small residential systems, the average price has stagnated around 15.0 SEK/W_p since 2014.

The slowdown of the price reduction of PV system is expected 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 reductions of 2–10 % that occurred both in 2015 and 2016 in the commercial sector are 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 account 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 account 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 2015, in which 15 Swedish installation companies 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 total project time from first contact to a completed system was 35 days in Germany in 2013 [7]. 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 3.2.1).

A third reason for the stagnation of the system prices in recent years could also be the fact that the subsidy levels in the Swedish direct capital subsidy system haven't been changed since 2014 (see section 3.2.1). This means that the installers can take the same prices, as the customers have the same profitability, even if module and other hardware costs has continued to go down.

The turnkey prices presented in Figure 8, Figure 9, Table 9 and

Table 10 are a weighted average of what different installers considered to be their typical price at the end of 2016. The typical price reported from each installer has been weighted by the market share of that specific installer.

Table 9: 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.	20.4 SEK/W_p
Grid-connected, roof mounted, up to 20 kW_p (residential)	Systems installed to produce electricity to grid-connected households. Typically roof mounted systems on villas and single-family homes.	15.0 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.	12.3 SEK/W_p
Grid-connected, roof mounted, above 20 kW_p (commercial)	Systems installed to produce electricity to grid-connected industrial buildings.	11.6 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 specific customer and the purpose is to produce electricity for sale.	9.2 SEK/W_p

Table 10: National trends in system prices for different applications (excluding VAT) [SEK/W_p].

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Off-grid PV systems, 1–5 kW_p	95.0	90.0	80.0	70.0	38.1	25.9	28,1	20.4	20.1	20.4
Residential PV systems, 3–20 kW_p	-	-	-	63.3	32.1	21.4	16.6	15.2	15.1	15.0
Commercial and industrial PV system, 20–500 kW_p	60.0	67.0	47.0	40.8	24.4	16.1	13.7	12.6	11.8	11.6
Centralized Ground-mounted PV system, 100–1 000 kW_p	-	-	-	-	-	-	12.7	11.6	10.6	9.2

2.3 Cost breakdown of PV installations

The cost breakdown data presented here were collected in a survey done in 2016 for the year 2015. It is the same data as were published in the Swedish NSR report from the last year. The reason for not presenting an updated cost structure analysis is that the prices for residential and commercial roof mounted haven't changed much under 2016 (see

Table 10).

The survey from 2015 was done with 15 installation companies that contributed with estimations on what was their typical cost structure is for a PV system with a size of 4–6 kW_p which is mounted on the roof of a villa. In the survey five installation companies also contributed with a similar estimation on what their typical cost structure is for a PV system with a size of 40–60 kW_p that is mounted on the roof of a commercial building.

Since there are so few utility scale PV parks that have been installed in Sweden so far, no survey of the cost structure for these kinds of PV parks has been made yet.

The “average” category in Table 11 and Table 12, 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 five Swedish installation companies. The average cost is taking the whole system into 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 costs 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 must pay value added tax (VAT) when installing a system, which a company usually does not have to do. Secondly, a larger commercial PV system usually needs 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.

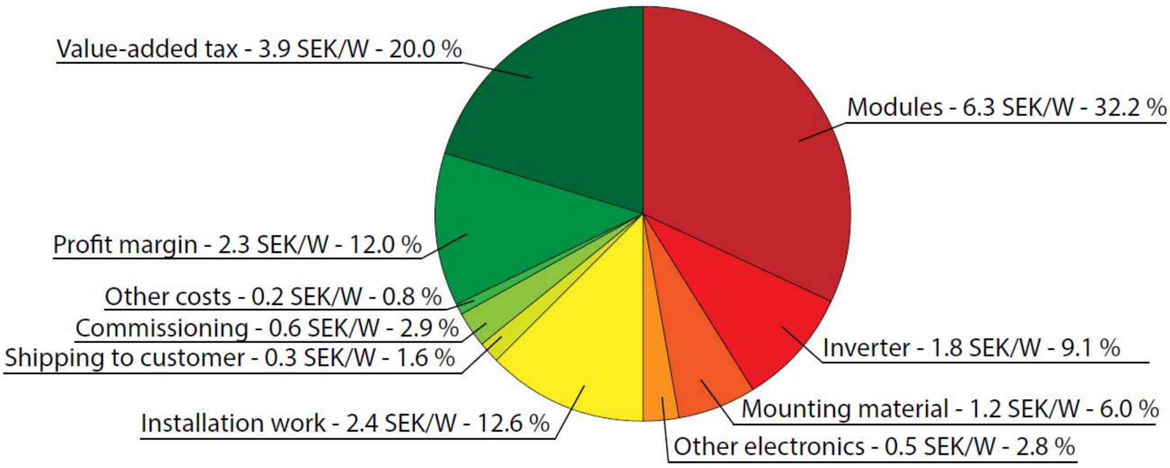

Figure 10: Average of 15 Swedish installation companies cost structures for a typical turnkey grid-connected roof-mounted residential PV system (4–6 kW_p) to the end customer in the end of 2015. The average price was 19.45 SEK/W_p.

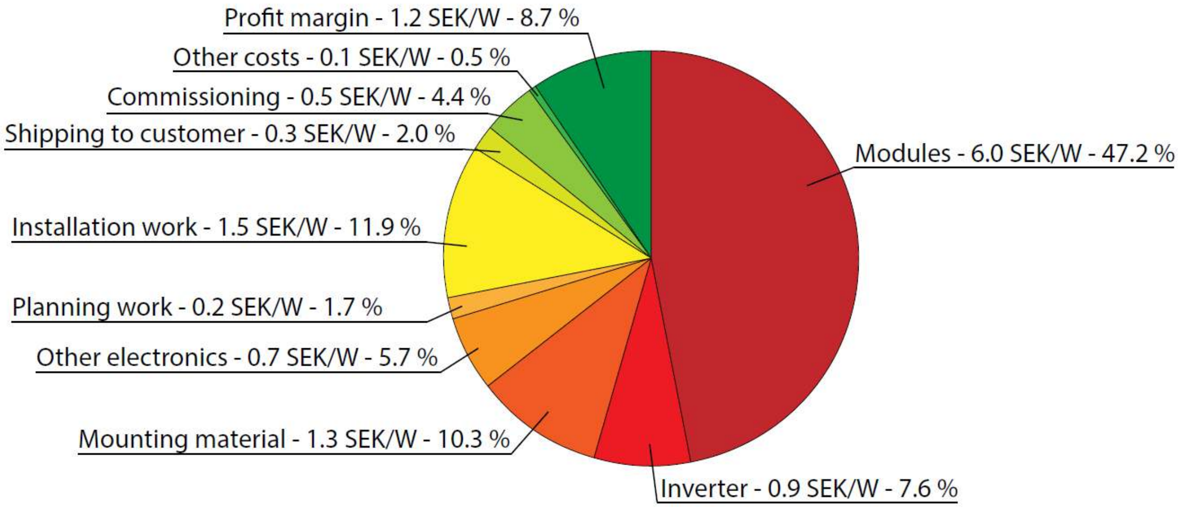

Figure 11: Average of five Swedish installation companies cost structures for a typical turnkey grid-connected roof-mounted commercial PV system (40–60 kW$_p$) to the end customer in the end of 2015. The average price was 12.7 SEK/W$_p$.

Table 11: 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 12: 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 and specific financing programs

The interest rate (reporäntan) of the central bank of Sweden (Riksbanken) started at -0.35 % in 2016 and was gradually lowered to -0.5 % under the year [8]. Changes in interest rate by the central bank have a direct impact on the market rates, which therefore have been very low in 2016. The cost of capital for a PV system has consequently been low.

In Table 13 the average mortgage rate in 2016 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 13: PV financing information.

Average rate of loans – residential installations [9]	1.9 %
Average rate of loans – commercial installations [10]	4.0 %
Average cost of capital – industrial and ground-mounted installations	6.0 %

2.5 Specific investments programs

Already in 2009, the first PV cooperative, Solel i Sala & Heby ekonomisk förening, started in Sweden. This PV cooperative has a FiT agreement with the local utility company Sala-Heby Energi, who buys the electricity from the cooperatives PV systems. From the start in 2009 the cooperative now has built six systems with a total capacity of 599 kW_p. Other examples of PV cooperatives are building systems co-owned PV systems are Åsbro Solel, Solel i Lindesberg ekonomisk förening and Zolcell 1:1 ekonomisk förening.

The more locally created PV cooperatives that have in later years been followed by initiatives by utility companies that have built large PV parks or systems that any private person or company can buy a share in. The shares represent a certain yearly production, which the utility company deduct from the share owner's electricity bill. One examples of this is the 1 MW_p big park with solar tracking outside of Västerås, which the utility company Mälarenergi and the installation company Kraftpojkarna manage together. Another example is Kalmar Energi that installed a crowd funded 600 kW_p system on the roof of a local farm called Nöbble Gård. Kalmar Energi has received positive feedback from the first system and is now expanding this business offer with plans of a 3 MW big crowd funded PV park close to the Kalmar Airport. This park will be built in four stages, and the first one on 750 kW_p is planned to be finalized in the end of September 2017.

In 2014 there was no company offering PV leasing contracts. However, in 2015, the company Eneo Solutions AB started to offer solar leasing contracts to owners of commercial and public buildings. In 2016 two utility companies, Umeå Energi and Egen El started to offer solar leasing contracts to private persons.

Table 14: Summary of existing investment schemes.

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

2.6 Additional Country information

Sweden is a country in northern Europe. With a land area of 407 310 km² [11], Sweden is the fifth largest country in Europe and has a population of about ten million people [12]. The population density of Sweden is therefore low with about 25 inhabitants per km², 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 15: Country information.

Retail Electricity Prices for a household (range)	1.0–1.8 SEK/kWh (including grid charges and taxes)			
Retail Electricity Prices for a commercial company (range)	1.0–1.5 SEK/ kWh (including grid charges and taxes)			
Retail Electricity Prices for an industrial company (range)	0.55–1.0 SEK/kWh (including grid charges and taxes)			
Population at the end of 2016 [12]	9 995 153			
Country size (km²) [11]	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) [3]	Share of grid Subscribers (2015) [13]	Number of retail customers (2016) [14]
	Vattenfall	41 %	16 %	19 %
	E.ON	16 %	19 %	14 %
	Fortum	16 %	-	13 %
	Ellevio[1]	-	17 %	-

[1] Ellevios grid used to belong to Fortum.

2.6.1 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.

High production in hydropower and wind power in 2015 contributed to very low electricity prices in the Nordic countries. With lower water inflows in 2016, the price rose to more normal levels. The average price at the Nord Pool Spot market was approximately 0.20 SEK/kWh in 2015, and in 2016 it had increase to 0.26 SEK/kWh. The monthly average spot price varied from 0.19 in February to 0.38 SEK/kWh in October in 2016. The maximum hourly rate for the year amounted to just under 2.00 SEK/kWh on January the 21st at 08–09, while the minimum hourly rate was as low as 0.04 SEK/kWh on December 31st at 04–05 [5].

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 to better meet consumption in that area, and thus reduce the need to transport electricity long distances.

The average Nord Pool spot prices in 2016 for the different areas were 0.275 SEK/kWh in area 1 (Luleå), 0.275 SEK/kWh in area 2 (Sundsvall), 0.278 SEK/kWh in area 3 (Stockholm) and 0.281 SEK/kWh in area 4 (Malmö). The very small difference between the areas does not influence the distribution of PV systems over the country to the same extent as the population distribution does (see section 1.5).

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 evolution of the average electricity price for private end consumer over the years. 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 3.9.1), the newly introduced tax credit system (see section 3.2.5) and with and without the green electricity certificate, since few PV owners are using the green electricity certificate system (see section 3.2.3).

The reader should note that the electricity price in Figure 13 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 the self-consumed electricity and the excess electricity can have a higher value than in Figure 13.

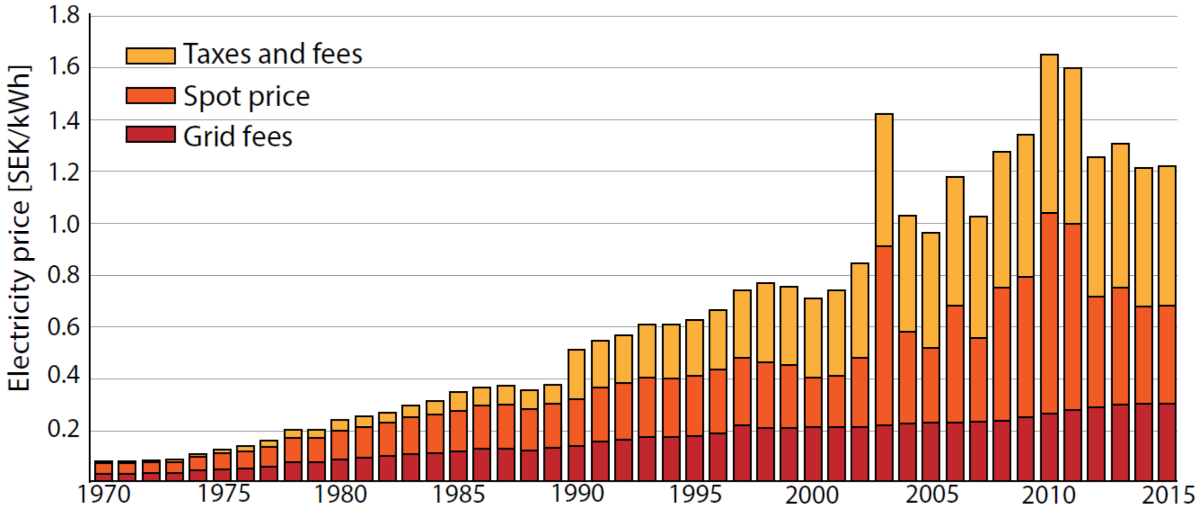

Figure 12: Evolution of the average electricity price (in January) for private end consumer with a single-family house with electric heating [3].

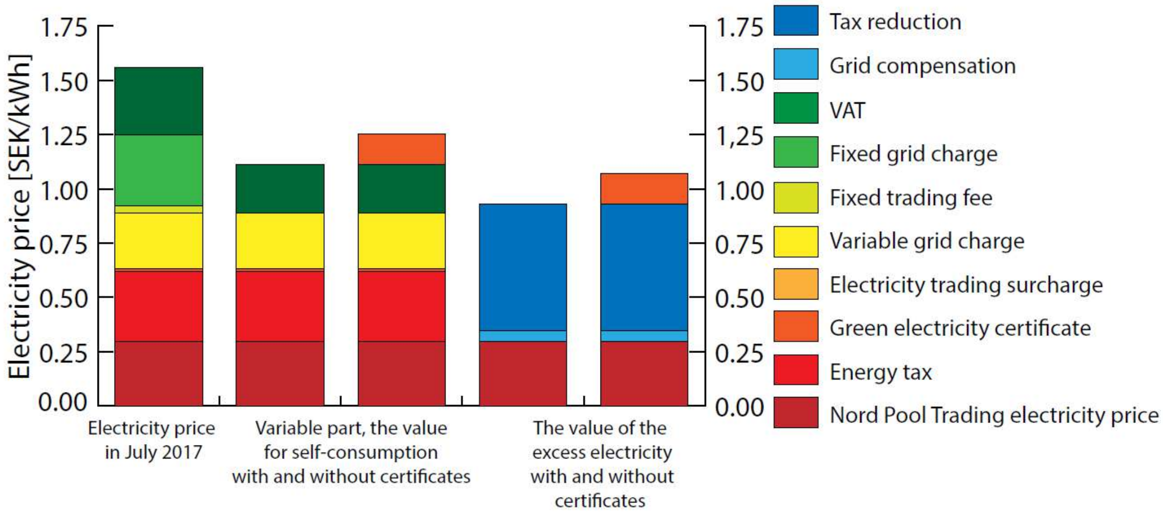

Figure 13: The lowest available electricity price for a typical house with district heating in Stockholm with an annual electricity consumption of about 10 000 kWh/year, a 16-ampere fuse and Vattenfall as the grid owner. Furthermore, the compensation for the excess electricity, with and without the extra remuneration from green electricity certificates.

2.6.2 Global solar radiation

The total amount of solar radiation that hits a horizontal surface is called the global radiation. The global solar radiation thus consists of the direct radiation from the sun and the diffuse radiation from the rest of the sky and the ground. The solar radiation therefore depends on the weather, on the position on the globe and the season of the year. Sweden has a lower solar radiation than in many countries farther to the south, since the maximum solar altitude 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 1 000 kWh/m². 2016 was a little bit less sunny year in Sweden compared with the record year of 2013, but still received 943 kWh/m^2 [15].

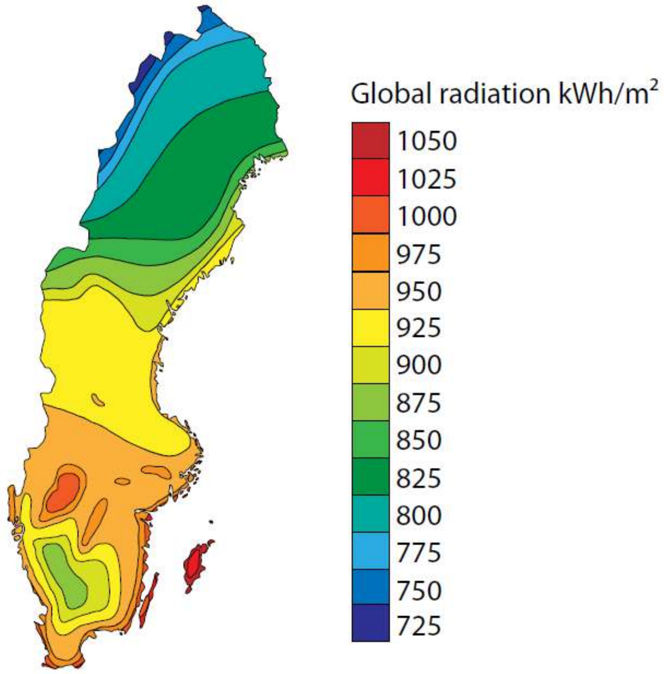

Figure 14: Global solar radiation in Sweden in one year [15].

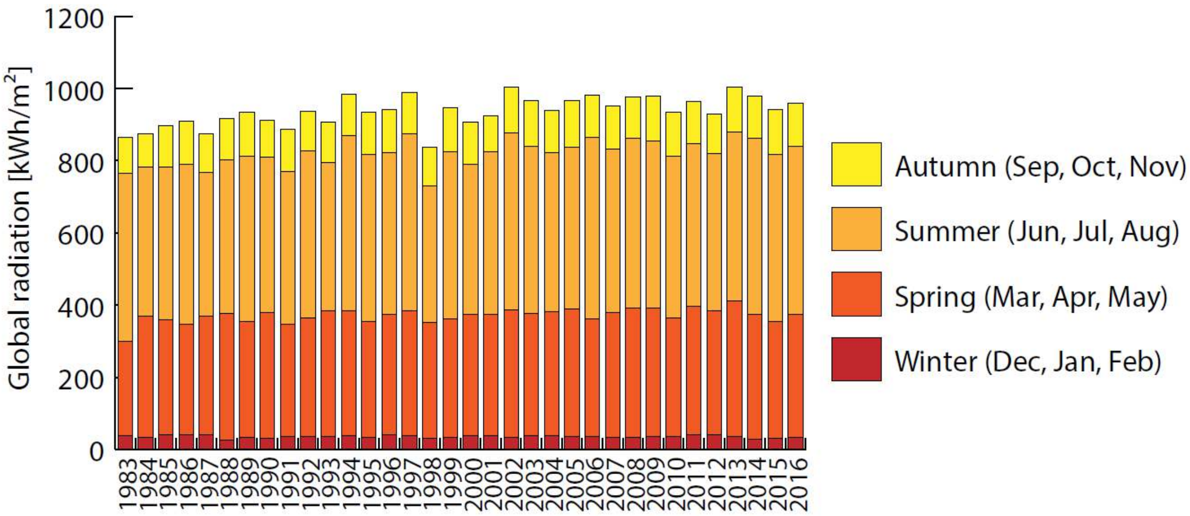

Figure 15: The development of global solar radiation in Sweden from eight weather stations [15].

2.6.3 Levelized cost of electricity

When including the Swedish value added tax (VAT) of 25 % the investment cost was about 18.75 SEK/W for a typical residential installation at the end of 2016 (se section 2.2). To calculate the levelized cost of electricity (LCOE) the following equation can be used [16];

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

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 16, 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 2.6.1).

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 savings 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 from the direct capital subsidy program (see section 3.2.1), the LCOE drops to 0.68 SEK/kWh.

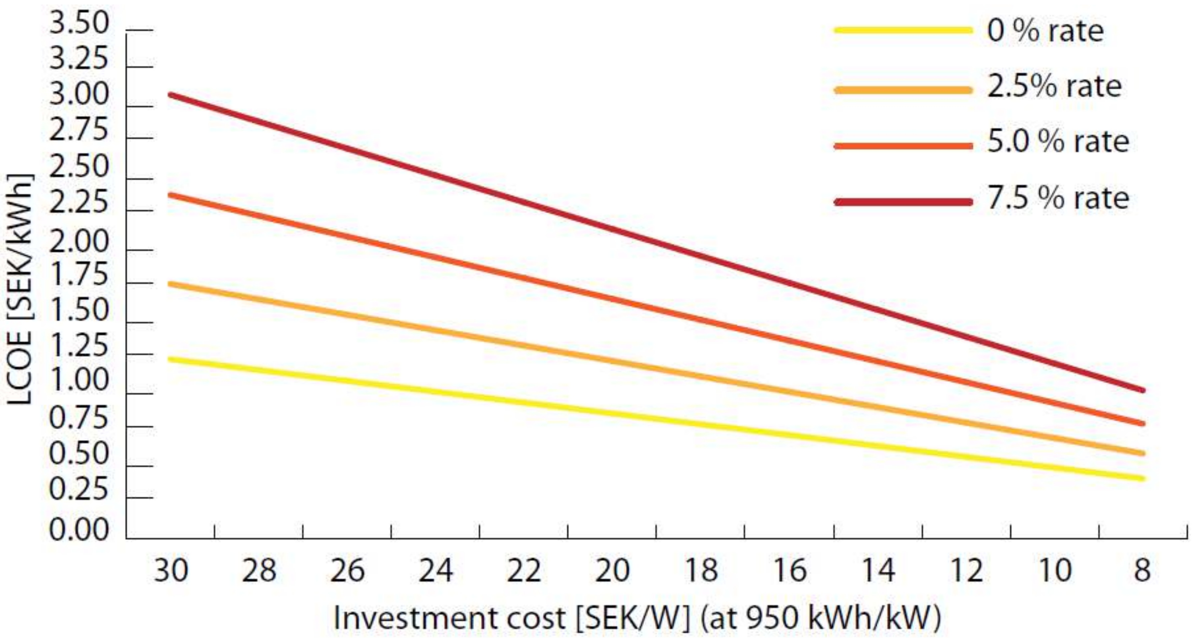

Figure 16: LCOE dependence on investment cost and interest rate.

Table 16: 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 [17]
Interest rate [%]	2.0	Average mortgage rate in 2016 [9].

3 POLICY FRAMEWORK

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

3.1.1 The broad political agreement on the future of the Swedish electricity market

The Swedish Energy Commission was set up in March 2015 with the purpose of coming to a general political consensus on the future of Swedish electricity system beyond 2025. Although eight parties were originally involved, it ended up with an agreement between five of the country's political parties, including the Swedish Social Democrats, the Moderate Coalition Party, the Green Party, the Centre Party and the Christian Democrats.

The coalition agreed on the goal that Sweden will have 100 % renewable generation by 2040, while still planning to be a net exporter of power. The agreement that has been reached intends to, not right away but in the long perspective, phase out the Swedish nuclear reactors that are coming to age and continue pushing renewable energies. More concretely, the Government plans on continuing investment in transmission capacity, demand flexibility and energy efficiency, plus it will extend the Swedish green electricity certificate system from 2020 to 2030. A lot of the coming political introduced legislation changes in the coming years will spring from this political agreement, and the Swedish PV market will most likely benefit from this agreement.

The agreement that was first communicated in June 2016 was only a framework, but in 2016 and 2017 this framework has been filled with more concrete measures.

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 (see section 3.2.3). 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 [18].

3.2 Direct support policies for PV installations

Table 17: PV support measures summary table.

	On-going measures – Residential	Measures that commenced during 2016 – Residential	On-going measures – Commercial + industrial	Measures that commenced during 2016 – Commercial + industrial	On-going measures – Ground-mounted	Measures that commenced during 2016 – Ground mounted
Feed-in tariffs	-	-	-	-	-	-
Feed-in premium (above market price)	Yes	-	(Yes)[1]		-	-
Capital subsidies	Yes	-	Yes	-	Yes	-
Green certificates	Yes	-	Yes	-	Yes	-
Renewable portfolio standards (RPS)	-	-	-	-	-	-
Income tax credits	Yes[2]	-	(Yes)[2]			
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.
[2] The feed in premium is compensated as income tax credits. It is the same system.

3.2.1 Direct capital subsidy for PV installations

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 installation costs 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 Table 5. However, a new subsidy program was introduced in mid-2009, now open for all actors [19]. 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.

In an effort to meet the increased interest in PV in Sweden 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.

Until 2011 the new version of the subsidy covered 60 % (55 % for big companies) of the installation costs 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 can 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 18).

Since the start of the first program in 2006, 910 million SEK had been assigned and 696.5 million SEK had been disbursed at the end of 2016 [20]. This capital has supported a total installation of 78.0 MW_p. This means that on average subsidy for all systems since 2006 to 2016 has been 8.9 SEK/W_p, down from 11.8 SEK/W_p from last year.

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 2016 about 14 380 applications have been received by the county administrative boards (Länsstyrelser), of which about 6 290 have been granted support and 4 864 have been disbursed [20]. The waiting time for the investment subsidy decision can therefore in some cases be longer than two 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 [21].

Table 18. Summary of the Swedish direct capital subsidy program.

	Total 2006 – 2008	2009	2010	2011	2012	2013	2014	2015	2016	Total 2009–2016
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	235	**767**
Granted resources [million SEK] [22]	138	28.4	74.1	71.2	57.9	115.9	61.1	85.8	278.3	**772.6**
Disbursed funds [million SEK] [22]	138	0.05	33.2	81.0	78.3	73.2	75.6	78.2	138.9	**558.5**
Installed capacity based with support from the direct capital subsidy [MW_p][1]	2.96	0.18	2.04	3.12	6.30	11.51	21.16	16.78	14.234	**75.32**
Yearly installed grid connected PV capacity according to the sales statistics [MW_p]	2.83	0.52	1.76	3.41	7.13	18.02	34.25	46.98	77.65	**189.78**[2]

[1] Extract from Boverket's database 2017-01-18. The numbers are probably higher for several of the later years, as there is a large delay in the system.
[2] Cumulative grid connected PV capacity according to sales statistics.

Listed in Table 18 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 statistic 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 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 are 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 3.9.2).

• 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 Figure 17 the budget and the disbursed funds of the direct capital subsidy are compared with the annual marked of grid-connected systems in Sweden. As can be seen the annual Swedish PV market has almost doubled itself several years in a row even if the disbursed funds have been on a constant level. The budget of the coming years is much higher, which promises a continued growing Swedish solar cell market.

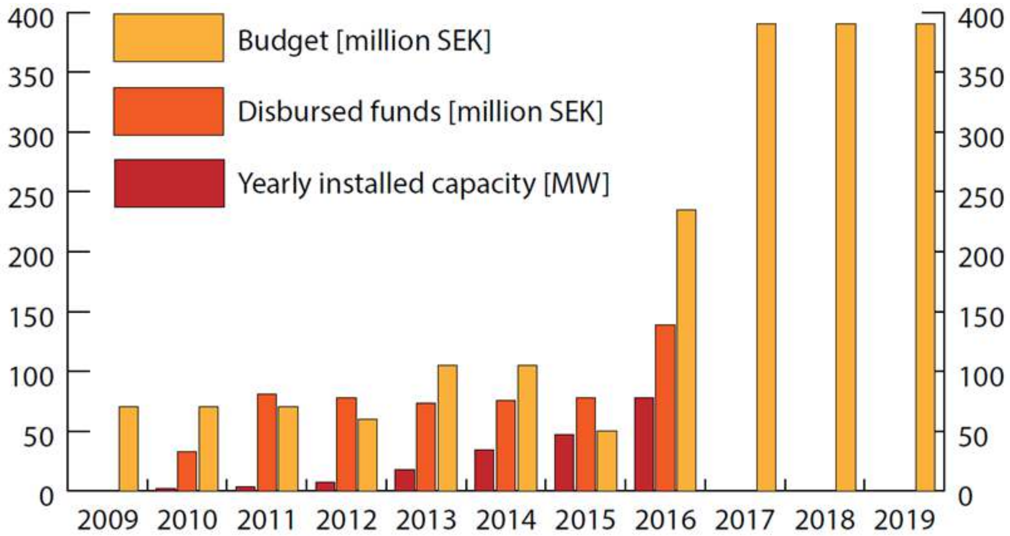

Figure 17: The budget and disbursed funds of the direct capital subsidy along with the annual grid-connected Swedish PV market.

3.2.2 *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, gardening or herding. The subsidy is given to support production renewable energy for both self-consumption in agricultural activities and for sale. This may be in the form of biomass, wind, hydropower, geothermal or PV [23].

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) [23].

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 3.4.1), 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 [24].

So far, this program has granted support to 49 PV projects with a total capacity of 1,57 MW_p for a total amount of 8 128 876 SEK under 2015 and 2016.

3.2.3 *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 end consumers' 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) [25].

The system was introduced in Sweden in 2003 to increase the use of renewable electricity. The 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 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 [26]. In March 2015, the Swedish and Norwegian governments made a new agreement that raised the common goal with 2 TWh to 28.4 TWh until 2020. This increase will only be funded by Swedish consumers [27].

Furthermore, in the wake of the broad political agreement on the future Swedish electricity system (see section 3.1.13.2.3) it was decided in 2017 that the electricity certificate system will be extended to 2030 with another 18 TWh of renewable electricity. The proposal involves a linear escalation of the 18 TWh with 2 TWh from 2022 to 2030. The proposed legislation bill also contains proposals that imply changes in the quota duty for certain electricity supplies, including vehicle charging stations. For the prolonged certificate system to be valid it is necessary that an agreement is reached between Sweden and Norway since Norway don't want to prolong the common system. Therefore, the Swedish Government aims to introduce this prolongation as a separate system as compared to current common Norwegian/Swedish system.

In 2015, the quota obligation for electricity suppliers was 14.3 %, and after the new agreement with Norway, the quota obligation was raised to 23.1 % in 2016 and 24.7 % in 2017 [28]. Further adjustments to the quota levels have then be made for the prolongation to 2030 (see Figure 18). The average price for a certificate decreased to 147.0 SEK/MWh in 2016 from the average price of 161.2 SEK/MWh in 2015 [29], which is part of a long going decreasing trend for the certificate prices (see Figure 19). The established trend in the level of the quota duties is summarized in Figure 18 and the price trend in Figure 19. Since the start in 2003 to the end of 2016, certificates corresponding to 219 TWh has been issued in Sweden [29].

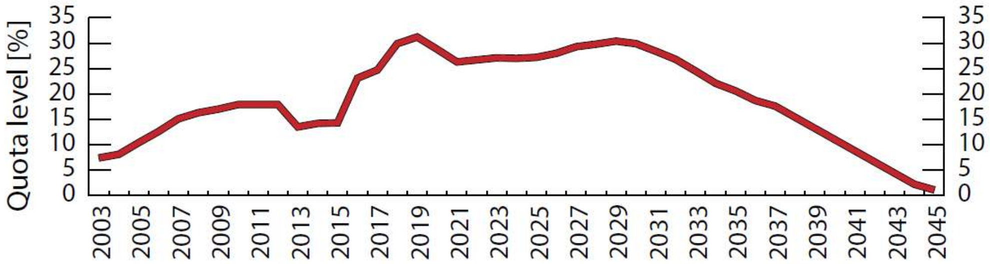

Figure 18: The quota levels in the green electricity certificate system [28].

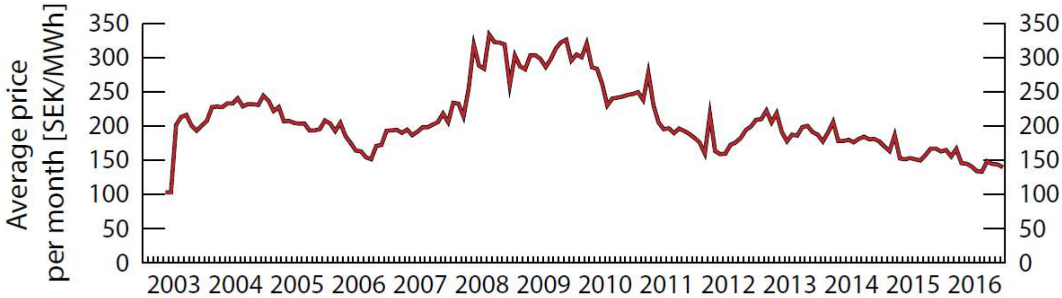

Figure 19: The price development of the green electricity certificates [29].

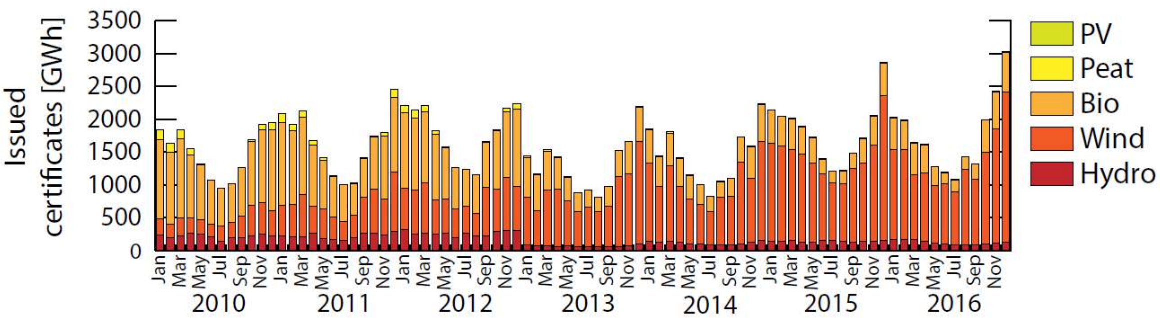

Figure 20: The allocation of green electricity certificates to different technologies in Sweden [29].

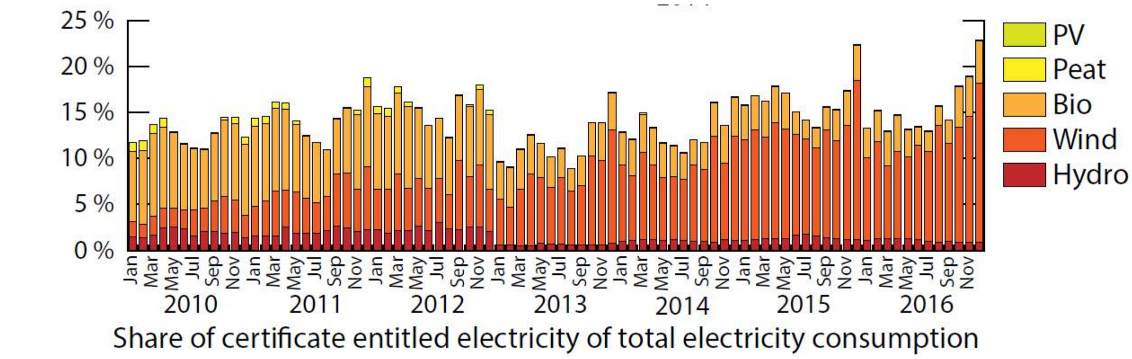

Figure 21: The share of certificate entitled electricity as of total electricity consumption in Sweden [29][30].

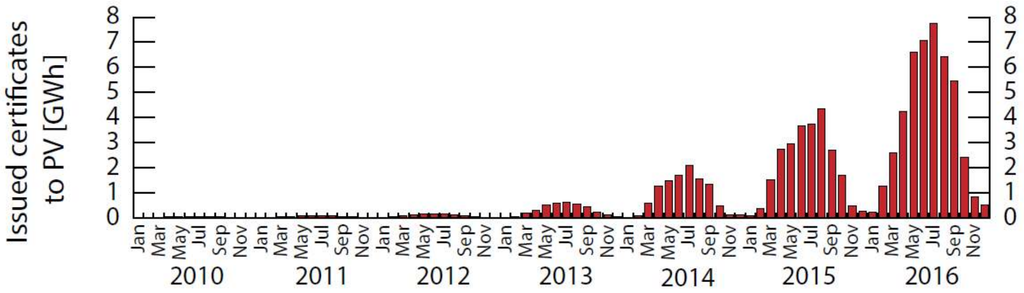

Figure 22: Green electricity certificates issued to PV produced electricity [29].

Until 2006 there were no solar systems in the electricity certificate system. However, as Table 19 and Figure 20 show, 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, most of the certificates go to wind and bio mass power, which produces more in the winter months. Even after considering 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 94.3 MW_p of PV power were at the end of 2016 accepted in the certificate system, making it only 49 % of the total installed PV capacity obtained from the sales statistics. 45 467 certificates were issued to PV in 2016, which corresponds to 45 467 MWh of PV electricity production. This can be compared to the theoretical production of 192.9 MW_p × 950 kWh/kW_p ≈ 183 GWh from all grid-connected PV systems in Sweden. So only about a 25 % of the PV produced electricity received certificates in 2016. 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 refrains 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 19.

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 19, where the proportion of approved solar power owned by private persons is increasing.

Table 19: Statistics about PV in the electricity certificate system [29][31].

	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	2 %	129 MWh	428.6 kWh/kW
2009	10	361 kW_p	2 %	212 MWh	587.3 kWh/kW
2010	18	1 628 kW_p	8 %	278 MWh	170.3 kWh/kW
2011	42	2 011 kW_p	19 %	556 MWh	276.5 kWh/kW
2012	123	3 462 kW_p	37 %	1 029 MWh	297.2 kWh/kW
2013	462	10 949 kW_p	48 %	3 705 MWh	338.4 kWh/kW
2014	1 125	24 158 kW_p	49 %	10 770 MWh	445.8 kWh/kW
2015	2 553	49 177 kW_p	52 %	24 544 MWh	499.1 kWh/kW
2016	4 327	84 604 kW_p	50 %	45 467 MWh	537.4 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 smaller PV installations in Sweden in general.

3.2.4 Guarantees of origin

Guarantees of origin (GOs) are electronic documents that guarantee the origin of the electricity. Electricity producers receive a guarantee from the Government for each MWh of electricity. The electricity producer can then sell GOs 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. GOs are issued for all types of power generation and applying for guarantees of origin is still voluntary.

When the electricity supplier has bought the GOs and sold electricity to a customer, the GOs 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 company 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 2016 in Sweden 37 003 GOs from PV were issued, 28 599 were transferred within Sweden and 20 097 were nullified [29]. Some utility companies have attempted to get the trade going by, e.g. buying PV GOs to a quite high price, but the volumes are still too small for a working trading market. Therefore, the real value of GOs from PV in Sweden is still uncertain.

3.2.5 Tax credit for micro-producers of renewable electricity

The 1 of January 2015, an amendment to the Income Tax Act was introduced [32]. 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 are 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 following 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 3.9.1) and revenues for selling green electricity certificates and guarantees of origins (see section 3.2.3 and 3.2.4). 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 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.

According to the Swedish Tax Agency 5 463 micro producers of renewable electricity received a total 11 366 806 SEK for excess electricity fed into the grid in 2015. In 2016 these number were 8 157 micro producers and 19 065 239 SEK. Since the tax credit is 0.60 SEK/kWh these numbers correspond to 18 945 MWh and 31 776 MWh for 2015 and 2016, respectively. The average production fed into the grid by micro producers that had capacity of less 100 amperes was thereby 3 895 kWh in 2016.

These numbers contain, not only PV, but all small scale renewable production. To get an estimation of the share of PV in the tax reduction one can look at the power of systems that had a production capacity below 69 kW_p (which corresponds to the 100-ampere limit of the tax reduction) in the green electricity certificate system. Summarizing the systems with an individual power of below 68 kW_p that was installed before 2016-12-31 total power becomes 70 262 kW_p. Of this power 64 657 kW_p was PV, and the rest was 2 471 kW_p wind, 2 301 kW_p hydro and 768 kW_p biofuel or peat system [31]. If one uses this relationship, a rough estimation is that 28 000 000 SEK of the total 30 432 045 SEK has been paid to PV system owners through the tax credit for micro-production system under 2015 and 2016. This calculation should be seen as just a rough estimation since both the total produced electricity under a year and the self-consumption ratio differ between the different renewable energy technologies, and also between all the individual systems.

In august 2017 the Government launched an investigation that aims at simplifying this tax credit and expand it to also include shared-owned renewable electricity to make it possible for those who live in apartments to also invest renewable electricity. The outcome of this investigation is at the time of writing unknown.

3.2.6 PV support measures phased out in 2016

No PV support measures were phased out in 2016 in Sweden.

3.2.7 PV support measures introduced in 2016

No PV support measures were introduced in 2016 in Sweden.

3.3 Support for electricity storage and demand response measures

3.3.1 Direct capital subsidy for storage of self-produced electricity

To help increase individual customers possibility to store their own produced electricity the Swedish Government has introduced a direct capital subsidy for energy storage for households.

The subsidy is given for energy storages that fulfil these criteria's [33];

- connected to an electricity production system for self-consumption of renewable electricity,
- connected to the grid,
- helps to store electricity for use at a time other than the time of production,
- which increases the annual share of self-produced electricity used in within the property to better meet the electricity consumption.

The state aid is not given to installations of storage that has received the ROT tax deduction (see section 3.9.2) or any other public support. Eligible costs are the costs of installing electrical energy storage systems, such as battery, cabling, control systems, smart energy hubs and work time. The subsidy is only granted to private persons with a maximum of 60 % of the eligible costs, but no more than 50 000 SEK [33].

The state aid for storage program was introduced in November 2016, but all storage installations that meet the criteria's that were installed in 2016 are entitled to apply for the subsidy. The budget for the storage subsidy program is 25 million SEK for 2016 and 50 million per year for 2017 through 2019 [34]. The actual disbursement of funds started at the turn of the year 2016/2017, so no money was granted in 2016.

3.4 Self-consumption measures

Self-consumption of PV electricity is allowed in Sweden, but no national net-metering system exists. However, several utilities offer various agreements for the excess electricity of a micro producer (see section 7.2).

Since the spring of 2014 an ongoing debate about what tax rules that apply to micro producers, and consequently several changes in the different tax laws has occurred since then. Listed in this section are some specific tax laws that affect self-consumption and micro-producers.

Table 20: Summary of self-consumption rules for small private PV systems in 2016.

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	one 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
	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

3.4.1 *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 3.9.4), 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 SEK in 2016 [3].

The taxes associated with electricity consumption are mainly the energy tax on electricity and the related value added tax (VAT). The manufacturing and agriculture industry paid 0.005 SEK/kWh in energy tax in 2016. The rate for residential customers was increased from 0.294 SEK/kWh (excluding VAT) to 0.325 SEK/kWh the first of July 2017. The exception is some municipalities in northern Sweden where the energy tax was 0.229 SEK/kWh (excluding VAT) [35]. 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 and certificates in 2016.

3.4.2 VAT on the revenues of the excess electricity

A PV system owner that sells the excess electricity will receive compensation from the electricity trading utility company (see section 7.2) and from the grid owner (see section 3.9.1). If the compensation under a tax year exceeds 30 000 SEK, excluding VAT, the PV system owner needs to register for VAT and handle the VAT streams between the utilities that buy the excess electricity and the tax agency (see Figure 23). If the total annual sales do not exceed 30 000 SEK the PV system owner are exempted from VAT [36].

At a reimbursement from an utility company of 0.5 SEK/kWh, 60 000 kWh can be sold per year before reaching the limit. At a self-consumption rate of 50 % it corresponds to a PV system of a size of about 120 kW. So as a general rule of thumb, the 30 000 SEK limit corresponds to PV systems of 100–200 kW_p, which is very large PV systems for private persons.

The limit of 30 000 SEK was implemented the 1st of January 2017, and is an improvement for Swedish PV market. In 2016 a private person needed to go through the administration of register for VAT and report the VAT to the Government. The new set of rules makes it much easier for a private person to invest in PV in Sweden. Furthermore, it also reduces the administration for the tax agency as it doesn't need to handle the registration of several thousands of private PV owners. As the Government is not losing any tax income, as illustrated in Figure 23, it is a win-win situation for all parties as compared to before the 1st of January 2017.

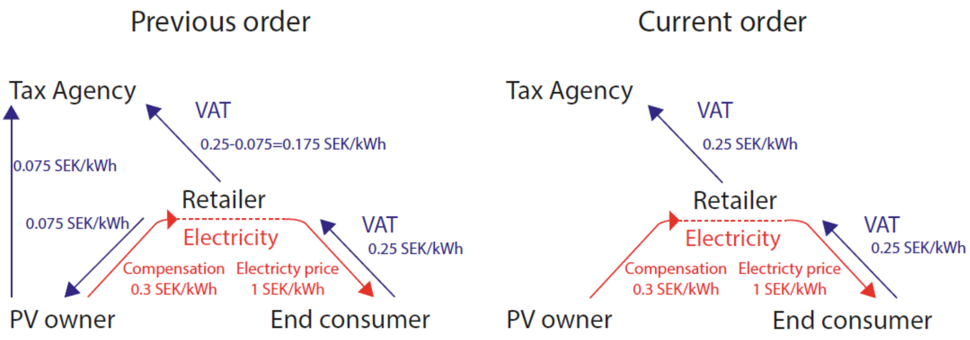

Figure 23. Illustration over the revenue and VAT streams for the excess electricity for a private PV owner before and after the 1st of January 2017.

3.4.3 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 [37].

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.

3.4.4 Energy tax on self-consumption

Before the 1st of July 2016, owning a PV system was not regarded as a business activity and electricity from a PV system was in general excluded from the energy tax of 0.294 SEK/kWh. The producer of PV electricity did not have to pay the energy tax neither for the self-consumed nor for the delivered excess electricity. This applied provided that:

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

When the Swedish Government wanted to extend its national ambition level to 30 TWh of renewable electricity, Norway required that the Swedish Government should remove the existing energy tax exemptions for wind power, and for other electricity from renewable energy sources, which are not delivered professionally. Norway also wanted the proposal to apply to installations which were put into operation after July 1, 2016, and whose installed production capacity leads to an annual electricity production exceeding the annual electricity production corresponding to approximately the 100 kVA power limit in Norway [27].

Against the above background, the Swedish Government presented a proposal that was adopted in connection with the Government's budget. The new rules that came into force on the 1st of July 2016 was [34]:

Exemption from energy taxation shall apply to electric power produced:

- In a plant with an installed generator power of less than 50 kW_p,
- by a producer that control a total installed generator power output of less than 50 kW_p, and
- which has not been transferred to an electricity grid covered by a grid concession.

The installed generator power of 50 kW_p is equivalent to 125 kW_p electric power produced by wind or wave power, to 255 kW_p for PV and to 50 kW_p and other power source without generator.

When electric power is produced from different sources, the installed effects should be added together. In the aggregation, the individual power capacities shall first be converted to the equivalent 50 kW_p of installed generator power in the assessment of the conditions.

The positive aspect of this legislation, as compared to what was valid before the 1st of July 2016, is that the exemption from tax liability for the energy tax also apply to the micro producers who sell their excess production, i.e. deliver electricity.

However, this legislation also had negative consequences for the expansion of PV systems in Sweden, since the power limit of 255 kW for PV is applied per legal person (same organization number). Several major real estate owners who had begun to installed PV systems on their roofs stopped further PV expansions on their buildings when they reached the total 255 kW_p limit.

To further stimulate the production of electricity produced and consumed behind one and the same connection point, and to overcome the negative consequences of the previous rules for major real estate owners, the Government introduced an addition to the above tax rules the 1st of July 2017. This addition leads to the (at the time of writing) current situation:

- The owner of one or more PV systems with a total power of less than 255 kW_p does not have to pay any energy tax on the self-consumed electricity.
- The owner of several smaller PV systems that has a total power of 255 kW_p or more, but where all the individual plants are below 255 kW_p, report and pay a reduced energy tax of 0.005 SEK/kWh on self-consumed electricity from the PV systems.
- The owner of a single PV system that exceeds 255 kW_p pays the normal energy tax of 0.325 SEK/kWh on the self-consumed electricity produced in that facility, but 0.005 SEK/kWh in energy tax on the self-consumed electricity from other PV systems if these systems have a power capacity that is less than 255 kW_p.

The main economic obstacle for real estate owners that plan to build several PV systems has with this new legislation been removed. However, the administrative burden of measuring and reporting the self-consumed electricity if the total power limit of 255 kW_p remains.

3.5 Collective self-consumption

Collective self-consumption from a PV system in an apartment building is allowed in Sweden if all the apartments share the same grid subscription. A number of housing companies and housing societies are using this option. The general approach for such a solution is that the whole apartment building share one electricity contract with the utility and that the electricity is included in the rent, but that electricity consumption is being measured internally by the housing company/society and the monthly rent is affected by this consumption.

Collective self-consumption where the electricity is transported over a grid that is covered by a grid concession is currently not allowed.

3.6 BIPV development measures

There were no specific measures for BIPV development in 2016 in Sweden.

3.7 Tenders, auctions and similar schemes

There were no national or regional tenders, auctions or power purchase agreements in 2016 in Sweden.

3.8 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 558 513 006 SEK have been disbursed from 2009 to the end of 2016 [20]. This system is financed by the Swedish state budget and the money is distributed by the 21 county administrations).

In addition, the direct capital subsidy for renewable energy production in the agriculture industry program has under 2015 and 2016 granted a total support of 8 128 876 SEK to PV systems. This system is financed by the European Agricultural Fund for Agricultural Development (EJFLU), so the funding comes from the European Union.

Furthermore, PV systems have benefited from the green electricity certificate system and had at the end on 2016 received 86 744 certificates. By taking the monthly average prices for the certificates and multiply these prices with the number of certificates that has been issued to PV in each month the total support to PV by the end of 2016 becomes 13 472 719 SEK [29]. The green electricity certificate system is financed by electricity consumers, except for electricity-intensive industries that have certificate costs only for the electricity that is not used in the manufacturing process.

At last, a rough estimation is that a total of 28 000 000 SEK (see section 3.2.5) have been paid to small scale PV system owners through the tax credit for micro producers of renewable electricity subsidy in 2015 and 2016. This subsidy financed by the Swedish state budget.

Adding all the above subsides (with start in 2006 when the first PV systems was included in the green electricity certificate system) the Swedish PV market had at the end of 2016 in total received about 750 646 000 SEK in direct subsidies. This corresponds to roughly 75 SEK/capita in total over the years.

3.9 Indirect policy issues

3.9.1 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 [38].

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 and 0.10 SEK/kWh.

3.9.2 ROT tax deduction

The ROT-program is an incentive program for private persons that buy services from 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 2016 was 30 % of the labour cost and of maximum 50 000 for the installation of a PV system. The requirements are that the house is older than five years and that the client has not received the direct capital subsidy for PV. Installation or replacement of solar panels are entitled ROT, while services of solar panels are not [39].

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 9 % in 2016. 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. Some private persons therefor install their PV systems with the ROT tax deduction and later pay this back to the Government if they receive the direct capital subsidy for PV.

3.9.3 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 [40].

3.9.4 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 [41].

A recent Governmental investigation suggests 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 [41].

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 [41].

4 HIGHLIGHTS OF R&D

4.1 Highlights of R&D

The Swedish solar cell related research consists largely of fundamental research in new types of solar cells and photovoltaic materials. Several of the research groups in this category are at the forefront and are highly regarded internationally. Furthermore, there are some smaller groups that focus on PV systems and PV in the energy system oriented research. In the table below the different Swedish PV or battery research groups are summarized:

Research group name	**Research topics**	**Estimated number of full time jobs in 2016**
Center of Molecular Devices	Dye-sensitized, perovskite and quantum dot solar cells	35
Chalmers, Architectural Theory and Methods	Roof renovation with PV	1
Chalmers, Architecture and Civil Engineering	Solar energy applications and energy efficiency	3
Chalmers, Chemistry and Biochemistry, Abrahamsson Research Group	Photocatalytic conversion of CO2 with light	3
Chalmers, Chemistry and Biochemistry, Albinsson Research Group	Technology for down and up conversion of sunlight	2
Chalmers, Chemistry and Chemical Engineering	Organic solar cells	6
Chalmers, Chemical physics	Surface physics and catalysis by advanced calculation methods	2
Chalmers, Condensed Matter Physics	Battery research	15
Chalmers, Molecular Materials, Moth-Poulsen Research Group	Design and synthesis of new self-collecting materials based on molecules and nanoparticles	6
Dalarnas University, Center for Solar Research	System research, PV and heat pump smart systems, microsystems smart grid business models	4
Glafo AB	Module glass research	3
Swerea IVF	Dye-sensitized solar cells and implementation of PV in real estates	4
JTI – Swedish Institute of Agricultural and Environmental Engineering	PV in agriculture applications	1
Karlstads University, Molecular Materials for Electronics	Polymer-based, perovskite and hybrid solar cells	4
Karlstads University, Characterizing and Modeling of Materials	Multi crystalline silicon solar cells	3
KTH Royal Institute of Technology, Applied Thermodynamics and Refrigeration	PV system in Swedish housing association	3
KTH Royal Institute of Technology, Concentrating Solar Power and Techno-economic Analysis	Techno-economic analyses, design and experimental verification for CSP	4
KTH Royal Institute of Technology, Electric Power Systems	Power grid control at coordinated input of PV electricity	1
KTH Royal Institute of Technology, Material and Nanophysics	Direct III-V/Si heterocycle for solar cells and silicon-based tandem cell	2

Linköping University, Biomolecular and Organic Electronics	Plastic solar cells	12
Linköping University, Chemistry and Biology	Cubic silicon carbide as light emitting material	2
Linköping University, Organic Electronics	Solar heat-charged super capacitor as energy storage	3
Linköping University, Technology and Social Change	Social studies of micro-producers	1
Luleå University of Technology, Electric Power Engineering	Stochastic planning of smart electricity distribution networks	1
Luleå University of Technology, Experimental Physics	New nanomaterials for third generation solar cells	5
Lund University, Chemical Physics	Dye-sensitize and plastic solar cells, semiconductor nanowires and organometal halide perovskites	14
Lund University, Energy and Building Design	Social issues with regards to solar energy, urban planning and building design	1
Lund University, Nanolund	Tandem transitions in nano threads, Intermediate band gap solar cells and piezoelectric solar cells	5
Lund University, Polymer & Materials Chemistry	Nano-structured materials for higher PV efficiency	3
Mid Sweden University, Electronic Construction	Converters and supercapacitor	6
Mid Sweden University, Fibre Science and Communication Network	Lithium-ion batteries	1
Mid Sweden University, KM2	Solar cells of paper	1
Mälardalen University, Future Energy Center	Efficient distribution of energy	7
Solelprogrammet	National development program for solar cell systems	0
RISE Research Institute of Sweden AB	Testing of PV components and systems	10
Umeå University, The Organic Photonics and Electronics Group	Photonic and electronic devices based on novel organic compounds	2
Uppsala University, Built Environment Energy Systems	PV grid integration studies and modelling of; PV systems, building systems, self-consumption and solar-powered transports	10
Uppsala University, Solid State Electronics	CIGS and CZTS thin film solar cells and materials	25
Uppsala University, Ångström Advanced Battery Centre	Li-ion batteries and the combination of Li with other materials	30

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

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*. This program 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 was 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 included projects of various kinds, from research and development projects carried out by various research institutions to experimental development and demonstration in companies. *El och bränsle från solen* was running between 2013-01-01 and 2016-12-31, and in total 137,5 million SEK was dispersed over the four years.

Overlapping *El och bränsle från solen*, another Swedish Energy Agency research funding program was started in 2016-06-05, which is called *El från solen*. This program focuses only on electricity production from the sun. This program has a preliminary end date late 2020. However, the structure is a bit different for this program compared to the previous one, which means that after two years an evaluation of the program will be made and depending on the outcome of this evaluation, the program may be extended with another two years.
The total budget for *El från solen* is 160 million SEK.

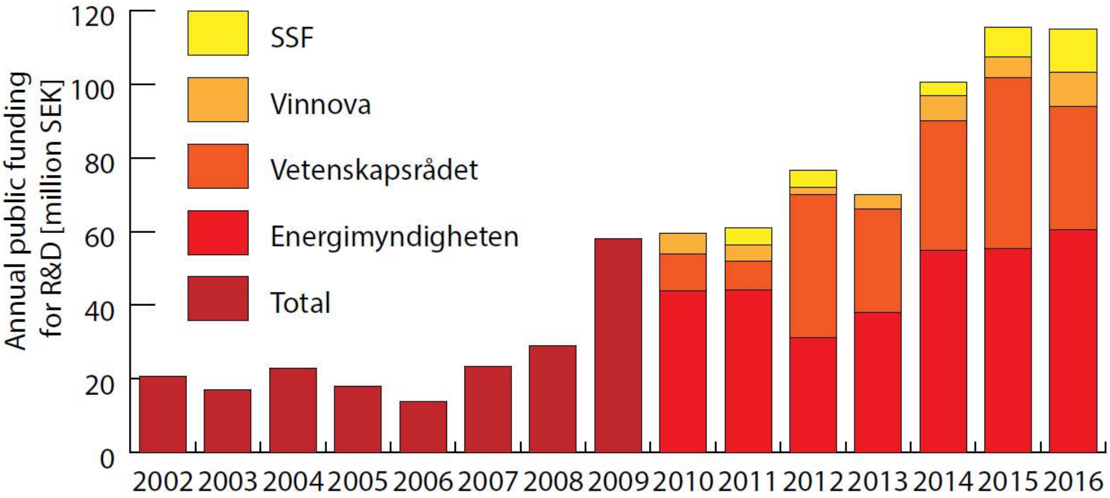

Figure 24: Annual public funding for PV related R&D in Sweden.

The Swedish Energy Agency has in addition to the public funding for R&D presented in Figure 24 in 2016 also distributed 2.6 million SEK in conditional loans for PV related technological and business development.

Table 21: Public budgets for R&D, demonstration/field test and business development programmes in 2016.

	R & D	Demo/Field test
National/federal	114.9 million SEK	2.6 million SEK
State/regional	unknown	unknown
Total	117,5 million SEK	

4.2.1 Demonstration and field test sites

4.2.1.1 Kullen

On a hill close to Katrineholm lies the company Egen El's production and demonstration facility Kullen. The hill is littered with several small PV systems and wind turbines. It works both as a power plant that sells electricity and as a place where people can come and have a look at different kinds of small-scale renewable electricity systems, suitable for private persons. Several guided tours and information days are arranged each year for the interested public. The park also offers individuals and companies that do not own land or a suitable property, a place where they can set up their own PV systems or rent space on existing ones, and thereby contribute to renewable electricity production. The park is growing each year and had at the end of 2016 a PV capacity of 1 017 kW_p.

4.2.1.2 Glava Energy Center

Located 35 km south east of Arvika in Värmland is Glava Energy Center, 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 consists of two systems, totalling 74 kW_p, one of which is fully owned by Fortum and the other is owned by Glava Energy Center. Fortum and Bixia buy all the electricity that the two grid-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 RISE (Research Institutes 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 Centre that school classes visit on a regular base in order to carry out experiments related to renewable energy.

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 199 companies that sold and/or installed PV modules and/or systems in the Swedish market (see section 5.6). There were also 11 companies active in manufacturing of production machines or balance of systems equipment (see section 5.4) in 2016. Furthermore, the author was aware of 14 companies that can be classified as R&D companies, or companies that had R&D divisions in Sweden (see section 5.5), in 2016. Since the bankruptcy of SweModule, Sweden does 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 170 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 2016 and there are currently no plans for this kind of production in the future.

Table 22: Production information for 2016 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. In the acceleration of PV module price reductions on the world market in 2011 and 2012 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. Renewable Sun Energy Sweden AB and Misummer AB did produce some commercial modules as part of their product development in 2016, which amounted to 0.13 MW_p in total. This was the only module production that took place in Sweden in 2016.

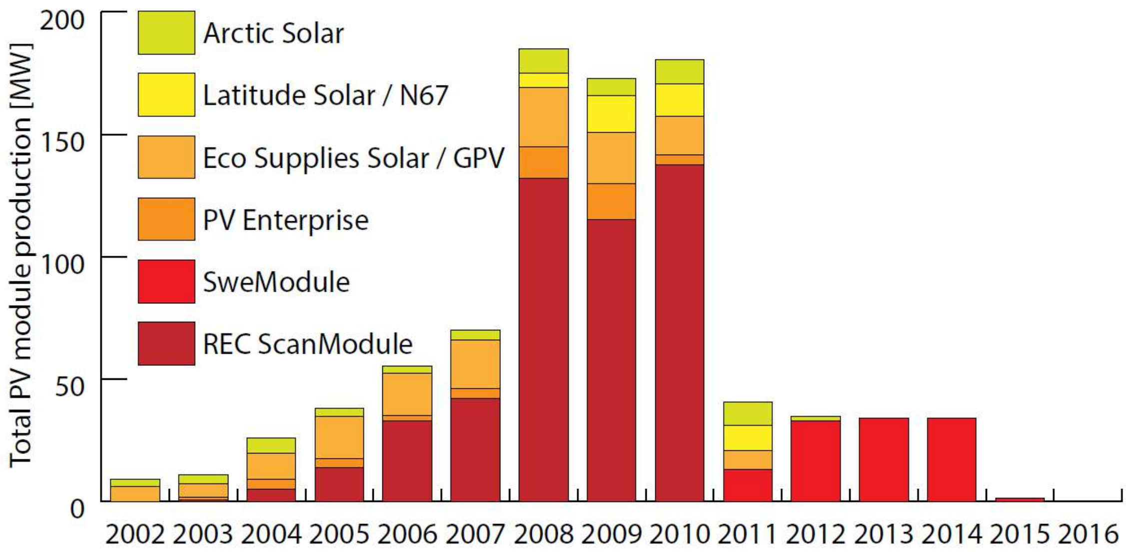

Figure 25: Yearly PV module production in Sweden over the years.

Table 23: Production and production capacity of Swedish module producers in 2016.

Cell/Module manufacturer	Technology	Total production (MW_p)		Maximum production capacity (MW_p/year)	
		Cell	Module	Cell	Module
Wafer-based PV					
Renewable Sun Energy	Mono-Si	-	0,03	-	0,03
Thin film					
None	CIGS	0,1	0,1	3,0	3,0
Cells for concentration					
None		-	-	-	-
TOTALS		0	0,13	3,0	3,03

5.3.1.1 Jowa Energy Vision

Jowa Energy Vision bought in 2012 the production equipment from the former Swedish producer Eco Supplies Europe AB and has assembled the equipment in a factory in Alingsås. The plan is to produce modules for building integrated systems with a 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 has been put on hold since 2014. However, a decision has been made to start ramping up production in 2017.

5.3.1.2 Renewable Sun Energy Sweden AB

Module production has taken place in Glava, Värmland since 2003 when REC ScanModule AB built a module production facility there. In end of 2010 REC ScanModule AB closed down their production, but the facilities were taken over by SweModule AB that continued to produce modules from imported silicon solar cells. In 2015 SweModule went bankrupt. In total, over 2 500 000 multi crystalline silicon modules, corresponding to 0.5 GW, have been produced at the site since 2003. However, it seems like these numbers will increase in the coming years as the production facilities in September in 2016 were acquired by the newly formed company Renewable Sun Energy Sweden AB. The company begun with refurbishment and repairing of some of the equipment and produced at the end of 2016 approximately 100 of panels from imported three-busbar monocrystalline solar cells to test the factory. Right now, the company is going through a certification process of their modules and when this is done the plan is to start production in the autumn of 2017 with the same product name as before, i.e. SweModule.

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, and since the beginning of 2017 also in Italy. In addition to the module production the company developed their own ground-mounting stand. In 2014 Windon also started to develop inverters within the range of 1–20 kW_p. These inverters were started to be manufactured in 2016 and 300 units was sold in 2016. The parts for the inverters come from all over the world, but are assembled at a O&M production facility in China. However, Windon plans to move the assembling of the inverters to the Swedish town Tranås as soon as the annual quantities reaches around 1000 units.

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 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 3.2.3) 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 2016 the company sold about 800 of their metering products.

5.4.1.3 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. The battery cells come from China, but the production and mounting of all the components takes place in Sweden. Shipments of scalable PV solar and Energy Storage solutions started in 2016, and about 125 of variable sizes were delivered under the year. Now, all the distribution and manufacturing processes are set and Ferroamp plan for a much larger rollout in 2017 as the company has received many orders.

Another interesting project is that between Ferroamp and 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. In 2016 Ferroamp delivered the products to Finland and the concept will now be tested there.

5.4.1.4 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 2016 98 % of their products were sold in Sweden.

5.4.1.5 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 flexible solar 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 line called DUO produces 6-inch wafer-like CIGS thin film solar cells deposited on stainless steel substrates using a proprietary all sputtering process. With the rapid price decline of PV products, Midsummer has developed a niche with flexible modules that weigh about 25 % of a corresponding crystalline silicon module. Midsummer's customers are thin film solar cell manufacturers all over the world. Midsummer has also developed a generic research tool called UNO that they 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.

Over the years there have been continuous research and improvements in the lab and the company has been able to increase the efficiency for 156×156 mm cells to 15.7 % total area efficiency (18.0 % aperture area), on solar cells made in normal production at a customer site in Asia. A flexible solar module from the same manufacturing site measured 14.1 % efficiency (15.4 % aperture area) at the independent test laboratory Chemitox in Japan in fall 2016.

In 2016 Midsummer, has secured multiple follow-up order from the same company for its thin-film solar cell sputtering tools with deliveries in 2017. Midsummer's customers are mainly focusing on the BIPV-market and especially the roof-top segment.

5.4.1.6 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). The interest in 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. 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 were installed. In 2016 the company didn't install any PV in connection to their DC-systems, but about 300 kWh of battery capacity.

5.4.1.7 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. In 2015, the company started two PV related projects. The first is about a storage solution for telecom and PV. These battery packages are scalable and can be delivered in sizes from 1 kWh storage capacity up to several MWh. The solutions are planned to be commercialised in mid-2017. In the second project Nilar works in collaboration with Ferroamp to integrate their batteries in Ferroamp's energy-hub. This project is on-going and a first system was installed in 2016. Furthermore, Nilar has initiated collaboration with two of Sweden's major PV wholesale companies with the aim to sell batteries in combination with PV. But right now, the Swedish market is just marginal one for Nilar. The major markets for the company are rather England, Holland, Germany, Italy and Portugal.

5.4.1.8 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 are now producing aluminum profiles for BIPV solutions.

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 185 systems from the start, of which about 50 systems were sold in 2016.

5.4.1.10 Swedish Box of Energy AB

Box of Energy is a battery technology provider that has specialized on battery systems for PV and wind production. The company buys second hand lithium-ion batteries from the electrical car industry and assembled the battery system product 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 four systems that are monitored for testing and certification, and approximately another 35 systems has been sold and installed at different customers since the start in 2014.

5.4.1.11 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. During this process Absolicon has developed a model that can deliver steam with a temperature of up to 160 degrees, which can be used to drive industrial processes. In 2016 Absolicon managed to sell a fully automated production line for this thermal power generations system, which will be installed in the Sichuan-province in China and will be finished at the end of 2017. In parallel the company plans to build a similar automated production line in Härnösand in Sweden.

Even if the focus now is on purely thermal product. 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, both for grid-connected and off-grid systems. But the focus is on off-grid systems. These inverters 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 dye-sensitized solar cells suitable for mass production. Exeger is one of the companies in the world that has made most progress in commercializing the DSC technology as a screen-printing production line was demonstrated already in 2014. Since then Exeger have been building the world's largest DSC production plant located in Stockholm. 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 first product will probably by self-charging e-reader/tablet covers. In 2016 Exeger worked with several partners to develop commercial consumer electronics prototypes. Fortum also invested 5.2 million Euros in the company, which enabled Exeger to increase their production capacity in their new factory from 10 to 15 million units of e-reader sized cells annually.

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 and that was still the status in the beginning of 2017.

5.5.1.7 Optistring Technologies AB

Optistring Technologies, which was founded in 2011 as a spin-off from KTH research, 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. The company finalized the third generation of their products in 2014, which were deployed in pilot installations in both Sweden and abroad. In 2015 Optistring started to develop their fourth generation, which is designed for large-scale production. This development work was finalized in 2016 and the company are now preparing for certification and large-scale production of their product.

5.5.1.8 SolAngel Energy AB

SolAngel is a start-up company that has developed a product that allows the solar panels to be disconnected from each other automatically in an emergency situation. This could for example be by a thermal fuse or by the request of the owner, firefighters through a remote signal. When the switch is activated, all the solar panels will be disconnected from each other and the voltage goes down to the voltage of each PV panel instead, which is maximum 50 V, and the current will be equal to the open circuit current, which is 0 amps. This eliminates the risks for electric chocks during an emergency. The SolAngel produced a prototype in 2016, which will now be tested in collaboration with Akademiska Hus and KTH.

5.5.1.9 Solarus Sunpower Sweden AB

Solarus is a solar energy company with their roots in 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 Venlo in the Netherlands. This production facility is owned by the Dutch sister company Solarus Sunpower BV. The production was ramped up in 2015 and around 400 PV/T modules was produced in the first year. This number increased to around 600 PV/T modules in 2016. In total, the plant has a production capacity of 30 000 modules per year and Solarus plans for a larger production in 2017.

5.5.1.10 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 Zibo, China, which will use the Solibro technology and have a production capacity of 300 MW_p, which will be finished in 2017.
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 have been constructed by the company and systems are available to customers. The manufacturing of the mounting systems will be outsourced.

The main development for the Solibro Group in 2017 was a major change of their business model. From being a CIGS module producer, the company has switch to sell CIGS module factory supplier and Solibro have in the first half of 2017 sold two factories with a production capacity of 300 MW each in China.

5.5.1.11 SolTech Energy Sweden AB

Stockholm based SolTech Energy Sweden develops two different kind of solar energy products. One of them is a kind of building integrated PV panel, a type of a BIPV roof tiles. SolTech Energy are also offering transparent thin film solar cells that combine electricity generation with shading effects and that can replace ordinary glass facades or windows. The product development of the different technologies is carried out by SolTech in Sweden, while production of the products is being subcontracted/outsourced to producers in Europe and China.

SolTech Energy is also an installation company with operation in Sweden. However, the company's major installation activities are in China, where they sold and installed about 30 MW in 2016 through their joint venture company ASRE.

5.5.1.12 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 claims that their technology can boost module efficiencies by up to 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 200 cm^2 area. 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. This record cell was stable with no degradation after being stored in normal atmosphere for over one year. In 2017, the first fully functional Aerotaxy PV wire was produced, bringing nanowire solar modules yet a step closer.

5.5.1.13 Sundaya Nordic AB

Sundaya Nordic AB is part of the Sundaya group, which is a company that develops, produces and sells micro production systems for rural electrification that includes PV. The main headquarter is in Singapore and the group has manufacturing facilities in Jakarta, Indonesia and Xiamen, China. The Swedish office handles sales in the European, Middle East, African and American markets and is also involved in some production development.

5.5.1.14 Swedish Algae Factory

Swedish Algae Factory was founded in 2014 around the discovery of the traits of certain diatom species. This specific trait is their ability to harvest light in a very efficient way through their nanostructured silica shell. The company has developed an algae cultivation and wastewater treatment system from which they harvest this silica frustule of the algae. The actual organic algae biomass that is left after the extraction of the silica frustule, could be utilized in several applications such as for feed production or energy and organic fertilizers. The silica material on the other hand has been identified as a higher value product and in 2016 the company started to test this material's ability to enhance the efficiency of solar cells. Initial lab tests have shown that the nanostructured silica material can be utilized to enhance the efficiency of silicon solar panels with over four relative percentage. The next steps for the company are to find partners to further test this material on silicon solar panel surfaces as an add-on solution to already produced solar panels and to develop a coating method.

5.6 Installers and retailers of PV 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 2016, and that have contributed with data and information to this report. There is a broad range of reported capacity between the different companies, from only a few kW_p as solar cells for charging of electronics to a few MW_p for grid-connected PV systems. If the reader knows of any other active company, please contact the author at: johan.lindahl@ieapvps.se

24 Volt	Agera Energi AB	Agronola
Air By Solar Sweden AB	Aktiv Sol i Nöbbele AB	Albinsons Energicenter AB
Aldu Solenergi AB	Alfa SolVind i Skåne AB	Apptek Teknik och Applikationer AB
Attemptare AB	Awimex International AB	Baltic Suntech AB
Bevego Byggplåt & Ventilation AB	Billesol AB	Bråvalla Solteknik AB
Ce-Ce Elservice AB	Cell Solar Nordic AB	Celltech AB
Clas Olsson	Co2Pro AB	Comne Work AB
Dala Värmesystem AB	Delabglava AB	Deson AB
DrivhusEffekten ApS	Ecoklimat Norden AB	Ecologisk Kraft Eskilstuna AB
EDT Service AB	Effecta Energy Solutions AB	Egen El AB
Ekologisk Energi Vollsjö	El & Energi Center i Kungsbacka AB	EL Av Sol Nordic AB
El B-man El o Energiteknik	Electronic Technic LS AB	Electrotec Energy AB
Elektra AB	Elfa AB	Elkatalogen i Norden AB
Elkontakten i Ale AB	Elmco AB	Elproduktion i Stockholm AB
Elterm i Allingsås AB	Elverket Vallentuna AB	Emulsionen Ek. För.
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	Everöds Elbyrå AB	EWF ECO AB
EWS GmbH & Co. KG	FG Light Energy AB	ECOScience
Futura Energi	Gaia Solar A/S	Gari EcoPower AB
Garo Gnosjö	GermanSolar Sverige AB	GFSol AB
Green Savings Scandinavia AB	Gridcon Solcellsteknik AB	Hallands Energiutveckling AB
Helio Solutions AB	Herrljunga Elektriska AB	HESAB
Highlands International AB	Hilmeko AB	Hjertmans Sweden AB
Holje-El AB	Högsbo el AB	Höjentorps solenergi AB
Implementa Hebe AB	Ing. firma Leif Karlsson AB	Innosund AB
INKA Energi	Isacsson Pansol AB	JN Solar AB
KAMA Fritid AB	Kinnan AB	Kraftpojkarna AB
Kretsloppsenergi Kummelnäs AB	Lambertsson Sverige AB	Lego Elektronik AB
Levins Elektriska AB	Lundgrens El AB	Lundgrens Elektriska AB
Measol	MeraSol AB	Miljö- VVS- & Energicenter AB
Modern Miljöteknik i Varberg	Mälar Bygg och Montageservice AB	Mälardalens Solenergi
MälarEnergi	NIBE Energy Systems	Nirosys AB
Norden Solar	Nordens Solvärme AB	Nordh Energy
Nordic Solar Power AB	Nordic Solar Sweden AB	Nordisk System Teknik AB
Nossebro Energi	NTS Group AB	Nyedal Solenergi
Orust Engineering	Parkys Solar AB	Pascal Elektriska AB
Penthon AB	Plannja AB	PPAM Solkraft AB
Prolekta Gotland AB	Rexel Sverige AB	Rigora AB
Runsten El AB	Rågård rör och teknik AB	Samster AB
Sandhult-Standareds Elektrisk Ek. För.	Save-by-Solar Sweden AB	Scandinavian PV Solutions
Simply Solar AB	Skånska Energi AB	SolEye
Solar Supply Sweden AB	Solarenergy Scandinavia AB	Solarit AB
Solarlab Sweden HB	SolarOne	SolarWave AB
Solcellsbyggarna Boxholm AB	Solcellsmontörerna i Sverige AB	Solcellsproffsen AB

Solect Power AB
Solenergi Göteborg AB
Solexperten i Värmland
Solibro Research AB
Solitek
Solkraft i Viby AB
Solorder AB
Spindel AB
Suncellhouse Solenergi AB
Sunwind Exergon AB
SVEA Renewable Solar AB
Svenska Sol i Sverige AB
Svenskt Byggmontage AB
Södra Hallands Kraft
Upplands Energi AB
Vancos Munka Ljungby AB
Veosol Teknik AB
Wikmans Elektriska AB
Windon AB (försäljning)
Yokk Solar AB
Östgöta Solel AB
Solelia Greentech AB
Solenergi i Undrom
Solfabriken Ugglum AB
Soliga Energi AB
Solkompaniet Sverige AB
Solkraft TE
Solortus AB
Sun of Sunne
SunnyFuture AB
Susen AB
Swede Energy Power Solutions AB
Svenska Solenergigruppen AB
Svesol värmesystem AB
Taksmide i Borlänge AB
UPS-teknik i väst AB
Warm-Ec Skandinavia AB
West El AB
Villavind AB
Vindtech Halmstad AB
Yorvik Solar
Solenergi & Teknik i Åmål AB
SolensEnergi i Skåne AB
Solgrossen
Solinnovation i Värnamo AB
Solkraft EMK AB
Solkungen AB
SolTech Energy Sweden AB
SUNBEAMsystem Group
Sunsolutions by Telecontracting AB
Sustainable Energy Nordic AB
Sweden Sol
Svenska Solpanelmontage AB
Sydpumpen AB
Ten Star Solar AB
Vallacom AB
VCA VVS & Cad Assistans
Viessmann Värmeteknik AB
Windforce Airbuzz Holding AB
VOE Service AB
Åkerby Solenergi

6 PV IN THE ECONOMY

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

6.1 Labour places

With the bankruptcy and shut down of several of the Swedish PV module factories in 2010 and 2011 the number of labour places in the Swedish PV module production industry decreased dramatically. However, the number of people involved in selling and installing PV systems increases as the Swedish PV market grows. The growing 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 work only 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.

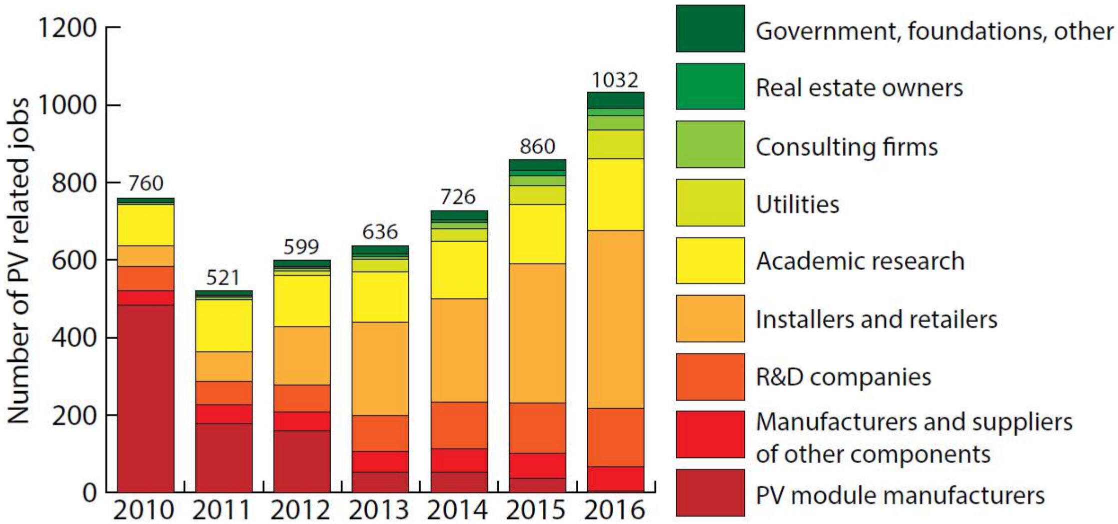

Figure 26: Estimated total full-time jobs within the Swedish PV industry over the years.

Table 24: Estimated total full-time jobs within the Swedish PV industry in 2016.

Market category	Number of full-time jobs in 2016
PV module manufacturers	4
Manufacturers and suppliers of machinery and other components	62
R&D companies	152
PV system installers and retailers	457
Academic research	186
Utilities	75
Consulting firms	36
Real estate owners	20
Government and others	40
Total	1 032

6.2 Business value

In Table 25 some very rough estimations of the value of the Swedish PV business can be found.

Table 25: Rough estimation of the value of the PV business in 2016 (VAT is excluded).

Sub-market		Capacity installed in 2016 [MW_p]	Average price [SEK/W_p]	Value
Off-grid		1.5	29.2	~ 44 million SEK
Grid-connected distributed	Residential 0–20 kW_p	21.7	15.0	~ 325 million SEK
	Commercial 0–20 kW_p	9.7	12.3	~ 119 million SEK
	Commercial >20 kW_p	39.3	11.5	~ 452 million SEK
Grid-connected centralized		5.6	9.2	~ 51 million SEK
Value of the PV market				**~ 991 million SEK**
Export of PV products		Unknown[1]		N/A
Import of PV products		Included in the value of PV market		N/A
Change in stocks held		Unknown		N/A
Value of PV business				**~ 991 million SEK**

[1] 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 Swedish state 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 132 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 2016 are: Ale Energi, BestEl, Bixia, C4 Energi, Dalakraft, E.ON, ETC El, Elverket Vallentuna, Enkla Elbolaget, Fortum, Gislaved Energi, Gotlands Elförsäljning, Gävle Energi, Jämtkraft, Kalmar Energi, Kraftringen, Kungälv Energi, MälarEnergi, Mölndal Energi, Nordic Green Energy, Nossebro Energi, Sala-Heby Energi, Sandhult-Standareds Elektrisk Ek. Förening, Sollentuna Energi & Miljö, Södra Hallands Kraft, Telge Energi, Umeå Energi, Upplands Energi, Utellus, Vattenfall and Varbergs Energi. These utility companies have in common that most of them collaborate with local Swedish installation companies that provide the actual system and execute the installation. Only a few of the have the installation competence and product distribution lines in-house.

Two utility companies, Umeå Energi and ETC El, have also started to offer leasing of PV system to private persons.

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 [42].

A few utilities have started to work with centralized PV parks. Since there are no subsidies, except for the green electricity certificate system (see section 3.2.3), for large-scale PV parks in Sweden the proactive utility companies that have started to work with PV parks have had to test different financial arrangements. Some of the utility companies that in one way or another are involved in different Swedish PV parks are MälarEnergi, Varberg Energi, Kalmar Energi and Sala-Heby Energi and example of their business models are share-owned PV parks, power purchase agreements and PV electricity offers to end consumers.

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 [43] 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 [44]. 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 have 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 [45]. 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 so called *sun maps*. These *sun maps* illustrate in colour scale the incoming solar radiation on all 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 sun maps that the author is aware of are; Alingsås, Blekinge, Eskilstuna, Forshaga, Göteborg city, Helsingborg, Härryda, Höganäs, Katrineholm, Kristianstad, Kumla, Köping, Landskrona, Linköping, Lund, Eslöv, Hörby and Lomma, Motala, Mölndal, Norrköping, Sollentuna, Stockholm, the region of Stockholm (21 municipalities), Umeå, Uppsala city, Varberg, Vellinge, Värnamo, Västerås city, 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 2016 as the annual market grew with 63 % to a yearly installed power of 79.2 MW_p. This led to Sweden passing the 200 MW_p threshold as the cumulative installed capacity according to the sales statistics at the end of 2016 was 205.5 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 2016.

The major policy change in 2016 was the change in the law that led to that private persons no longer need to register for VAT if they want to sell their excess electricity to the grid. This change reduces the administrative burden private persons had and makes it more attractive for them to invest in PV.

On the industry side Sweden produced less than 1 MW of modules for the first time since 2002. 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, are 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 in 2015, the extension and budget increase in the direct capital subsidy, the ongoing reforms and investigation to reduce the administrative burdens for PV investors and the increase of activity from utilities have made the situation for private persons and small companies quite good.

For larger real estate owners, the tax law, which means that they must pay energy tax also on the self-consumed PV electricity, is a major hurdle. This tax has a very negative impact on the market segment of large commercial PV systems (>255 kW_p). However, the reduced energy tax to 0.005 SEK/kWh for real estate owners that own several small systems (<255 kW_p), introduced the first of July 2017, has removed the major economical barrier for real estate owners who to want to build many PV systems, but the administrative barrier remains.

The off-grid market has shown stable installation values for a few years now. As off-grid installations are not in need of subsidies, this market is expected to continue to be stable the coming years.

The market of large centralized PV parks is still marginal occurrence in Sweden, even if a 2.7 MW_p PV park was finalized outside of Varberg in western Sweden in 2016 [46]. This market segment has been expected to play a minor role also in future as it has been believed that the electricity spot prices must increase, or the system prices decrease for PV parks to become profitable. However, the author has talked to several utility companies that have expressed plans of building PV parks in the sizes of 1–7 MW_p in the near future. The, at the time of writing, ongoing investigation of extending the tax credit system for micro production of renewable energy to include share-ownership could be the reform that taps the potential in the utilities interest and gets the Swedish centralized PV market started in the next couple of years.

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 public is very positive towards the technology. In a survey done in the beginning of 2014 [47], 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 was presented the in October 2016 and it includes a vision that 5 to

10 % of Sweden's total electricity demand could come from PV in 2040, which would correspond to roughly 7–14 TWh [48].

Furthermore, the goal of the broad political agreement of The Swedish Energy Commission that Sweden shall have a 100 % renewable electricity consumption by 2040 [18] forebodes a policy framework in which PV should be able to flourish. The renewable goal means that a lot of renewable electricity production shall be built until 2040, and in such circumstances PV should have a role to play.

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.

9 REFERENCES

[1] Energimyndigheten, “Förslag till heltäckande solelstatistik,” Eskilstuna, 2016.

[2] SCB, “Antal solcellsanläggningar och installerad effekt (kW), efter region. År 2016.” [Online]. Available: https://www.scb.se/hitta-statistik/statistik-efter-amne/energi/tillforsel-och-anvandning-av-energi/installerade-solcellsanlaggningar/#_TabelleriStatistikdatabasen. [Accessed: 25-Sep-2017].

[3] Svensk Energi, “Elåret 2015,” Stockholm, 2016.

[4] SCB, “Månatlig elstatistik.” [Online]. Available: http://www.sverigeisiffror.scb.se/hitta-statistik/statistik-efter-amne/energi/tillforsel-och-anvandning-av-energi/manatlig-elstatistik/. [Accessed: 23-Aug-2017].

[5] Energiföretagen, “Energiåret 2016,” Stockholm, 2016.

[6] European Commission, “The European Union’s measures against dumped and subsidised imports of solar panels from China,” 2015.

[7] J. Seel, G. L. Barbose, and R. H. Wiser, “An analysis of residential PV system price differences between the United States and Germany,” *Energy Policy*, vol. 69, pp. 216–226, 2014.

[8] Riksbanken, “The deposit and lending repo rate.” [Online]. Available: http://www.riksbank.se/sv/Rantor-och-valutakurser/Reporanta-tabell/2017/-rate-table/2015/. [Accessed: 16-Aug-2017].

[9] Compricer, “Historisk snittboränta.” [Online]. Available: https://www.compricer.se/bolan/jamfor_bindningstider/. [Accessed: 16-Aug-2017].

[10] Nasdaq, “Fixed income - Sweden - STIBOR, Historical fixing.” [Online]. Available: http://www.nasdaqomx.com/transactions/trading/fixedincome/fixedincome/sweden/stiborswaptreasuryfixing/historicalfixing. [Accessed: 16-Aug-2016].

[11] SCB, “Land- och vattenareal i kvadratkilometer efter region, arealtyp och år.” [Online]. Available: http://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__MI__MI0802/Areal2012/table/tableViewLayout1/?rxid=55ac2603-a882-49a2-8d81-72ade05d2451. [Accessed: 17-Aug-2016].

[12] SCB, “Sveriges folkmängd från 1749 fram till idag.” [Online]. Available: http://www.scb.se/hitta-statistik/sverige-i-siffror/manniskorna-i-sverige/befolkningsutveckling/. [Accessed: 17-Aug-2017].

[13] Energimarknadsinspektionen, “Sammanställning lokalnäten 2008-2015 - Särskilda rapporten - Teknisk data.” [Online]. Available: http://www.energimarknadsinspektionen.se/sv/Publikationer/Arsrapporter/elnatsforetag-arsrapporter/. [Accessed: 17-Aug-2017].

[14] Energimarknaden, “Energimarknaden - Branschens viktigaste framtidsfrågor,” 2016.

[15] SMHI, “Klimatindikator - globalstrålning.” [Online]. Available: http://www.smhi.se/klimatdata/meteorologi/stralning/stralning-1.17841. [Accessed: 02-Jul-2016].

[16] B. Stridh, S. Yard, D. Larsson, and B. Karlsson, “Production cost of PV electricity in Sweden,” in *EU PVSEC 2014 Amsterdam*, 2014, pp. 1–5.

[17] D. C. Jordan, R. M. Smith, C. R. Osterwald, E. Gelak, and S. R. Kurtz, “Outdoor PV Degradation Comparison,” in *35th IEEE Photovoltaic Specialists Conference*, 2010, no. February, pp. 2694–2697.

[18] Energikommissionen, “Ramöverenskommelse mellan Socialdemokraterna, Moderaterna, Miljöpartiet de gröna, Centerpartiet och Kristdemokraterna,” Stockholm, 2016.

[19] Sveriges Riksdag, *Svensk författningssamling – Förordning (2009:689) om statligt stöd till solceller*. Sweden, 2016.

[20] B. Statistiksystem, “Stöd för installation av solceller – månadsrapport juli 2017,” 2017.

[21] A. Palm, “An emerging innovation system for deployment of building-sited solar photovoltaics in Sweden,” *Environ. Innov. Soc. Transitions*, vol. 15, pp. 140–157, 2014.

[22] Boverkets statistiksystem, “Stöd för installation av solceller – månadsrapport mars 2016,” 2016.

[23] Jordbruksverket, “Investeringsstöd till förnybar energi.” [Online]. Available: http://www.jordbruksverket.se/amnesomraden/stod/stodilandsbygdsprogrammet/investeringar/fornybarenergi.4.6ae223614dda2c3dbc44f7d.html. [Accessed: 23-Aug-2017].

[24] I. Norberg, O. Pettersson, A. Gustavsson, P. Kovacs, M. Boork, P. Ollas, J. Widén, D. Lingfors, J. Marklund, D. Larsson, D. Ingman, and H. Jältorp, “Solel i lantbruket – Realiserbar potential och nya affärsmodeller,” 2015.

[25] Energimyndigheten, “Elcertifikatsystemet - Kvotpliktig.” [Online]. Available: http://www.energimyndigheten.se/fornybart/elcertifikatsystemet/kvotpliktig/. [Accessed: 13-Jul-2016].

[26] “Elcertifikatsystemet – ett stödsystem för förnybar elproduktion,” Eskilstuna, 2012.

[27] “Avtal mellan konungariket Sveriges regering och konungariket Norges regering om ändring av avtal om en gemensam marknad för elcertifikat.” 2015.

[28] Energimyndigheten, “Kvotnivåer.” [Online]. Available: http://www.energimyndigheten.se/fornybart/elcertifikatsystemet/kvotpliktig/kvotnivaer/. [Accessed: 01-Sep-2017].

[29] Energimyndigheten, “Cesar – Statistik elcertifikat.” [Online]. Available: https://cesar.energimyndigheten.se/. [Accessed: 05-Sep-2017].

[30] SVK, “Statistik för Sverige per månad 2015.” [Online]. Available: http://www.svk.se/aktorsportalen/elmarknad/statistik/. [Accessed: 07-Jun-2016].

[31] Energimyndigheten, “Godkända anläggninar i elcertifikatsystemet.” [Online]. Available: http://epi6.energimyndigheten.se/SharePoint/Eugen/Godkända anläggningar.xlsx. [Accessed: 02-Feb-2016].

[32] A. Borg, “Lagrådsremiss – Skattereduktion för mikroproduktion av förnybar el.” Stockholm, p. 48, 2014.

[33] Sveriges Riksdag, *Förordning (2016:899) om bidrag till lagring av egenproducerad elenergi*, no. december. 2016, pp. 1–6.

[34] S. Löfven and P. Brolund, “Regeringens proposition 2015/16:1 - Budgetpropositionen för 2016.” Stockholm, pp. 293–303, 2015.

[35] Sveriges Riksdag, *Svensk författningssamling – Lag (1994:1776) om skatt på energi*. Sweden, 2016, pp. 1–40.

[36] Skatteverket, “Försäljning av överskottsel.” [Online]. Available: https://www.skatteverket.se/privat/fastigheterochbostad/mikroproduktionavfornybarel/forsaljningavoverskottsel.4.3aa8c78a1466c58458750f7.html?q=solceller. [Accessed: 19-Sep-2017].

[37] Skatteverkets ställningstagande, “Dnr: 131 603903-15/111, Avdragsrätten vid inköp och

installation av en solcellsanläggning för mikroproduktion av el; Mervärdesskatt.” [Online]. Available: https://www4.skatteverket.se/rattsligvagledning/349307.html?date=2015-12-01.

[38] Sveriges Riksdag, *Ellag (1997:857)*. Sweden, 2015, p. 32.

[39] Skatteverket, “Villkor för att få rotavdrag.” [Online]. Available: https://www.skatteverket.se/privat/fastigheterochbostad/rotochrutarbete/villkorforattfarotavdrag.4.5947400c11f47f7f9dd80004014.html. [Accessed: 17-Aug-2017].

[40] Hittaprivatlån, “Ränteavdraget.” [Online]. Available: http://www.hittaprivatlån.se/artiklar/lanfakta/ranteavdraget. [Accessed: 17-Aug-2017].

[41] M. Haapaniemi, J. Berghök, T. Eurenius, T. Sundqvist, and D. Waluszewski, “Fastighetstaxering av anläggningar för el- och värmeproduktion (SOU 2016:31),” Statens Offentliga Utredningar, Stockholm, 2016.

[42] Svensk Solenergi, “Prosumentportalen.” [Online]. Available: http://www.prosument.se/. [Accessed: 01-Jul-2017].

[43] A. Palm, “Peer effects in residential solar photovoltaics adoption — A mixed methods study of Swedish users,” *Energy Res. Soc. Sci.*, vol. 26, pp. 1–10, 2017.

[44] A. Palm, “Local factors driving the diffusion of solar photovoltaics in Sweden: A case study of five municipalities in an early market,” *Energy Res. Soc. Sci.*, vol. 14, pp. 1–12, 2016.

[45] Uppsala kommun, “Miljö- och klimatprogram,” Uppsala, 2015.

[46] Varbergs Energi, “Solsidan - Sveriges största solcellspark.” [Online]. Available: http://www.varbergenergi.se/?id=8532. [Accessed: 02-Jul-2016].

[47] U. Minds, “Svensk Energi - Elmätaren 5,” Stockholm, 2014.

[48] Energimyndigheten, “Förslag till strategi för ökad användning av solel,” Eskilstuna, 2016.

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