IEA INTERNATIONAL ENERGY AGENCY

Task 1 Strategic PV Analysis and Outreach

National Survey Report of PV Power Applications in Sweden 2018

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PHOTOVOLTAIC POWER SYSTEMS
TECHNOLOGY COLLABORATION PROGRAMME

PVPS

Swedish Energy Agency

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PV system on a Swedish farm © Hallands Energiutveckling AB

WHAT IS IEA PVPS TCP

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The IEA carries out a comprehensive programme of energy cooperation among its 30 member countries and with the participation of the European Commission. The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the collaborative research and development agreements (technology collaboration programmes) within the IEA and was established in 1993. The mission of the programme is to "*enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems*."

In order to achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct 'Tasks,' that may be research projects or activity areas. This report has been prepared under Task 1, which deals with market and industry analysis, strategic research and facilitates the exchange and dissemination of information arising from the overall IEA PVPS Programme.

The IEA PVPS participating countries are Australia, Austria, Belgium, Canada, Chile, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, Morocco, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, and the United States of America. The European Commission, Solar Power Europe, the Smart Electric Power Alliance (SEPA), the Solar Energy Industries Association and the Copper Alliance are also members.

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WHAT IS IEA PVPS task 1

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation. An important deliverable of Task 1 is the annual "Trends in photovoltaic applications" report. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the country National Survey Report for the year 2018. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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DISCLAIMER:

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1 INSTALLATION DATA

The PV power systems 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, possibly batteries and all installation and control components for modules, inverters and batteries. Other applications such as small mobile devices are not considered in this report.

For the purposes of this report, PV installations are included in the 2018 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2018, although commissioning may have taken place at a later date.

1.1 Applications for Photovoltaics

The installation of grid connected PV systems in Sweden can be said to have taken off in 2006, when about 300 kW was installed that year. Before that only a few grid-connected systems were installed each year. Until 2006, 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 has been quite stable throughout the years. Since 2007 more grid-connected capacity than off-grid capacity has been installed annually and Sweden had at the end of 2018 about twenty-seven times more grid-connected PV capacity than off-grid capacity. The grid-connected market is almost exclusively made up by distributed roof-mounted systems installed by private individuals, companies, municipalities, farmers, etc. Already at the beginning, the Swedish distributed market has been driven by the self-consumption business model, as there has never existed a feed-in-tariff in Sweden, and capital subsidies in combination with different types of schemes that add value for the excess electricity. About 33 % of the installed grid-connected PV power comes from privately owned systems on single family houses. The other large market segment is commercial facilities, which stand for approximately 47 % of the installed PV power in Sweden. The rest is in general installed on multi-family houses, public buildings, cultural buildings and industrial facilities. So far only a couple of relatively small centralized PV parks, 5 % of the grid-connected market, have been built. The largest of them, commenced before the end of year 2018, is 5.5 MW_p and located in Gothenburg.

1.2 Method

The numbers for total installed PV capacity by the end of 2018 listed in this report are based on two data sources. All the grid-connected PV capacity is collected through surveys sent out by Statistics Sweden, SCB, (Statistiska Centralbyrån) on behalf of the Swedish Energy Agency (Energimyndigheten) to all the Swedish grid operators [1]. As it is mandatory to notify the grid operator when a PV system is connected to the grid, the grid operators should have all the grid-connected PV systems within their grid area registered, and they are obliged to share this information with the Swedish Energy Agency.

However, the numbers for off-grid PV systems are by definition impossible to get from the grid operators. The information about total installed off-grid PV capacity is therefore based on cumulative sales statistics that have been collected directly from company representatives throughout the years by the Swedish representatives in IEA PVPS task 1. The companies that have contributed off-grid data for 2018 are listed in section 5.6. Older Swedish National Survey Reports list the active companies for the sales statistics for respective year.

The total installed off-grid PV capacity listed in this report are however not the straightforward cumulative value of the yearly sold off-grid capacity. As the off-grid systems usually are installed at either holiday cottages or as mobile applications on boats or caravans the lifetime of the off-grid systems is believed to be limited. For example, leisure boats and caravans have a limited lifetime before they in many cases are considered too unmodern for further use. Therefore, the lifetime of off-grid PV systems has in this report been assumed to be 20 years. So, the total off-grid PV capacity, by the end of 2018, listed in this report is the sum of the annual installed off-grid capacity from 1999 until 2018. In the same way, the total installed off-grid capacity at the end of 2017 is the sum of the annual installed off-grid capacity from 1998 until 2017, and so on.

The official collection of grid-connected PV capacity by the surveys to the grid operators has only been carried out for the years of 2016, and thereafter. The historic numbers for the installed grid-connected PV capacity (and off-grid PV capacity) in Sweden until the end of 2015 are therefore exclusively based on the yearly collection of the sales statistics by the Swedish representatives in IEA PVPS task 1.

This method has had its flaws, which makes these historic numbers a little uncertain. It has not been a problem to acquire data from the installers and retailers of PV systems, but the quality and exactness of the data from different companies has varied throughout the years. Most installers have reported data with the accuracy down to the kW_p-level. However, not all installers have had the internal routines or time to do this, and some companies have therefore provided estimates at an accuracy of 100 kW_p. 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 have reported 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, have therefore counted for in the sales statistics. Nevertheless, there have still probably been some errors in the quantities reported to be bought from abroad or from Swedish companies, that have led to a certain double counting, and thus to a possible overestimation of the installed PV power.

A third source of error for the sales statistics throughout the years has been that Swedish representatives responsible for the collection of the sales statistics have not been aware of all installers active on the Swedish market, and therefore missed some installations that are not included in the sales statistics. This flaw in the method may have led to an underestimation of the installed PV capacity. The main author of this report, which has been responsible for the collection of sales statistics since 2010, has however supplemented previous years installation numbers when a previously unknown installation company was discovered.

As mentioned above, the first national survey to the grid operators was made in 2017 to get the total installed PV capacity at the end of 2016. Through this method, the Swedish Energy Agency collects the number of grid-connected systems and the total AC 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 the official published data due to secrecy reasons. The total power within each market segment is however official and doesn´t lack any of the reported systems.

For the year of 2016 and 2017 installation numbers were collected both through sales statistics (carried out by the Swedish representatives in IEA PVPS task 1) and by surveys to the grid operators (on behalf of the Swedish Energy Agency) due to the uncertainty of the quality of the two methods and the possibility to compare the results. As can be seen in Table 1 there is a clear divergence between the grid-connected PV capacity collected through the grid operators and sales statistics from the Swedish installation companies. The difference for 2016 is more than 48 MW_p and for 2017 about 73 MW_p.

Table 1. Grid-connected distributed PV at the end of each year (2015-2018) from the grid operators and sales statistics, respectively [1][3], along with the weighted average of the two data sources for the years 2016 and 2017.

	2015 [MW]	2016 [MW]	2017 [MW]	2018 [MW]
Total grid-connected PV capacity at the end of each year according to the installation companies collected by the Swedish representative in IEA PVPS task 1	113.02	188.44	303.78	-
Total grid-connected PV capacity at the end of each year according to the grid operators collected by the Swedish Energy Agency	-	140.03	230.91	411.06
Final total grid-connected PV capacity at the end of each year used in this report	**113.02**	**172.30**	**255.20**	**411.06**

This difference can partly be explained by the fact that the sales statistics report DC power of the modules and that in the notification to the grid operator the maximum power capacity of the system should be reported, which often is the AC power of the inverter as these often are dimensioned lower than the DC power of the modules (in some cases for peak shaving and in some cases for not exceeding a certain fuse size). This explain a certain part of the difference, but not the whole divergency. Other reasons for the disparity are the uncertainties in the collection of the sales statistics discussed above, and errors in the data from the grid operators. When the data from the grid operators for these two years is examined closer, it is believed that some PV systems are missing in the grid operators' statistics.

How many PV systems and the amount of capacity missing in the grid operators' statistics in 2016 and 2017 is impossible to quantify. But they were at the end of 2017 judged not to be negligible, by the Swedish representative in IEA PVPS task 1 together with representatives from SCB and the Swedish Energy Agency. That's why the installation data in the *National Survey Report of PV Application in Sweden 2017* reported the sales statistics numbers as the official installed capacity in Sweden.

However, when reporting data about the Swedish PV market to the Swedish Energy Agency becomes a routine for the grid operators, the quality of this data is expected to be better and better for each year. An improvement of quality of the data could be seen just comparing the grid operators' 2017 data with the grid operators' 2016 data when the analyses were carried out by the above-mentioned authorities. The grid operator´s in 2017 did report systems they missed to report in 2016, and it seems as that the data for 2018 has been improved even further. The Swedish Energy Agency is also continuously working 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 of misunderstandings.

The Swedish Energy Agency decided in 2018 that from 2018 and onwards, the official data will be based on the grid operator's data. The reason is that 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 what the sales statistics method has been able to deliver through the years. The quality was also assessed to now be on a satisfying level and much better than when the survey was first carried out in 2016. So, it was decided that sales statistics should only be collected for the off-grid installations from 2018 and onwards.

However, due to the known errors and missing systems in this grid operators' data for the first two years (2016 and 2017), along with the perception that the sales statistics probably has overestimated the installation of grid-connected PV in Sweden, the Swedish Energy Agency has together with the Swedish representative in IEA PVPS task 1 concluded that a weighted average between the sales statistics and the grid operator statistics probably are closer to the truth than using either of these source for these two specific years. The weighted average of 2016 is calculated by using two thirds the sales statistics and one third grid operators' statistics as;

$$\text{Grid connected capacity} = \frac{\text{Sales statistics} + \text{Sales statistics} + \text{Grid operators' statistics}}{3}$$

While the weighted average for 2017 uses two thirds the grid operators' statistics and one third the sales statistics. The reason for weighting the two data sources this way is discussed above. I.e. the quality of the grid operators' statistics is assessed to have improved between 2016 and 2017. But still not reached a satisfying level for 2017, while the errors and drawbacks of the sales statistics become more critical as the market has grown and more installation companies entered the market.

To conclude, the reported grid-connected installation data in this report, for example in all the graphs and tables in section 1.3, are based only on the sales statistics until 2015. For 2016 and 2017 the grid-connected installation data are based on weighted average between the sales statistics and the grid operators' statistics, and for 2018 only the grid operators' statistics are used. On top of these numbers the off-grid installations are added, which comes from the sales statistics.

Table 2: Data collection process.

Is the data reported in AC or DC?	The reported data is in AC
Is the collection process done by an official body or a private company/Association?	Public body (and Company)
Link to official statistics (if this exists)	[1]

1.3 Installed photovoltaic power

1.3.1 Annual installed PV capacity

The installation rate of PV continues to increase at a high speed in Sweden. A total of approximately 158.48 MW_p were installed in 2018, as shown in Figure 1 and Table 3. This means that the annual Swedish PV market grew with 87 % as compared to the 84.95 MW_p that was installed in 2017.

In recent years, the market for grid-connected PV systems has grown rapidly in Sweden. This continued in 2018 as another 156.36 MW_p of grid-connected systems were installed under the year, an 89 % increase compared to the 82.89 MW_p installed in 2017.

Of the grid-connected PV capacity, 10.29 MW_p is estimated to be centralized PV parks and 146.07 MW_p distributed PV systems for primary self-consumption. By that, the annual market of centralized PV in Sweden grew with about 294 % and the distributed annual market by 82 % as compared with 2017, when approximately 2.62 MW_p of centralized and 80.28 MW_p of distributed PV was installed.

Sweden has a stable off-grid PV market. In 2016 and 2017 about 1.51 MW_p respectively 2.06 MW_p of off-grid applications were sold. In 2018 that off-grid market increased slightly to 2.12 MW_p.

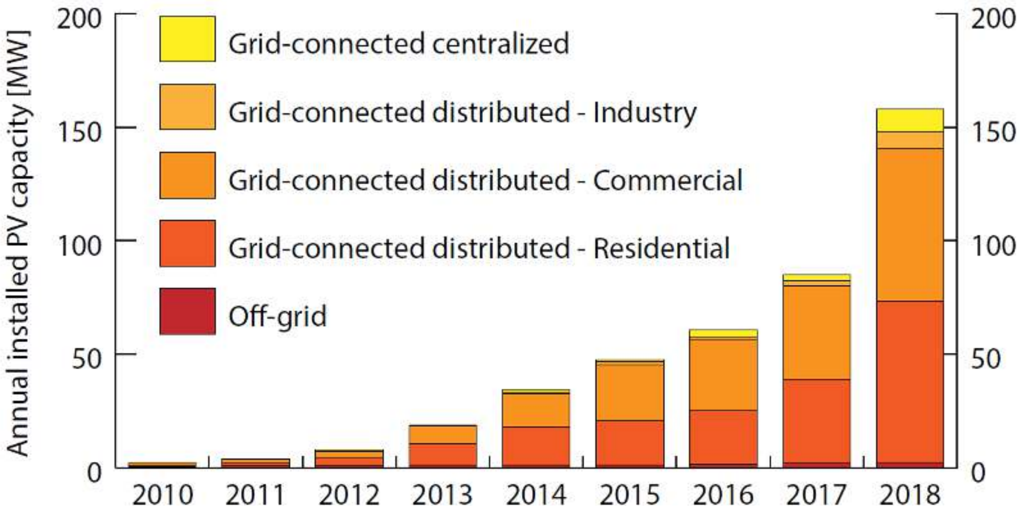

Figure 1: Annual installed PV capacity in Sweden.

Table 3: Annual PV power installed during calendar year 2018 in Sweden.

		Installed PV capacity in 2018 [MW]	AC or DC
PV capacity	Off-grid	2.12	DC
	Distributed	146.07	DC
	Centralized	10.29	DC
	Total	158.48	DC

Table 4: PV power installed during calendar year 2018 in Sweden.

			Installed PV capacity in 2018 [MW]	Installed PV capacity in 2018 [MW]	AC or DC
Grid-connected	BAPV	Residential	146.07[1]	71.62	DC
		Commercial		67.31	DC
		Industrial		7.13	DC
	BIPV	Residential	Unknown	Unknown	DC
		Commercial		Unknown	DC
		Industrial		Unknown	DC
	Utility-scale	Ground-mounted	10.29	10.29	DC
		Floating		0	DC
		Agricultural		0	DC
Off-grid		Residential	2.12	0.74	DC
		Commercial		0.10	DC
		Mobile off-grid (caravans, boats, etc.)		1.28	DC
Total			**157.99**		**DC**

1. This figure includes BIPV installation and ground-mounted distributed PV installation. However, a vast majority (estimated to >90 %) of all distributed PV installations in Sweden are regular BAPV.

1.3.2 Total installed PV capacity

The total grid-connected capacity was at the end of 2018 411.56 MW_p, according to the grid operators. Of the 411.56 MW_p, about 20.04 MW_p is estimated to be centralized PV and 391.52 MW_p to be distributed. In addition to that a total of 16.43 MW_p of off-grid PV applications have been sold in Sweden since 1993, whereas 14.17 MW_p is considered still up and running.

Summing up the off-grid and grid-connected PV capacities, one ends up at a total of 425.73 MW_p of PV that was up and running at the end of 2018, illustrated in Figure 2 and summarized in Table 5. The total installed PV capacity grew with 59 % under 2018, which is in line with the marked development over the last five previous years, where the total market has grown with 84 %, 84 %, 63 %, 50 % and 46 %, 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 since then been fuelled by the declining system prices (see section 2.2), high popularity among the public (see section 1.6.2), 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).

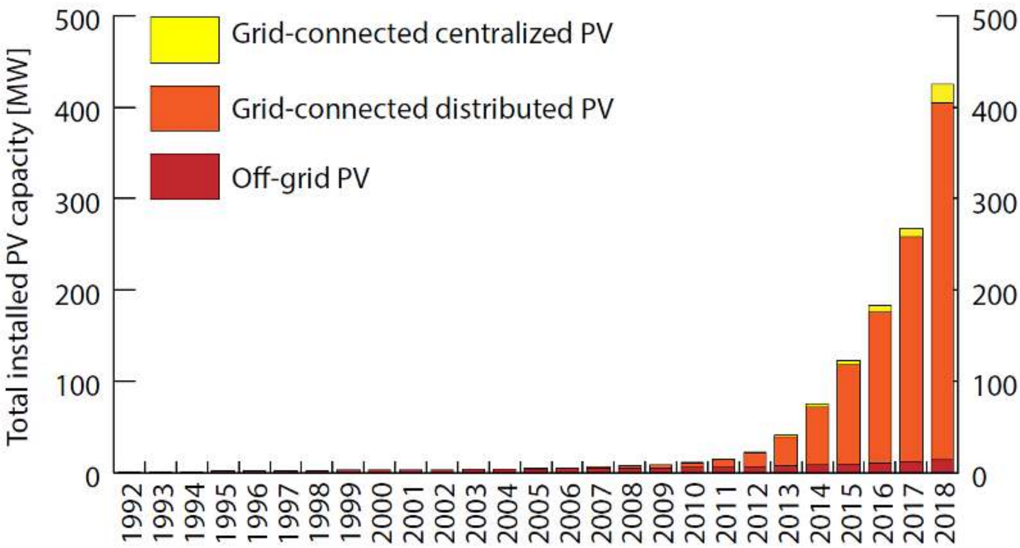

Figure 2: Cumulative installed PV capacity in Sweden.

Table 5: The cumulative installed PV power in 3 sub-markets.

Year	Off-grid [MW]	Grid-connected distributed [MW]	Grid-connected centralized [MW]	Total [MW]
1992	0.80	0.01	0.00	0.80
1993	1.03	0.02	0.00	1.04
1994	1.31	0.02	0.00	1.34
1995	1.59	0.03	0.00	1.62
1996	1.82	0.03	0.00	1.85
1997	2.03	0.09	0.00	2.13
1998	2.26	0.11	0.00	2.37
1999	2.46	0.12	0.00	2.58
2000	2.68	0.12	0.00	2.81
2001	2.88	0.15	0.00	3.03
2002	3.14	0.16	0.00	3.30
2003	3.39	0.19	0.00	3.58
2004	3.67	0.19	0.00	3.87
2005	3.98	0.25	0.00	4.24
2006	4.30	0.56	0.00	4.85
2007	4.57	1.68	0.00	6.24
2008	4.83	3.08	0.00	7.91
2009	4.97	3.54	0.06	8.57
2010	5.34	5.17	0.25	10.76
2011	5.78	8.47	0.25	14.50
2012	6.38	14.92	0.85	22.15
2013	7.31	32.14	1.31	40.77
2014	8.20	63.81	2.85	74.85
2015	9.16	109.19	3.83	122.17
2016	10.43	165.17	7.13	182.74
2017	12.27	245.45	9.75	267.47
2018	14.17	391.52	20.04	425.73

Table 6: Other PV market information.

	2018 Numbers
Number of grid-connected PV systems in operation in Sweden	25 486
Capacity of decommissioned PV systems during the year [MW]	0.25 MW
Capacity of repowered PV systems during the year [MW]	Unknown
Total capacity connected to the low voltage distribution grid [MW]	Unknown
Total capacity connected to the medium voltage distribution grid [MW]	Unknown
Total capacity connected to the high voltage transmission grid [MW]	Unknown

1.4 Swedish PV market segments

The official statistics of the grid operators, collected by the Swedish Energy Agency, only include segmentation in PV system sizes (power) in the ranges 0–20 kW, 20–1000 kW and >1000 kW. The total installations at the end of 2018, according to this source, are summarized in Table 7.

Table 7. Total installations of grid connected PV capacity and number of systems at the end of 2018, according to the grid operators [1].

	0–20 kW	20–1000 kW	>1000 kW
Total grid-connected PV capacity according to the grid operators collected by the Swedish Energy Agency [MW]	189.24	204.73	17.58
Total number of grid-connected PV systems according to the grid operators collected by the Swedish Energy Agency [#]	21535	3941	10

However, for market segmentation there is another data source. In the database of the Swedish direct capital subsidy, called Svanen, all PV systems that have been granted support from the start of the subsidy programme in 2009 until now is recorded. There is plenty of information about these systems in this database, including the identification number of the owner. By cross referencing between this database and Sweden's national business directory a business sector is able to be attached to each system owner. By doing this, the PV systems in the database can be categorized into if the owner of the system is a company, a natural person, a natural person's establishment, a public utility housing company, a municipality, a country council or a foundation/religious community. So, most PV systems in the database can be divided into centralized, industry, commercial or residential systems. It is also possible to sort the PV system into if they have been installed on "ground (mark)", "single-family houses/small buildings (småhus)", "multi-family houses (flerbostadshus)", "facilities (lokaler)" or "other (annat)". The Swedish standard classification names for the different type of buildings are added within the parenthesis to make it easier for the Swedish readers as there in some cases are no straightforward translations into English for these building types. The "other (annat)" classification includes all installations that do not fit into the other building types. This could be decentralised ground mounted systems, systems on churches or other cultural buildings, systems on schools just to mention a few.

A problem with the Svanen database is however that a lot of systems have been recorded in a wrong way, for example with the wrong power, granted subsidy or organization. When it is obvious that the information has been recorded in a wrong way these systems have for the analysis in this report manually been removed from the original database.

The installed PV capacity in the Svanen database for 2018 is much lower than the total installed as reported by the grid operators. But, by dividing the annual installed PV capacity in Svanen for each market segment by the total installed PV capacity in Svanen, the different market segments share of the annual installations can be calculated. For 2018, these shares are presented in detail in Figure 3 and the historic development is presented in Figure 4.

By taking these percentages and multiplying them by the numbers in Figure 1, one would end up with a rough estimation of the annual installed capacity under 2018 by different market segments. This is presented in Table 8. The reader should be aware as these numbers should be seen as indicators rather than exact number since they have been calculated from two different statistical sources, which use different methods in collecting the data.

As Figure 3, Figure 4 and Table 8 clearly illustrates, the biggest market segments in Sweden are residential single-family houses and commercial facilities. A slight variation over the years can be seen in Figure 4, but these two segments have always been the biggest. The reason for that is that the self-consumption business model is easy to implement for these types of buildings.

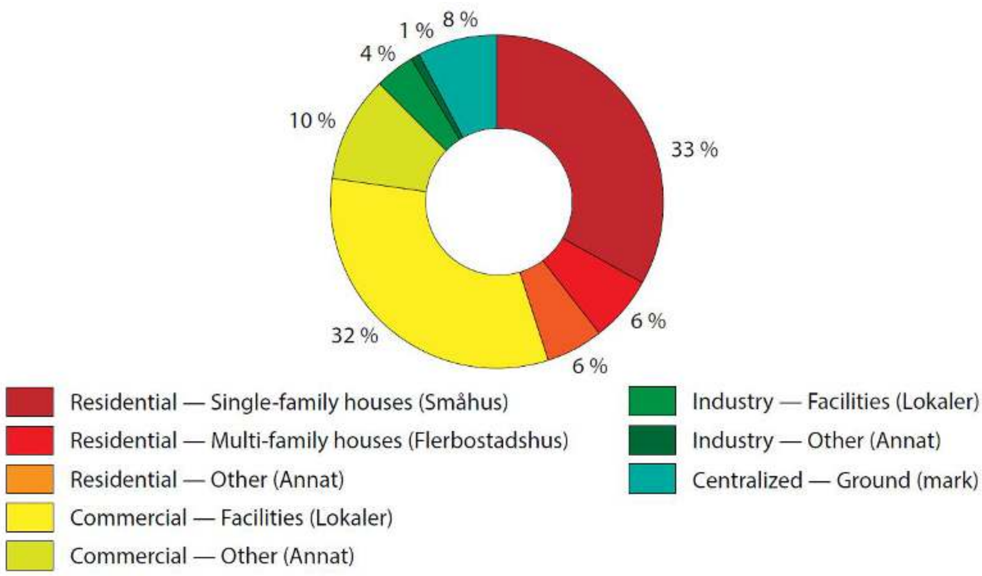

Figure 3: Various market segments share of the annual installed PV capacity in Sweden in 2018. Based on statistics from the capital subsidy database Svanen.

Table 8. Annual installations of PV capacity in 2018 by market segment calculated from the sales statistics, the grid operators' statistics [1] and the Svanen database.

		0–20 kW	20–1000 kW	>1000 kW
Off-grid [MW]		2.12	0.00	0.00
Grid-connected distributed	Residential [MW]	54.98	16.64	0.00
	Commercial [MW]	9.53	57.78	0.00
	Industry [MW]	0.07	5.21	1.85
Grid-connected centralized [MW]		0.0	3.41	6.88
Total		**66.7**	**83.04**	**8.73**

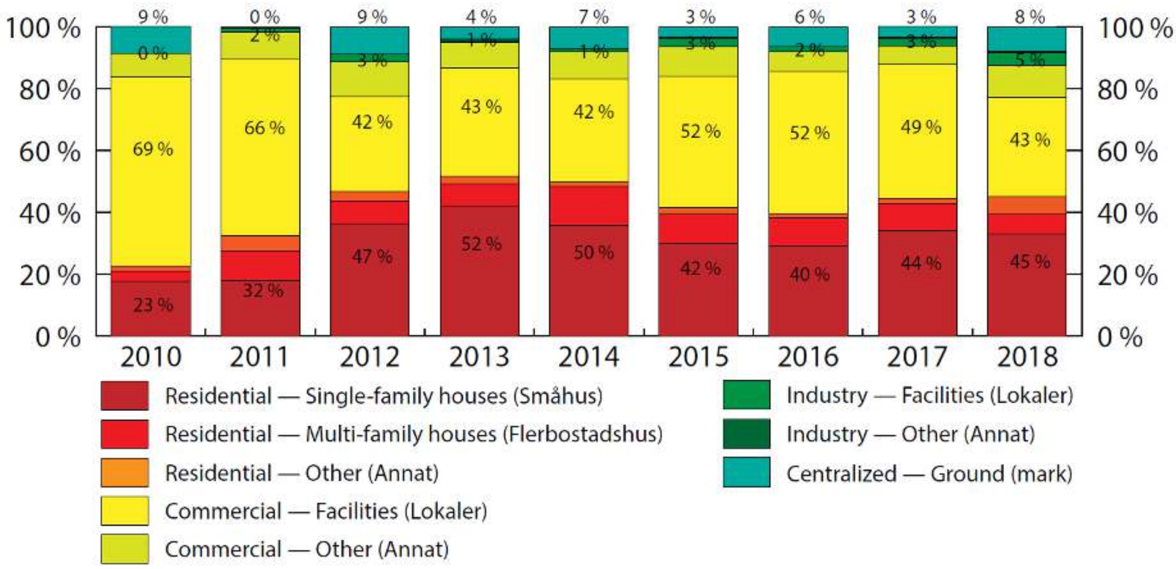

Figure 4. Various market segments share of the annual installed PV capacity in Sweden in 2018. Based on statistics from the capital subsidy database Svanen. The written percentages in the graph represents the total shares of Residential, Commercial, Industry and Centralized.

The low shares of the other market segments, such as centralized PV parks, industry and residential multi-family houses can all be explained by the current policy structure in Sweden.

The reason the underdeveloped market of centralized PV parks is that there principally are no support schemes for big PV parks in Sweden, except for the green electricity certificate system (see section 3.3.1), as the direct capital subsidy has a maximum aid limit per system of 1.2 million SEK (see section 3.2.1). Big centralized PV parks therefore must compete with the spot prices of the Nord Pool spot market plus the revenues of the certificates. However, this is a market sector that is expected to grow in the coming years. At the time of writing there are nine commenced PV parks in Sweden that are larger than 1 MW_p. But the authors are aware of plans for at least 14 more PV parks. It seems as though this sector is on the brink of managing without any subsidies, with the help of innovative business models such as PPA-contracts and PV cooperative models (see section 2.4).

The almost absent industry market segment can be explained by the current tax laws. First of all, the manufacturing industry in Sweden has a reduced energy tax. Instead of paying the full energy tax of 0.347 SEK/kWh they only pay 0.005 SEK/kWh. Therefore, the value of self-produced and consumed electricity becomes lower for manufacturing industries as compared with those actors that pay the full energy tax. The other major policy obstacle for this market segment is the 255-kW limit (see section 3.4.3), where an owner of a system larger than 255 kW_p pay energy tax on the self-produced and consumed electricity as well. Many larger industries consider PV systems of <255 kW_p too small to bother with, and therefor do not invest in PV, even if they have excellent roofs and high electricity consumption.

The general obstacle for residential multi-family houses is the current tax laws that makes it complicated to self-consume PV electricity in the apartments in a multi-family house. The most common situation is that the apartments have their own meter and contract with the grid operators and the whole multi-family house has one separate meter and contract for the electricity consumed in common areas of the house, e.g. elevators, laundry room, lighting. With this arrangement it is only possible to use the produced PV electricity (from a PV system on the building) for the electricity consumption of the common areas. If the owner of the multi-family house wants to export the PV electricity to the apartments the owner becomes a retailer of electricity, and must follow that regulation, and the Swedish energy tax is applied to this electricity (even if it has not left the building). So, it is difficult to reach a high self-consumption ratio in multi-family houses arranged this way. The value of the excess electricity exported to the grid drops if the fuse exceeds 100 amperes (see section 3.4.1), thus it becomes hard to achieve a decent profitability for such installations.

However, it is possible to self-consume the PV electricity in the apartments without taxes if the whole multi-family building, including the apartments, share one single meter and contract with the grid operator. This arrangement requires that the electricity consumption in the apartments is included in the general rent of the apartments. And then it is up to the owner of the multi-family house to decide if the residents in the apartments should pay a fixed price for the electricity regardless of their consumption, or handle the metering of the electricity consumption themselves and vary the level of the monthly rent for the residents depending on their electricity consumption. The former solution becomes more and more used in Sweden, but the general complicity to move to this arrangement is one reason for the low installation numbers for multi-family houses.

1.5 The geographical distribution of PV in Sweden

The data from the grid operators' statistics about the installed PV power in Sweden has a geographical resolution down to municipality-level. This data has been used to illustrate the geographical distribution of PV in Sweden in Figure 5 and Figure 6 for most of the municipalities in Sweden. However, some municipalities are marked as blank by the public Swedish Energy Agency due to secrecy reasons. For these municipalities, data from the green electricity certificate system (see section 3.3.1) has been used to complement the grid operators' data in creating Figure 5 and Figure 6.

For 2016 these municipalities were Ale, Arjeplog, Arvidsjaur, Bjurholm, Dorotea, Fagersta, Gällivare, Habo, Haparanda, Hedemora, Hofors, Jokkmokk, Kalix, Kiruna, Ljusnarsberg, Ludvika, Lycksele, Lysekil, Malå, Munkedal, Munkfors, Nordmaling, Pajala, Sala, Sorsele, Storuman, Sundbyberg, Sävsjö, Tanum, Tidaholm, Täby, Umeå, Vilhelmina, Vännäs, Åsele, Älvsbyn, Örebro and Överkalix.

For 2017 these municipalities are Ale, Arjeplog, Arvidsjaur, Avesta, Bjurholm, Dorotea, Fagersta, Grästorp, Gällivare, Habo, Haparanda, Hofors, Kalix, Laxå, Ljusnarsberg, Ludvika, Lycksele, Malå, Munkedal, Nordmaling, Ovanåker, Pajala, Partille, Sala, Skellefteå, Sorsele, Storuman, Sävsjö, Tidaholm, Umeå, Vilhelmina, Åsele, Älvsbyn, Överkalix and Övertorneå.

For 2018 these municipalities are Arboga, Arjeplog, Arvidsjaur, Askersund, Bjurholm, Dorotea, Fagersta, Grästorp, Gällivare, Hallsberg, Haparanda, Hofors, Lindesberg, Ovanåker, Pajala, Sorsele, Storuman, Tidaholm, Vindeln, Åsele, Älvsbyn and Övertorneå.

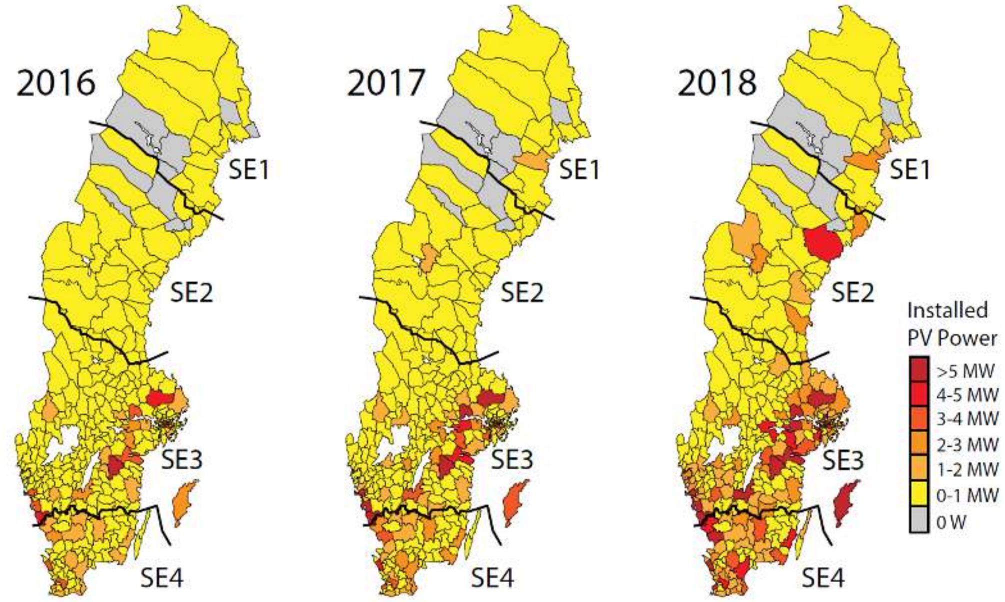

Figure 5: Total power of the PV systems in each of Sweden's municipalities [1]. For some municipalities data from the green electricity system has been used instead of grid operators' data due to secrecy reasons.

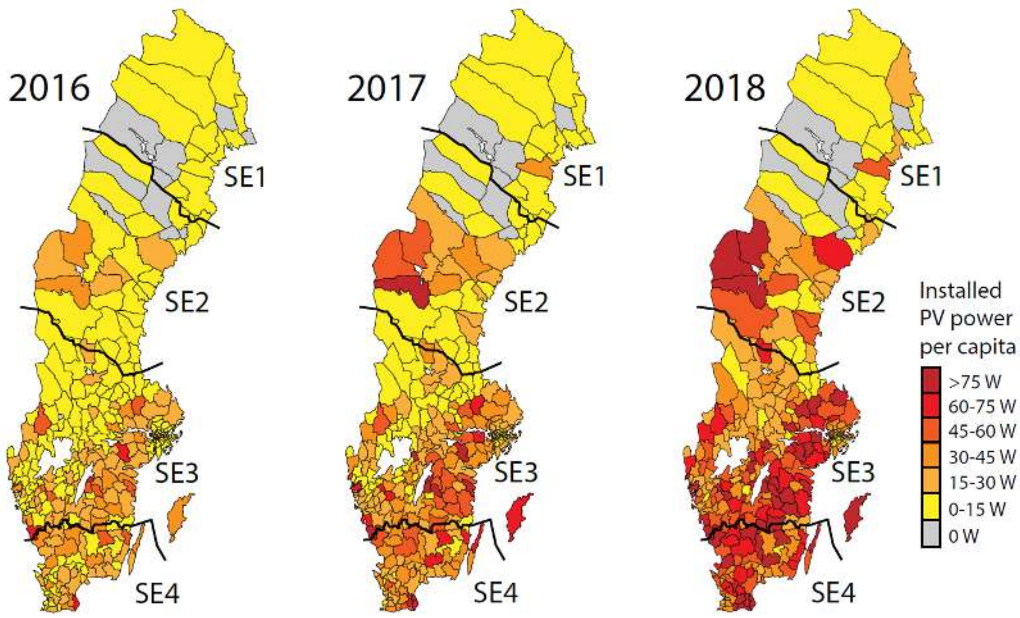

Figure 6: Total power of the PV systems per capita in each of Sweden's municipalities [1]. For some municipalities data from the green electricity system has been used instead of grid operators' data due to secrecy reasons.

Figure 5 and Figure 6 clearly show that the expansion of PV takes place at different speeds in Sweden's municipalities. When it comes to most installed PV capacity Gothenburg, followed by Stockholm and Uppsala were in the top at the end of 2018 with 14.7, 12.8 and 11.4 MW_p, respectively. Gothenburg, who overtook the lead from Linköping, was much helped by the 5.5 MW_p PV park that was finalised on Hisingen in December 2018.

If the installed PV capacity is divided by capita, Heby, Simrishamn and Orust were instead the top three municipalities in Sweden with 205.4, 164.4 and 146.9 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).

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), marked as SE1, SE2, SE3 and SE4 in Figure 5 and Figure 6. The reason is that northern Sweden has an excess of electricity production, since that is where a lot of the wind power and a majority of the hydropower are situated, while the demand is larger than the 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 the national grid needs to be expanded and where an increased electricity production is required to better meet the consumption. From this perspective, it is positive that a majority of the PV capacity is being installed in southern Sweden and mainly in the densely populated municipalities, as Figure 5 shows.

1.6 Key enablers of PV development

1.6.1 Other technologies

For three years 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 1 542 kWh was installed in combination with PV systems in 2016 and 2 416 kWh in 2017, as Table 9 summarizes. This number increased in 2018 to 3 904 kWh in 2018. The general global trend is decreasing battery prices, meaning that a growing battery market in Sweden is expected. In 2018 a clear shift can be seen, as compared to previous years, where the battery market for private households became larger than the market for commercial systems. This development can be explained by the introduced direct capital subsidy for batteries that started in 2016 (see section 3.10.2), which is now starting to have an effect.

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

Table 9. Annual installed grid connected battery capacity in combination with PV systems.

Year	Private system	Commercial system	Total
2016	177 kWh	1 365 kWh	1 542 kWh
2017	1 128 kWh	1 288 kWh	2 416 kWh
2018	2 384 kWh	1 520 kWh	3 904 kWh

The battery capacity of the electrical cars in Sweden was 1240 MWh in the end of 2018 [4]. If one adds the total battery capacity of stationary grid connected batteries connected to PV systems installed between 2016 and 2018 the total battery capacity at the end of 2018 became 1248 MWh.

Table 10: Information on key enablers. Values are at the end of 2018.

<table>
<tr><th></th><th>Description</th><th>Annual Volume</th><th>Total Volume</th><th>Source</th></tr>
<tr><td>Distributed storage systems [kWh]</td><td>Grid-connected private and commercial battery systems</td><td>3904 kWh</td><td>> 7 862 kWh[1]</td><td>This report</td></tr>
<tr><td>Heat Pumps [#]</td><td>Single-family houses</td><td>52 834</td><td>1 394 000</td><td>[5]</td></tr>
<tr><td rowspan="2">Electric cars [#]</td><td>Battery electric vehicles</td><td>6 333</td><td>19 522</td><td rowspan="2">[4]</td></tr>
<tr><td>Plug-in hybrid electric vehicles</td><td>62 653</td><td>49 282</td></tr>
<tr><td>Electric buses [#]</td><td>Battery electric buses</td><td>41</td><td>94</td><td>[4]</td></tr>
</table>

[1]Data collection started in 2016. So, the total number is for sure higher than the cumulative value of 2016–2018 data.

1.6.2 The public opinion about PV

The general opinion about PV in Sweden is very positive among the public. In an annual survey [6], sent out by SOM-institutet, randomly selected people have answered the question “How much should Sweden invest in the following energy sources during the next 5-10 years?”. The result is presented in Figure 7, and as can be seen a strong majority of 81 % of the respondents want more investments in PV in Sweden, which makes the PV technology by far the most popular electricity production technology in that aspect.

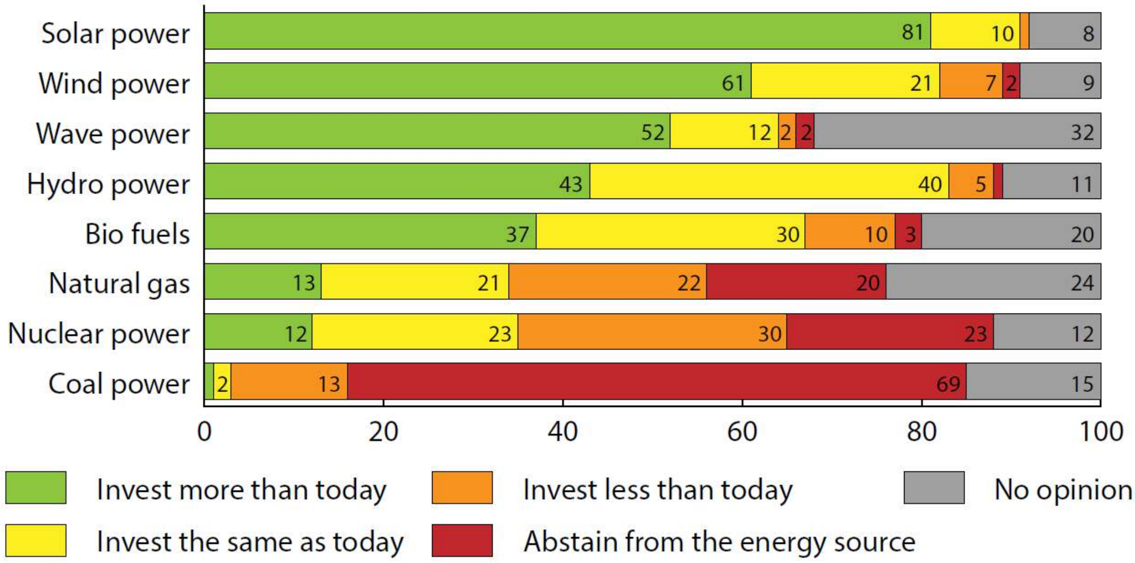

Figure 7. The public opinion in Sweden about different electricity production technologies [6].

1.7 PV in the broader Swedish electricity market

The complete statistics of the Swedish electricity production of 2018 is not available yet, so in Figure 8 the Swedish electricity production in 2017 is presented.

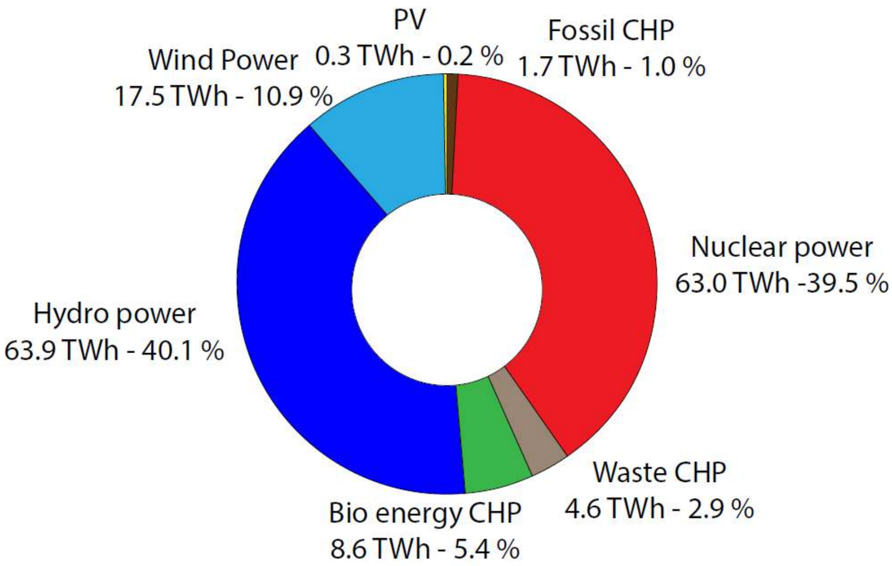

Figure 8: Total electricity production in Sweden in 2017 [7].

As can be seen in Figure 8, 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) counts as the two main reasons why the Swedish PV deployment started late compared to other European markets and still is rather small.

Table 11: PV power and the broader national energy market [8].

	2017 numbers	2018 numbers
Total power generation capacities [MW]	39 811	40 855
Total renewable power generation capacities (including hydropower) [GW]	31 225	32 241
Total electricity demand [TWh]	141	141
Total electricity production [TWh]	159	158
Change in generation capacity [MW]	-180	+ 1 044
Change in renewable power generation capacity (including hydropower) [MW]	+322	+ 1 016
Estimated total PV electricity production (including self-consumed PV electricity) in [GWh]	254	404
Total PV electricity production as a % of total electricity consumption	0.19	0.30

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. But also 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 European markets prices.

One of the reasons for the stabilization of module prices in Sweden is the import duties on Chinese PV modules and cells that were introduced in 2013 by the European Commission [9]. 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 September 2018 the European Commission terminated the duties on Chinese modules. After the termination of the duties many Swedish retailers lowered their module prices towards the Swedish installation companies with 20-30 percent. How big of a part of this price reduction that was transferred to the end-customers is uncertain. However, the sales statistics for module prices to the end consumer show that the typical module price went down with 14 % in 2018 (see Table 12).

Table 12: Typical module prices for a number of years. The prices are reported by Swedish installers and retailers [SEK/W_p]. The prices are the prices to the end consumer, not the import price for the installers and retailers.

Year	Lowest price of a standard module crystalline silicon [SEK/W_p]	Highest price of a standard module crystalline silicon [SEK/W_p]	Typical price of a standard module crystalline silicon [SEK/W_p]
2004	-	-	70
2005	-	-	70
2006	-	-	65
2007	-	-	63
2008	-	-	61
2009	-	-	50
2010	20	68	27
2011	12	50	19
2012	9.5	40	14
2013	6.0	16	8.6
2014	6.0	12	8.2
2015	5.1	10	7.6
2016	4.5	9.3	6.5
2017	4.1	6.6	5.5
2018	3.2	6.6	4.5

2.2 System prices

Sweden has experienced a large decrease in PV system prices since 2010, especially before 2013, as Figure 9 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 and/or installed modules or PV systems in Sweden. In the end of 2018, the corresponding figure had gone up to 282.

2.2.1 Estimated PV system prices by the sales statistics

When it comes to PV system prices, there are two different data sources. One is the sales survey that yearly goes out to the Swedish installers and retailers as part of the collection of data for this and previous Swedish National Survey Reports. These surveys have been conducted the same way since 2010, and they collect statistics about the prices that the installer and retailer companies regard as typical for some standard PV systems for their company. The reported prices have for the years 2010–2017 been weighted with regards to the number of kW_p each company installed in that market segment. For the 2018 numbers the reported prices have not been weighted (as installation numbers haven´t been collected this year) and the reported prices are a regular average. The price information collected in the sales surveys are presented in Figure 9, Figure 10 and Table 13.

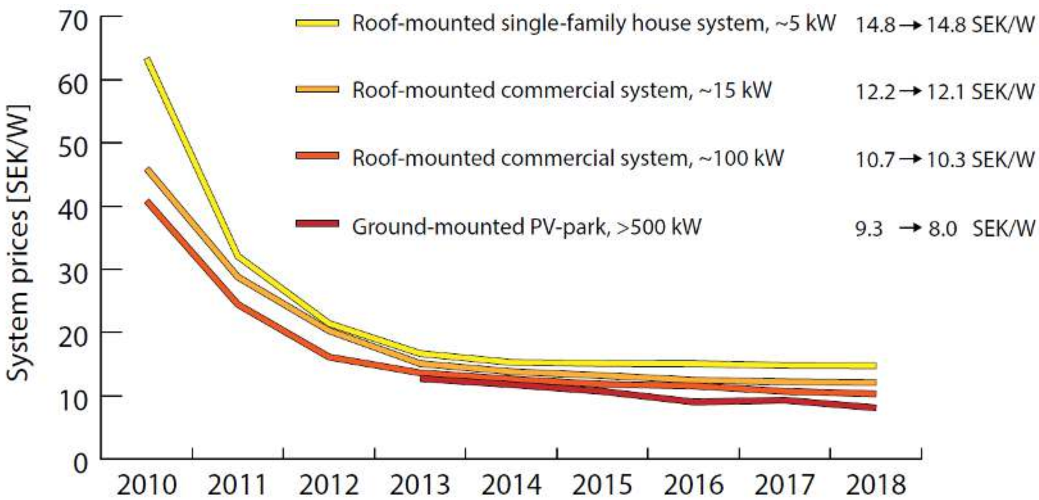

Figure 9: Historic development of the weighted average prices for turnkey photovoltaic systems (excluding VAT), reported by Swedish installation companies.

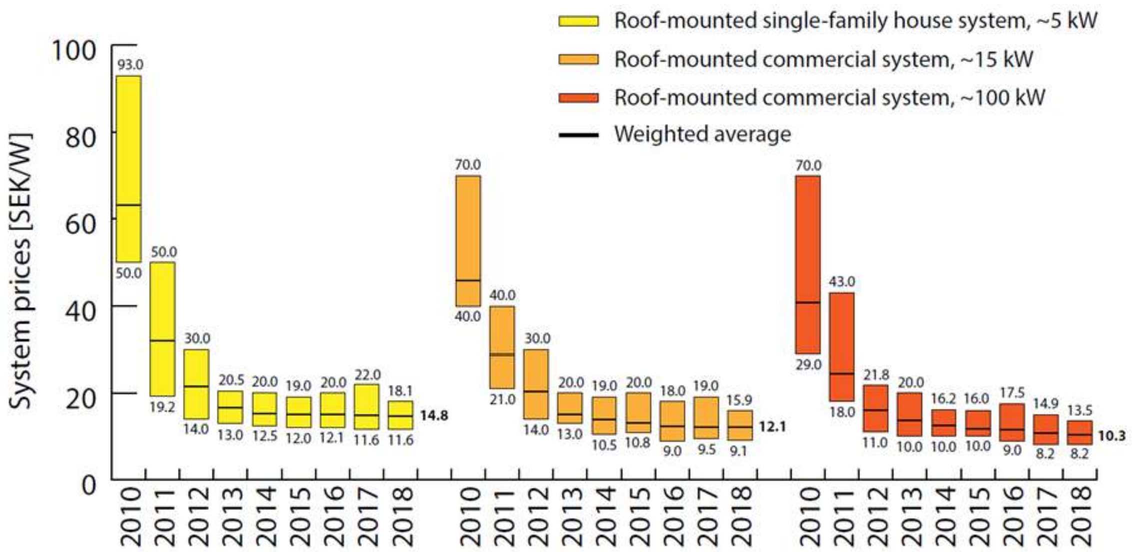

Figure 10: The price difference for typical turnkey PV systems between different Swedish installation companies (excluding VAT). Note that these are the prices that the companies regard as typical for their company, and that the graph therefore <u>does not</u> show the absolute highest and lowest prices in Sweden.

Table 13: National trends in system prices for different applications.

Year	**Residential BAPV** Grid-connected, roof-mounted, distributed PV system 5-10 kW [SEK/W_p]	**Small commercial BAPV** Grid-connected, roof-mounted, distributed PV systems 10-100 kW [SEK/W_p]	**Large commercial BAPV** Grid-connected, roof-mounted, distributed PV systems 100-250 kW [SEK/W_p]	**Small centralized PV** Grid-connected, ground-mounted, centralized PV systems 10-20 MW [SEK/W_p]
2007				
2008		96,00	60	
2009		76,00	67	
2010	63,33	45,89	47	
2011	32,07	28,77	40,79	
2012	21,43	20,29	24,44	
2013	16,68	15,09	16,13	12,73
2014	15,28	13,81	13,62	11,77
2015	15,13	13,20	12,63	10,69
2016	15,07	12,48	11,82	9,03
2017	14,81	12,21	11,56	9,30
2018	14,76	12,09	10,70	8,00

2.2.2 PV system prices recorded in the direct capital subsidy programme

The other source for system price statistics is the database of the Swedish direct capital subsidy, called Svanen. As described more in detail in section 1.4 it is possible to sort the PV systems into if they have been installed on “ground (mark)”, “single-family houses/small buildings (småhus)”, “multi-family houses (flerbostadshus)”, “facilities (lokaler)” or “other (annat)”. The Swedish standard classification names for the different type of buildings are added within the parenthesis to make it easier for the Swedish readers as there is some cases are no straightforward translations into English for these building types. So, most PV systems in the database can be divided into centralized, industry, commercial and residential systems, and as the system sizes (in kW_p), prices and commission dates are also recorded, it is possible to extract price information within the different market and size segments, as well as follow the price development over the years.

When it comes to the prices of turn-key grid connected roof-mounted PV systems there is of course a wide range, even for systems with similar size and type of owner. The range depends on many factors, such as type of building, type of roof, type of modules and BoS, etcetera. Furthermore, it is not possible to derive if the PV systems are building applied (BAPV) or building integrated (BIPV), or if the owner has carried out some of the installation work him/herself. These factors lead to that the prices of several recorded PV systems (especially in the segment of small residential single-family systems) are unusually high >30 SEK/W_p or low <10 SEK/W_p. So, there is a need to derive the average from a certain number of PV systems in order to reduce the influence of these outliers.

Furthermore, there is also the economies of scale, where larger systems are relatively less expensive to install due to the fact that some costs, such as for example designing of the system, erection of scaffolding, commissioning etc, depends little on the number of modules that are being installed.

For this report a number of size (power) ranges for residential and commercial systems have been selected and an average has been derived within these size ranges for PV systems. The reason for choosing these size intervals is because the number of systems should be sufficient to derive a reasonable average price and that the economies of scale becomes less profound the larger the system becomes. For the residential sector the size ranges are 5–10 kW_p and 10–20 kW_p for single-family houses, and 20–50 kW_p and 50–100 kW_p for multi-family houses. The average prices for residential systems are presented in Figure 11 and Table 14. For the commercial sector the size ranges are 10–20 kW_p, 20–50 kW_p, 50–100 kW_p and 100–255 kW_p, presented in Figure 12 and Table 15. The reason for choosing 255 kW_p as the upper boundary for the largest commercial systems is due to the current tax legislation (see section 3.4.3), which has led to that very few distributed rood-mounted PV systems larger than 255 kW_p have been built.

Table 14 and Table 15 also list how many systems that the presented average prices have been derived from so that the reader can get a sense of relevance of the average price presented.

The reason for only presenting prizes from 2013 and onwards, and not include 2009–2012 even if they exist in the database, is that the number of systems installed those years where so few and the spread of prices between them so high that deriving an average price of these systems would be precarious and could be misleading.

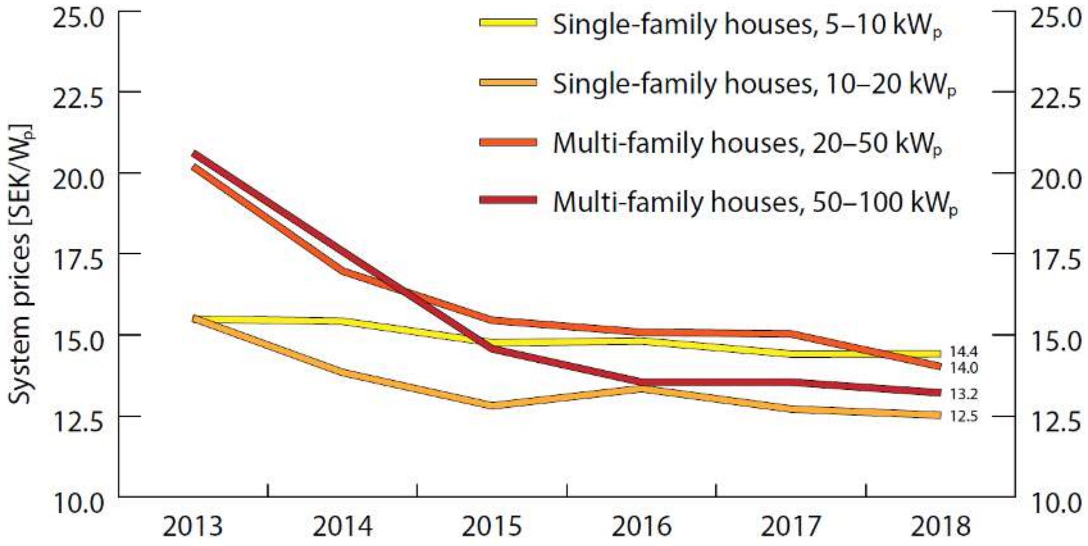

Figure 11. Average prices for turnkey grid-connected residential PV systems (excluding VAT) from the database of the direct capital subsidy programme.

Table 14. Average prices for turnkey grid-connected residential PV systems (excluding VAT) from the database of the direct capital subsidy programme, along with the number of PV systems of that specific type and power range that the average price has been derived from.

Year	**Single-family houses, 5–10 kW$_p$**		**Single-family houses, 10–20 kW$_p$**		**Multi-family houses, 20–50 kW$_p$**		**Multi-family houses, 50–100 kW$_p$**	
	Average price [SEK/W$_p$]	# systems	Average price [SEK/W$_p$]	# systems	Average price [SEK/W$_p$]	# systems	Average price [SEK/W$_p$]	# systems
2013	15.49	350	15.52	73	20.20	16	20.62	3
2014	15.42	485	13.84	200	16.97	45	17.58	11
2015	14.76	522	12.81	248	15.45	34	14.57	11
2016	14.81	989	13.34	431	15.08	57	13.54	18
2017	14.41	1399	12.71	868	15.03	71	13.54	21
2018	14.42	2029	12.52	1623	14.02	95	13.21	36

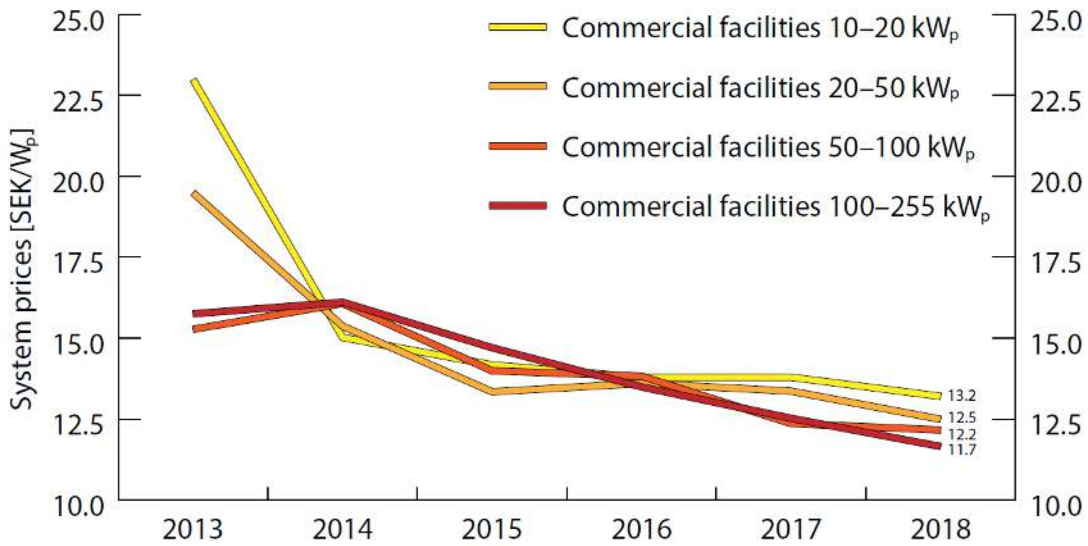

Figure 12. Average prices for turnkey grid-connected commercial PV systems (excluding VAT) from the database of the direct capital subsidy programme.

Table 15. Average prices for turnkey grid-connected commercial PV systems (excluding VAT) from the database of the direct capital subsidy programme, along with the number of PV systems of that specific type and power range that the average price has been derived from.

Year	Commercial facilities, 10–20 kW_p		Commercial facilities, 20–50 kW_p		Multi-family houses, 50–100 kW_p		Multi-family houses, 100–255 kW_p	
	Average price [SEK/W_p]	# systems	Average price [SEK/W_p]	# systems	Average price [SEK/W_p]	# systems	Average price [SEK/W_p]	# systems
2013	22.99	33	19.49	55	15.27	13	15.75	5
2014	15.02	77	15.37	89	16.07	27	16.11	10
2015	14.17	134	13.34	140	13.99	43	14.70	19
2016	13.79	206	13.60	234	13.82	77	13.49	36
2017	13.79	321	13.36	333	12.36	108	12.52	58
2018	13.20	364	12.49	398	12.16	135	11.65	69

2.2.3 PV system price discussion

The fast decrease in PV system prices in Sweden the last few years has slowed down, but a declining price trend can still be seen.

For small PV systems on residential single-family houses of approximately 5 to 10 kW_p, both Table 13 (that is based on the installations companies estimates) and Table 14 (that is based on prices statistics derived from the Swedish direct capital subsidy programme) show that the price under 2018 was stable at 14.8 SEK/W_p (Table 13) and 14.4 SEK/W_p (Table 14), respectively. However, somewhat larger PV systems on residential single-family houses of about 10–20 kW_p continued to experience a price decline of about 2 % as the average prices in this market segment went down from 12.7 to 12.5 SEK/W_p (see Table 14).

For residential PV system for multi-family houses Table 14 show that the prices went down with 7 % and 2 % within the size ranges of 20–50 kW_p respectively 50–100 kW_p under 2018.

For roof-mounted PV systems on commercial buildings the price decline seems to have been a little bit faster in general as the prices went down with 4 % for ~100 kW_p systems, from an average of 10.7 SEK/W_p to 10.3 SEK/W_p according to installation companies (see Table 13). Also Table 15 show prices decline of between 2–7 % within all size ranges for commercial systems.

It is interesting to note that for small residential single-family houses the installation companies estimate slightly higher typical system prices (14.8 SEK/W_p) as compared to the recorded systems in the direct capital subsidy programme (14.4 SEK/W_p), while for large commercial systems of about ≥100 kW_p the opposite is observed. Here the installation companies estimate slightly lower typical system prices (10.3 SEK/W_p) as compared to the average of the recorded systems in the direct capital subsidy programme (11.7 SEK/W_p).

The largest price decline in 2018 occurred for centralized utility scale PV parks, where the typical price went down with 13 % from 9.3 SEK/W_p to 8.1 SEK/W_p (see Table 13). A large reason for that is that one of Sweden's largest PV parks, a 5.5 MW_p park just outside of Gothenburg, was finalized just before the end of the year, and this park set a record low price in Sweden of 5.8 SEK/W_p at that time.

The general 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 stagnation of the prices for the residential and small commercial sector might be explained by the very high demand for PV in Sweden and that the subsidy levels in the Swedish direct capital subsidy system haven't been lowered since 2014 until it was changed in May 2019 (see section 3.2.1). This means that the installers could take the same prices, as the customers have the same profitability, even if module and other hardware costs has continued to go down.

Table 16 summarizes the PV system prices in 2018. The price ranges presented are appraisals made by the authors and are based on data from both the installer and retailers' surveys and the Svanen-database of the direct capital subsidy.

Table 16: Turnkey PV system prices of different typical PV systems in 2018.

Category/Size	Typical applications and brief details	Current prices [SEK/W_p]
Off-grid 2 kW	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. The price is for a small off-grid system on a cottage for seasonal use (summer) that is not connected to main grid.	25–30
Residential BAPV 5-10 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected households. Typically roof-mounted systems on villas and single-family homes.	12–18
Small commercial BAPV 10-100 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	12–18
Small commercial BIPV 10-100 kW	Grid-connected, building integrated, distributed PV systems installed to produce electricity to grid-connected commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	8–16
Large commercial BAPV 100-250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected large commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	7–14
Industrial BAPV >250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected industrial buildings, warehouses, etc.	7–16
Small centralized PV 1-20 MW	Grid-connected, ground-mounted, centralized 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.	6–10
Large centralized PV >20 MW	Grid-connected, ground-mounted, centralized 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.	not applicable

2.3 Financial parameters and specific financing programs

The interest rate (reporäntan) of the central bank of Sweden (Riksbanken) started at -0.5 % in 2018 and was kept at that level under the whole year [10]. Changes in interest rate by the central bank have a direct impact on the market rates, which therefore have been very low in 2018. The cost of capital for a PV system has consequently been low.

In Table 17 the average mortgage rate in 2018 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 a slightly higher capital cost than those achieved in the more mature German market has been chosen.

Table 17: PV financing information in 2018.

Different market segments	Loan rate [%]
Average rate of loans – residential installations [11]	1.5 %
Average rate of loans – commercial installations [12]	4.0 %
Average cost of capital – industrial and ground-mounted installations [13]	4.0 %

2.4 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, that buys the electricity from the cooperatives PV systems. Since the start in 2009 the cooperative has now built six systems with a total capacity of 599 kW_p. Other examples of PV cooperatives that has built co-owned PV systems are Solel i Lindesberg ekonomisk förening, with two systems totalling 68 kW_p, and Zolcell 1:1 ekonomisk förening, with 2 systems totalling 27 kW_p.

PV cooperative models have in later years been adapted by utility companies that have built large PV parks or systems. Any private person or company can buy a share in such a park and 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 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 response from the first system and is now expanding this business offer with plans of a 2.7 MW_p big crowd funded PV park close to the Kalmar Airport. This park will be built in four stages of 750 kW_p each. The first one was finalized in the end of September 2017, and the second in June 2018. The PV park off Affärsverken is a third example. The first stage, 0.6 MW, of their share financed PV park was finalized in January 2019, and they plan for 10 more phases.

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 ETC El started to offer solar leasing contracts to private persons.

Table 18: Summary of existing investment schemes.

Investment Schemes	Introduced in Sweden
Third party ownership (no investment)	Yes
Renting	Yes
Leasing	Yes
Financing through utilities	Yes
Investment in PV plants against free electricity	Yes
Crowd funding (investment in PV plants)	Yes
Community solar	Yes
International organization financing	No

2.5 Additional country information

Sweden is a country in northern Europe. With a land area of 407 284 km² [14], Sweden is the fifth largest country in Europe. In January 2017 Sweden passed ten million inhabitants for the first time in history [15]. The population density of Sweden is therefore low with about 25 inhabitants per km², but with a much higher density in the southern part of the country. About 85 % of the population lives in urban areas.

Table 19: Country information.

Retail Electricity Prices for a household (range)	1.2–2.2 SEK/kWh (including grid charges and taxes)
Retail Electricity Prices for a commercial company (range)	1.2–1.8 SEK/ kWh (including grid charges and taxes)
Retail Electricity Prices for an industrial company (range)	0.6–1.0 SEK/kWh (including grid charges and taxes)
Population at the end of 2018 [15]	10 230 185

Country size (km²) [14]	407 284			
Average PV yield in kWh/kW$_p$ [16]	950 kWh/kW$_p$ (800–1 100 kWh/kW$_p$)			
Name and market share of major electric utilities		Electricity production (2017) [17]	Share of grid Subscribers (2017) [18]	Number of retail customers (2018) [19]
	Vattenfall	42 %	16 %	20 %
	Uniper	15 %	-	-
	Fortum	14 %	-	21 %
	Statkraft	4 %	-	-
	Skellefteå Kraft	3 %	1 %	4 %
	E.ON	-	19 %	15 %
	Ellevio	-	17 %	-

2.6 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 the nuclear reactors and the outside temperature. In recent years, a lot of wind power has been built and more connection to surrounding countries have come online, which affect the spot prices on windy days.

The electricity market in the Nordic region in 2018 was characterized by a cold and windy spring that was followed by an extremely dry and hot summer, which meant that the hydro balance at the end of July was -33 TWh. Only in mid-August was the barometric high pressure broken down and autumn began with heavy rainfall and wind production. During the late autumn, the high pressure again dominated the very sunny year of 2018 (see section 2.7) which led to a total hydro balance at -22 TWh.

The average price at the Nord Pool Spot day-ahead market in electricity area 3 (Stockholm) was 0.278 SEK/kWh in 2016, 0.301 SEK/kWh in 2017, and the price increased rapidly in 2018, see Figure 13, so the average price ended up at 0.458 SEK/kWh [20]. The monthly average spot price varied from 0.318 in January to 0.570 SEK/kWh in August in 2018 [20]. The maximum hourly rate for the year amounted to 2.00 SEK/kWh on March the 1st at 08–09, while the minimum hourly rate was as low as 0.02 SEK/kWh on October 15th at 00–01 [20].

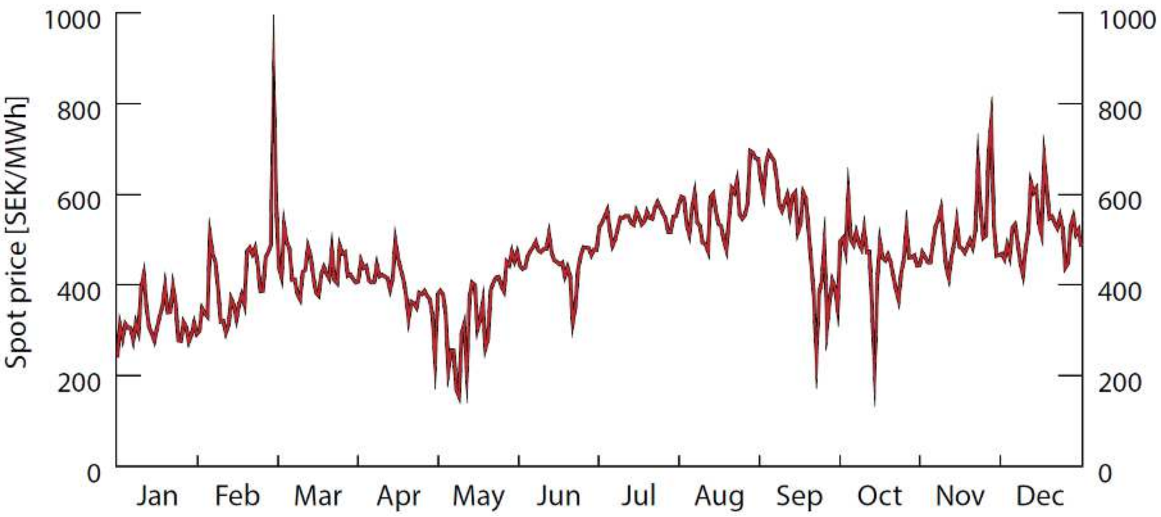

Figure 13. Daily average day-ahead spot prices in electricity area 3 (Stockholm) in 2018 [20].

The value factor[1] for PV during 2018 was very high, 1.13, due to the very sunny and dry summer [21]. For previous years 2013-2016 the average value factor has been 1.04, with individual yearly values at 1.03 (2013), 0.96 (2014), 1.08 (2015) and 1.06 (2016) [22].

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, and thus reduce the need to transport electricity long distances.

The average Nord Pool spot prices in 2018 for the different areas were 0.455 SEK/kWh in area 1 (Luleå), 0.455 SEK/kWh in area 2 (Sundsvall), 0.458 SEK/kWh in area 3 (Stockholm) and 0.477 SEK/kWh in area 4 (Malmö) [20]. The very small difference between the areas does not influence the distribution of PV systems over the country to the same extent as solar radiation (see section 2.7) and the population distribution does (see section 1.4).

The consumer price of electricity varies between different categories of clients, between urban and rural areas and depends on the variable distribution costs, differences in taxation, subsidies, Government regulation and electricity market structure. Household electricity costs consist of several components. The base is the Nord Pool Spot price of electricity. On top of that, energy tax, the cost of green electricity certificates, the variable grid charge, the fixed grid charge, VAT and sometimes an electricity surcharge and a fixed trading fee are added. Figure 5 illustrates the evolution of the average electricity price for private end consumer over the years. In Figure 15 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

[1] A value factor is calculated as the market value of a certain production relative to the average price on the market. A value factor greater than one indicates that the value of electricity generation exceeds the average spot price for a certain period of time (typically one year), and vice versa for value factors under one. A value factor over one for a power supply indicates that the electricity market is demanding electricity production that is in line with the power supply's production profile.

compensation from the grid owner (see section 3.4.6), the newly introduced tax credit system (see section 3.4.1) and with and without the green electricity certificate, since few PV owners are using the green electricity certificate system (see section 3.3.1).

The reader should note that the electricity price in Figure 15 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 15.

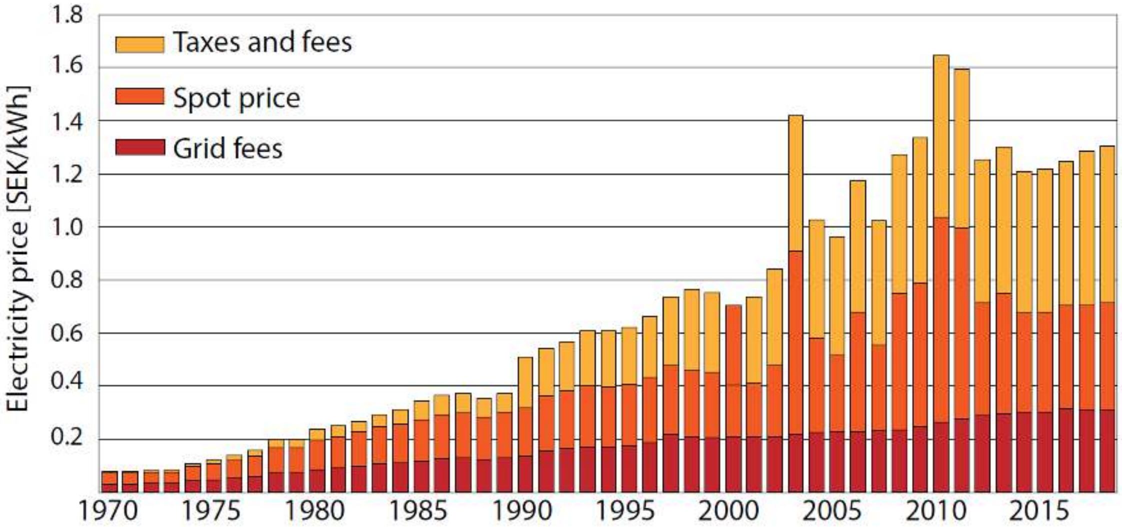

Figure 14: Evolution of the average electricity price (in January) for private end consumer with a single-family house with electric heating [23].

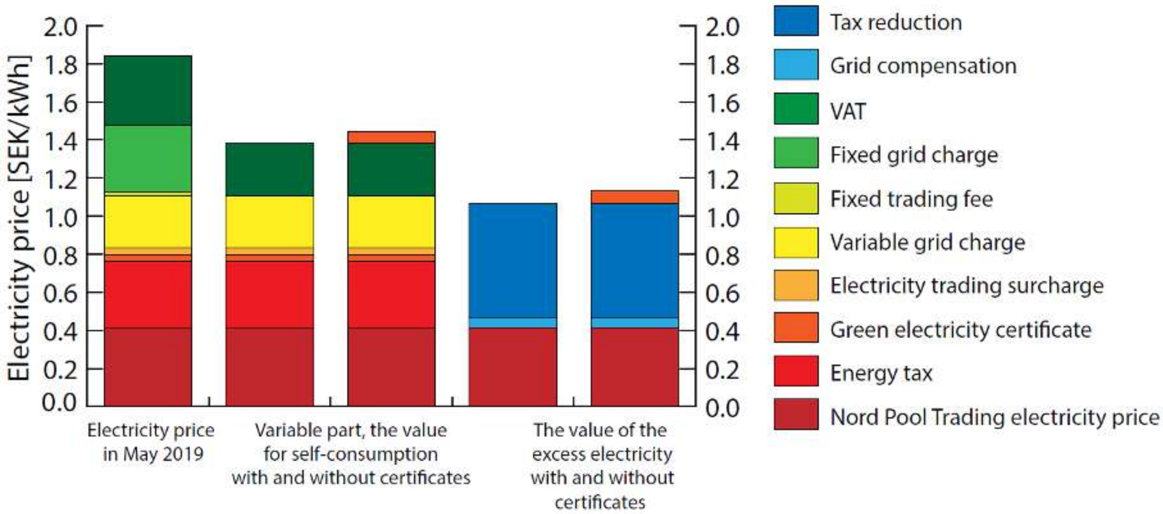

Figure 15: The lowest available electricity price for a typical house with district heating in Stockholm with an annual electricity consumption of about 10 000 kWh/year, a 16-ampere fuse and Vattenfall as the grid owner. Furthermore, the compensation for the excess electricity, with and without the extra remuneration from green electricity certificates.

2.7 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.

In the long-term variation of global radiation in Sweden a slight upward trend has been noted and the average solar radiation has increased with about 8 % from the mid-1980s until today, from about 900 kWh/m^2 in 1985 to the current level of the recent years, which is about 1 000 kWh/m². In 2018 very long periods of anticyclone weather (where barometric pressure is high) over Scandinavia gave very sunny weather during mainly May and July, and the global radiation was noted for a top record in Sweden in 2018, as Figure 17 illustrates. The total annual average accumulated global radiation was 1050,8 kWh/m^2 [24].

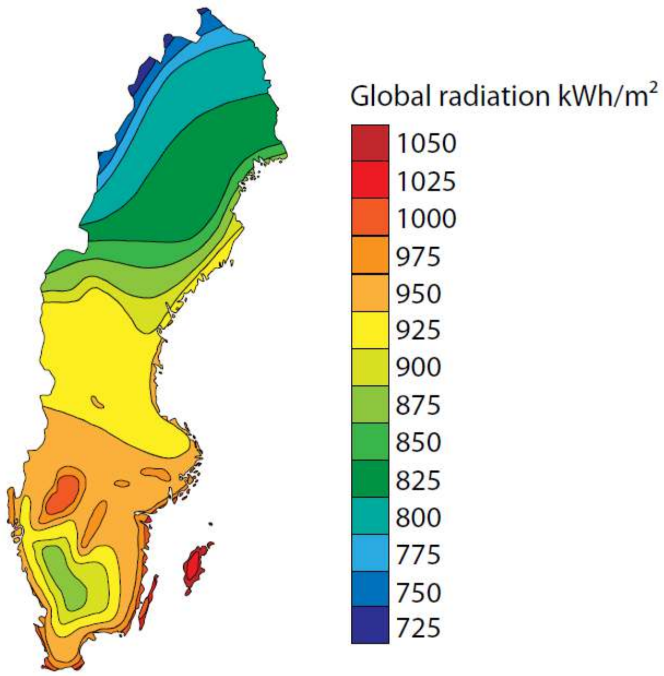

Figure 16: Global solar radiation in Sweden in one year [24].

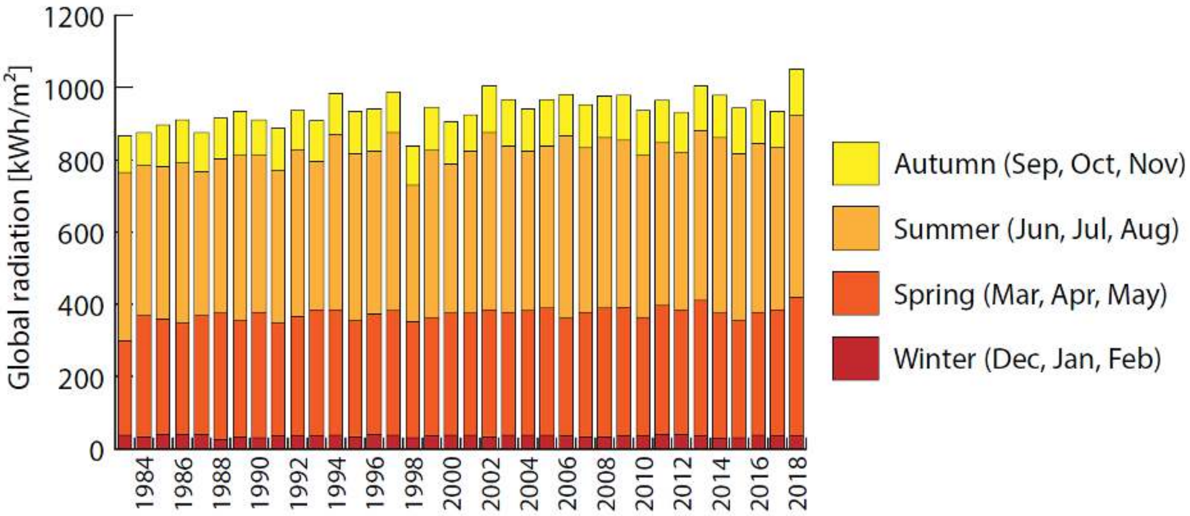

Figure 17: The global solar radiation in Sweden between 1984 and 2018 [24].

2.8 Competitiveness of PV electricity

2.8.1 Levelized cost of electricity

To calculate the levelized cost of electricity (LCOE) the following equation is 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. Figure 18 illustrates how the changes in system prices (investment costs) and interest rates affects the LCOE under the for Sweden relevant assumptions of 30 years lifetime, annual costs of 100 SEK/year and kW_p, a first-year yield of 950 kWh/kW_p and system degradation of 0.5 %.

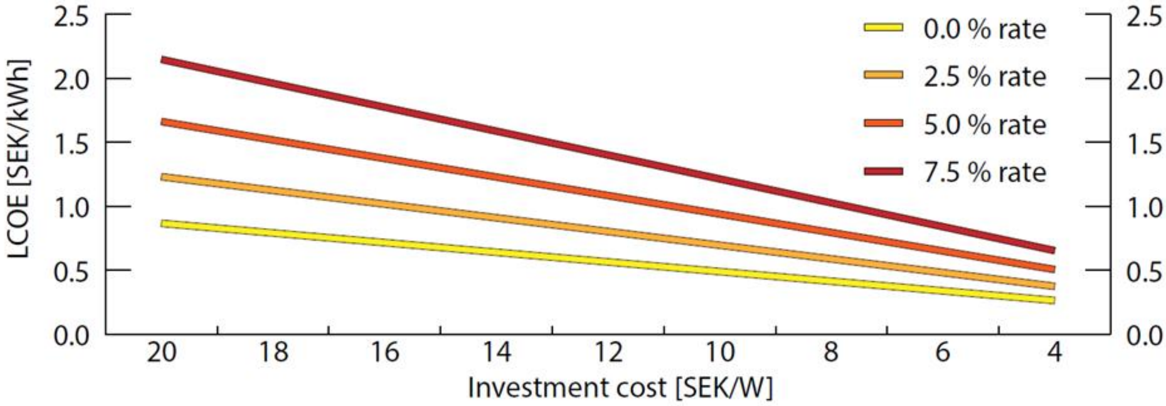

Figure 18: LCOE dependence on investment cost and interest rate.

One should note that LCOE values heavily depend on the made assumptions.

As a first example a small residential BAPV system on a single-family house can be used. Using the commonly used assumptions for a small residential PV system in Table 20, an unsubsidised LCOE of 1.04 SEK/kWh is obtained. This value is 0.4 SEK/kWh lower than the variable part of the end consumer electricity price and in parity of the compensation for the excess electricity in Sweden (see Figure 15). If one subtracts the 30 % of the Swedish direct capital subsidy (see section 3.2.1) and keep the other assumptions constant, the LCOE becomes 0.77 SEK/kWh. Furthermore, right now, the interest rates are very low in Sweden, and for private individuals the rate on saving accounts is 0 % at 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 0.84 SEK/kWh without the capital subsidy program and 0.62 SEK/kWh with it.

If one looks at the other end of the spectrum, namely at a 5 MW PV park (with the assumptions in Table 20), the unsubsidised LCOE becomes 0.45 SEK/kWh, which is in parity with the yearly average spot prices in 2018 in the four Swedish electricity areas, which ranged between 0.46-0.48 SEK/kWh (see section 2.6).

Table 20: PV system performance assumptions for a 5 kW_p residential system and a 5 MW_p centralized PV park in Sweden.

Parameter	Assumptions 5 kW residential	Assumptions 5 MW centralized	Comment
Lifetime [Years]	30	30	A PV module usually has a warranty of 25 years, but the lifetime is probably longer.
Initial investment [SEK/kW_p]	18 100	5 800	See section 2.2
Annual cost [SEK/year and kW_p]	100	50	Replacement of inverter after 15 years.
Residual value [SEK/kW_p]	0	0	The value of a 30-year old system is currently unknown.
First year yield [kWh/kW_p and year]	900	1000	Based on existing PV systems in Sweden.
System degradation rate [%]	0.5	0.5	Median value of international degradation studies [25].
Interest rate [%]	1.5	4.0	Average mortgage rate in 2018 [11].

2.8.2 Payback time for a residential PV system

To calculate the payback time for a PV system in Sweden several assumptions must be made. Mälardalens Högskola has together with a reference group consisting of 50 property owners, installers, consultants and electricity companies developed a standardized calculating tool [26]. Using this tool, with the different assumption of seven specific cases summarized in Table 21, the effect of these assumption on the cash flow and payback of 5 kW_p residential system in Sweden is illustrated in Figure 19. All the assumptions are realistic assumptions regarding the situation in Sweden today (July 2019), however case 1 should be seen as a very pessimistic calculation, while case 7 might be seen as an optimistic development.

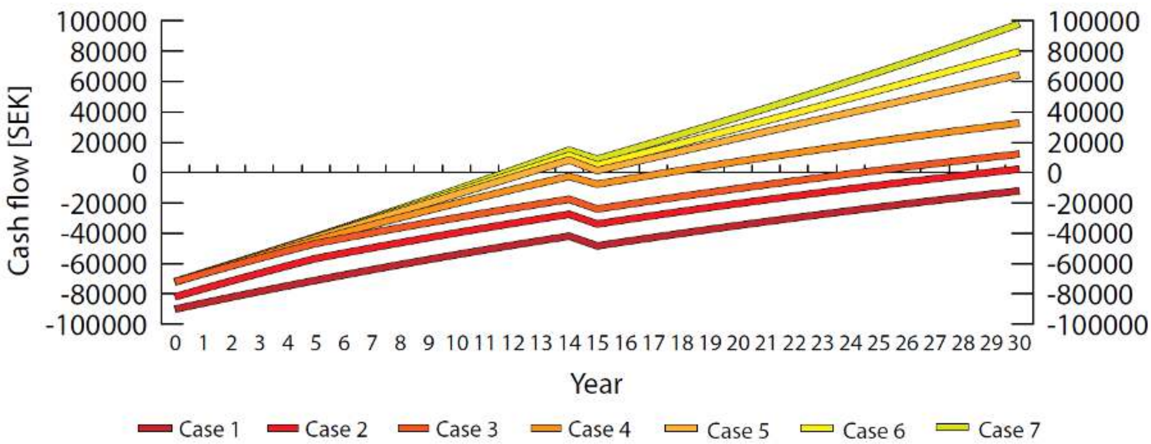

Figure 19. The cash flow and payback time of a 5 kW_p residential PV system in Sweden based on the assumptions in Table 21.

Table 21: Assumptions for cash flow and payback calculations of a 5-kW$_p$ residential PV system in Sweden. The changes between the previous case is market with bold.

Assumptions	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
System performance parameters							
Lifetime [Years]	30	30	30	30	30	30	30
System degradation rate [%]	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Annual cost [SEK/year and kW$_p$]	0	0	0	0	0	0	0
Residual value [SEK/kW$_p$]	0	0	0	0	0	0	0
First year yield [kWh/kW$_p$ and year]	900	900	900	900	900	900	900
Financial parameters							
Initial investment [SEK]	90 000	-	-	-	-	-	-
Investment after ROT (9%) [SEK]	-	**81 900**	-	-	-	-	-
Investment after capital subsidy (20%) [SEK]	-	-	**72 000**	72 000	72 00	72 00	72 00
Change of inverter after 15 years [SEK]	2 500	2 500	2 500	2 500	2 500	2 500	2 500
Interest rate [%]	2.0	2.0	2.0	2.0	**0**	0	0
Value of PV electricity parameters							
Self-consumption rate [%]	50	50	50	50	50	50	50
Variable part electricity price year 1 [SEK]	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Future electricity price development [%]	0	0	0	0	0	**1**	**2**
Payment for excess electricity from utilities [SEK]	0.3	0.3	0.3	**0.5**	0.5	0.5	0.5
Tax reduction renumeration [SEK]	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Number of years with tax reduction [Years]	0	**5**	5	**15**	15	15	15

3 POLICY FRAMEWORK

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

Table 22: Summary of PV support measures.

	On-going measures in 2018 – Residential	Measures introduced in 2018 – Residential	On-going measures in 2018 – Commercial + Industrial	Measures introduced in 2018 – Commercial + Industrial	On-going measures in 2018 – Centralized	Measures introduced in 2018 – Centralized
Feed-in tariffs	-	-	-	-	-	-
Feed-in premium	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	-	-	-	-	-	-
Collective self-consumption and virtual net-metering	Yes	-	-	-	-	-
Commercial bank activities e.g. green mortgages promoting PV	-	Yes	-	-	-	-
Activities of electricity utility businesses	Yes	-	Yes	-	Yes	-
Sustainable building requirements	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.

3.1 National targets for PV

There is no official target for future PV installation in Sweden. However, there is a broad political agreement with a 100 % renewable electricity system by 2040.

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 is not a political stop date for nuclear, but if the goal is to be reached it means a phase out of the Swedish nuclear reactors that are coming to age and continuous pushing of renewable energies. More concretely, the Government plans on continuing investment in transmission capacity, demand response and energy efficiency, and an extension of the Swedish green electricity certificate system from 2020 to 2030 [27]. Many of the politically introduced legislation changes in the coming years will spring from this political agreement, and the Swedish PV market will most likely benefit from this it.

The agreement, that was first communicated in June 2016, was only a framework. But in 2017 and 2018 this framework has been filled with more concrete measures.

One thing that is included in the agreement, which will have a definite impact on the PV market, is the prolongation of Swedish green electricity certificate system (see section 3.3.1). 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 [28].

3.2 Direct support policies for PV installations

3.2.1 Direct capital subsidy for PV installations

The current capital subsidy for solar cells was introduced on July 1, 2009. Prior to that, there was support for energy efficiency in public premises, where solar cells were included as eligible investments that could be applied for. In this program, PV systems could get 70 % of the installation costs covered and the program got the grid-connected PV market started in Sweden. The support program for public premises was introduced in 2005 and ended after 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 [29]. Support rates were 55% for large companies and 60% for all others. Originally, 50 million SEK was deposited annually for three years. This support program has since been extended, support levels have changed, and more money has been allocated, summarized in Table 23 and Table 24.

Table 23. Summary of changes in the direct capital subsidy programs ordinance, support level and duration [30].

Ordinance	Start date	Maximum coverage of the installation costs	Initial stop date
2005:205 Energieffektivisering i offentliga lokaler	2005-04-14	70 %	2008-12-31
2009:689 Stöd till solceller	2009-07-01	55 % for large companies 60 % all others	2011-12-31
2011:1027 ändring av 2009:689	2011-01-01	45 %	2012-12-31
2012:971 ändring av 2009:689	2013-02-01	35 %	2016-12-31
2014:1582 ändring av 2009:689	2015-01-01	30 % companies 20 % all other	2016-12-31
2016:900 ändring av 2009:689	2016-10-13	30 % companies 20 % all other	2019-12-31
2017:1300 ändring av 2009:689	2018-01-01	30 %	2020-12-31
2019:192 ändring av 2009:689	2019-05-08	20 %	2020-12-31

The original program was planned to end by the 31st of December 2011 but has been prolonged several times.

In 2017 the budget was increased even more as the government added 200 million SEK for 2017 and 525 million SEK for each of the years 2018–2020. Later another 170 million SEK was added to the 2018 budget, summing up to 1,085 million SEK in total. After the election in the autumn 2018 the parliament passed an autumn budget which decreased the annual budget for the direct capital subsidy to 436 million SEK for 2019. In the spring of 2019, the new formed government added 300 million SEK to the budget. The budget over the years is summarized in Figure 20. The budget for 2020 is at the time of writing not decided by the Government.

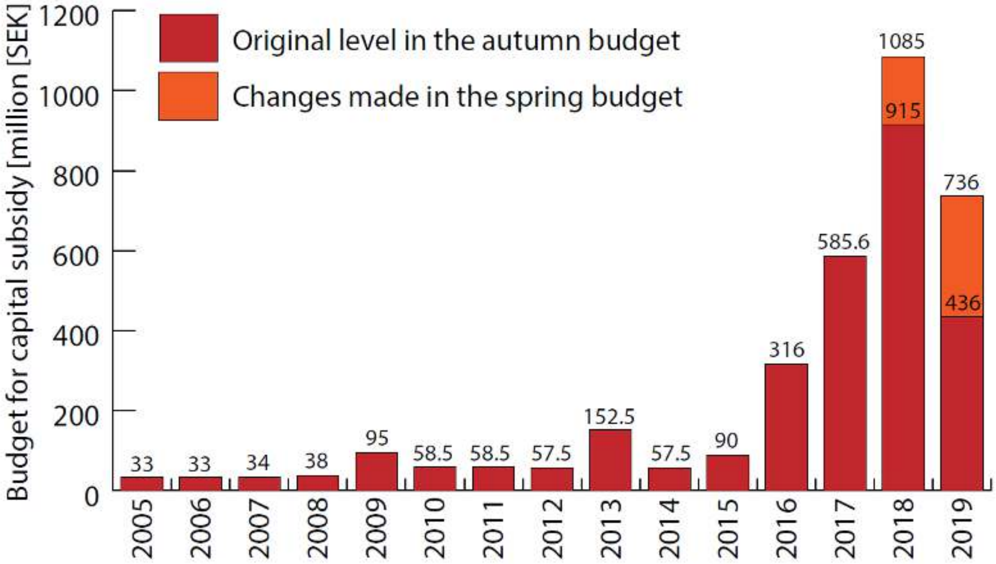

Figure 20: The annual budget of the direct capital subsidy program.

Since its introduction, the interest in the capital subsidy program has always been greater than the budget allocated. When the support was introduced the 1st of July 2009, there had been a gap since the 31th of December 2008 when support for public premises was ended, and many actors were prepared to invest. The 50 million SEK that were allocated for 2009 were therefore all applied for already day 3 [30]. Since then, the applied money has each year been much higher than the allocated budget. Therefore, a long que to get the subsidy has arisen as applications do not fall out of the line at the end of a year.

When the situation was at its worst in 2016, average waiting time was around 722 days, i.e. almost 2 years [30]. The effect of the previous long waiting times led to that the program not solely stimulated, but also constituted 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 [31].

Until 2011 the new version of the subsidy covered 60 % (55 % for large 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 %. From 2015 the level was decreased to maximum 30 % for companies and 20 % for other stakeholders. From the first on January 2018 the Swedish government increased the subsidy level for “others” to 30 % so all actors had the same level.

From the 8th of May 2019 the level has been decreased to 20 % for all as a consequence of declining PV prices and increasing electricity prices for end customers.

In the current version of the statue, 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 24).

Table 24. Summary of the Swedish direct capital subsidy program [30][32][33].

	Total 2006 – 2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total 2009– 2018
Maximum coverage of the installation costs	70 % Only for public building	55 % Companies 60 % Others			45 %	35 %		30 % Companies 20 % Others			30 %	
Upper cost limit per PV system [million SEK]	5	2			1.5	1.3		1.2			1.2	
Maximum system cost per W (excluding VAT) [SEK/W]	-	75			40	37		37			37	
Budget [million SEK]	138	212			57.5	210		90	316	585.6	1085	**2556.1**
Granted resources [million SEK][1]	138	28.43	74.12	70.99	57.70	108.66	59.06	72.42	226.80	338.65	1110.99	**2147.82**
Disbursed funds [million SEK]	138	0.05	33.23	81.02	78.35	73.16	75.60	78.17	138.79	235.71	601.70	**1395.76**
Yearly installed grid connected PV capacity based with support from the direct capital subsidy [MW_p][2]	2.96	0.18	2.15	3.69	6.85	12.02	22.69	30.25	52.45	75.03	128.53	**333.83**
Yearly total installed grid connected PV capacity according to the sales and grid operators' statistics [MW_p]	2.83	0.52	1.83	3.30	7.05	17.69	33.21	46.36	59.28	82.89	155.87	**411.06[3]**

[1] Extract from Boverket's database 2019-04-30. The granted resources are expected payments which may change if the circumstances change in individual cases.
[2] Extract from Boverket's database 2019-06-01. The numbers are probably higher for several of the later years, as there is a large delay in the system due to the long ques.
[3] Cumulative grid connected PV capacity according to the grid operators' statistics based on information from the grid operators.

Since the start of the first program in 2006 until the end in 2018, 2285.82 million SEK had been granted and 1533.76 million SEK had been disbursed [33]. This capital has supported a total installation of 336.76 MW_p so far. This means that the average subsidy for all PV systems since 2006 to 2018 has been 4.6 SEK/W_p, down from 11.8 SEK/W_p in 2015, 8.9 SEK/W_p in 2016 and 5.3 SEK/W_p in 2017.

Listed in Table 24 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. A second reason could be that there is a margin of errors in the sales statistics. The third explanation is that nowadays it is more common to complete the installation of the 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 3.10.6).

• 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.

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 of 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 [34].

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) [34].

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 the fact that many agriculture companies pay a lower level of the Swedish energy tax (see section 3.4.2), which makes the value of self-consumed electricity lower than for regular electricity consumers and therefore a PV system is 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 [35].

So far, this program has granted support to 60 PV projects with a total capacity of 1,9 MW_p for a total amount of 8 928 597 SEK from 2015 to 2018.

3.2.3 BIPV development measures

There was no specific BIPV measures in Sweden in 2018.

3.3 General support policies for renewable electricity production

3.3.1 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).

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 [36]. In March 2015, the Swedish and Norwegian governments made a new agreement that raised the common goal of 2 TWh to 28.4 TWh until 2020. This increase will only be funded by Swedish consumers [37].

Furthermore, in the wake of the broad political agreement on the future Swedish electricity system (see section 3.1) it was decided in 2017 that the electricity certificate system will be extended to 2030 with another 18 TWh of renewable electricity. The prolongation involves a linear escalation of the 18 TWh with 2 TWh from 2022 to 2030.

In 2018, the quota obligation was 29.9 %, up from 24.7 % in 2017 [38]. Further adjustments to the quota levels have then be made for the prolongation to 2030. The average price for a certificate increased to 147.6 SEK/MWh in 2018 from the average price of 94.2 SEK/MWh in 2017 [39]. The established trend in the level of the quota duties is summarized in Figure 21 and the price trend in Figure 22. Since the start in 2003 to the end of 2018, certificates corresponding to 43.5 TWh has been issued in Sweden [39].

Until 2006 there were no solar systems in the electricity certificate system [40]. However, as Table 25 and Figure 23, show the number of approved PV installations increased over the years and most of the 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 24, 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.

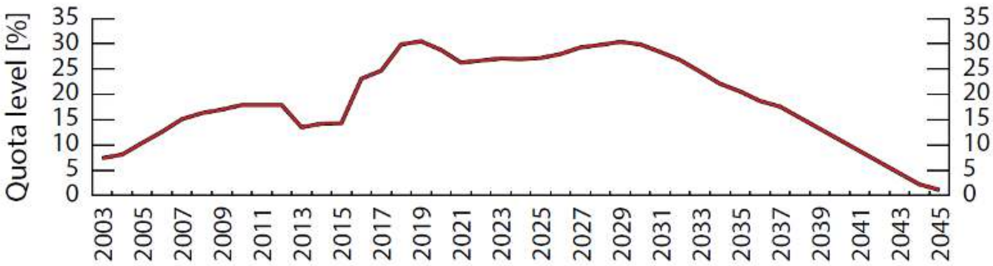

Figure 21: The quota levels in the green electricity certificate system [38].

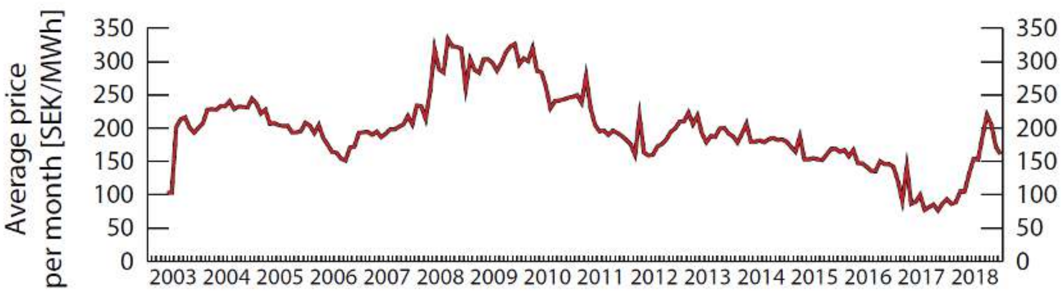

Figure 22: The price development of the green electricity certificates [39].

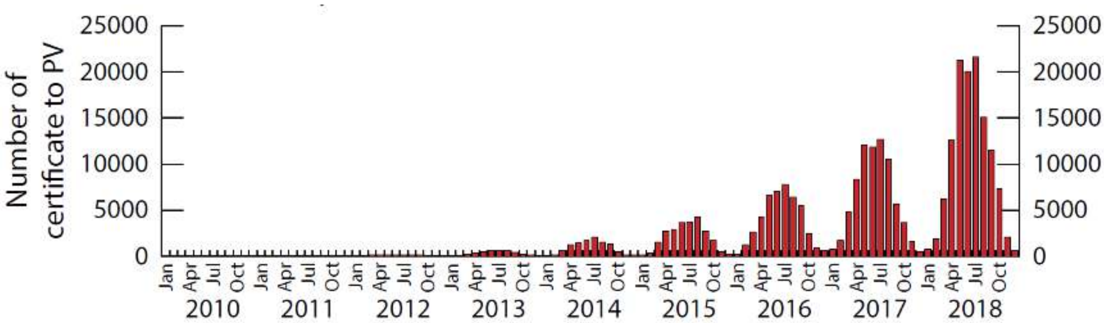

Figure 23: Green electricity certificates issued to PV produced electricity [39].

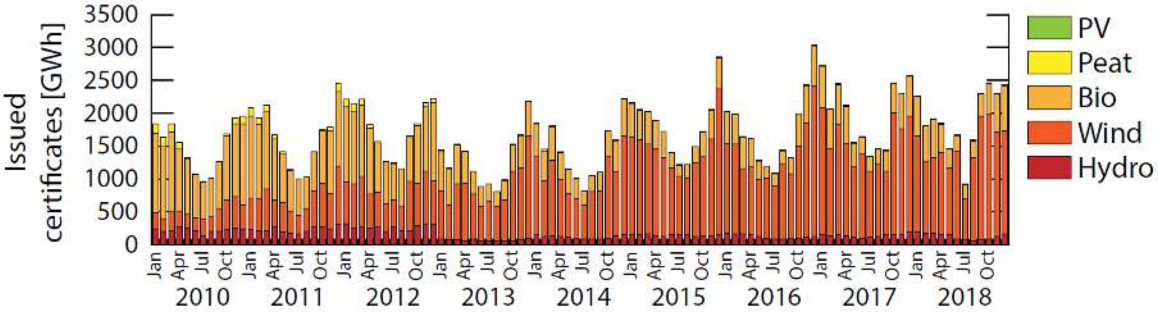

Figure 24: The allocation of green electricity certificates to different technologies [39].

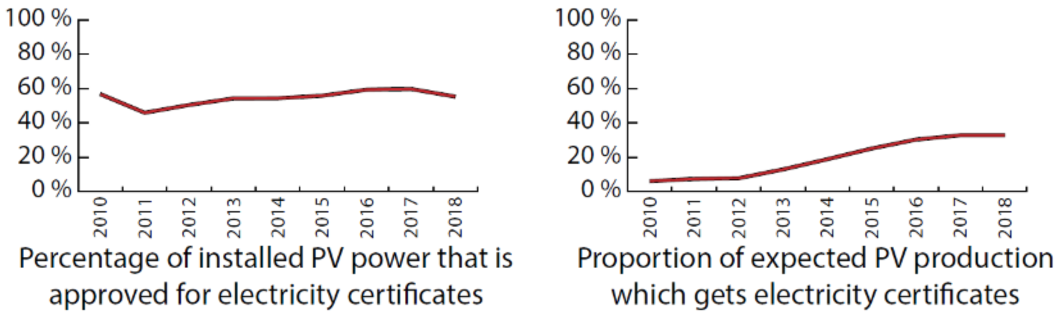

Figure 25: (a) Percentage of the installed PV power in Sweden that is approved for green electricity certificates [40]. (b) Allocated certificates to PV electricity divided by the theoretical yearly PV production [39].

Table 25: Statistics about PV in the electricity certificate system [39][40].

	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	Average size of PV systems in the certificate system at the end of each year	Number issued certificates from solar cells per year	Number produced certificates eligible kWh per installed power and year
2006	2	27 kW_p	13.5 kW_p	20 MWh	740 kWh/kW_p
2007	3	34 kW_p	11.3 kW_p	19 MWh	559 kWh/kW_p
2008	8	299 kW_p	37.4 kW_p	129 MWh	431 kWh/kW_p
2009	10	359 kW_p	35.9 kW_p	212 MWh	590 kWh/kW_p
2010	18	2 103 kW_p	116.8 kW_p	278 MWh	132 kWh/kW_p
2011	44	2 538 kW_p	57.7 kW_p	556 MWh	219 kWh/kW_p
2012	125	4 045 kW_p	32.4 kW_p	1 029 MWh	254 kWh/kW_p
2013	462	11 387 kW_p	24.6 kW_p	3 705 MWh	325 kWh/kW_p
2014	1 124	24 697 kW_p	22.0 kW_p	10 770 MWh	436 kWh/kW_p
2015	2 553	49 521 kW_p	19.4 kW_p	24 544 MWh	496 kWh/kW_p
2016	4 331	84 629 kW_p	19.5 kW_p	45 535 MWh	538 kWh/kW_p
2017	6 428	133 372 kW_p	20.7 kW_p	74 148 MWh	556 kWh/kW_p
2018	9 328	195 612 kW_p	21.0 kW_p	120 916 MWh	618 kWh/kW_p

Only 226.9 MW_p of PV power were at the end of 2018 accepted in the certificate system [40], making it only 55 % of the total installed PV grid connected capacity. As Figure 25a shows, that share has been rather constant over the years.

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 25 and why only 120 916 certificates were issued to PV in 2018 [39]. This is only about 33 % of the theoretical production of 411 $MW_p \times 900\ kWh/kW_p \approx 370$ GWh from all grid-connected PV systems in Sweden. The reader should note that the calculation above is very simplified since the whole cumulative grid-connected PV power at the end of 2018 was not up and running throughout the whole year.

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, and the fact that the system is getting relatively larger and larger as the prices are going down, may be the reason for the clear trend in in Figure 25b and Table 25 where the share of the produced PV electricity that receives certificates is increasing.

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.

3.3.2 Guarantees of origin

Guarantees of origin (GOs), were introduced in Sweden the first of December in 2010, and 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 to 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.

The GO acts (2010:601) and regulation (2010:853) was changed the first of June 2017 to enable the Swedish Energy Agency to issue GOs for electricity that can be transferred to another EU Member State [41]. Meaning that the Swedish GO system now has been adapted to the EECS standard.

As a result of the new legislation and due to the increase of PV system the trading with solar GOs in Sweden increased dramatically, as can be seen in Table 26. In 2017 a lot of solar GOs was imported to Sweden, and in 2018 a lot of them was exported.

Table 26: Statistics about solar guarantees of origin [39].

	Solar GOs issued in Sweden	Solar GOs transferred within Sweden	Solar GOs imported to Sweden	Solar GOs exported from Sweden	Solar GOs nullified in Sweden	Solar GOs that expired in Sweden
2011	194	96	-	-	0	0
2012	378	173	-	-	104	90
2013	2 337	1 373	-	-	324	294
2014	7 846	4 563	-	-	1 510	972
2015	18 953	11 301	-	-	5 314	2 830
2016	36 702	22 183	-	-	11 966	9 454
2017	58 806	65 936	1 481 437	69 279	96 442	16 146
2018	111 143	1 306 626	568 810	1 467 852	317 167	29 499

The trading volumes of solar GOs are still too small in Sweden for the system to really generate an actual market price. But according to Svensk Kraftmäkling (SKM), the largest brokerage firm in the Nordic electricity market, Solar GOs are in 2019 general traded for in Europe for 60 €-cents/MWh, which would translate the value 0.006 SEK/kWh. However, some Swedish utilities buy solar GOs issued in Sweden from small-scale PV owners for a much higher price.

3.4 Self-consumption measures

Self-consumption of PV electricity is allowed in Sweden and is the main business model that is driving the market. 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 has been going on, 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 27: Summary of self-consumption regulations for small private PV systems in 2018.

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 & Renewable Levies	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 (virtual self-consumption or metering)	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…)	Storage investment subsidy
	11	PV system size limitations	1.Below 43.5 kWp and 63 A, and net-consumer on yearly basis, for free feed-in subscription towards the grid owner. 2.Below 100 A and maximum 30 MWh/year for the tax credit. 3.Below 255 kWp for no energy tax on self-consumed electricity.
	12	Electricity system limitations	None
	13	Additional features	Feed in compensation from the grid owner

3.4.1 Tax credit for micro-producers of renewable electricity

The 1 of January 2015, an amendment to the Income Tax Act was introduced [42]. 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 within 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 Figure 15), the grid benefit compensation (see section 3.4.6) and revenues for selling green electricity certificates and guarantees of origins (see section 3.3.1 and 3.3.2). The tax credit system can be seen as a feed-in premium for the excess electricity. However, unlike the case in other European countries, the Swedish tax credit system does not offer a guaranteed revenue 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, increased or decreased by a political decision.

According to the Swedish Tax Agency 20 128 micro-producers of renewable electricity received a total 55 558 705 SEK for excess electricity fed into the grid in 2018. This amount is based on 93 234 MWh of excess electricity fed into the low voltage grid by micro producers, reported by the grid operators to the Swedish Tax Agency. The average production fed into the grid by micro-producers that had capacity of less 100 amperes was thereby 4 632 kWh in 2018. How these number has developed since the start in 2015 are summarized in Table 28.

Table 28: Statistics about tax credit for micro-producers.

Year	Number of micro-producers	Paid funds each year [SEK]	The basis (excess electricity) of the tax reduction [kWh]	Average electricity fed into the grid per micro-producer [kWh/micro-producer]
2015	5 390	11 413 785	18 831 690	3 494
2016	7 721	18 666 393	31 382 195	4 065
2017	11 752	29 240 575	48 735 443	4 147
2018	20 128	55 558 705	93 234 015	4 632

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 69 kW_p that was installed before 2018-12-31 the total power becomes 153 654 kW_p. Of this power 148 210 kW_p was PV, and the rest was 2 327 kW_p wind, 2 207 kW_p hydro and 910 kW_p biofuel or peat system [40]. If one uses this relationship, a rough estimation is that 110 809 000 SEK of the total 114 879 458 SEK has been paid to PV system owners through the tax credit for micro-production system until the end of 2018. This calculation is just a rough estimation since both the total produced electricity in a year and the self-consumption ratio differ between the different renewable energy technologies and between all the individual production facilities.

3.4.2 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 3.10.7), taxes on fuels, taxes on emissions to the atmosphere and tax on nuclear power.

The taxes associated with electricity consumption are mainly the energy tax on electricity and the related value added tax (VAT). The manufacturing and agriculture industry paid

0.005 SEK/kWh in energy tax in 2018. The Energy tax rate has been increased in steps for residential customers the last couple of years after the Swedish Energy Commission (see section 3.1) decided to remove the specific tax on nuclear and finance that with a higher energy tax [27]. The latest increase occurred the first of January 2019 when the energy tax was increased from 0.325 SEK/kWh (excluding VAT) to 0.347 SEK/kWh the first of January 2019. The exception is some municipalities in northern Sweden where the energy tax now is 0.251 SEK/kWh (excluding VAT) [43]. Additionally, a VAT of 25 % is applied on top of the energy tax. Altogether, roughly 41 % of the total consumer electricity price (including grid fees) was taxes, VAT and certificates in 2018.

3.4.3 Energy tax on self-consumption

There has been an ongoing modernization of the Swedish tax rules when it comes to taxation on self-consumed electricity. The current rules, which was implemented the 1st of July 2017, can be can be summarized as [43]:

- A solar electricity producer that owns one or more PV systems whose total power amounts to less than 255 kW_p power does not have to pay any energy tax for the self-consumed electricity consumed within the same premises as where the PV systems is installed.
- A solar producer that owns several PV systems, whose total power amounts to 255 kW_p or more, but where all the individual PV systems are smaller than 255 kW_p, pays an energy tax of 0.005 SEK/kWh on the self-consumed electricity consumed within the same premises as where the PV systems is installed.
- A solar producer that owns a PV system larger than 255 kW_p pays the normal energy tax of 0.347 SEK/kWh on the self-consumed electricity consumed within the same premises as where the PV systems is installed, but 0.005 SEK/kWh in energy tax for the self-consumed electricity from the other systems if they are less than 255 kW_p.

The current legislation has the effect that few PV systems over 255 kW_p are built for self-consumption in Sweden. The full energy tax on self-consumed electricity limits the profitability for those systems. This leads to that the large technical potential of PV systems within the industrial sector currently is unexploited.

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

But there is an ongoing discussion on how to tax self-consumption, and it is not unlikely that changes to this legislation will take place in the near future. One positive prospect in this matter is that the government has declared their purpose to remove the 0.005 SEK/kWh energy tax for real estate owners that own several small systems, and thereby remove the administrative barrier, by sending in a state aid notification to the EU Commission [44].

3.4.4 Deduction of the VAT for the PV system

Sweden has a non-deductible VAT for permanent residence. The possibility to deduct the input VAT for a PV system therefore depends on whether all produced electricity is sold, or if a portion of the generated electricity is consumed directly for housing and only the excess electricity is sold to an electricity supplier [45].

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.

3.4.5 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 3.4.6). If the total renumeration from the property (including other revenue streams than selling excess electricity) under a tax year exceeds 30 000 SEK, excluding VAT, the house 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 26). If the total annual sales do not exceed 30 000 SEK the PV system owner are exempted from VAT [46].

At a reimbursement from a 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_p. 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 the 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 has also reduced 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 26, it is a win-win situation for all parties as compared to before the 1st of January 2017.

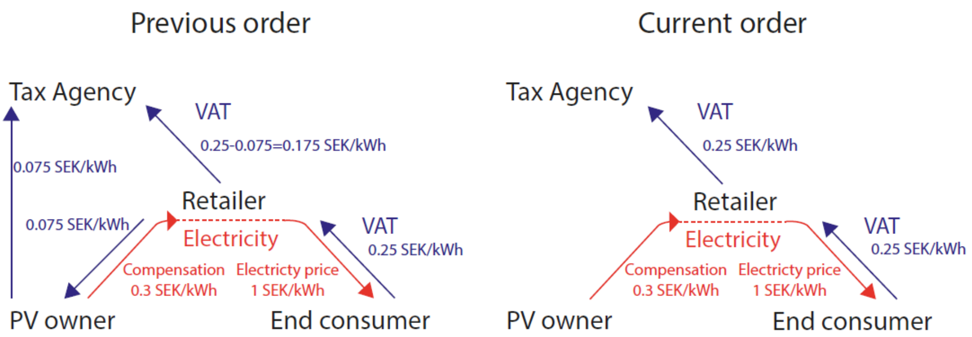

Figure 26. Illustration of the revenue and VAT streams for the excess electricity for a private PV owner before and after the 1st of January 2017.

3.4.6 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 [47]. The compensation varies between different grid owners and grid areas and is typically between 0.02 and 0.10 SEK/kWh.

3.5 Collective self-consumption, community solar and similar measures

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 Tenders, auctions & similar schemes

There were no national or regional tenders or auctions in 2018 in Sweden. However, commercial PPAs for PV exists in Sweden.

3.7 Other utility-scale measures

There were no specific national or regional measures for utility-scale PV in Sweden in 2018. The support and measures accessible for utility-scale PV are the general support schemes of the direct capital subsidy (see section 3.2.1), the green electricity certificate system (see section 3.3.1) and the guarantees of origin system (see section 3.3.2).

3.8 Social Policies

There were no social policy measures directed to PV in Sweden in 2018.

3.9 Retrospective measures applied to PV

There are currently no retrospective measures applied to any subsidies for PV in Sweden.

3.10 Indirect policy issues

3.10.1 Rural electrification measures

There were no rural electrification measures in Sweden in 2018.

3.10.2 Exemption for building permits for solar energy systems

As from the first of August 2018 PV and solar thermal system installations on buildings are exempted from building permit in general. Some installations still require building permits, and that is when the one of following situations applies [48]:

- When the PV or solar thermal system does not follow the shape of the current building.
- When the PV or solar thermal system is installed within a residential area that is classified as valuable from either a historical, cultural, environmental or artistic point of view.
- When the PV or solar thermal system is installed within a residential area where the municipality in the detailed development plan defined that building permits are required for solar systems.
- When the PV or solar thermal system is installed within an area that are of national interest for the military. Maps over these areas are located can be found here.

In these cases, a regular building permit must be submitted to the municipality.

This newly implanted change in the law lessen the administrative burden for many PV installations, and in some cases reduces the overall cost as several municipalities charge about 1000–8000 SEK for the building permit administration.

3.10.3 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 owned by private households. The subsidy is given for energy storages that fulfil these criteria's [49];

- 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 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 3.10.6) 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 installation work. The subsidy is only granted to private persons with a maximum of 60 % of the eligible costs, but no more than 50 000 SEK [49].

For other end customers than private households, that want to invest in PV with storage, the storage can be included in the overall system cost in the regular direct capital subsidy for PV (see section 3.2.1)

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 to 2019. However, the budget for this subsidy has not been used in any single year and the total disbursement of funds, since the start in 2016, was at the time of writing this report 14 947 44 million SEK [50].

3.10.4 Support for electric vehicles

3.10.4.1 The Bonus-Malus systems

The Bonus Malus system was introduced the 1st of July 2018 to replace the existing system of five-year tax exemption for vehicles classified as a green vehicle.

The main cause for the new law was to increase the share of vehicles with low carbon footprint and to lower the dependency of fossil fuels in the fleet of vehicles. For cars and light trucks taken into use from the 1st of July 2018, a private individual can get up to 60 000 SEK as a capital subsidy. For every gram carbon dioxide per kilometre the vehicle emits the bonus is reduced by 833 SEK. The lowest bonus is 10 000 SEK at 60 gCO_2/km and from there the bonus ceases. Furthermore, the maximum bonus cannot exceed 25 percent of the vehicles' price [51].

A company can also get a bonus. However, for companies the is up to 35 percent of the price difference between the price of the low emitting vehicles' price and the price for the closest comparable vehicle [52].

For petrol- and diesel-powered vehicles, an increased vehicle tax (malus) is added for the first three years. The tax increase is based on how much carbon dioxide the vehicle emits. If the vehicle emits 96-140 gCO_2/km the tax increase is 82 SEK per gram carbon dioxide emitted per kilometre. If the vehicle emits more than 140 gCO_2/km the tax increase is 107 SEK per gram carbon dioxide emitted per kilometre. From year four the tax is 22 SEK per gram carbon dioxide emitted per kilometre if the vehicle emits more than 111 gCO_2/km [51].

For 2019, there is 1.24 billion SEK allocated for the bonuses and it's administered by the Swedish Transport Agency [53].

3.10.4.2 Subsidies for charging infrastructure

To favour the development of the electrical vehicle market it is important to create a liable charging infrastructure. In 2015 a capital subsidy (Klimatklivet) was established aimed to support local and regional investments that lower carbon dioxide emissions. The grant is administered by the Swedish Environmental Protection Agency (Naturvårdsverket) and can be applied by everyone besides private individuals. Investments in charging infrastructure is one of the types of projects that can be subsidised. Since 2015 to 2018, 2108 charging infrastructure projects have been granted adding up to 448.39 MSEK [54].

The grant is up to 50 percent of the eligible costs [55]. Eligible costs are the costs needed to achieve the objectives of the project. A basic requirement for the cost to be eligible is that it must be necessary for the implementation of the project.

From 2015 the applications for Klimatklivet could be granted for charging infrastructures for both public and private use. But in 2019 another type of grant was established for charging infrastructure for private persons [56]. The capital subsidy for private charging infrastructure is also administrated by the Swedish Environmental Protection Agency (Naturvårdsverket) but will no longer be a part of Klimatklivet. This new subsidy program was implemented to make the application procedure easier. The capital subsidy is up to 50 percent of the eligible costs, however, there is a maximum of 15,000 SEK per charging point. Eligible costs are the material and labour costs that are needed to install the charging point, such as the cost for the charging box and for the electrical wiring. Costs that has received any other public support do not qualify as eligible costs [56].

In December 2017 the government decided to implement a grant for investments in charging infrastructure for electrical vehicles. The grant (Ladda-hemma) is only given to private individuals and the charging point must be installed on a property that the applicant owns [57].

The grant is up to 50 percent of the eligible costs, however, there is a maximum of 10,000 SEK per property. Eligible costs are the material and labour costs that are needed to install the charging point, such as the cost for the charging box and for the electrical wiring. Labour costs that have received the ROT tax deduction (see section 3.9.5) or any other public support do not qualify as eligible costs [57].

In the autumn budget for 2019 the government increased the budget for the three grants with 750 million SEK, adding up to a total of 1.5 billion for 2019. It is not yet known how the allocation will be divided between them.

3.10.5 Curtailment policies

There were no rules when it comes to curtailment of renewable electricity in Sweden in 2018.

3.10.6 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. Reparations 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 [58].

The ROT-tax deduction in 2018 was 30 % of the labour cost and of maximum 50 000 [58] 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.

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 2018. If it can be proved that the labour costs constitute a higher proportion than 30 %, the total deduction then consequently becomes higher.

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.

3.10.7 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 [59].

A Governmental investigation from 2016 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 [60], however the government has so far not finalized this change.

3.11 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 1 395 762 137 SEK has been disbursed from 2009 to the end of 2018 (see section 3.2.3). 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 to 2018 granted a total support of 8 928 597 SEK to PV systems (see section 3.2.4). This system is financed by the European Agricultural Fund for Agricultural Development (EJFLU), meaning the funding comes from the European Union.

Furthermore, PV systems have benefited from the green electricity certificate system and had at the end of 2018 received a total of 281 876 certificates over the years. By taking the monthly average prices for the certificates and multiplying 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 2018 becomes 43 503 583 SEK [39]. 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 110 809 000 SEK (see section 3.2.7) have been paid to small scale PV system owners through the tax credit for micro-producers of renewable electricity subsidy under 2015– 2018. This subsidy financed by the Swedish state budget.

Adding all the above subsides the Swedish PV market had at the end of 2018 in total received about 1 702 million SEK in direct subsidies. This corresponds to roughly 166 SEK/capita in total as from 2005 to the end of 2018.

4 HIGHLIGHTS OF R&D

4.1 PV research groups

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.

Table 29. Research groups in Sweden that conducts research on either PV or battery related topics.

Research group name	Research topics	Estimated number of full-time jobs in 2018
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	0
Chalmers, Chemical physics	Surface physics and catalysis by advanced calculation methods	2
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	5
Chalmers, Chemistry and Chemical Engineering	Organic solar cells	5
Chalmers, Condensed Matter Physics	Battery research	18
Chalmers, Electrical Engineering	Studies and modelling of PV systems integrated to the grid and simulations of the campus system	1
Chalmers, Molecular Materials, Moth-Poulsen Research Group	Design and synthesis of new self-collecting materials based on molecules and nanoparticles	4
Dalarnas University, Center for Solar Research	System research, PV and heat pump smart systems, micro-systems smart grid business models	5
Karlstads University, Molecular Materials for Electronics	Polymer-based, perovskite and hybrid solar cells	6
Karlstads University, Characterizing and Modeling of Materials	Multi crystalline silicon solar cells	7
KTH Royal Institute of Technology, Applied Thermodynamics and Refrigeration	PV system in Swedish housing association	4
KTH Royal Institute of Technology, Concentrating Solar Power and Techno-economic Analysis	Techno-economic analyses, design and experimental verification for CSP	5
KTH Royal Institute of Technology, Electric Power Systems	Power grid control at coordinated input of PV electricity	1
KTH Royal Institute of Technology, Energy and Climate Studies	The distributed PV market in Sweden	3
KTH Royal Institute of Technology, Material and Nanophysics	Direct III-V/Si heterocycle for solar cells and silicon-based tandem cell	3

Linköping University, Biomolecular and Organic Electronics	Plastic solar cells	15
Linköping University, Chemistry and Biology	Cubic silicon carbide as light emitting material	1
Linköping University, Organic Electronics	Solar heat-charged super capacitor as energy storage	13
Luleå University of Technology, Electric Power Engineering	Stochastic planning of smart electricity distribution networks	4
Luleå University of Technology, Experimental Physics	New nanomaterials for third generation solar cells	12
Lund University, Chemical Physics	Dye-sensitize and plastic solar cells, semiconductor nanowires and organometal halide perovskites	12
Lund University, Energy and Building Design	Social issues with regards to solar energy, urban planning and building design	1
Lund University, International Environmental Institute	Social studies of private persons barriers and motives for PV investments	2
Lund University, Nanolund	Tandem transitions in nano threads, Intermediate band gap solar cells and piezoelectric solar cells	4
Lund University, Polymer & Materials Chemistry	Nano-structured materials for higher PV efficiency	2
Mid Sweden University, Electronic Construction	Converters and supercapacitor	4
Mid Sweden University, Fibre Science and Communication Network	Lithium-ion batteries and solar cells of paper	8
Mälardalen University, Future Energy Center	Efficient distribution of energy	4
RISE, Agrifood and Bioscience	PV in agriculture applications	0
RISE, Glas	Module glass research	1
RISE, Research Institute of Sweden AB	Testing of PV components and systems	15
Swerea IVF	Dye-sensitized solar cells and implementation of PV in real estates	1
Umeå University, The Organic Photonics and Electronics Group	Photonic and electronic devices based on novel organic compounds and perovskite solar cells	1
Uppsala University, Built Environment Energy Systems	PV grid integration studies and modelling of; PV systems, building systems, self-consumption and solar-powered transports	8
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	70

4.2 Public budgets for PV research

The majority of the Swedish government's funds to PV research are distributed by the Swedish Energy Agency (Energimyndigheten), which is tasked with leading the energy transition 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).

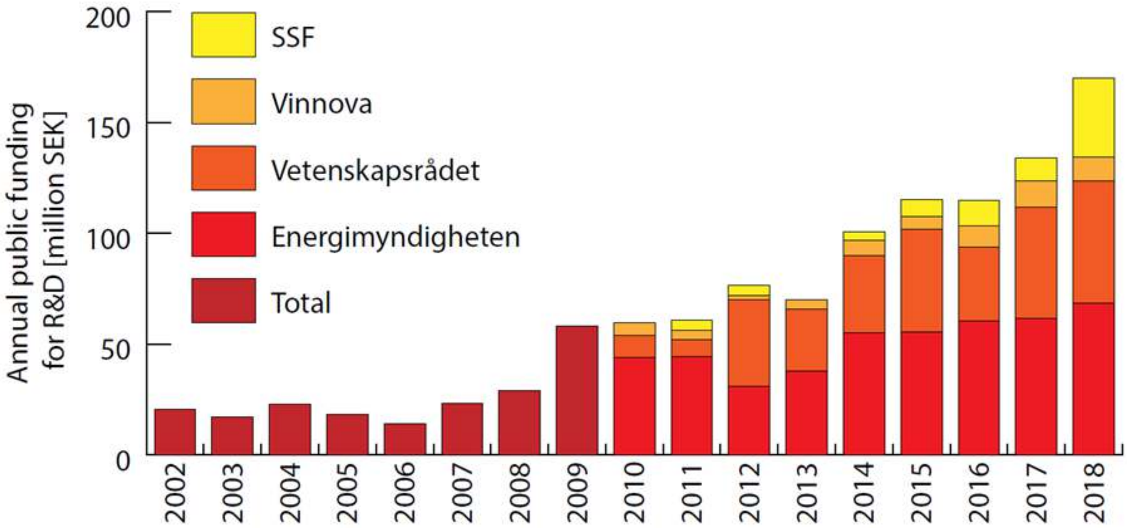

Figure 27: Annual public funding for PV related R&D in Sweden.

In addition to the public funding for R&D presented in Figure 27 the Swedish Energy Agency also distributed conditional loans for PV related technological and business development. In 2018, 3.7 million SEK in such loans were issued.

5 INDUSTRY

The Swedish PV industry mainly contains of small to medium size installers and retailers of PV modules or systems. At the writing of this report the author was aware of 282 companies that sold and/or installed PV modules and/or systems in the Swedish market (see section 5.6) in 2018. There were also 13 companies active in manufacturing of production machines or balance of systems equipment (see section 5.4) in Sweden in 2018. Furthermore, the author was aware of 13 companies that can be classified as R&D companies, or companies that had R&D divisions in Sweden (see section 5.5) in 2018. Since the bankruptcy of SweModule 2015 only very small volumes (< 1 MW) of PV module production has been taken place in Sweden. (see section 5.3).

5.1.1.1 Svensk Solenergi

Svensk Solenergi is a trade association which, with about 260 professional members, representing 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 is still 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 feedstocks, ingots and wafers (crystalline silicon industry)

Sweden did not produce any feedstock or wafers in 2018 and there are currently no plans for this kind of production in the future.

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.

Total PV cell and module manufacture together with production capacity information is summarised in Table below.

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, who bought the production equipment and the brand SweModule, and Misummer AB did produce some commercial modules as part of their product development in 2018, which amounted to 0,2 MW_p in total. This was the only module production that took place in Sweden in 2018. However, both SweModule And Midsummer has announced plans to produce larger quantities in 2019.

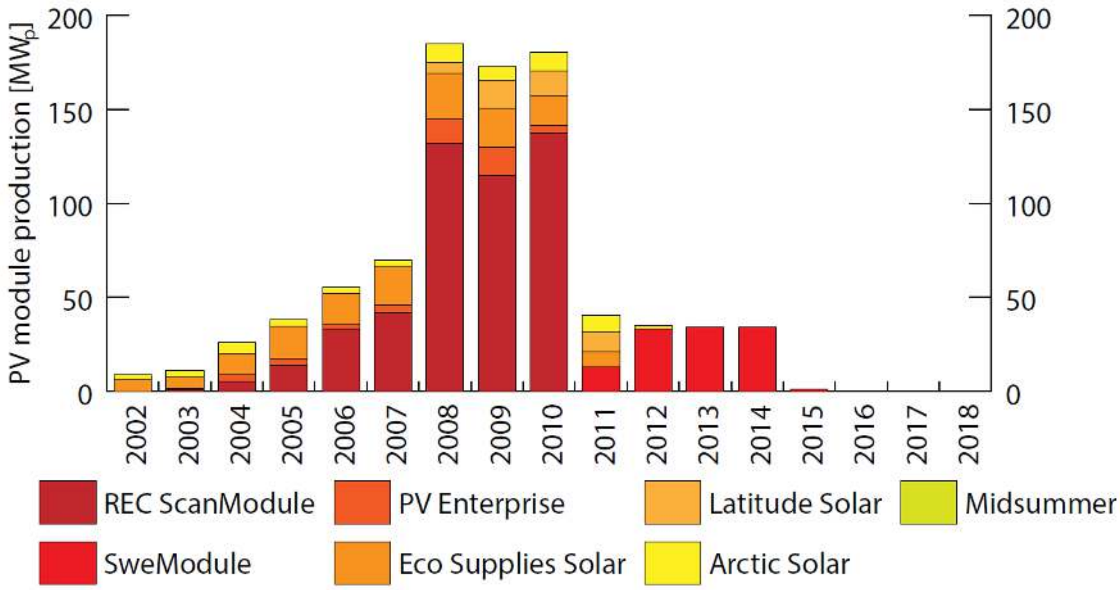

Figure 28: Yearly PV module production in Sweden over the years.

Table 30: PV cell and module production and production capacity information for 2018.

Cell/Module manufacturer	Technology	Total Production [MW$_p$]		Maximum production capacity [MW/yr]	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
SweModule	Mono-Si	-	0.1	-	100
Thin film manufacturers					
Midsummer	CIGS	0.1	0.1	5	5
Cells for concentration					
None	-	-	-	-	-
Totals		**0.1**	**0.2**	**5**	**105**

5.3.1.1 Midsummer AB

Midsummer is a supplier of equipment for manufacturing of CIGS thin film flexible solar cells as well as a developer and producer of thin film solar panels. As their main activity is to produce PV manufacturing equipment, they are further described under the section 5.4.

5.3.1.2 SweModule

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 in 2016 and in 2017 the equipment was upgraded to be able to produce monocrystalline modules with four- and five-busbars. Under 2018 the certification process of their four- and five-busbars modules was finalised and the factory is now ready to produce larger quantities. During 2016, 2017 and 2018 small quantities of approximately 100, 250 respective 500 modules was produced to test the equipment. In the spring of 2019, the company produced about 1000 modules for the Swedish PV market.

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 first moved their O&M production of modules to a factory in Poland, but since the beginning of 2017 almost all of Windons modules are produced in a production facility in northern Italy by Windons own staff. In addition to the module production the company also produces mounting material and inverters (see section 5.4.1.13).

5.4 Manufacturers and suppliers of machinery or balance of system 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 135 000 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.

In 2013 the ABB group acquired the inverter company Power One and are now selling the inverters under an ABB brand. The distribution of ABB inverters on the Swedish marked accelerated towards the end of 2017.

5.4.1.2 Checkwatt AB

Emulsionen Ekonomiska Förening has for many years been 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 3.3.1) for the self-consumed electricity as well. The system sits directly by the solar or wind power inverter and reports the gross production for allocation of certificates. In 2017 the consultant company Emulsionen placed their metering concept in the newly formed Checkwatt AB so that this company could solely focus on the metering business.

The actual meter of Emulsionen/Checkwatt is manufactured in China, but the company assembles the data logger in Sweden. In total Emulsionen/Checkwatt has sold about 2000 meters over the years. Of these around 800 was sold under 2018. Under 2017 Checkwatt also developed their product so that the meter and the IT system now are compatible with the data that the grid operator have and to data provided by solar radiation sensors. Among other services, Checkwatt offers; Power meters – MID-certified with gateway communicating with cloud server and associated visualisation and monitoring services, management of Green Electricity Certificates and Guarantees of Origin as a service for renewable electricity producers, equipment for sensor and system integration services, data collection from DSO of client’s electricity production and consumption, solar irradiance sensors for precise solar photovoltaics system evaluation and Solmolnet – tailor made IT system providing data management of metering and photovoltaics solar production for electricity retailers.

5.4.1.3 Comsys

PV modules produces DC current, which in traditional systems is converted via inverters to AC current. The AC current is in most installations later converted back to DC to run different applications such as lighting systems, servers, routers etc. Comsys, formerly Netpower Labs, is a company that develops DC-based backup power systems for data centres and tele-/datacom systems. They have developed hardware and a concept with DC-UPS systems with integrated PV regulators for running servers and lighting systems directly on DC current without conversions, thereby reducing the losses significantly.

The production of the components takes place in Sweden at two locations, Malmö and Söderhamn. The interest in DC current powering data centres, commercial buildings and lighting systems are increasing, which probably will mean that interest of using PV in these kind systems will be become more and more attractive. Comsys have installed the DC power system in more than 25 data centres and commercial buildings since 2011, of which 10 have integrated PV.

5.4.1.4 Ferroamp Elektronik AB

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

In 2014 Ferroamp reached a milestone as they started series shipment of the EnergyHub ACE system for energy efficiency, hence going from a solely R&D company to a production company. In the end of 2015 Ferroamp released its PV solar and energy storage solutions. 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. 2018 started with a listing on Global Clean Tech top 100 list for game changing technologies and in June, Ferroamp won the 2018 Intersolar Smarter E Award for its PowerShare technology. PowerShare allows buildings to share PV solar, energy storage and EV charge control via a local DC grid. Benefits include increased self-consumption, better utilization of energy storage and the potential to create Local Energy Communities with controlled energy flow.
Ferroamp currently has 15 such DC grids in operation in Sweden. The company has installed over 600 systems to date ranging from small residential systems to larger commercial facilities with integrated PV solar up to 168 kW and Energy Storage of 230 kWh.

5.4.1.5 MAPAB

MAPAB (Mullsjö Aluminiumprodukter AB) manufactures aluminium structures for the assembly of PV modules. The company provides solutions for mounting on roofs, facades or the ground. Previously, most of the production was exported to the European market, but in 2012 MAPAB started to deliver more to the growing Swedish PV market and in 2017 approximately 98 % of their mounting products were sold in Sweden. In 2017 MAPAB also started to produce and sell PV module frames for export.

5.4.1.6 Midsummer AB

Midsummer is a supplier of equipment for manufacturing of CIGS thin film flexible solar cells as well as a developer and producer of thin film solar panels.

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.

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 16.4 % total area efficiency on solar cells made in normal production at a customer site in Asia. In 2016-2018 Midsummer, has secured multiple orders for their DUO thin-film solar cell sputtering tool and have delivered several machines to Asia. Midsummer's customers are mainly focusing on the BIPV-market and especially the roof-top segment.

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.

In recent years Midsummer has developed its business to also include an interesting range of thin film solar panel products. In 2018 Midsummer launched Midsummer solar roofs, which are long CIGS modules integrated directly onto regular standing seam metal roof. Midsummer has also bought a sheet metal production line which they will ramp up under 2019. The thin film solar panels as well as the production of sheet metal, with or without solar cells, for roof applications will take place in Järfälla and the main market will be Sweden.

Midsummer continuously develops new customer applications for its thin film solar panels. The latest addition in the product portfolio is Palema SunWave, a Midsummer flexible solar panel that follows the wave shape of Sweden's most popular roof tile, Palema from the supplier Benders. This product will also be produced at the factory in Järfälla.

In addition to the above Midsummer sell 60-cell thin film CIGS solar panels for applications on membrane and metal roofs. Typically, these are installed on factories or warehouses which usually can't handle the weight of conventional panels in countries which don't get snow during the winter. Another popular market is that for sport halls and arenas.

5.4.1.7 Nilar 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. 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 collaborates with one of Sweden's major wholesale companies, Celltech, with the aim to sell batteries in combination with PV. Right now, the Swedish market is just marginal one for Nilar. The major markets for the company are the major PV markets in Europe and in 2019 Nilar further expanded their sales to Italy. To meet the high customer demand Nilar scaled up the production and in 2018 added the first of multiple automated production line to their factory.

Nilar together with Stockholm University has developed a method for multiplying the life of its Nilar Hydride® batteries. Normally, in a hydride battery, the water-based electrolyte is consumed by the metal hydride in one of the electrodes, but the new design for Nilar Hydride® batteries makes it possible to add oxygen that causes new electrolyte to form and restores the internal electrode balance. With the right balance of oxygen and hydrogen, Nilar batteries can reach a lifetime that surpasses other corresponding battery technologies. Nilar plans to launch the new patented technology for the Nilar Hydride® batteries in 2019.

5.4.1.8 Northvolt

Northvolt was founded in 2015 under the name SGF Energy. In 2017 Northvolt announced its plan to build Europe's largest lithium ion battery factory with an annual production of 32 GWh. In the beginning of 2018, the cell design team developed Northvolt's first test cell and in august the battery system team delivered Northvolts first product.

In April 2018, after attaining several industrial partnerships, a grant from the Swedish Energy Agency and a loan from the European Investment Bank, Northvolt started the construction of Northvolt Labs, a demonstration line and research facility, in Västerås, Sweden. Northvolt received an environmental permit for the battery factory Northvolt Ett in Skellefteå and started building the factory's first part with a production capacity of 8 GWh. It is expected to be operational in 2021. During 2018 Northvolt also began establishing a new facility in Gdansk, Poland, for battery system assembly.

In the beginning of 2019 Northvolt produced its first prismatic cell in a temporary R&D facility and in April 2019 Northvolt Battery Systems assembled its first stationary energy storage unit, Voltrack.

5.4.1.9 Sapa Building Systems AB

Sapa has for long been producing aluminium mounting systems for doors, windows, glass roofs and glass facades. Most of the production are situated in Vetlanda, Sweden. In 2015 the company initiated a collaboration with the BIPV product and installation company SolTech Energy Sweden AB and Sapa are now producing aluminium profiles for BIPV solutions.

5.4.1.10 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 and Ethiopia. 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 500 systems from the start, of which about 200 systems were sold in 2018.

5.4.1.11 Swedish Box of Energy AB

Swedish Box of Energy was a battery technology provider that has specialized on battery systems for PV and wind production. The company filed for bankruptcy in the beginning of 2018. For further information about the company's previous business, please check older versions of the Swedish National Survey Report.

5.4.1.12 *Weland Stål AB*

Weland Stål in Ulricehamn manufactures a range of roof safety products. In the last years, the company has experienced a growing interest in their products from the Swedish PV market. In the wake of this Weland Stål developed a new line of attachment parts for mounting solar panels on roofs in 2014. The production is situated in Ulricehamn and the products have so far only been sold at the Swedish market, but since 2017 some products have been exported to Norway.

5.4.1.13 *Windon AB*

Windon AB has developed their own mounting materials which they produce in the Swedish town Tranås.

In 2014 Windon also started to develop inverters with an individual capacity range of 1–20 kW_p. These inverters were started to be manufactured in 2016. Approximately 300 units was sold in 2016, 300 in 2017 and 700 in 2018. The parts for the inverters come from all over the world but are assembled at an O&M production facility in China. However, Windon plans to move the assembling of the inverters to Tranås as soon as the annual quantities reaches around 1000 units.

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 2017 the model achieved a world record for a small parabolic trough with an optical efficiency of 71.61 % and in the beginning of 2019, it became the first sun tracking solar collector with the Solar Keymark certification. Absolicon sold a fully automated production line for the thermal power generations system in the Sichuan-province in China and at the same time the company built a similar automated production line in Härnösand, Sweden, both finished during 2018. Besides this, Absolicon installed a system in a factory in Athens, installed a system integrated with the local district heating system in Graz, Austria, and in 2019 the company will install two pilot plants in Kenya.

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, manufacturing equipment and characterization equipment for research and production of chemistry-based solar technologies, primarily dye-sensitized solar cells, perovskite solar cells and solar fuels. Parallel to this, the company coaches their customers on their way to optimum device-chemistry, processes and/or strategic decision-making. Dyenamo is part of the ESPRESSO consortium, which has been granted a three-year EU-funded Horizon 2020 project on perovskite solar cells.

5.5.1.3 *Eltek Valere AB*

Eltek is a strategic technology partner for power solutions. The company is a global leader in telecom power including solar solutions for remote areas with installations all over the world. Eltek also has a range of flexible and modular PV solutions, scalable to meet any micro-grid requirement in an off or poor grid environment. As a part of the Delta group, Eltek also has a wide range of grid tied string and central inverters. 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/m2, which indicate that the production and transportation costs will be very low. The cells have today a conversion efficiency about 1 % which proves the manufacturing process. In research, these types of cells have reached 10 %, which show the future potential. During 2017 the company raised enough funding's to start building an industrial production line, and it was done in 2018. Their first product is a small module that harvests indoor lighting and are optimized for eliminating or extending battery lifetime in consumer electronics. The plan is to start selling the modules during 2019.

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 be 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 *Peafowl Solar Power AB*

Peafowl Solar Power is a spin-off company from Uppsala University developing a new kind of plasmonic solar cell technology. The solar cells are highly transparent and suitable for outdoor and indoor usages. The current focus is on design of manufacturing processes, establishment of industrial partnerships and on product development together with pilot customers. During 2019 Peafowl Solar Power started collaborating with ChromoGenics to test if their solar cells can power the ChromoGenics dynamic glass.

5.5.1.7 *Samster AB*

Samster has developed a so-called hybrid panel, which is a panel that supplies both electrical and thermal energy. The product consists of solar thermal pipes under a regular PV module. Samster is using the Windons modules and the thermal pipes are produced by the Swedish solar thermal company Asoluna AB. Samster is responsible for the development of the product and the sales. The PV/T panels are optimal for hybrid systems, reinforcing poorly functioning geothermal heating systems, this lowers the electricity consumption while prolonging the life span of the geothermal heat pump.

5.5.1.8 *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 700-800 PV/T modules in 2017. In total, the plant has a production capacity of 30 000 modules per year. During 2017 the PV/T module stared a testing process at TÜV and Solarus Sunpower started installing their PV/T solar systems on several hotels in South Africa. The systems perform according to expectations and in some cases even better than expected.

5.5.1.9 *Solibro Research AB*

The CIGS thin film solar cell company Solibro started as a spin-off company from Uppsala University and there is still a close collaboration between the company and the university. Solibro was in September 2012 acquired from Q-cells by Hanergy, a Chinese group focused on power production (hydro, wind as well as solar power) and sales of PV systems based on thin film modules produced within the group. Since September 2013 Solibro Research, situated in Uppsala, is owned by Hanergy Thin Film Power Group Ltd. 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. The construction of the factory was complete in 2017 and was commissioned in 2018. Meanwhile, in 2017, Hanergy started to convert seven existing module factories to the Solibro technology.

The task of Solibro Research AB is to further develop the Solibro technology. In 2014 the company achieved a new world record for the efficiency of a thin film solar cells of 21.0 %. Solibro beat its own internal record, in 2017, by producing a small-scale CIGS cell with a conversion efficiency of 22.9 %. During 2018 Solibros production headquarters in Thalheim, Germany set a new world record for a CIGS solar panel with an efficiency of 17.52 %, based on technology from Solibro Research. The record is verified by TÜV Rheinland.

In 2017 Solibro Research also started a new development project with perovskite solar cells and thin film tandem solar cells with a perovskite layer on top of a CIGS layer. During 2018 the research started reaching competitive levels.

Furthermore, Solibro Research AB has also developed a utility field mounting system as well as a 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 parent company, Hanergy, started selling a new power generation wall system solution in 2018 based on the technology developed by Solibro Research AB.

5.5.1.10 SolTech Energy Sweden AB

Stockholm based SolTech Energy Sweden is listed on Nasdaq First North and develops and sells three different BIPV products. The products are ShingEl, RooF and Façade. ShingEl and RooF are a type of a BIPV roof tile that has the same dimensions and specifications as Benders roof tile Carisma. The ShingEl and RooF tile, which feature CdTe thin film solar cells, can thereby in an aesthetic way be integrated in a regular tile roof. Façade is for BIPV facades. These three BIPV solutions are sold on the Swedish market through the company's subsidiaries Nyedal Solenergi, Swede Energy and NP-Gruppen. They are also distributed by Rexel and Kraftpojkarna.

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 China.

Another area of business for SolTech Energy is sales, marketing and installation of traditional PV systems. The company's major installation activities are this far in China, where they sold and installed about 69 MW_p until the end of 2018 through their joint venture company ASRE.

5.5.1.11 Sol Voltaics AB

Box of Energy was a company that developed methods of improving the efficiency of solar cells by the use of thin-film of nanowires. The company filed for bankruptcy in the beginning of 2019. For further information about the company's previous activities, please check older versions of the Swedish National Survey Report.

5.5.1.12 Sundaya Nordic AB

Sundaya Nordic AB is part of the Sundaya group, which is a company that develops, produces and sells micro-production systems and energy storage 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.

5.5.1.13 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. During 2017 the company started product testing together with partners to further test this materials ability to enhance the efficiency of silicon solar panel by being incorporated into coatings in and on silicon solar panels, reaching an enhancement of 4 % in panel efficiency so far. The company also further validated the potential of the material to enhance the efficiency of DSSC (dye sensitized solar cell) of up to 30 %. During 2018 Swedish Algae Factory built a large pilot facility of 300 m^2 producing diatoms in Kungshamn, Sweden.

5.6 Installers and retailers of PV systems

The list below contains all 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 2018, 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. On top of these companies there are several utilities that also offers turn-key PV systems to end consumers (see section 7.2), often in collaboration with one of the companies in the list below. If the reader knows of any other active company, please contact the author at: johan.lindahl@ieapvps.se

24 Volt	2electrify	ABB
AddSolar	Agera Energi	Agronola
Air By Solar Sweden	Aktea Energy	Aktiv Sol i Nöbbele
Albinsons Energicenter	Alcasol Nordic	Alfa SolVind i Skåne
AM Villabutiken	APM Avesta Persienn & Markis	Apptek Teknik Applikationer
Artic Sunlight Innovation	ATI's Elinstallationer	Atlas Solenergi
Attemptare	Awimex International	Baltic Suntech
BayWa r.e. Scandinavia	Bengt Dahlgren	Better Solar Nordic A/S
Bevego Byggplåt & Ventilation	Billesol	Brael Norden
Braxel Solutions	Bredsands El & Solteknik	Bråvalla Solteknik
Caverion Sverige	Ce-Ce Elservice	Cell Solar Nordic
Co2Pro	Comne Work	Consize
Dagö Entreprenad	Dalasolenergi	Dalecarlia Solel
Delglava	DT Energi	DT Micro Computer Systems
Echion	Ecoklimat Norden	EcoKraft Sverige
ECOscience	Effecta Energy Solutions	Ekologisk Energi Vollsjö
El & Energi i Skåne	El & Projektering	El av Sol Nordic
El-agenten i Skillingaryd	El-B-man El o Energiteknik	Electronic Technic LS
Electrotec Energy	Elektra	Elektroline i Kungsbacka
Elkatalogen i Norden	Elkontakten i Ale	Elproduktion i Stockholm
Elteknik i Bräcke	Elterm i Alingsås	Enable Energy Sve
Eneo Solutions	Energi & Innovation i Norden	Energi Solvind ESV
Energibanken	Energi-Center Nordic	EnergiEngagemang Sverige
Energiförbättring Väst	Energihem i Sverige	Energihuset i Vimmerby
Energiprojekt Stockholm	Energiteknik i Kungälv	Energy Effective Solutions
Enklare Husliv BIM	Enstar	Ergus El-Konsult
Ester Solar System	Etab Energi	Everöds Elbyrå
EWF ECO	EWS GmbH & Co. KG	Falu Solenergi
Fasadglas Bäcklin	FG Light Energy	Fire Mountain
Forsbergs VVS & Energiteknik	Franzén Energiteknik	Fronius Danmark Aps
Futura Energi	Fyrstads El	Gari EcoPower
Garo Elflex	GermanSolar Sverige	GFSol
Gisle Innovations	Gosol Energi	Gridcon Solcellsteknik
Grön Sol	Helio Solutions	HESAB
Highlands International	Holje-El	HPSolartech
HS Energi & Klimat	Höjentorps Solenergi	IATEK
IBC Solar	Implementa Sol	Incoord Installationscoordinator
INKA Energi	Iq Energi	Isacsson Pansol
JB EcoTech	JJ Solkraft	JN Solar
JoDatec HB	Johanneshovs El	Jöta El
KAMA Fritid	Kjells Elektronik & Digital-Tv	Klimatprojekt i Mälardalen
Knuttes El	Kopernicus	Kraftpojkarna
Krannich Solar	Kretsloppsenergi Kummelnäs	Krylbo Elmontage
K-Utveckling Engineering	KWh Sverige Bygg & konsult	Lambertsson Sverige
Laxviks El och Solpanel	Lego Elektronik	Levins Elektriska
Lorex	Lundgrens El	Lundgrens Elektriska

MagnusEnergy
Midsummer
Monier Roofing
Niro Solar
Nordens Solvärme
Nordic Solar Sweden
Northern-Nature-Energy
Orust Engineering
OX2 Distributed Solutions
Parkys Solar
PPAM Solkraft
Rejlers Sweden
RoslagsSOL-Forslund & Co
Rågård rör och teknik
Samvets Elteknik
Sell Power Nordic
Sol Eye
SolarClarity Group
Solarit
Solcellen
Solcellsmontörerna Sverige
Solelexperten Umeå
Solelsbyggarna
Solenergi i Undrom
SolensEnergi i Skåne
Solgruppen Norden
Solkatten
Solkraft i Viby
SolNord
Solteamet i Västerbotten
Solvision
Stockholm Solenergi
Sunavia
SunnyFuture
Sunwind Gylling
Sustainable Business Partner
Sweco Systems
Svenska Solenergigruppen
Svenskt Byggmontage
Södra Solteknik
Temagruppen
Vancos Munka Ljungby
Veosol Teknik
White Arkitekter
Windforce Airbuzz Holding
VOE Service
Vårgårda Solenergi
ÅF-Infrastructure

Measol
Miljö- VVS- & Energicenter
MR Service & Teknik
Norconsult
Nordh Energy Solar
Nordisk System Teknik
Nyedal Solenergi
OTM Eko Energi
Paneltaket
PE Teknik och Arkitektur
Prolekta Gotland
Rexel Sverige
Runsten El
Rådalens Energi
Save-by-Solar Sweden
SHS Gruppen
Solar Supply Sweden
SolarEdge Technologies Sweden
Solarlab Sweden HB
Solcellsbyggarna Boxholm
Soldags i Sverige
Solelgrossisten
Solenergi Göteborg
Solenergimontage i Sverige
Solexperterna Värmland
Soliga Energi
Solkompaniet Sverige
Solkraft TE
Solorder
SolTech Energy Sweden
Spindel
Sun of Sunne
SUNBEAMsystem Group
Sunroof
Susanna - Sustainle and Natural
Sustainable Energy Nordic
Swede Energy Power Solutions
Svenska Solenergiparker
Svesol Värmesystem
Söne El
Tröingebergs EL&VVS
Varmitek Energisystem
West El
Viessmann Värmeteknik
Windon
WOJAB
Värmekällan Väst
Åkerby Solenergi

MeraSol
Modern Miljöteknik i Varberg
NIBE Energy Systems WFE
Norden Solar
Nordic Energy Partner
Nordpolen Energi
Nästegården Energi
Otovo
Paradisenergi
Penthon Installation
Ramböll Sverige
Rigora
Rustabo Sverige
S:t Eriks
SEBAB
Sol & Byggteknik i Grythyttan
Solar Teknik Norden
Solarenergy Scandinavia
Solarwork Sverige
Solcellsgrossen
Select Power
Solelia Greentech
Solenergi i Nynäshamn
Solenergispecialisten i norden
Solfabriken Ugglum
Solinnovation i Värnamo
Solkraft EMK
Solkraftverket Norden
Solortus
Solvio
Spotscale
Sun4energy
Suncellhouse Solenergi
Sunsolutions
Susen
SVEA Renewable Solar
Sweden Sol
Svenska Solpanelmontage
Sydpumpen
Tellux
VallaCom
Watt-s
Wettersol
Villavind
WindSpace A/S
WSP Sverige
Yokk Solar
Östgöta Solel

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 just estimations.

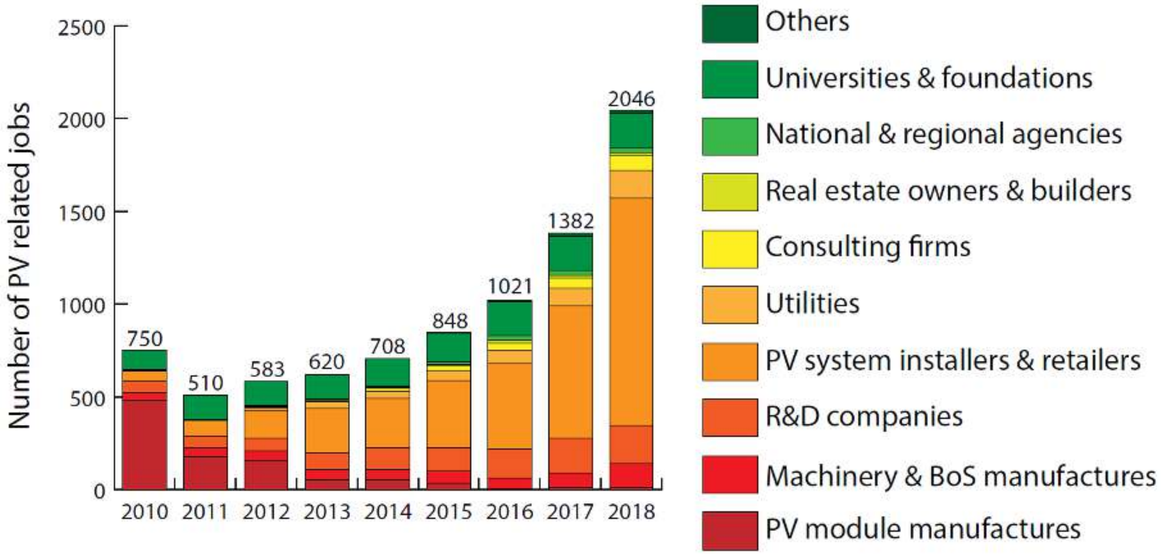

Figure 29: Estimated total full-time jobs within the Swedish PV industry over the years.

Table 31: Estimated PV-related full-time labour places in 2018.

Market category	Number of full-time labour places
PV module manufacturers	10
Machinery and balance of systems manufactures	128
Research and development companies	207
PV system installers and retailers	1225
Utilities	148
Consulting firms	78
Real estate owners and building companies	20
National and regional agencies	27
Universities, foundations and educations companies	184
Others	19
Total	2046

6.2 Business value

In Table 32 some very rough estimations of the value of the Swedish PV business can be found based on the installed capacity per market segment (see section 1.4) and typical prices within those segments (see section 2.2).

Table 32: Rough estimation of the value of the PV business in 2018 (VAT is excluded).

<table>
<tr><th colspan="2">Sub-market</th><th>Capacity installed in 2018 [MW$_p$]</th><th>Average price [SEK/W$_p$]</th><th>Market value</th></tr>
<tr><td colspan="2">Off-grid</td><td>2.12</td><td>27.0</td><td>~ 57 million SEK</td></tr>
<tr><td rowspan="9">Grid-connected distributed</td><td>Residential 0–20 kW$_p$</td><td>54.98</td><td>14.0</td><td>~770 million SEK</td></tr>
<tr><td>Residential 20–1000 kW$_p$</td><td>16.64</td><td>13.0</td><td>~ 216 million SEK</td></tr>
<tr><td>Residential >1000 kW$_p$</td><td>0</td><td>-</td><td>-</td></tr>
<tr><td>Commercial 0–20 kW$_p$</td><td>9.53</td><td>13.0</td><td>~ 124 million SEK</td></tr>
<tr><td>Commercial 20–1000 kW$_p$</td><td>57.78</td><td>11.5</td><td>~ 664 million SEK</td></tr>
<tr><td>Commercial >1000 kW$_p$</td><td>0</td><td>-</td><td>-</td></tr>
<tr><td>Industry 0–20 kW$_p$</td><td>0.07</td><td>12.5</td><td>~ 1 million SEK</td></tr>
<tr><td>Industry 20–1000 kW$_p$</td><td>5.21</td><td>10.0</td><td>~ 52 million SEK</td></tr>
<tr><td>Industry >1000 kW$_p$</td><td>1.85</td><td>9</td><td>~ 17 million SEK</td></tr>
<tr><td colspan="2">Grid-connected centralized</td><td>10.29</td><td>8.0</td><td>~ 82 million SEK</td></tr>
<tr><td colspan="4">Value of the Swedish PV market 2018</td><td>~ 1983 million SEK</td></tr>
</table>

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 was 134 electricity trading companies and 173 grid owners in Sweden in 2017 [61]. However, the Swedish retail market is dominated by three companies; Vattenfall, Fortum and E.ON, which together have 56 % of all customers. The grid market is dominated by Vattenfall, E.ON and Ellevio that covers 52 % of all customers.

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. The utility companies that the author is aware of that offered these kinds of turnkey PV systems in 2018 were: Affärsverken Karlskrona, Bixia, C4 Energi, Dalakraft, E.ON, Enkla Elbolaget, ETC El, Fortum, Fyrfasen Energi, Gislaved Energi, Gotlands Elförsäljning, Gävle Energi, Jämtkraft, Jönköping Energi, Kalmar Energi, Kraftringen, Kungälv Energi, LEVA i Lysekil, Luleå Energi, MälarEnergi, Mölndal Energi, Nossebro Energi, Piteå Energi, Sala-Heby Energi, Sandhult-Standareds Elektrisk, SEVAB Strängnäs Energi, Skellefteå Kraft, Skånsk Energi, Sollentuna Energi & Miljö, Stockholm Exergi, Storuman Energi, Switch Nordic Green, Södra Hallands Kraft, Telge Energi, Tekniska Verken i Linköping, Trollhättan Energi, Umeå Energi, Upplands Energi, Utellus, Varbergs Energi, Vattenfall, Västra Orust Energitjänst and Öresundskraft. 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 them have the installation competence and product distribution lines in-house.

One utility company, Umeå Energi also offer leasing of PV system to private persons.

Furthermore, in 2011, several utility companies started introducing 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 vary 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 0.70 SEK/kWh. Some utilities offer even higher compensation if the customer buys the PV system from the company.

A few utilities have started to work with centralized PV parks. Since there are no subsidies for large-scale PV parks in Sweden, except for the green electricity certificate system (see section 3.3.1) and the maximum 1.2 million SEK[2] from the direct capital subsidies (see section 3.2.1), the proactive utility companies that have started to work with PV parks have had to test different financial arrangements and business models such as share-owned PV parks, power purchase agreements and PV electricity offers to end consumers. The utility companies that so far have built PV parks over 1 MW_p are Mälarenergi, Arvika Kraft, Varberg Energi ETC El, Kalmar Energi, Luleå Energi and Göteborg Energi.

7.3 Interest from municipalities and local governments

As can be seen in Figure 5 and Figure 6 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 [62] 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 [63]. 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 [64]. 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 considering 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, Borlänge, Borås, Botkyrka, Danderyd, Ekerö, Eskilstuna, Eslöv, Falkenberg, Falun, Forshaga, Göteborg, Haninge, Helsingborg, Huddinge, Håbo, Härnösand, Härryda, Höganäs, Hörby, Järfälla, Kalmar, Karlshamn, Karlskrona, Karlstad, Katrineholm, Kramfors, Kristianstad, Kumla, Köping, Landskrona, Lidingö, Lidöping, Linköping, Ljungby, Lomma, Ludvika, Lund, Malmö, Motala, Munkfors, Mölndal, Nacka, Norrköping, Norrtälje, Nykvarn, Nynäshamn, Olofström, Ronneby, Salem, Sigtuna, Skövde, Smedjebacken, Sollefteå, Sollentuna, Solna, Stockholm, Strängnäs, Strömstad, Sundbyberg, Sundsvall, Södertälje, Sölvesborg, Timrå, Trosa, Tyresö, Täby, Umeå, Upplands Väsby, Upplands-bro, Uppsala, Vallentuna, Varberg, Vaxholm, Vellinge, Värmdö, Värnamo, Västerås, Ånge, Örebro, Örnsköldsvik, Östersund and Österåker.

There are 15 regional energy agencies (Energikontoren) in Sweden whose purpose is to promote energy efficiency and the use of renewable energy at local and regional level. With support from the Swedish Energy Agency (Energimyndigheten) they coordinate national initiative project with the municipality's energy and climate advisers. 2018 was the third year of the collaboration, and about half of Sweden's municipalities participated in a national initiative project to increase and spread information about PV systems to homeowners.

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, the regional energy agency of Skåne (Energikontoret Skåne) and Lund University. Solar Region Skåne is a network and knowledge centre for solar energy activities in the Skåne province.

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[2] A higher total subsidy from the direct capital subsidy for PV program can be achieved if the PV park is built on land that covers more than one property.

8 HIGHLIGHTS AND PROSPECTS

8.1 Highlights

The positive PV market development in Sweden continued in 2018 as the annual market grew with 86 % to a yearly installed power of 158 MW_p. This led to Sweden passing the 400 MW_p threshold as the cumulative installed capacity according to the sales statistics at the end of 2018 was 425 MW_p. The PV system prices continued to decrease for larger system, both ground- and roof-mounted, but remained at about the same level for small residential systems in 2018.

The major policy changes in 2018 that will affect the Swedish PV market the most was the prolongation of the Swedish green electricity certificate system, which meant a new goal that the programme would generate an extra 18 TWh of renewable electricity until 2030, the termination of the import duties on Chinese modules by the European Commission and the general exemption for building permits for solar energy systems.

On the industry side, basically no module production occurred in Sweden. 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 of the direct capital subsidy in 2017, the applied (and coming) reforms to reduce the administrative burdens for PV investors, the launch of an information platform by the Swedish Energy Agency and the increase of activity from utilities have made the situation for private persons and small companies to invest in PV quite good. One example of an up-coming suggested reform that will make it easier for investors in small PV system is the harmonization of the definition “micro-producer” that is defined different in different laws [42][47].

However, one critical issue that must be handled in the coming two years is how to close down, or prolong, the direct capital subsidy programme. The current programme will currently officially expire 31st of December 2020. Since the interest for this subsidy for several years have been larger than the budget, it is estimated that the government need to allocate about 2.4 billion SEK if everyone who has applied for the support will receive support. 2.4 billion SEK is a very large increase of the budget (The budget for 2019 is 736 million SEK). So, how the government handle this situation will have a large effect on the installation numbers in 2020.

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 negative impact on the market segment of large commercial PV systems (>255 kW_p). One positive prospect in this matter is that the government has declared their purpose to remove the 0.005 SEK/kWh energy tax for real estate owners that own several small systems, and thereby remove the administrative barrier, by sending in a state aid notification to the EU Commission [44].

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.

Large centralized PV parks has been a marginal occurrence in Sweden until now. However, at the time of writing there are nine PV parks in Sweden that are larger than 1 MW_p that has been commenced and the authors are aware of plans for at least 14 more PV parks. This market segment is therefore believed to grow a lot in the coming years, as it seems to be on the brink of manage without any subsidies.

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. The Swedish Energy Agency presented in October 2016 a broad PV strategy for Sweden. This strategy 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 [65]. Furthermore, the goal of the broad political agreement of The Swedish Energy Commission that Sweden shall have a 100 % renewable electricity consumption by 2040 [28] forebodes a policy framework in which PV should be able to flourish.

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