Technology Collaboration Programme
by iea

International Energy Agency
Photovoltaic Power Systems Programme

Task 1 Strategic PV Analysis and Outreach

PVPS

National Survey Report of PV Power Applications in Sweden

2020

Swedish Energy Agency

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 Technology Collaboration Programme (TCP) was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of 6.000 experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the TCP's 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.

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 Cop- per 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 2020. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

Authors

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COVER PICTURE

Swedens biggest PV park (14 MW_{DC} / 11.6 MW_{AC}) at the end of 2020, Härad, Strängnäs, next to E20, Sweden

Foto: EnergiEngagemang AB

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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, 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 2020 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2020, 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 the majority constituted of systems for holiday cottages, marine applications and caravans. This domestic off-grid market has been quite stable throughout the years. But since 2007 more grid-connected capacity than off-grid capacity has been installed annually. The grid-connected market is almost exclusively made up by distributed roof-mounted systems installed by individual homeowners, companies, municipalities, farmers, etc. Already from the start, the Swedish distributed market has been driven by the self-consumption business model, as there has never existed a feed-in-tariff in Sweden. Capital subsidies in combination with different types of schemes that add value for the excess electricity has until now been crucial for this business model to work in Sweden. About 49 % of the installed grid-connected PV power are residential systems, 42 % are installed on commercial facilities and 2 % on industrial buildings.

So far only 7 % of the grid-connected market are ground-mounted centralized PV parks, and by international standards they are relatively small in size. But the interest and activity in this market segment has increased a lot in 2020 and the number and sizes of centralized PV parks are expected to increase in the coming years.

1.2 Annual installed PV capacity

The installation rate of PV continues to increase at a high speed in Sweden. A total of 400.08 MW was installed in 2020, out of which 398.47 MW were grid-connected, as shown in Figure 1 and Table 2. This means that the annual Swedish PV market grew with 42 % compared to the 281.81 MW that was installed in 2019.

Of the grid-connected PV capacity installed in 2020, 40.37 MW is estimated to be centralized PV parks and 358.10 MW distributed PV systems for primary self-consumption. By that, the annual market of centralized PV in Sweden grew with about 253 % and the distributed annual market by 33 % as compared with 2019, when approximately 11.45 MW of centralized and 268.43 MW of distributed PV was installed.

Sweden has a stable off-grid PV market. In 2017 and 2018, about 2.06 MW respectively 2.03 MW of off-grid applications were sold. In 2019 and 2020 the annual off-grid market decreased slightly to 1.94 MW and 1.61 MW, respectively.

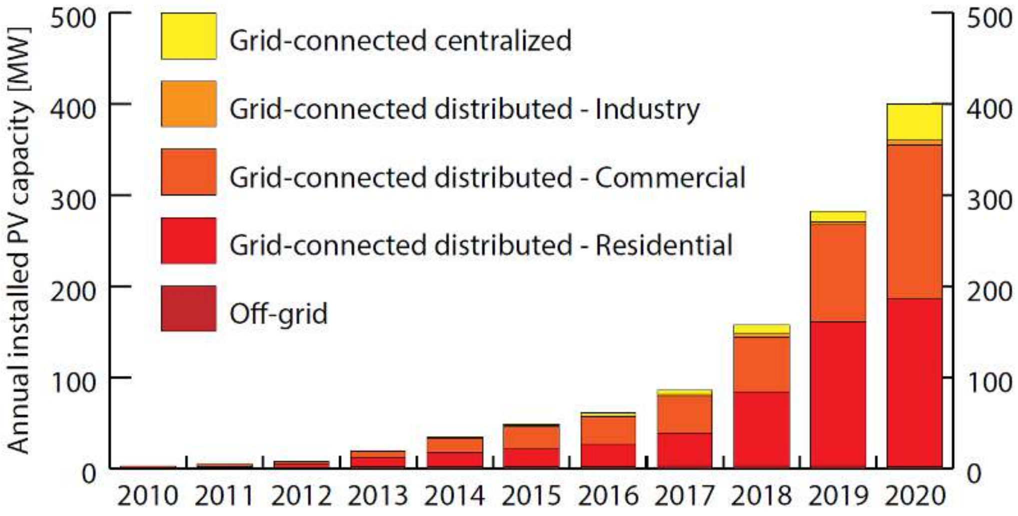

Figure 1: Annual installed PV capacity in Sweden.

Table 1: Annual PV power installed during calendar year 2020.

		Installed PV capacity in 2020 [MW]	AC or DC
PV capacity	Off-grid	1.605	DC
	Decentralized	358.103	DC
	Centralized	40.367	DC
	Total	400.075	DC

Table 2: PV power installed during calendar year 2020.

			Installed PV capacity [MW]	Installed PV capacity [MW]	AC or DC
Grid-connected	BAPV	Residential	358.10	184.43	DC
		Commercial		168.85	DC
		Industrial		4.82	DC
	BIPV	Residential	Unknown (Included in BAPV)	Unknown	DC
		Commercial		Unknown	DC
		Industrial		Unknown	DC
	Utility-scale	Ground-mounted	40.37	40.37	DC
		Floating		0	DC
		Agricultural		0	DC
Off-grid		Residential	1.61	0.68	DC
		Commercial		0.12	DC
		Mobile applications		0.81	DC
Total			400.08		DC

Table 3: 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, the Swedish Energy Agency (grid connected data) Company, Becquerel Sweden (off-grid data)
Link to official statistics (if this exists)	http://www.energimyndigheten.se/statistik/den-officiella-statistiken/statistikprodukter/natanslutna-solcellsanlaggningar/
The different data sources used for this report are all described and discussed in APPENDIX I - DATA SOURCES AND THEIR LIMITATIONS	

1.3 Total installed PV capacity

The total grid-connected capacity at the end of 2020 was 1 089.40 MW, according to the grid operators. Out of this capacity about 72.92 MW is estimated to be centralized PV and 1 016.48 MW to be distributed. In addition, a total of 19.88 MW of off-grid PV applications have been sold in Sweden since 1993, wherein 17.20 MW is estimated to still be in operation.

By adding the off-grid and the grid-connected PV capacities together, one can conclude a total of 1 106.6 MW of electricity producing PV power by the end of 2020, illustrated in Figure 2 and summarized in Table 4. The total installed PV capacity grew by 57 % in 2020, which is in line with the development over the five previous years, where the total market grew by 66 % (2019), 59 % (2018), 47 % (2017), 49 % (2016), 64 % (2015) and 84 % (2014).

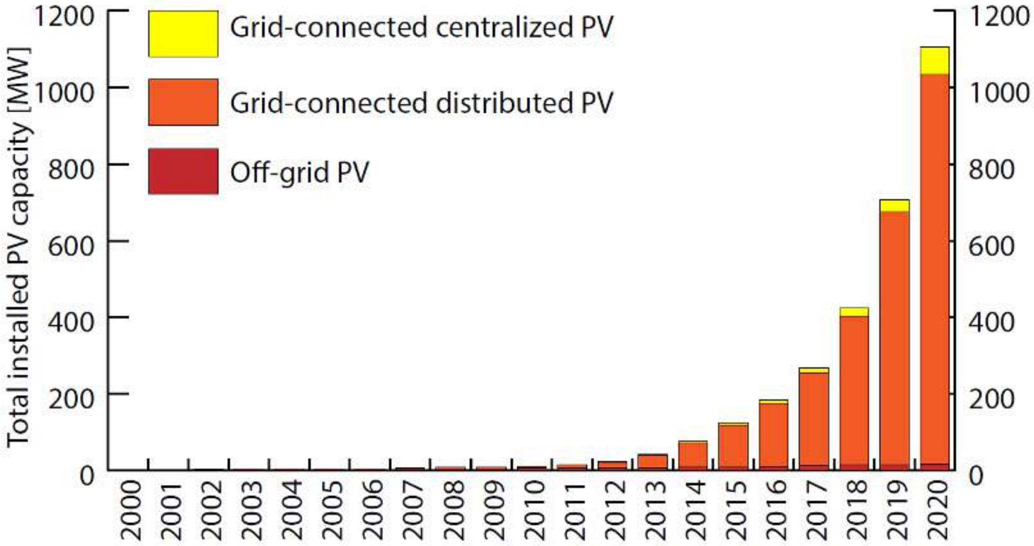

Figure 2: Total installed PV capacity in Sweden.

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 7.2) and an ongoing reformation work from the Government to simplify the rules for micro-producers (see section 3.3).

In total there were 65 797 grid-connected PV systems in Sweden by the end of 2020. The number of off-grid systems is unknown. A majority of the grid-connected PV systems, 56 655, are small systems below 20 kW. 9 106 are in between 20 kW – 1000 kW and only 22 systems are above 1 MW according to the official statistics (summarized in Table 5). However, the official statistics count everything behind one single connection point to the grid as one system. Several of the centralized PV parks built in Sweden have several connection points to the low voltage distribution grid. These PV parks are divided into several systems in the statistics, and often in sizes below 1 MW. So, the actual number of PV systems above 1 MW in Sweden is larger than 22 systems the way most people would see it.

With regards to the number of installed PV systems in Sweden, statistics are available for grid-connected system for the years 2016 to 2020. The number of systems at the end of each year, and the corresponding average system size is presented in Table 6. As can be seen at the end of 2020, Sweden had 65 797 grid-connected PV system, and the corresponding average system size was about 16.6 kW. That is a relatively small system size and it clearly illustrates that the Swedish PV market mainly consist of small distributed PV systems.

Table 4: 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	0.81
1993	1.03	0.02	0.00	1.05
1994	1.31	0.02	0.00	1.33
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	2.12
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	2.80
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	3.86
2005	3.98	0.25	0.00	4.23
2006	4.30	0.56	0.00	4.86
2007	4.57	1.68	0.00	6.25
2008	4.83	3.08	0.00	7.91
2009	4.97	3.54	0.06	8.57
2010	5.34	5.12	0.25	10.71
2011	5.78	8.47	0.35	14.60
2012	6.38	14.92	1.08	22.38
2013	7.31	32.14	1.81	41.26
2014	8.20	63.81	4.14	76.15
2015	9.16	109.19	5.83	124.18
2016	10.43	165.17	7.12	182.72
2017	12.27	244.05	11.85	268.17
2018	14.09	389.95	21.11	425.15
2019	15.82	658.37	32.58	706.75
2020	17.20	1 016.48	72.92	1 106.60

Table 5: Other PV market information.

<table>
<tr><th colspan="2"></th><th colspan="2">2020</th></tr>
<tr><td rowspan="5">Number of PV systems in operation in Sweden</td><td rowspan="4">Grid connected PV</td><td>Under 20 kW</td><td>56 655</td></tr>
<tr><td>20 kW – 1000 kW</td><td>9 106</td></tr>
<tr><td>Above 1000 kW</td><td>22</td></tr>
<tr><td>Total</td><td>65 797</td></tr>
<tr><td colspan="2">Off-grid PV</td><td>Unknown</td></tr>
<tr><td colspan="2">Decommissioned PV systems during the year [MW]</td><td colspan="2">221 kW of off-grid system is estimated to have been decommissioned</td></tr>
<tr><td colspan="2">Repowered PV systems during the year [MW]</td><td colspan="2">Unknown</td></tr>
</table>

Table 6: Number and average sizes of grid connected PV systems in Sweden at the end of each year.

	2016	2017	2018	2019	2020
Number of systems	10 006	15 273	25 486	43 343	65 797
Average size per system for the total number of systems at the end of each year [kW]	14.0	15.1	16.1	15.9	16.6
Average size per system for the annual market [kW]	17.3	17.3	17.6	15.7	17.7

1.4 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 2020, 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 2020, 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]	543.70	491.71	53.99
Total number of grid-connected PV systems according to the grid operators collected by the Swedish Energy Agency [#]	56 655	9 106	22

However, for market segmentation there is another data source. In the database of the Swedish direct capital subsidy (see section 3.2.1) all PV systems that have been granted support from the start of the subsidy programme in 2009 until now are recorded. By cross-referencing between this database and Sweden's national business directory, a business sector can be assigned to each system owner. By doing this, the database can be divided into centralized, industry, commercial or residential systems (see section 9.1.4).

By dividing the annual installed PV capacity for each market segment by the total installed PV capacity the different market segments share of the annual installations can be estimated. The historic development of these shares is presented in Figure 3. Clearly, the biggest market segments in Sweden have been residential single-family houses and commercial facilities. A slight variation over the years can be seen, 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. 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.

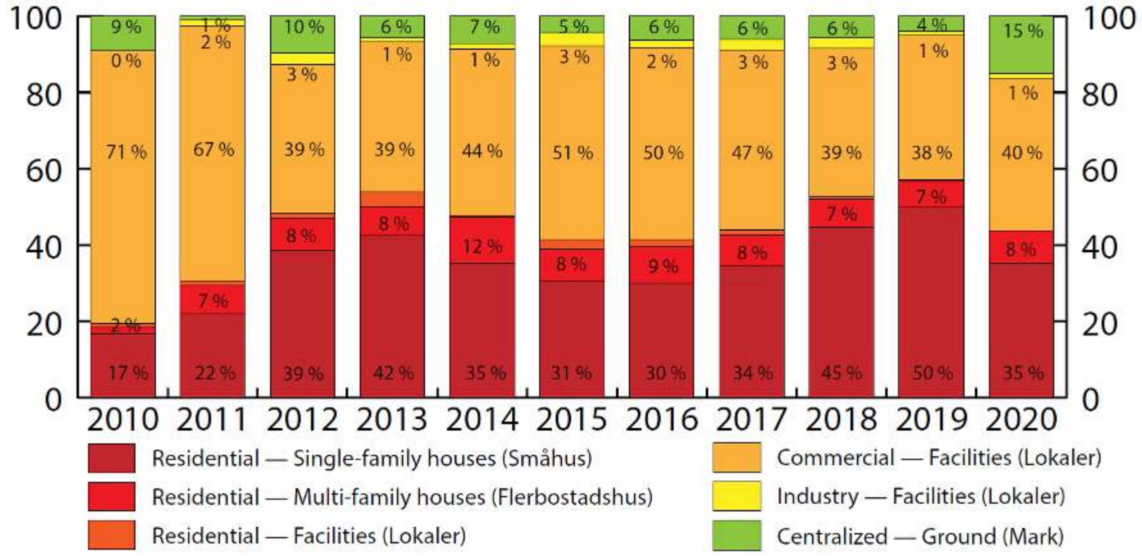

Figure 3: Various market segments share of the annual installed PV capacity in Sweden in 2020. Based on statistics from the capital subsidy database.

The reason for the underdeveloped Swedish market of centralized PV parks, as compared to in many other countries, is that the current support schemes has not been enough do drive PV park development in Sweden until basically 2020. The two support schemes that has been available has been the renewable electricity certificate system (see section 3.2.3) and a maximum 1.2 million SEK per system from the direct capital subsidy programme (see section 3.2.1). However, this is a market sector that is expected to grow in the coming years. At the end of 2020 there was 21 commissioned PV parks in Sweden that with a capacity of above 0.5 MW. Besides those mentioned, the authors are aware of additional plans for several larger 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 general obstacle for residential multi-family houses is the current tax laws which makes it complicated to self-consume PV electricity in the apartments of 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 sell the PV electricity to the apartments, the owner becomes a retailer of the electricity and must follow the regulations which come along with that role including the Swedish energy tax that is applied to the electricity (even if it has not left the building). Hence, it is difficult to reach a high degree of self-consumption 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 3.3.5), 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 latter solution becomes more and more common in Sweden, but the general complexity to move to this arrangement is one reason for the low installation numbers for multi-family houses. Several proactive housing and property companies have however experienced added values after investments in PV, such as sustainability, fair cost, and induced innovativeness [2]. These experiences are likely to spread over time to other actors and motivate them to overcome the perceived legislative barriers.

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 4 and Figure 5 for most of the municipalities in Sweden. However, some municipalities are marked as blank by the public Swedish Energy Agency due to confidentiality reasons. For these municipalities, data from the green electricity certificate system (see section 3.2.3) has been used to complement the grid operators' data in creating Figure 4 and Figure 5.

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

In 2020 these municipalities were Arjeplog, Arvidsjaur and Kiruna.

Figure 4 and Figure 5 clearly show that the expansion of PV takes place at different speeds in Sweden's municipalities. When it comes to most installed PV capacity, Gothenburg, followed by Linköping and Uppsala were in the top at the end of 2020 with 39.8, 33.1 and 25.5 MW, respectively. Gothenburg, that overtook the lead from Linköping in 2018, is much helped by the three PV parks of 5.5, 5.5 and 3.7 MW_p, respectively, that have been commissioned in the recent years.

When the installed PV capacity is divided by capita, as in Figure 5, Strängnäs municipality overtook the last year's leader Sjöbo in 2020. The main reason for that is that Sweden's so far biggest PV park, "HSB Solcellspark" at 14 MW_p was commissioned in Strängnäs last autumn. It is also undergoing expansion with the end goal of becoming 21 MW_p. Strängnäs has about 37 300 inhabitants, so the PV park had a large effect on the PV capacity per capita. The top three municipalities then became Strängnäs, Sjöbo and Borgholm with 500.4, 456.4 and 385.8 W/capita, respectively. It is no coincidence that Sjöbo is also in the forefront. In Sjöbo, Sweden's at the time largest PV park, "Sparbanken Skånes Solcellspark" was commissioned in 2019, with 5.8 MW_p installed.

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 4 and Figure 5. 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 is 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 4 shows. The value of the PV electricity is also higher in SE4 and SE3, as the average market value between 2014 and 2020 (see section 2.6 for further explanation and discussion) of PV in these bidding areas was 335.1 and 318.7 SEK/MWh respectively, as compared to 301.3 and 302.0 in SE2 and SE1 respectively [3].

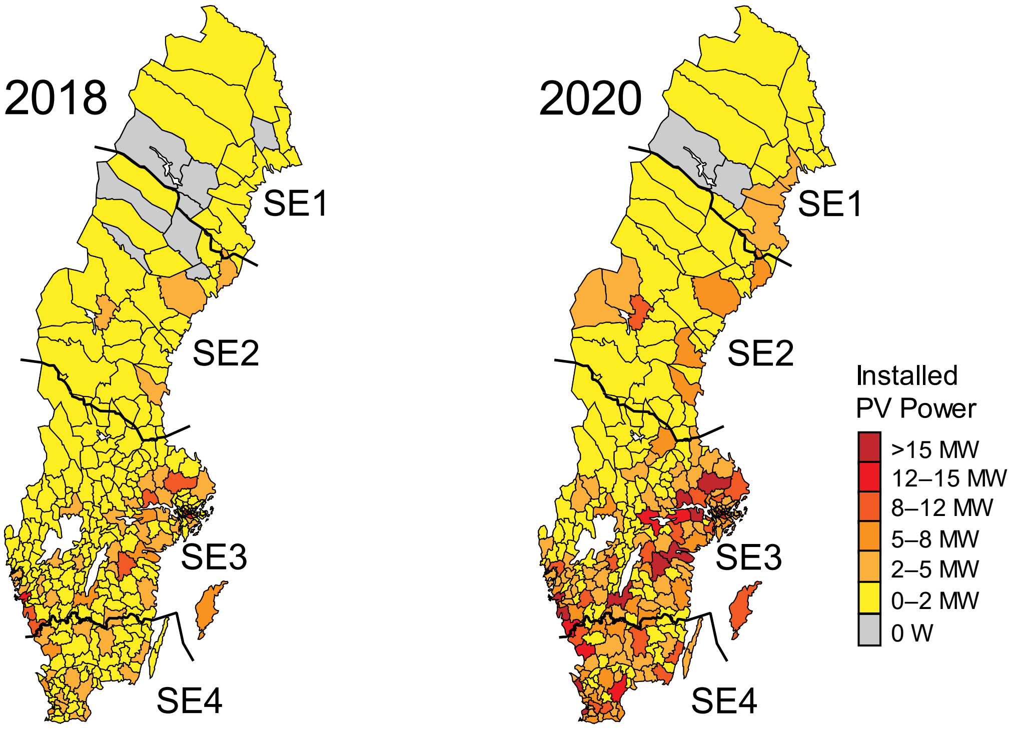

Figure 4: Total power of the PV systems in each of Sweden's municipalities. For some municipalities data from the green electricity system has been used instead of grid operators' data due to confidentiality reasons.

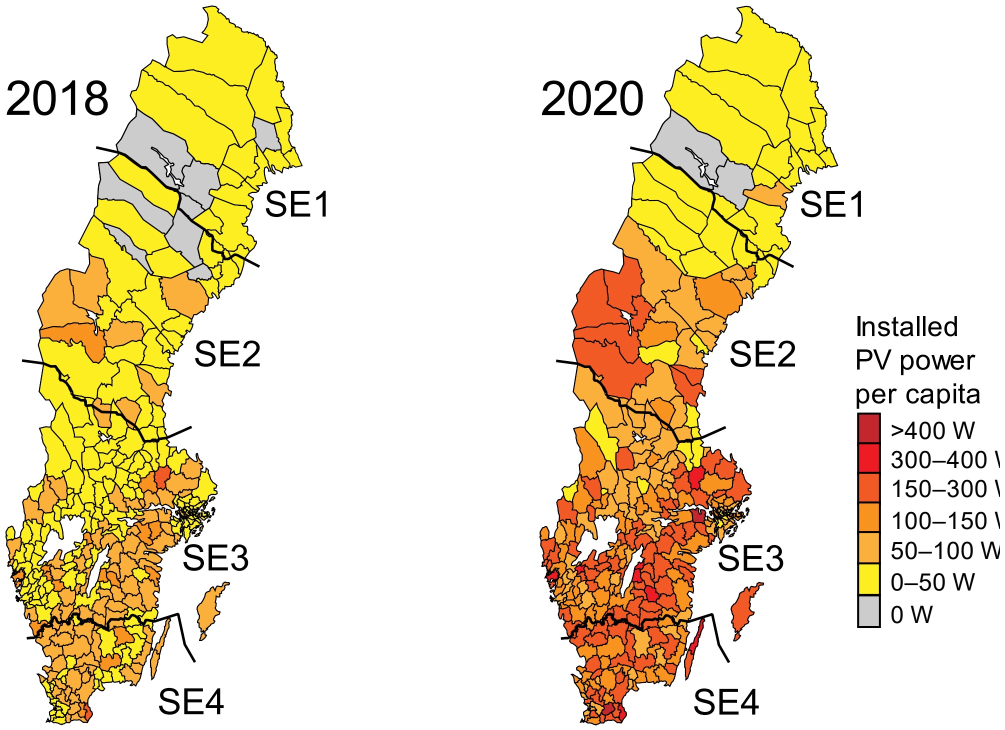

Figure 5: Total power of the PV systems per capita in each of Sweden's municipalities. For some municipalities data from the green electricity system has been used instead of grid operators' data due to confidentiality reasons.

1.6 Key enablers of PV development

1.6.1 Other technologies

For five years the surveys that went out to the installation companies included questions about grid connected battery capacity that had been installed. According to the installations companies a total battery capacity of 12.4 MWh was installed in 2020, an increase of 92 % compared to 2019 as Table 8 illustrates. The general global trend of decreasing battery prices [4], signals that a growing battery market in Sweden is expected. In 2018 a clear shift can be seen in Table 8, 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 introduction of the capital subsidy programme for storage (see section 3.9.3), which now has an effect on the storage market.

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 8: Annual installed grid connected stationary battery capacity installed by PV installation companies.

Year	Private system	Commercial system	Total
2016	177 kWh	1 365 kWh	1 542 kWh
2017	1 138 kWh	1 288 kWh	2 426 kWh
2018	2 414 kWh	1 520 kWh	3 934 kWh
2019	3 506 kWh	2 956 kWh	6 462 kWh
2020	8 879 kWh	3 498 kWh	12 378 kWh

The battery capacity of the electrical cars in Sweden was 4 500 MWh in the end of 2020 [5]. If one adds the total battery capacity of stationary grid connected batteries connected to PV systems installed between 2016 and 2020 the total battery capacity at the end of 2020 became 4 512 MWh.

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 the SOM-institute, randomly selected respondents 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, indicating a strong majority of 82 % 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.

When it comes to the willingness of homeowners to install PV on their house, the results from two different surveys conducted with national representative samples of Swedes, are presented in Figure 6. The survey presented in Figure 6a is from 2016 [7] and the one presented in Figure 6b from 2018 [8]. The results from the two surveys are similar and show that about 60 % of the homeowners in Sweden are interested in having a PV system on their roof. Finally, there is also a great interest for larger PV systems, and scientific analysis has shown that the installation of PV systems creates a number of added values for commercial and multi-family building owners [2].

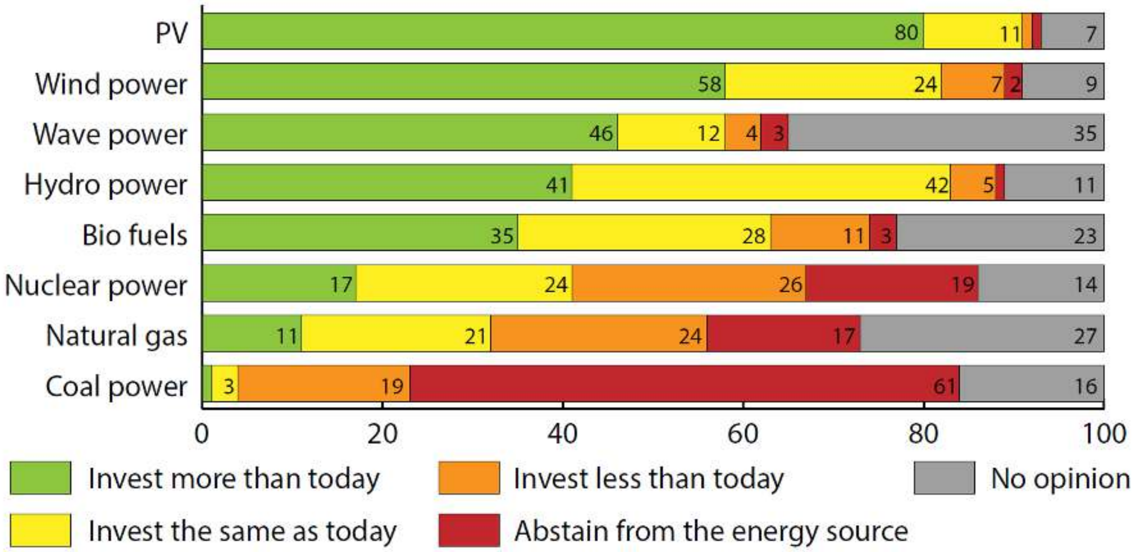

Figure 7: The public opinion in Sweden about different electricity production technologies.

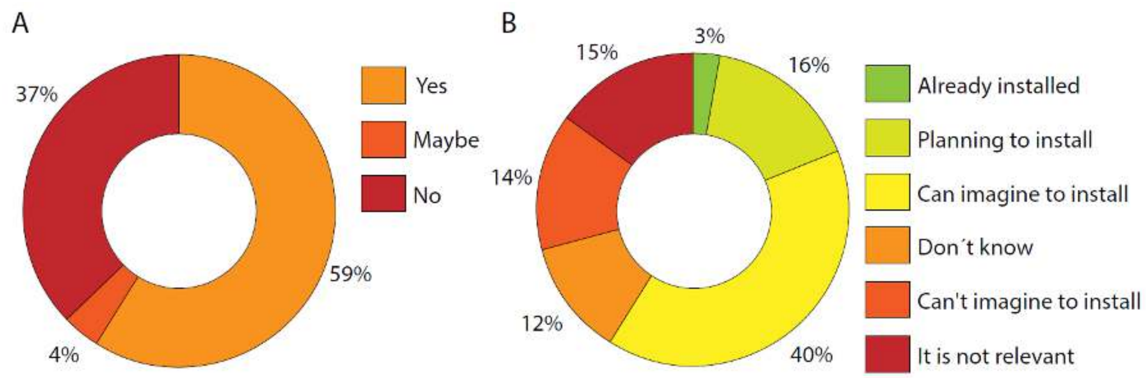

Figure 6: The result of two different surveys conducted with a national representative sample of Swedes. In (A) the question was "If you had the opportunity, would you then like to produce your own electricity?" In (B) the question was "As a homeowner, have you installed PV or are you planning to do so?".

1.7 PV in the broader Swedish power system

The Swedish power system has been divided into four bidding areas (SE1–SE4) since November 1st, 2011, 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. This 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 geographical borders of the areas are marked in Figure 4 and Figure 5.

The major changes in the Swedish power production the last years has been the expansion of wind power, the decommission of two nuclear power reactors and the closure of the last coal power plant. The nuclear reactors Ringhals 2 (905 MW) was taken out of service on the morning of 30 December 2019 and Ringhals 1 (881 MW) in the evening on 31 December 2020. The last coal power plant, Värtaverket, was shut down in 2020.

Another recent change in the system is that the yearly average allocated transmission capacity between SE2 and SE3, respectively SE3 and SE4, by the Swedish TSO, has decreased in recent years. For the whole year of 2020 the average transmission capacity between SE2 and SE3 was 6,132 MW, which is approximately 1 200 MW less than the boundary´s maximum capacity of 7 300 MW, and the lowest value of the last 8 years. About the same reduction is observed between SE3 and SE4. On average, the price area boarder had a transmission capacity of 4 198 MW in 2020, which can be compared with the maximum capacity of 5 400 MW. The allocation of transmission capacity is made hour by hour. The explanation for the decreasing average allocated transmission capacity in recent years given by the Swedish TSO is interruptions on cables due to maintenance work and changed energy flows in the electricity grid [9].

Lastly, the off shore transmission capacity from the Nordic region to the continental Europe and Baltic countries are steadily increasing as several transmission cables has been built in last decades, such as the Baltic Cable (Germany to SE4, 600 MW, in operation 1994), the Swe-Pol Link (SE4 to Poland, 600 MW, 2000), Nordbalt (SE4 to Lithuania, 700 MW, 2016), Nordlink (Norway to Germany, 1400 MW, 2021) and there are more transmission projects planned to be commissioned in the near future, such as the North Sea Link (Norway to UK, 1 400 MW, 2021). This enables “import” of the higher spot prices of the different European price areas to the Nordic region [10][11][12][13], which can increase the internal congestion in Sweden [10]. The higher electricity prices will benefit both variable renewable technologies, such as wind power and PV and reservoir hydropower through a transfer of wealth from thermal power technologies on the European continent, which will receive reduced revenues with increasing interconnection levels [13]. The consequences of offshore transmission capacity extensions can lead to higher prices in the Swedish price areas SE3 and SE4, which will be beneficial for PV as most of the PV capacity in Sweden are being installed in these two price areas, see section 1.5.

In Figure 8 the Swedish electricity production in 2020 is presented. The electricity production data used in Figure 8 and Figure 9, along with Table 9, were retrieved from Svenska Kraftnät [14] but with complementary data from SCB [15] with regards to the fuels used in the Swedish CHP power plants. The exception is the produced PV power. Since a large share of the total PV power production is self-consumed by prosumers it is not registered in the statistics from Svenska Kraftnät as they only measure electricity fed into the grid. The PV production used in the figures and table below were therefore instead generated through simulations using a model that have a proven high correlation of 0.95–0.99 to reported historical production data [16].

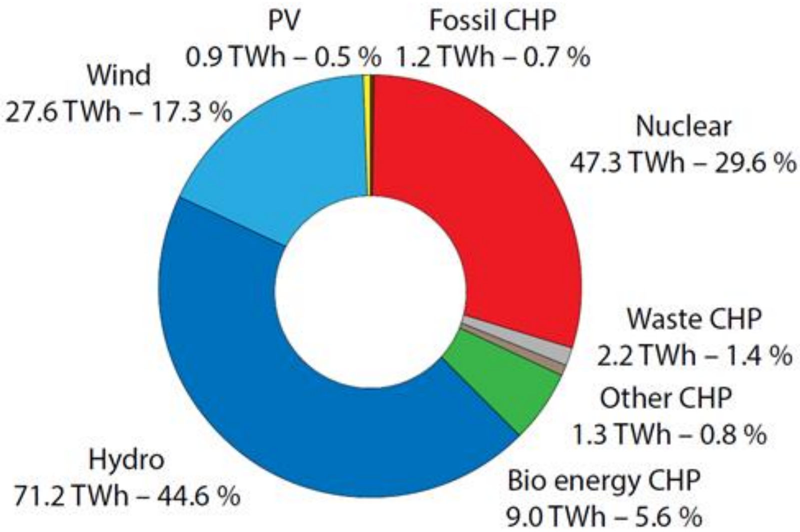

Figure 8. Total electricity production in Sweden in 2020.

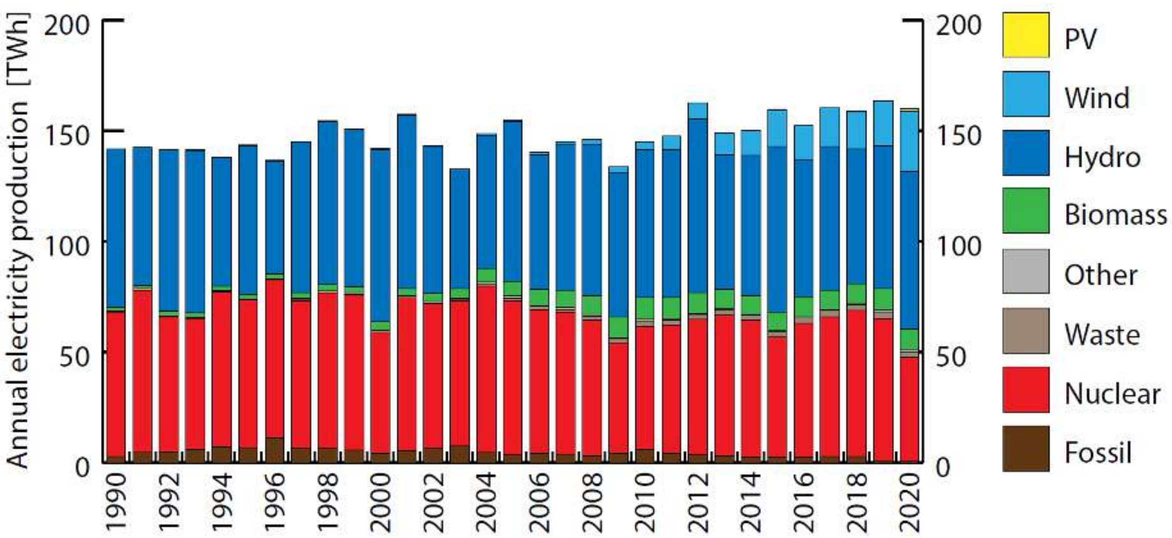

Figure 9. Total annual electricity production in Sweden between 1990 to 2020.

The simulation result was generated in proportion to the geographical location of the population and the available solar radiation, this was done in order to ensure that the solar production was distributed realistically. For each year the production was calculated from the average installed power at the beginning and the end of the year and was weighted against values on the installed capacity.

As can be seen in Figure 9, the Swedish electricity has historically been produced by technologies that have a low CO_2-footprint. 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 9. PV power and the broader national energy market

	Data	Year
Total power generation capacities [MW]	41 199	2020
Total renewable power generation capacities (including hydropower) [MW]	31 168	2020
Total electricity demand [TWh]	134.9	2020
New power generation capacities installed [GW]	1 591	2020
New renewable power generation capacities (including hydropower) [GW]	1 333	2020
Estimated total PV electricity production (including self-consumed PV electricity) in [GWh]	854.1	2020
Total PV electricity production as a % of total electricity consumption	0.5 %	2020
Average yield of PV installations [kWh/kW$_p$]	950	2020

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 rapid decline in price for PV modules between 2008 and 2013 due to a growing domestic market, which allowed retailers to import larger quantities. Between 2013 and 2016, the price decline in Sweden was more moderate. The main reasons for the stabilization of the module prices under this time period was the import duties on Chinese PV modules and cells that were introduced in 2013 by the European Commission [17]. In these measures, a minimum import price (MIP) was introduced, which means that no silicon modules could be imported to the European Union at a price lower than 0.56 €/W_p, which corresponded to about 5.2 SEK/W_p. After the termination of the duties many Swedish retailers lowered their module prices towards the Swedish installation companies with 20-30 %. That resulted in a price drop of the average typical module price to the end consumer by 14 % in 2018, which continued with a price decline of 4 % in 2019 and 7 % n 2020 (see Table 10).

In addition to the collected sales statistics, which should be read as the module price to the end customer, the result of an recent study showed that the internal module cost from the perspective of the installer was 3.1 SEK/W_p for 10 kW_p residential systems [18]. The result of study is further discussed in section 2.2.3.

Table 10: The historical development of typical module prices. The prices are reported by Swedish installers and retailers. The prices are the prices to the end costumer, not the import price for the 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	8.9
2014	6.0	12	8.2
2015	5.1	10	7.6
2016	4.5	9.3	7.1
2017	4.0	6.6	5.3
2018	3.2	6.6	4.5
2019	2.9	5.4	4.3
2020	2.5	6.6	4.0

2.2 System prices

Sweden has experienced a large decrease in PV system prices since 2010, especially before 2013, as Figure 10 shows. The major reason for the decline in system prices in Sweden is that the prices of modules and the balance of system (BoS) equipment has dropped in the international market. Another reason is that the Swedish market is growing, providing the installation firms a steadier flow of orders and an opportunity to streamline the installation process, thus reducing both labour and cost margins. A clear trend of decreasing yearly full-time labour positions per installed MW is illustrated in By summarizing the labour places related to the actual Swedish PV market, i.e. PV system installers and retailers, utilities, consulting firms, real estate owners and building companies, and divide it with the annual installed PV capacity, one can get an estimation of how many labour places that is created per installed PV capacity. As Table 33 shows, the estimated number of created labour places per installed MW was 6.5 in 2020. A clear trend of fewer and fewer created labour places per installed MW can also be seen, which cannot be explained by changes in general system sizes (as Table 6 shows). The reason is probably that the companies are becoming bigger and more effective in their marketing and installation processes. The decreasing created labour places is probably one of the reasons for the declining PV prices in Sweden (See section 2.2).

Table 32 further corroborate this hypothesis. Competition in the market has also increased. In 2010 the authors of the NSR reports were aware of 111 active companies that sold and/or installed modules or PV systems in Sweden. In the end of 2020, the corresponding figure had gone up to 339.

2.2.1 Estimated PV system prices by the sales statistics

The price information from the sales surveys is presented in Figure 10 and Table 10. The methodology for collecting the price statistic is explained in section 9.1.5 and the price development is discussed in section 2.2.4 PV system price discussion below.

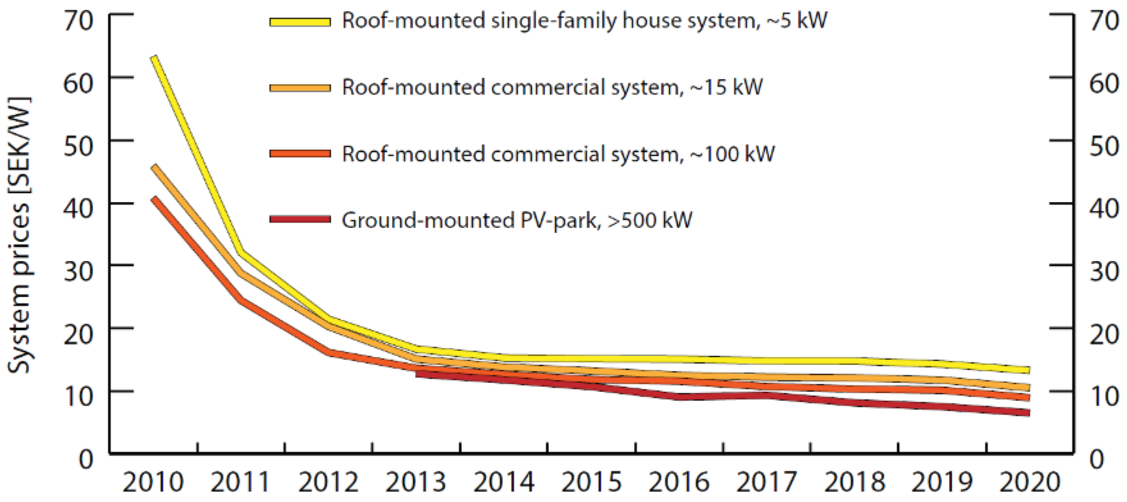

Figure 10: Historic development of the weighted average typical prices for turnkey photovoltaic systems (excluding VAT), reported by Swedish installation companies.

Table 11: National trends in system prices for different applications.

Year	**Residential BAPV** Grid-connected, roof-mounted, distributed PV system ~5 kW [SEK/W_p]	**Small commercial BAPV** Grid-connected, roof-mounted, distributed PV systems ~15 kW [SEK/W_p]	**Large commercial BAPV** Grid-connected, roof-mounted, distributed PV systems ~100 [SEK/W_p]	**Small centralized PV** Grid-connected, ground-mounted, centralized PV systems >0.5 MW [SEK/W_p]
2007				
2008		96.00	67.00	
2009		76.00	47.00	
2010	63.33	45.89	40.79	
2011	32.07	28.77	24.44	
2012	21.43	20.29	16.13	
2013	16.68	15.09	13.62	12.73
2014	15.28	13.81	12.63	11.77
2015	15.13	13.20	11.82	10.69
2016	15.07	12.48	11.56	9.03
2017	14.81	12.22	10.70	9.30
2018	14.76	12.09	10.31	8.18
2019	14.40	11.74	10.28	7.50
2020	13.27	10.50	8.92	6.50

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, in depth described in section 9.1.4.

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 module 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 by him/herself. These factors result in several recorded PV system prices (especially in the segment of small residential single-family systems) that are unusually high >30 SEK/W_p or low <10 SEK/W_p.

Furthermore, there is also the economies of scale, where larger systems are comparatively cheaper 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 several 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 suffice to derive a reasonable average price and that the economies of scale become 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 12 and Table 12. 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 11 and Table 13. The reason for choosing 255 kW_p as the upper boundary for the largest commercial systems is due to the tax legislation in place in 2020 (see section 3.3.2). Table 12 and Table 13 also list how many systems that the presented average prices have been derived from, in order for the reader to get a sense of relevance of the average price presented.

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

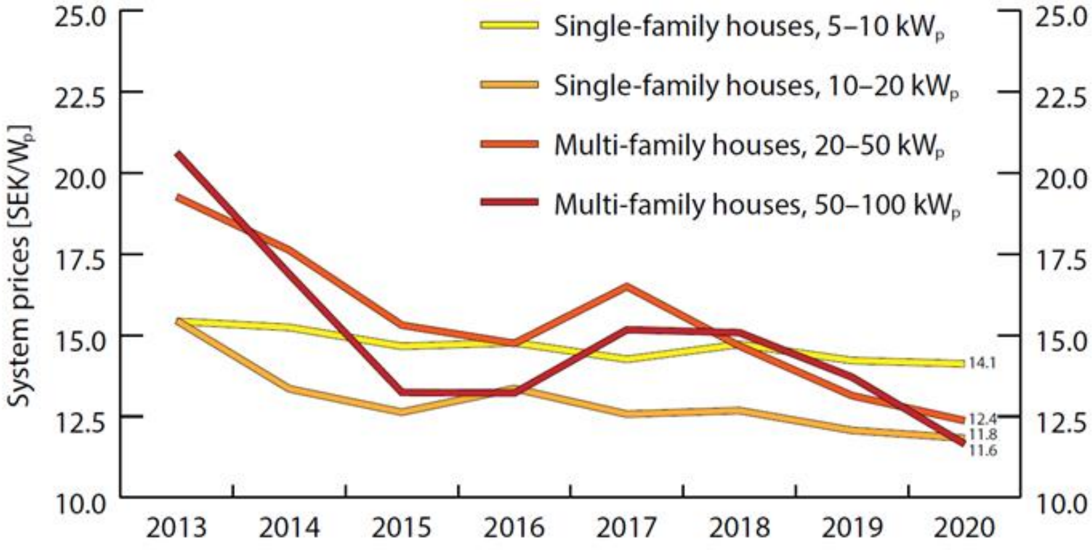

Figure 12: Average prices for turnkey grid-connected residential PV systems (excluding VAT) from the database of the direct capital subsidy programme.

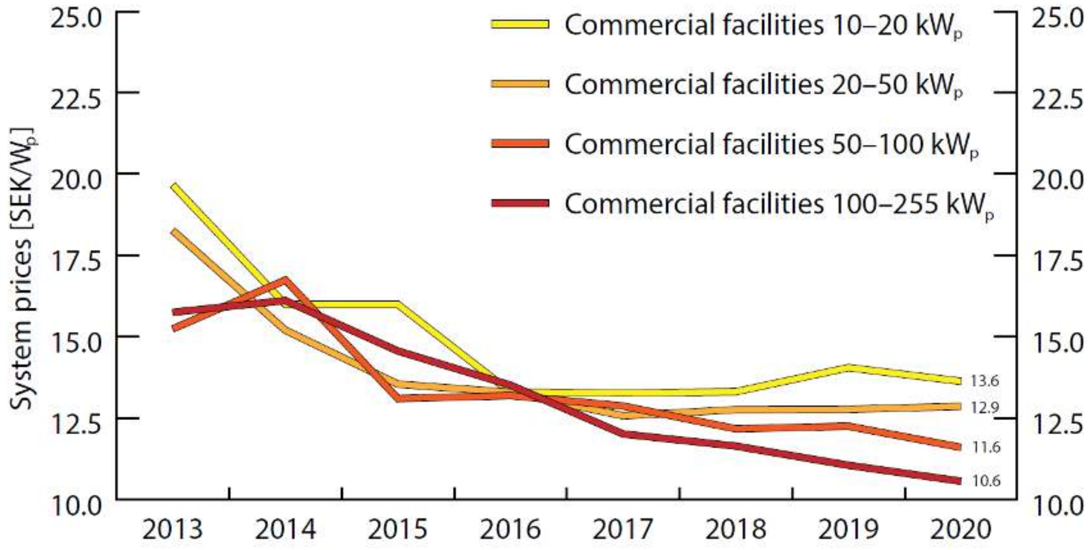

Figure 11: Average prices for turnkey grid-connected commercial PV systems (excluding VAT) from the database of the direct capital subsidy programme.

Table 12: 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	15.43	317	15.45	90	19.26	15	20.62	3
2014	15.24	441	13.35	229	17.62	39	16.88	11
2015	14.66	461	12.63	300	15.31	32	13.24	11
2016	14.77	929	13.36	471	14.75	62	13.22	19
2017	14.26	1 403	12.57	943	16.50	78	15.17	27
2018	14.72	3 462	12.68	2932	14.67	147	15.08	49
2019	14.22	5 695	12.07	6172	13.14	228	13.71	72
2020	14.12	3 508	11.83	4282	12.37	169	11.65	114

Table 13: 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$_p$		Commercial facilities, 50–100 kW$_p$		Commercial facilities, 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	19.66	48	18.26	67	15.24	12	15.75	5
2014	15.99	85	15.20	122	16.74	24	16.11	10
2015	15.99	155	13.54	183	13.10	46	14.56	18
2016	13.30	219	13.29	267	13.19	81	13.51	34
2017	13.27	349	12.57	366	12.87	123	12.01	65
2018	13.31	523	12.76	630	12.17	194	11.64	112
2019	14.05	783	12.77	892	12.25	340	11.05	210
2020	13.63	584	12.86	793	11.60	354	10.56	226

2.2.3 Cost breakdown of residential PV systems

In addition to the PV system prices extracted from the database for the direct capital subsidy programme and the sales statistics, a study on Swedish grid-connected roof-mounted residential PV system has been conducted [18]. This will translate to the category "single-family houses/small buildings (småhus)" in Figure 13.

The inherent cost structure of Swedish villa systems has not before been explored, except for results from a small survey conducted in 2015 and 2017 inside the scope of IEA PVPS [19]. The cost structures presented in Table 14, Figure 13 and Figure 14 are based on 115 PV system projects that were carried out in 2020, and display the supplier cost structure without VAT or profit margin. Eight supplier companies that focuses on the private residential market reported a detailed cost breakdown on 10–15 projects each and participated in both individual semi-structured interviews and group discussions amongst each other. Comparing the result of this study and the average cost for grid connected roof mounted PV systems on single-family houses from the statistics is the database of the Swedish direct capital subsidy the profit margin seems to about 10 %. In addition, the end customer also pays 25 % in VAT for the system.

Apart from the cost structure, the results showed that the average villa system size was 9 kW_p, which seemed to correspond well do the average system size recorded in the Svanen database for Swedish single-family house systems installed in 2019–2020. Monocrystalline cells are dominating in terms of cell technology, followed by half cut monocrystalline cells, and the string inverter was the most common inverter type amongst the studied projects.

Table 14: Cost breakdown for a grid-connected roof-mounted residential PV system 2020 in SEK/W_p. The table presents a supplier cost structure excluding VAT and profit margins.

Cost category	Average [SEK/W_p]	Low [SEK/W_p]	High [SEK/W_p]
Hardware			
Modules	3.17	2.53	3.93
Inverter	2.04	1.21	2.40
Mounting materials	0.38	0.60	3.02
Other electronics	1.49	0.13	0.73
Subtotal hardware	**7.08**	-	
Soft costs			
Installation work	3.50	1.41	5.01
Permits and reporting	0.13	0.01	0.49
Working travel time	0.23	0.02	0.74
Planning and sales	0.48	0.11	1.33
Shipping to customer	0.16	0.02	0.27
Travel costs	0.09	0	0.32
Other	0.04	0	0.25
Supplier margin	1.17	-	
VAT	3.22	-	
Subtotal soft costs	**9.01**	-	
Total	**16.09**	-	

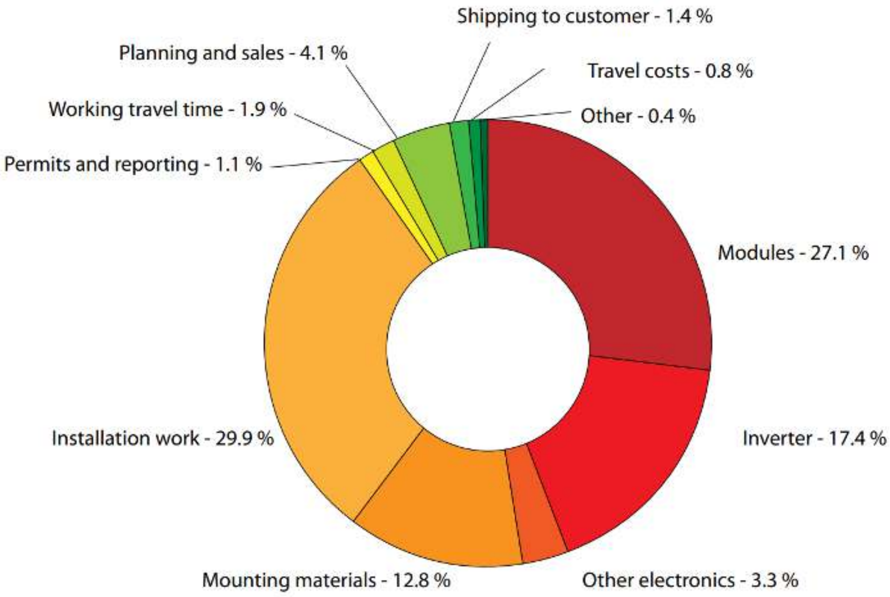

Figure 13: The supplier cost structure for a typical Swedish grid-connected roof-mounted residential PV system in 2020. The total price was 11.70 SEK/W_p.

The results, presented in Figure 13, show that the single largest cost for all suppliers was that for installation work which include both the mounting of the system and the electrical installation. In the category of hardware costs, module costs are the most extensive. In a supplier cost structure for costs per kW_p, hardware costs make up 60.5%, labor costs 32.9 % and other costs 6.6%. In actual costs, this corresponds to 7 082, 3 849 and 770 SEK/kWp, respectively.

A standardized supplier cost structure for a 10 kW_p system, presented in Figure 14, shows that the total cost amounts to 109 840 SEK. Noticeable in that cost structure is that the module costs surpass the cost for installation work and becomes the largest single cost.

As discussed further in 3.2.1, the direct capital subsidy for private individuals is replaced by a tax reduction for green technology ("Skattereduktion för installation av grön teknik") in 2021. In the direct capital subsidy programme, a fixed percentage of the total system costs were covered, which means that the size and distribution of the underlying cost posts did not matter in terms of the level of economic compensation. The green tax reduction, on the other hand, does not provide support for all costs associated with a villa system, but only labor and hardware costs. Knowledge of the cost distribution is therefore becoming more important.

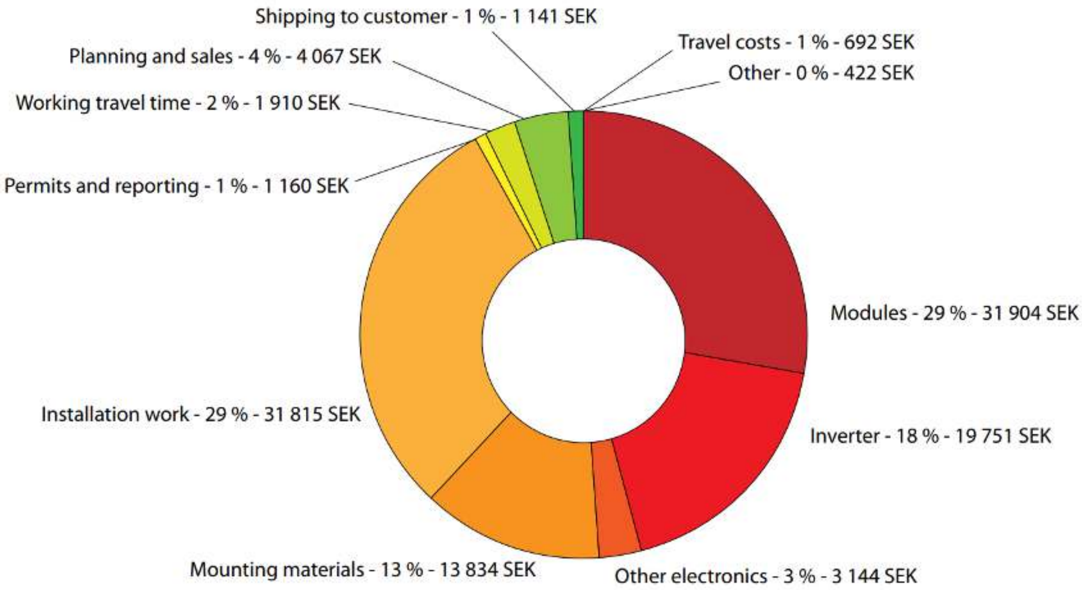

Figure 14: The supplier cost structure for a typical Swedish grid-connected roof-mounted residential PV system [10kWp] in 2020. The total price was 109 840 SEK.

2.2.4 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 11 (that is based on the installations companies estimates) and Table 12 (that is based on prices statistics derived from the Swedish direct capital subsidy programme) show that the price decreased in 2020, with around 8 % according to the installers, and 1 % according to the statistics of the direct capital subsidy programme to reach an average between 13.3 SEK/W_p or 14.1 SEK/W_p depending source of information. The price of somewhat larger PV systems on residential single-family houses of about 10–20 kW_p declined with about 2 %, as the average prices in this market segment went down from 12.1 to 11.8 SEK/W_p (see Table 12). For residential PV systems on multi-family houses the prices went down with 6 % and 15 % in 2020, to 12.4 SEK/W_p and 11.7 SEK/W_p, within the size ranges of 20–50 kW_p and 50–100 kW_p respectively.

For roof-mounted PV systems on commercial buildings the price decline was 13 % for ~100 kW_p systems, to 8.9 SEK/W_p, and 10 %, to 10.5 SEK/W_p, for ~15 kW_p systems according to installation companies (see Table 12). However, Table 14 show that the installation companies might exaggerate their low prices, as the statistics of the direct capital subsidy programme are indicating average prices of 11.6 SEK/W_p and 13.6 SEK/W_p for systems of the sizes 50–100 kW_p and 10–20 kW_p on commercial facilities.

It is interesting to note that installation companies estimate typical system prices are lower than the average in the direct capital subsidy programme database. Looking in the database of the direct capital subsidy programme a few outlier systems with system prices are noted for all categories, which pull up the average prices.

The largest price decline in 2020 occurred for centralized utility scale PV parks, where the typical price went down with 15 % from 7.8 SEK/W_p to 6.6 SEK/W_p (see Table 12). An explanation is that ten >1 MW_p PV parks were commissioned in Sweden in 2020.

The general slowdown of the price reduction of PV system the last years, as compared to the beginning of the decade, 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 somewhat faster price decline between 2019 and 2020, as compared to the few previous years, might be explained by the fact that the subsidy level of the Swedish direct capital subsidy system was on the same level between 2014 and May 2019 (see section 3.2.1). During this period the installers could charge the same prices, as the customers would have the same profitability, even if module and other hardware costs has continued to go down.

Table 15 summarizes the PV system prices in 2020. 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 15: Turnkey PV system prices of different typical PV systems in 2020.

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.	10–17
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.	7–16
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.	7–13
Industrial BAPV >250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected industrial buildings, warehouses, etc.	6–11
Small centralized PV 1-20 MW	Grid-connected, ground-mounted, centralized PV systems that work as central power stations. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale.	5–7
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 -0.25 % in 2020, but was increased to 0.00 % on the 8th of January and was then kept at that level for the entire year [20]. Changes in interest rate by the central bank have a direct impact on the market rates, which therefore have been quite low in 2020. The cost of capital for a PV system has consequently been low.

In Table 16 the average nominal mortgage rate in 2020 has been used for residential installations. For commercial installations in Sweden a realistic nominal loan rate has been reported to be the STIBOR rate plus 450 dps. A study to derive the levelized cost of electricity (LCOE) of Swedish centralized PV parks projects under 2019 and 2020 are taking place right now, and preliminary average weighted average cost of capital (WACC) from this study is used for industrial and ground-mounted installations in Table 16.

Table 16: PV financing information in 2020.

Different market segments	Loan rate [%]
Average rate of loans – residential installations [21]	1.6 %
Average rate of loans – commercial installations [22]	4.5 %
Average nominal cost of capital – industrial and ground-mounted installations	3.4 %

Several commercial Banks have started to offer specific "solar loans" directed to private individuals with single family houses. To the knowledge of the authors, the first loan specifically directed to PV installations in Sweden was launched by Sparbanken Syd in 2019, from which private PV system buyers at the time of writing can loan 250 000 SEK at a variable interest rate of 1.90 % and a repayment period of up to 10 years [23]. Other examples are the offers of Swedbank and SEB, who both present "solar loans" for up to 350 000 SEK at a variable interest rate of 1.90 % and a repayment period of up to 12 years [24][25]. A third example is Vattenfall, that in collaboration with Handelsbanken, offer a solar loan at an interest rate of 2.9 % [26].

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 similar PV cooperatives that has built co-owned PV systems are Solel i Bergslagen ekonomisk förening, with three systems totalling 156 kW_p, and Zolcell 1:1 ekonomisk förening, with 2 systems totalling 27 kW_p.

The PV cooperative business model 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 cooperative and the shares represent a certain yearly production or renumeration, which the cooperatibe organization deduct from the share owner's electricity bill or pay in real money. One example of this business model 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 the cooperative Törneby driftförening Ek. Förening, initiated by Kalmar Enerig, that installed a crowdfunded 600 kW_p system on the roof of a local farm called Nöbble Gård. Following the positive response of Nöbble Gård, Kalmar Energi is now stepwise building a PV park close to the Kalmar Airport on the behalf of the coopertive. This park is built in stages of 750 kW_p each. The first one was finalized in the end of September 2017, the second in June 2018 and the third in May 2019. In 2017, Öresundskraft initiated the cooperative Solar Park Ek. Förening, which in two phases have built a PV park with a total capacity if 530 kW_p on a former landfill close to Helsingborg. A fourth PV park cooperative is Karlskrona Solpark drift Ek. Förening, initiated by the utility Affärsverken. Their first stage of 0.6 MW of their crowd funded PV park was finalized in April 2019, the second stage of another 0.6 MW was complete in October 2019. The utility Jämtkraft has also created a cooperative, Östersunds Solpark Drift Ek. Förening, which owns a 3 MW PV park outside of Östersund which was commenced in late 2019. In addition, the local utilities Tranås Energi and C4 Energi have initiated similar cooperatives, Bredstorp Sol Ek. Förening and Solpunkten Kristianstad Ek. Förening, respectively. These two cooperatives are as of 2020 running PV parks at the size of 1.2 MW and 4 MW outside of Tranås and Kristianstad, respectively.

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 homeowners.

Table 17: 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 [27], Sweden is the fifth largest country in Europe. In January 2017 Sweden passed ten million inhabitants for the first time in history [28]. The population density of Sweden is therefore low with about 25.5 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 18: 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)
Liberalization of the electricity sector	Sweden currently has one of the most liberalized and top ranked electricity systems in the world [29], due to its (1) *high operational reliability* - the delivery security was 99.974 % in 2019 [30], (2) *high electrification level* – 100 % of total population have access to electricity [31], and (3) *low greenhouse gas emissions* – emissions from fossil fuels associated with the domestic electricity production, in 2020 was only 1.2 TWh, which corresponds to 0.7 % of the total Swedish electricity production of 159.7 TWh [32].

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, which affect the spot prices, and more transmission connections to surrounding countries have come online, on windy days.

2020 marked a year with record low electricity prices due to several reason, amongst them more precipitation than usual paired with mild temperatures and a lot of wind power production. Since the Swedish electricity mix is characterized by a large share of hydropower while having problems with power congestions, a year of high precipitation results in large variations between the bidding areas (see Figure 15) since the north experience a surplus of electricity because of their low consumption and the opposite in the south. The overall average electricity price was 0.11 SEK/kWh on the Swedish electricity market, which is a 73% decrease compared to the 2019 average of 0.41 SEK/kWh.

In 2020 the spot prices were quite unstable over the year, with general low spot prices, but with several days of very high prices in the south, as Figure 15 illustrates. The yearly average ended up at 0.150 in SE1, 0.150 in SE2, 0.221 in SE3 and 0.270 in SE4. The very small price difference between the areas until 2020, have probably not influenced 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). However, if the price difference between the different price areas will be in the same order of magnitude as in 2020 in the future, this could affect the distribution of PV in Sweden.

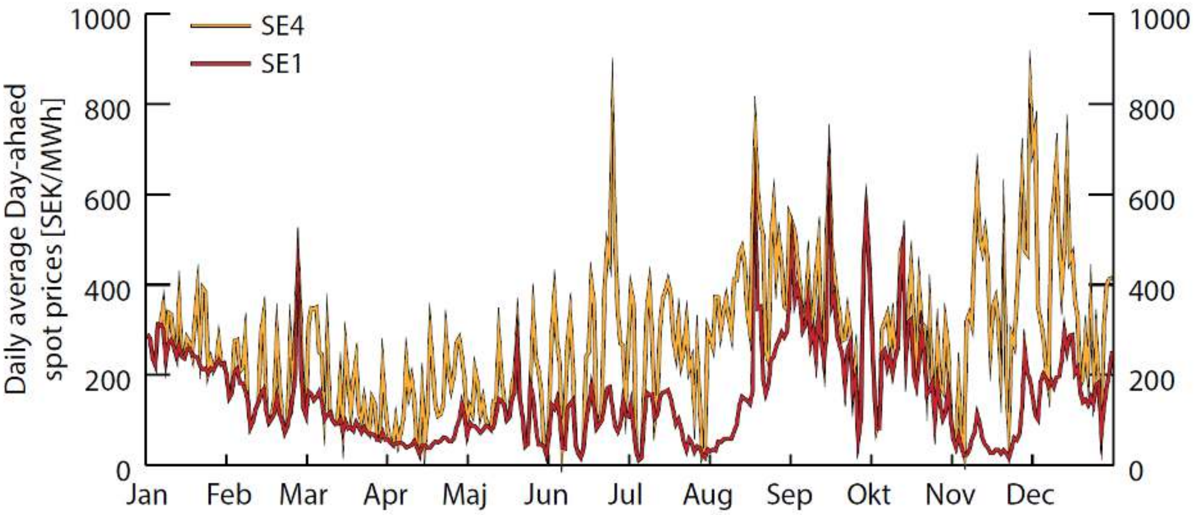

Figure 15: Daily average day-ahead spot prices in area 1 (Luleå) and area 4 (Malmö) in 2020.

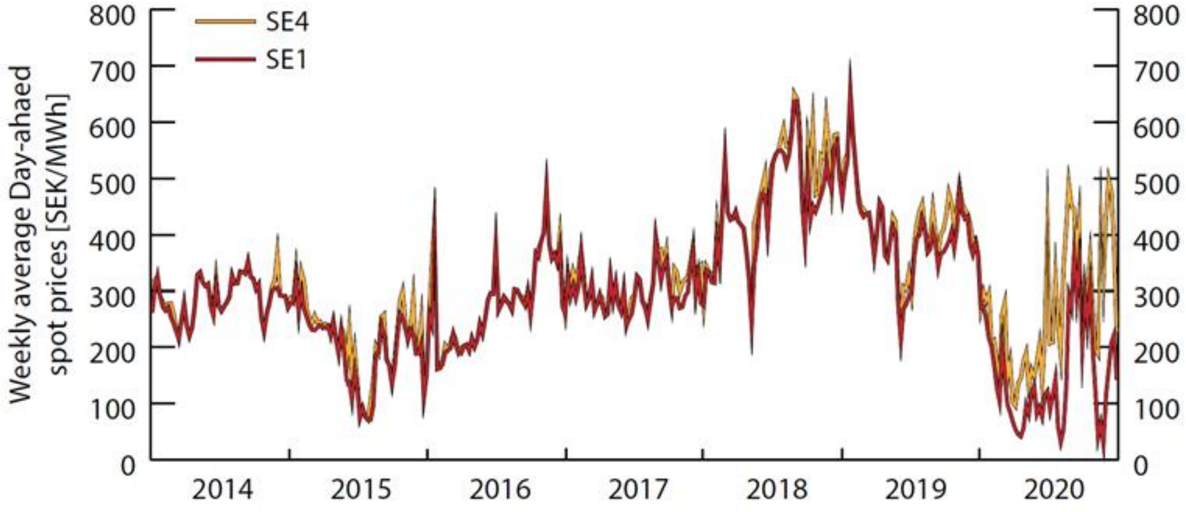

Figure 16: Weekly average day-ahead spot prices in area 1 (Luleå) and area 4 (Malmö) in 2014–2020.

Looking back over the last seven years, the spot prices have varied quite substantially in Sweden, as Figure 16 and Table 19 illustrates, which makes it harder to predict the renumeration of centralized PV parks. One method of determining the actual value of power from a certain electricity generation technology on a shifting spot market is to calculate the market value over a certain period [33][34][35][13]. The market value of an electricity generation technology over a time period represents the relationship between the average spot price of the electricity produced by a power source and its' production share on the market. Furthermore, by comparing the market value a technology with the time-weighted average wholesale electricity price of the same market and time period a "value factor", VF (or sometimes referred to as "capture rate"), can be determined.

A value factor above one is a result of a positive correlation between the production profile of an electricity generating technology (or an individual power plant) and the price fluctuations on the spot market. It can therefore be seen as an indication that the power system would benefit from more production with a similar production profile. As can be derived from Table 19, the market value of PV electricity in Sweden has on average been 5 SEK/MWh and 12 SEK/MWh higher than the average spot prices in Sweden under the time period 2014 to 2020 in SE1 and SE4, respectively. The market value was achieved in 2018, which was also the year with highest global radiation records in Sweden (see section 2.7).

From one can also see that the market value of PV electricity is higher in the two southern price areas (SE3 and SE4) than in the two northern ones (SE1 and SE2). This is fortunate, as the average global radiation is higher in the southern part of Sweden Figure 19. Analysing the value factor of PV, Table 19 show that the value factor has varied over the years. In 2015 and 2019 it was below 1.0, while it was higher than 1.0 in 2014, 2016, 2017 and 2018. In 2020, the value factor was above 1.0 in SE3 and SE4, but below in SE1 and SE2.

If one compares the value factor of PV with the value factor of the other power sources in Table 19, one can see that hydro power, PV and CHP in general has value factors above 1.0, while nuclear are very close to 1.0 and wind power consistently have value factors below 1.0. A simplified conclusion is that the price indicates that the Swedish electricity system would benefit if production with the production profiles similar to either hydro power, PV or CHP would be added. However, this does not by default correlate with profitability for these power sources.

Table 19. The market value, in €/MWh, and corresponding value factor for the major electricity generation technologies in Sweden from 2014 to 2020 in each of the price areas. Nuclear power only appears in SE3 since every active reactor under this time period is located in that region.

Spot price area	Year	PV	Hydro	Wind	CHP	Nuclear	PV	Hydro	Wind	CHP	Nuclear
		Market value (Capture rate) [SEK/MWh]					Value factor				
SE1	2014	305,3	299,9	279,2	280,3	-	1,073	1,049	0,976	0,980	-
	2015	188,4	211,4	201,9	224,1	-	0,925	1,068	1,020	1,132	-
	2016	279,6	288,5	268,0	272,7	-	1,034	1,049	0,974	0,991	-
	2017	308,1	314,4	290,0	295,7	-	1,038	1,058	0,976	0,995	-
	2018	490,9	473,6	443,8	444,1	-	1,103	1,042	0,976	0,977	-
	2019	389,7	433,7	386,6	417,5	-	0,952	1,082	0,964	1,041	-
	2020	151,8	161,6	135,6	161,0	-	0,985	1,075	0,902	1,071	-
	Average	**302,0**	**311,9**	**286,4**	**299,4**	-	**1,016**	**1,060**	**0,970**	**1,027**	-
SE2	2014	303,1	291,6	277,2	281,0	-	1,060	1,020	0,969	0,982	-
	2015	191,3	201,1	196,6	226,9	-	0,965	1,015	0,993	1,145	-
	2016	281,8	282,3	265,5	278,8	-	1,024	1,026	0,965	1,013	-
	2017	310,1	310,2	284,1	301,0	-	1,044	1,044	0,956	1,013	-
	2018	484,0	455,8	433,8	447,3	-	1,065	1,003	0,954	0,984	-
	2019	391,6	415,5	387,7	415,1	-	0,976	1,036	0,967	1,035	-
	2020	147,3	156,1	132,1	163,3	-	0,980	1,038	0,879	1,086	-
	Average	**301,3**	**301,8**	**282,4**	**301,9**	-	**1,016**	**1,026**	**0,955**	**1,037**	-
SE3	2014	305,7	286,8	272,6	284,4	284,7	1,062	0,996	0,947	0,988	0,989
	2015	202,8	211,6	200,9	236,2	211,1	0,985	1,028	0,976	1,147	1,025
	2016	283,6	275,5	272,9	295,6	275,1	1,021	0,992	0,982	1,064	0,990
	2017	315,9	315,4	285,6	305,0	298,3	1,050	1,048	0,949	1,014	0,991
	2018	480,8	439,4	434,9	450,6	452,4	1,050	0,960	0,950	0,984	0,988
	2019	394,0	410,7	391,6	439,5	407,2	0,972	1,013	0,966	1,084	1,004
	2020	248,5	239,3	176,4	244,9	214,0	1,124	1,083	0,798	1,108	0,968
	Average	**318,7**	**311,3**	**290,7**	**322,3**	**306,1**	**1,038**	**1,017**	**0,938**	**1,056**	**0,994**
SE4	2014	307,3	290,4	277,3	294,7	-	1,058	1,000	0,955	1,015	-
	2015	217,6	235,1	200,1	247,8	-	1,015	1,097	0,934	1,157	-
	2016	287,1	257,2	269,4	280,6	-	1,023	0,917	0,960	1,000	-
	2017	320,9	322,2	288,8	315,4	-	1,035	1,039	0,932	1,017	-
	2018	509,5	430,9	445,2	462,2	-	1,069	0,904	0,934	0,970	-
	2019	413,1	433,5	402,5	446,5	-	0,982	1,030	0,956	1,061	-
	2020	290,2	265,1	208,7	280,6	-	1,076	0,983	0,774	1,041	-
	Average	**335,1**	**319,2**	**298,8**	**332,6**		**1,037**	**0,996**	**0,921**	**1,037**	

As the electricity mix in Sweden changes, (more wind and PV are expected to be built while two nuclear reactors at Ringhals 1 and Ringhals 2 was decommissioned as of 30 of December 2019 and 31st of December 2020) the value factor of the different power sources will change. E.g. in a recent study it was simulated that the value factor of PV will go from in general being above 1.0 to in general be below 1.0 if PV reaches above 5 % of the total power production in the electricity mix [36].

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 17 illustrates the evolution of the average electricity price for the average end consumer over the years [32]. In Figure 18 the variable part of the electricity price, which is what can be saved if the micro-producer replaces purchased electricity with self-generated PV electricity, is illustrated. Furthermore, the value of the excess electricity is shown for two base cases with the Nord Pool spot price as a base compensation offered by electricity trading utility companies (see section 7.2), energy compensation from the grid owner (see section 3.3.6), the tax credit system (see section 3.3.5) and with and without the green electricity certificate, since few PV owners are using the green electricity certificate system (see section 3.2.3).

The reader should note that the electricity price in Figure 18 was the lowest achievable in July 2021. The reason for illustrating the values in 2021 instead of 2020 is partly that the spot prices in 2020 was unrepresentative due to the COVID-19 outbreak, and partly because the grid operator Vattenfall lowered the grid fees for household customer as of the 1st of January 2021. So, July 2021 gives more up to date illustration of the values. 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 would have been higher than in the figure.

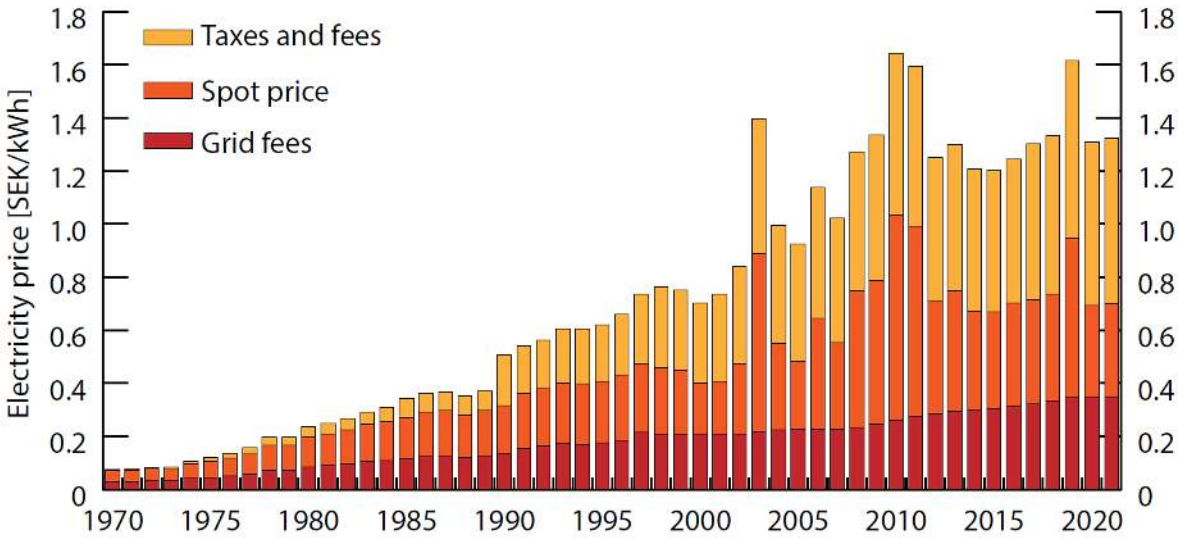

Figure 17: Evolution of the average electricity price (in January) for private end consumer with a single-family house with electric heating.

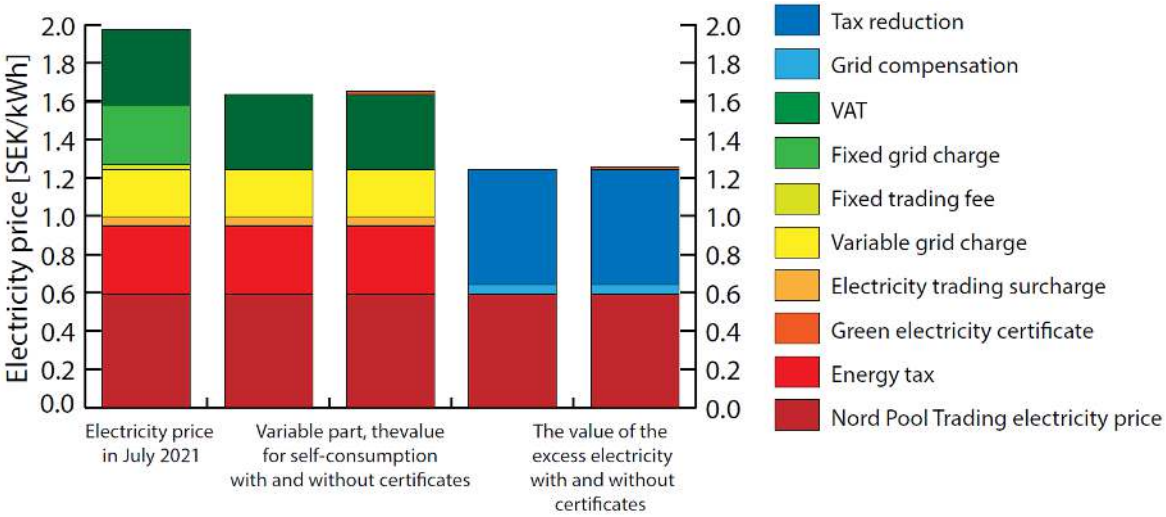

Figure 18: The lowest available electricity price for a typical house with district heating in Stockholm with an annual electricity consumption of about 10 000 kWh/year, a 16-ampere fuse and Vattenfall as the grid owner in July 2021. Furthermore, the compensation for the excess electricity, with and 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. The distribution of annual average global radiation over Sweden is presented in Figure 19 [37].

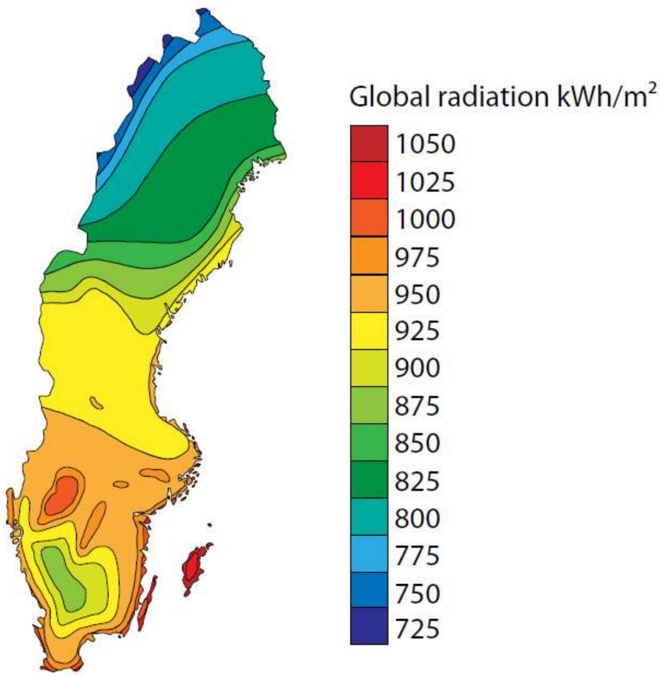

Figure 19: Average global solar radiation in Sweden in one year.

In the long-term variation of global radiation in Sweden a slight upward trend has been noted and the average solar radiation has increased by about 8 % from the mid-1980s until 2005–2006, from about 900 kWh/m^2 in 1985 to the current level of the recent years, which has varied between 900–1 000 kWh/m². Recent years have seen some further increase. A similar trend is seen in large parts of Europe. In 2020 annual average accumulated global radiation reached 1009.6 kWh/m² [37], the second highest radiation since the mid-1980s. From a PV production perspective good year but below the historic record of 1050.6 kWh/m^2 in 2018, when long periods of anticyclone weather (where barometric pressure is high) over Scandinavia gave very sunny weather during May and July.

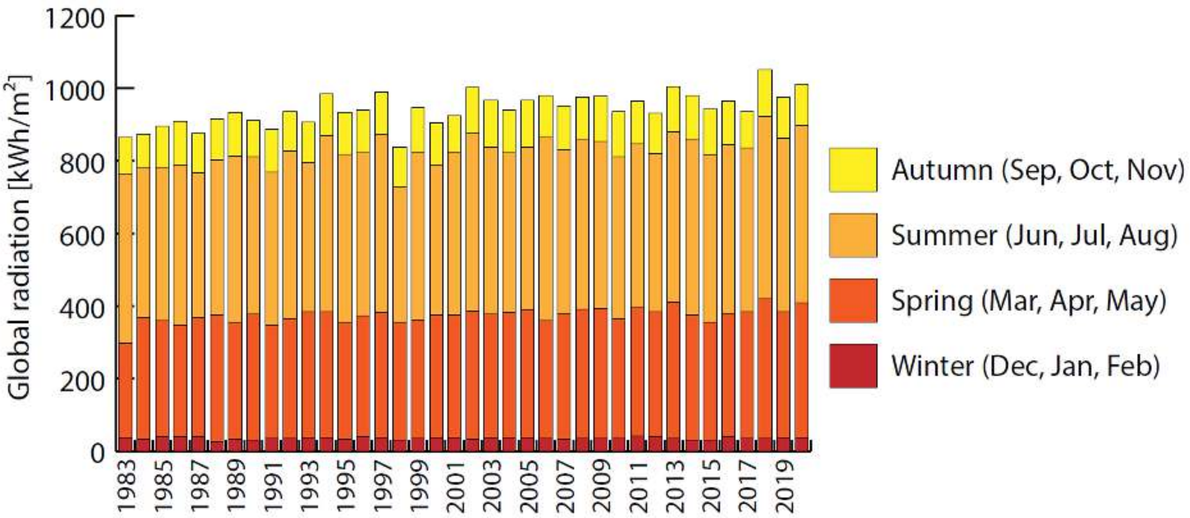

Figure 20: The annual average accumulated global solar radiation in Sweden between 1984 and 2019.

2.8 Production costs of PV electricity

Levelized cost of electricity, LCOE, is a transparent measure of generating costs of different power plants and a widely used tool for comparing the costs of different power generating technologies. The definition of the LCOE can be expressed as the real fixed price of electricity that would exactly cover the sum of costs in terms of present value. To simply, two assumptions are usually used. Firstly, that the real interest rate, r, used for discounting costs and revenues is constant during the lifetime of the power plant. Secondly, that the real electricity tariff, Py, is assumed not to change during the lifetime of the power plant and that all the produced electricity is sold at this tariff. With this as a starting point, along with some simplifications and additions based on characteristics of the PV technology, the following equation can be used to calculate the LCOE of PV electricity:

$$LCOE = \frac{CAPEX_0 + \sum_{t=1}^{N}\left[\frac{O\&M_f + O\&M_v * Y_0 * (1-Dg)^t}{(1+WACC_r)^t}\right] + \frac{ReInv_1}{(1+WACC_r)^{x_1}} + \frac{ReInv_2}{(1+WACC_r)^{x_2}} + \frac{ResC}{(1+WACC_r)^N}}{\sum_{t=1}^{N}\left[\frac{Y_0 * (1-Dg)^t}{(1+WACC_r)^t}\right]}$$

where *t* is the year number ranging from 0 to *N*, *N* the operational lifetime of the PV park, $CAPEX_0$ the total capital expenditure of the system in year 0 expressed in SEK, $O\&M_f$ the fixed operation and maintenance cost in year *t* expressed in SEK, $O\&M_v$ the variable operation and maintenance cost per produced unit of energy in year *t* expressed in SEK/MWh, Y_0 the initial annual electricity production (yield) in the year when operation start expressed in MWh, *Dg* an annual degradation factor expressed in %, $ReInv_1$ the first major reinvestment needed to reach expected lifetime in year x_1 expressed in SEK, $ReInv_2$ the second major reinvestment needed to reach expected lifetime in year x_2 expressed in SEK, *ResC* and the residual cost of the system at the end of the lifetime expressed in SEK and $WACC_r$ the real weighted average cost of capital per annum in %.

The LCOE of PV electricity very much depend on the size of the PV system and the type of actor owning the system, as the CAPEX and WACC parameters are the two most influential ones for the result. The typical LCOE of two type of PV systems in 2020 in Sweden, namely centralized ground mounted PV parks and decentralized roof mounted PV system for residential villa system of about 10 kW_p, have been thoughtfully investigated in [38]. In this report the interested can find information and discussions about the different parameters needed to calculate the LCOE and the end result. In this report the derived LCOE parameters and final LCOE of [38] is summarized in Table 20.

Table 20: Average values for the parameters need to calculate LCOE and the final LCOE value for a 10 kW_p residential system and a 5 MW_p centralized PV park in Sweden [38].

Parameter	10 kW_p residential	5 MW_p centralized
Lifetime, *N* [Years]	30	33
Initial annual yield, *Y* [kWh/kW_p/a]	849	969
System degradation rate, *Dg* [%]	0.2	0.2
CAPEX [SEK/kW_p]	16 496	7 232
Yearly fixed operation and maintenance, $O\&M_{fix}$ [SEK/kW_p/a]	64	87
Variable operation and maintenance, $O\&M_{var}$ [SEK/kWh]	-0.04	-0.02
Major reinvestment needed to reach expected lifetime in at t=x, *ReInv* [SEK/kW_p]	2 300	582
Years after operation start when major reinvestment is needed, *x* [Years]	15	16.7
Residual cost of the system at the end of the lifetime [SEK/kW_p]	0	19
Nominal weighted average cost of capital per annum, $WACC_{nom}$ [%]	2	3.4
Real weighted average cost of capital per annum, $WACC_{real}$ [%]	0	1.4
Levelized cost of electricity	**0.79 SEK/kWh**	**0.43 SEK/kWh**

As can be seen in Table 20 the average LCOE of a 10 kW_p villa system was derived to be 0.79 SEK/kWh. This is with no subsidies whatsoever. If the direct capital subsidy is used, which gave a 20 % rebate on the CAPEX in 2020, the LCOE becomes 0.6 SEK/kWh. These 0.6 SEK/kWh in production cost can be compared with the revenues of the self-consumed electricity and excess electricity in Figure 18 for assessments of profitability of small residential systems in Sweden in 2020.

The LCOE of PV parks was concluded to be 0.43 SEK/kWh on average. Comparing this production cost with the market value of PV the last six years in Table 19, it can be concluded that profitability for a merchant business model would only be reached with spot prices at levels seen in 2018. Hence, for the 2020 market of centralized PV parks in Sweden it was still important that additional value to PV electricity is added through business models such as PPAs or cooperative owned PV parks (see section 2.4).

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, simplifying or defining adequate policies. Indirect support policies change the regulatory environment in a way that can push PV development.

Table 21: Summary of PV support measures.

Category	Residential		Commercial + Industrial		Centralized	
Measures in 2020	**On-going**	**New**	**On-going**	**New**	**On-going**	**New**
Feed-in tariffs	-	-	-	-	-	-
Feed-in premium (above market price)	Yes	-	(Yes)[1]	-	-	-
Capital subsidies	Yes	-	Yes	-	Yes	-
Green certificates	Yes	-	Yes	-	Yes	-
Renewable portfolio standards with/without PV requirements	-	-	-	-	-	-
Income tax credits	Yes[2]	-	(Yes)[2]	-	-	-
Self-consumption	Yes	-	Yes	-	-	-
Net-metering	-	-	-	-	-	-
Net-billing	-	-	-	-	-	-
Collective self-consumption and virtual net-metering	Yes	-	-	-	-	-
Commercial bank activities e.g. green mortgages promoting PV	Yes	Yes	-	-	-	-
Activities of electricity utility businesses	Yes	-	Yes	-	Yes	-
Sustainable building requirements	Yes	-	Yes	-	-	-
BIPV incentives	-	-	-	-	-	-
Guarantees of origin	Yes	-	Yes	-	Yes	-

[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 exist a political agreement that sets a goal that Sweden will have a 100% renewable electricity system by 2040, while still planning to be a net exporter of power. The agreement is not a political stop date for nuclear, but to reach the goal, this implies phasing out the Swedish nuclear reactors that are coming of age and continuously pushing for new renewable energy production. Many of the introduced legislation changes in the coming years are expected to spring from this political agreement, and the Swedish PV market will most likely benefit from it.

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 a 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 for grid-connected PV and the installation rate went down in 2009, as can be seen in Table 4. However, a new subsidy program was introduced in mid-2009, now open for all actors [39]. 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 22 and Table 23.

Table 22: Summary of changes in the direct capital subsidy ordinance, support level and duration [40]**.**

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
2020:489 ändring av 2009:689	2020-06-30	20 %	2021-06-30
2020:1263 ändring av 2009:689	2021-01-15	10 % companies	2021-09-30

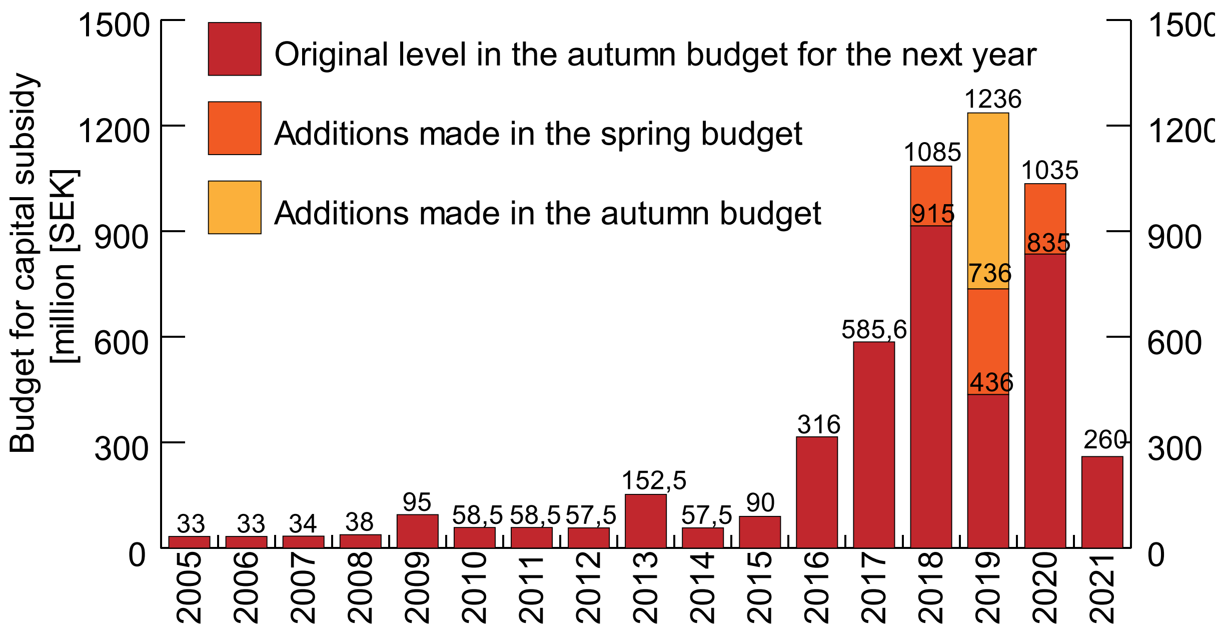

Figure 21: The annual budget of the direct capital subsidy program.

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 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 and later another 500 million SEK in the next autumn budget. At the same time, it was communicated that the original budget for 2020 would be 835 million SEK. In the spring budget of 2020, another 200 million SEK was added. The budget over the years is summarized in Figure 21.

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 31st 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 in day 3 [40]. Ever since then, the amount of money applied for each year has been much higher than the allocated budget. Therefore, a long queue 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 peak in 2016, average waiting time was on average 722 days, i.e. almost 2 years [40]. 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.

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 lowered further in 2013 to 35 %. From 2015 the level was decreased to maximum 30 % for companies and 20 % for other stakeholders. From January 1st, 2018 the Swedish government increased the subsidy level for “others” to 30 % so that all actors had the same level. From the 8th of May 2019 the level has been decreased to 20 % for all following the decline of PV prices and increase in electricity prices for end consumers.

In the last version of the statute, active in 2020, funds could only be applied for if the system costs were less than 37 000 SEK excluding VAT/kW$_p$. Solar power/heat hybrid systems could cost up to 90 000 SEK plus VAT/kW$_p$. If the total system costs exceed 1.2 million SEK, capital support was only granted for the part of the system cost that was less than this value (see Table 23). The 1.2 million SEK cap effectively lowered the subsidy level available for big PV systems. For example, if a large, centralized PV park of 10 MW at a cost of 70 million SEK received the 1.2 million SEK subsidy, it would only cover 1.7 % of the total system cost.

Table 23: Summary of the Swedish direct capital subsidy program [40][41][42]**.**

	Maximum coverage of the installation costs	Upper support limit per PV system [MSEK]	Maximum system cost per W [SEK/W]	Budget [MSEK]	Granted funds[1] [MSEK]	Disbursed funds [MSEK]	Yearly PV capacity with support from the direct capital subsidy[2] [MW_p]	Yearly total installed grid connected PV capacity [MW_p]
Total 2006 –2008	70% Only for public building	5.0	-	138	138	138	2.96	2.83
2009	55 % Companies 60 % Others	2.0	75	212	28.43	0.05	0.20	0.52
2010					74.12	33.23	2.08	1.77
2011					70.93	81.02	3.12	3.45
2012	45%	1.5	40	57.5	57.70	78.35	6.28	7,18
2013	35%	1.3	37	210	108.61	73.16	11.54	1.95
2014					58.85	75.60	21.94	34
2015	30% Companies 20% Other	1.2		90	71.62	78.17	29.50	47.07
2016				316	218.22	138.79	50.93	57.27
2017				585.6	313.18	235.71	76.81	83.61
2018	30%			1085	997.44	601.70	164.92	155.16
2019	20%			1236	642.27	676.53	283.26	279.89
2020	20%			1035	1 331.57	840.12	272.74	398.45
Total	**-**	**-**	**-**	**4965.10**	**3 972.95**	**2 912.42**	**926.28**	**1089,15**

[1]Extract from Boverket's database 2021-04-07. The granted resources are expected payments which may change if the circumstances change in individual cases.

[2]The numbers are probably higher for several of the later years, as there is a large delay in the system due to the long queues. The numbers are retroactively updated in these publications.

Since the start of the first program in 2006 until the end in 2020, 4406.03 million SEK had been granted and 3 050.43 million SEK had been disbursed [42]. This capital has supported a total installation of 926.28 MW_p so far. This means that the average subsidy for all PV systems since 2006 to 2020 has been 3.3 SEK/W_p, down from 8.9 SEK/W_p in 2016, 5.3 SEK/W_p in 2017, 4.6 SEK/W_p in 2018 and 3.7 SEK/W_p I 2019.

Listed in Table 23 is the annual installed PV capacity that has received support from the direct capital subsidy as compared to the statistics of yearly installed grid connect PV capacities. The statistic from direct capital subsidy program correlates well with the yearly installation statistics, except for 2009 and 2020. For 2009 it can be explained with a backlog of installations from the older direct capital subsidy program. The difference in the statistics for 2018 onwards can probably be related to the switch from sales statistics to collecting the statistics from the grid owner. A general explanation for the higher number of annual installed capacities compared to yearly PV capacity with support from the direct capital subsidy 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 explanation for the incoherence of 2020 between the supported capacity and the total installed capacity is that the Swedish Government announced to close the capital subsidy system for new applications by July 7th, 2020 in June of 2020 [43]. For private persons, this marked the end of a more than 10-year long support program for PV. Instead, the capital subsidy is replaced by a green tax deduction (see section 3.2.4). At the same time, they communicated that the completion period would be prolonged until the June 30th, 2021 instead of the 31st of December. This was a measure to meet the need for possible project time extensions due to the corona pandemic. For municipalities and companies, a total of SEK 260 million has been set aside for capital subsidy program in 2021. It is not possible to apply for the funds for new projects, but support can be disbursed to those who have applied before July 7th, 2020. The support level is 10 percent for these projects.

3.2.2 Direct capital subsidy program 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 has 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 [44].

The subsidy is granted for the purchase of materials, services of consultants to plan and carry out the investment, but not salary to employees or work done by the applicant. The level of the direct capital subsidy is 40 % of the total expenses. The total project cost must exceed 100 000 SEK for the subsidy program to apply. The maximum amount of aid a company can receive is decided by the respective County Administration (Länsstyrelse) or by the Sami Parliament (Sametinget) [44].

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 agricultural companies pay a lower level of the Swedish energy tax (see section 3.3.1), which makes the value of self-consumed electricity lower than for regular electricity consumers and therefore a PV system or any other renewable system is less profitable. A higher subsidy level increases the profitability of PV installations on barns and other agriculture buildings, which is a market segment with large potential [45].

Until the end of 2020, the program has granted and disbursed support to 161 PV projects with a total capacity of 6 877 kW for a total amount of 29 163 257 SEK, in accordance with Table 24.

Table 24: Summary of the PV projects in the direct capital subsidy program for renewable production in the agriculture industry.

Year	Number of financed PV projects	Disbursed funds [SEK]	Installed PV capacity [kW_p]	Average cost per kW_p
2016	5	1 026 096	203	13.6
2017	25	2 865 775	632	13.2
2018	31	5 180 719	1 109	12.3
2019	39	7 159 718	1 740	11.9
2020	61	12 930 949	3 193	12.0
Total	161	29 163 257	6 877	12.2

3.2.3 The renewable electricity certificate system

The basic principle of the renewable 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 renewable electricity certificates for a maximum of 15 years and limited to the end of year 2045.

The quota-bound stakeholders are: electricity suppliers; electricity consumers who use electricity that they themselves produced if the amount used is more than 60 MWh per year and 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; producers who produce electricity to a grid which is used without support of grid concession (nätkoncession), provided the electricity used amounts to more than 60 MWh per year and if the electricity is commercially supplied to consumers who use the electricity on the same grid; 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 at that time was to increase the annual electricity production from renewable energy sources by 17 TWh in 2016 compared to 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 [46]. 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 [47].

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 per year from 2022 to 2030. However, due to the rapid construction of wind power, the Swedish Energy Agency anticipate that the 2030 goal could be reached by as early as 2021 [48]. To avoid prices of the certificates to drop down to zero due to over-establishment of renewable energy sources, which would be detrimental to early investors, a new change in the system was decided on by the Swedish government on November 11^{th}, 2020. The amendment stated that no power production constructed after 2021 would be eligible for certificates, and that the termination of the certificate system would be advanced to 2035 rather than the previous 2045 end date [49].

In 2020, the average price for a certificate was reduced to 36.6 SEK/MWh from the average price of 89,8 SEK/MWh in 2019 and 144.7 SEK/MWh in 2018 [50], and the quota obligation was decreased to 28.8 %, from 30.5 % in 2019 [51]. The established trend in the level of the quota duties is summarized in Figure 23 and the price trend in Figure 22. Since the start in 2003 until the end of 2020, certificates corresponding 329.0 TWh has been issued in Sweden with PV accounting for 753.9 GWh of them [50].

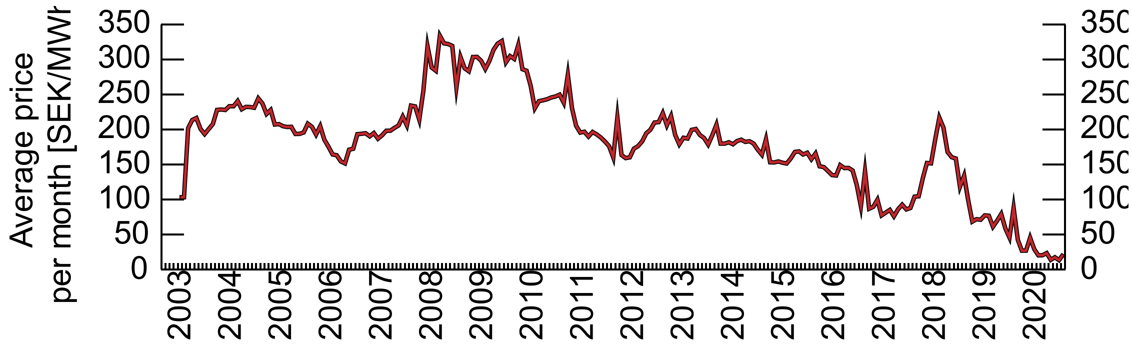

Figure 22. The price development of the renewable electricity certificates [50].

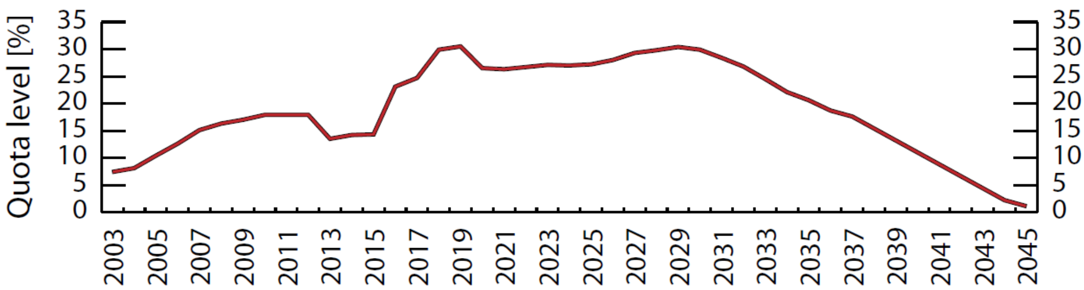

Figure 23. The quota levels in the renewable electricity certificate system [52].

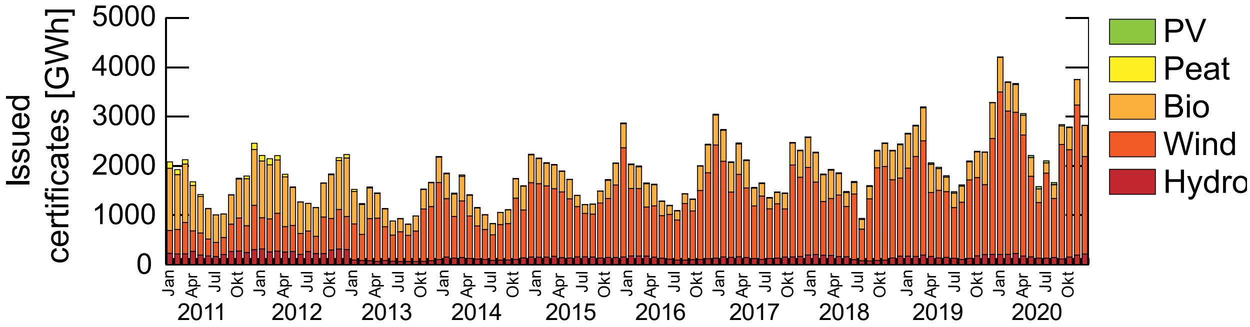

Figure 25. The allocation of renewable electricity certificates to different technologies [50].

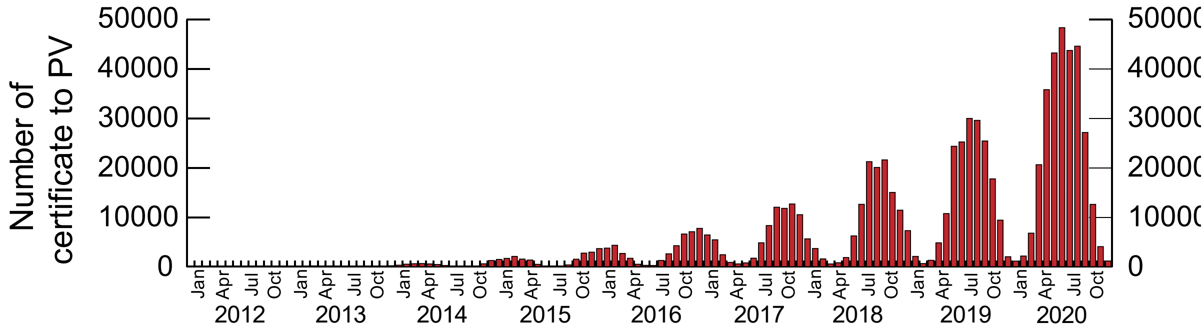

Figure 24. Renewable electricity certificates issued to PV produced electricity [50].

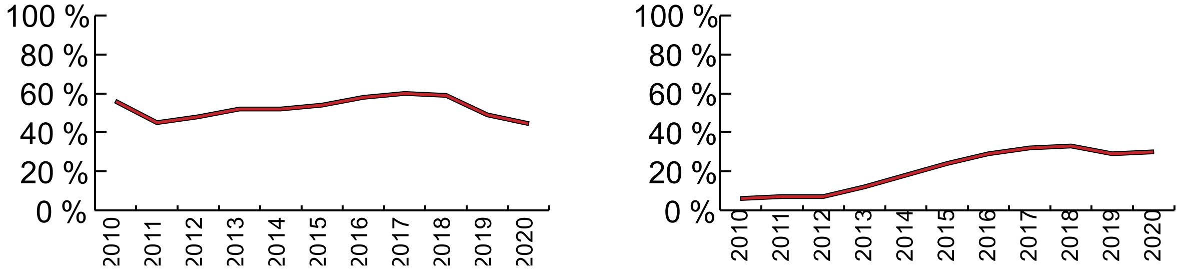

Figure 26: (a) Percentage of the installed PV power in Sweden that is approved for renewable electricity certificates. (b) Allocated certificates to PV electricity divided by the theoretical yearly PV production[50]**.**

Until 2005 there were no PV systems in the electricity certificate system [52]. However, as Table 25 show, the number of approved PV installations increased over the years and a majority of the approved plants in the certificate system are now PV 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 25, most of the certificates go to wind and biomass power, which produce 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. By comparing Figure 25 and Figure 24, it is easy to see the potential for solar to level out the seasonality of certificate issuance. However, the installed solar capacity would have to increase dramatically in magnitude.

492.8 MW of PV power was accepted in the certificate system at the end of 2020 [52], making it 45 % of the total installed PV grid connected capacity. As Figure 26a shows, that share has been rather constant over the years.

Table 25: Statistics about PV in the electricity certificate system [50][50][50][52]**.**

	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 of issued certificates from solar cells per year	Number of produced certificates eligible in kWh per installed power and year
2006	3	103 kW	34.3 kW	20 MWh	194 kWh/kW
2007	6	184 kW	30.6 kW	19 MWh	103 kWh/kW
2008	16	508 kW	31.7 kW	129 MWh	254 kWh/kW
2009	27	1 059 kW	39.2 kW	212 MWh	200 kWh/kW
2010	62	3 227 kW	52.1 kW	278 MWh	86 kWh/kW
2011	138	4 196 kW	30.4 kW	556 MWh	133 kWh/kW
2012	395	8 104 kW	20.5 kW	1 029 MWh	127 kWh/kW
2013	972	18 419 kW	19.0 kW	3 705 MWh	201 kWh/kW
2014	1 866	36 437 kW	19.5 kW	10 771 MWh	296 kWh/kW
2015	3 270	63 934 kW	19.6 kW	24 544 MWh	384 kWh/kW
2016	5 107	104 070 kW	20.4 kW	45 535 MWh	438 kWh/kW
2017	7 428	159 050 kW	21.4 kW	74 148 MWh	466 kWh/kW
2018	11 282	250 912 kW	22.2 kW	120 919 MWh	482 kWh/kW
2019	16 683	380 227 kW	22.8 kW	181 908 MWh	478 kWh/kW
2020	19 903	492 759 kW	24.8 kW	290 152 MWh	589 kWh/kW

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 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 for the self-consumed electricity as well 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 proportion of PV production that receive certificates per year is so low in Table 25 and why only 290 152 certificates were issued to PV in 2020 [50]. This is only about 30 % of the theoretical production of 1 089 MW × 900 kWh/kW ≈ 980 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 2020 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 may be the reason for the trend in Figure 26b and Table 25 where the share of the produced PV electricity that receives certificates is increasing.

To summarize, the renewable 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. However, an early termination of the system was decided on in 2020 and the end date for entering new power production is approaching.

3.2.4 Tax reduction for green technology

As mentioned in paragraph 3.2.1 on the expiration of the direct capital subsidy for PV installations for private individuals in July 2020, the possibility of receiving compensation for residential PV installation will remain. A tax reduction program for green technology gained legal effect January 1st 2021 and replaced three existing support systems, namely the direct capital subsidy for PV installations (2009:689) [39] for private persons, the subsidy for storage of self-produced electricity (2016:899) [53] and the subsidy for private installations of charging points for electric vehicles (2017:1318) [54]. It is often referred to as the green deduction.

Unlike the direct capital subsidy for PV installations, this is a support system that is managed and administered by the system suppliers and ultimately by the Swedish Tax Agency (Skatteverket). It is design much like the ROT tax deduction, see 3.9.6. This means that instead of the system owner applying for the economic support and handling the process, the tax deduction will reduce the price for the house owner already on the invoice, while the system suppliers will report the deducted amounts to the tax authorities [18].

This system provides a percentual tax deduction for the hardware and installations costs of the three energy efficiency measures for private house owners. PV installations are offered a 15% deduction, while batteries and charging points for electric vehicles get a 50% tax deduction. This deduction can be made by private persons and can be used once per year and person. There is a maximum annual accepted amount of 50,000 SEK. In the case of all three measures being installed at once, which has both cost and installation benefits, there is a possibility that the maximum amount will be reached. Since PV have the lowest deduction level, the ROT- tax deduction might be applied to the PV installation while the charging point and the battery installation is included in the green deduction.

To facilitate the administration for both companies and the Swedish Tax Agency, a level of 97 percent of the total investment cost has been approved as deductible costs for the green deduction [55]. This means that the direct capital subsidy for private individuals of 20 percent of the total cost is replaced by a support of 15% of 97 percent of the cost, 14.55% percent, by 2021. The advantage is that there is no limiting budget and thus no queue in this system, but everyone who meets the requirements can take advantage of the tax deduction.

3.2.5 BIPV development measures

There were no specific BIPV measures in Sweden in 2020.

3.3 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.

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

Table 26: Summary of self-consumption regulations for small private PV systems in 2020.

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 + Feed in compensation from the grid owner
	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

3.3.1 General taxes on electricity

In Sweden, taxes and fees are charged at both the production of electricity and at the consumption of electricity. Taxes that are associated with the production of electricity are property taxes (see section 3.6.1), taxes on fuels and taxes on emissions to the atmosphere.

The taxes associated with electricity consumption are mainly the energy tax on electricity and the value added tax (VAT). The manufacturing and agriculture industry paid 0.005 SEK/kWh in energy tax in 2020. 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 [56]. The latest increase occurred the first of January 2020 when the energy tax was increased from 0.347 SEK/kWh (excluding VAT) to 0.353 SEK/kWh. The exception is some municipalities in northern Sweden where the energy tax now is 0.257 SEK/kWh (excluding VAT) [57]. Additionally, a VAT of 25 % is applied on top of the energy tax. Altogether, roughly 40 % of the total consumer electricity price (including grid fees) was taxes, VAT and certificates in 2020.

3.3.2 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 were implemented on July 1st, 2017, can be can be summarized as [57]:

- A solar electricity producer that owns one or more PV systems whose total power amounts to less than 255 kW_p 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, which 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 used 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 used 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 systems smaller than 255 kW_p the main economic obstacle for real estate owners that plan to build several small PV systems has been removed with this legislation. However, the administrative burden of measuring and reporting the self-consumed electricity if the total power limit of 255 kW_p is exceeded remains.

However, there is an ongoing discussion on how to tax self-consumption, and the budget proposition declared September 14th, 2020 proposed an increased limit to 500 kW_p, which gained legal power January 1st, 2021. Another 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 [58].

3.3.3 Deduction of the VAT for the PV system

Sweden has a non-deductible VAT for permanent residents. 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 [59].

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.

However, according to Case 6174-18 of the Swedish Supreme Administrative Court, it is stated that the VAT deduction waiver for permanent housing does not include homeowner's association's (BRF) acquisition of PV systems. The homeowner's association is granted the right of deduction for VAT as long as the acquisition is attributable to the association's VAT liable sales of surplus electricity. In summary, this means that a homeowner's association may deduct VAT on the investment in a PV system corresponding to the proportion of electricity that will be sold to the electricity grid.

3.3.4 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 and from the grid owner (see section 3.3.5). 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 27). If the total annual sales do not exceed 30 000 SEK the PV system owner are exempted from VAT [60].

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. Hence, as a general rule of thumb, the 30 000 SEK limit corresponds to PV systems of 100–200 kW_p, which is a very large PV system size for regular homeowners.

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 homeowner needed to go through the administration of registering for VAT and reporting the VAT to the Government. The new set of rules makes it much easier for a household 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 thousands of private PV owners. As the Government is not losing any tax income, as illustrated in Figure 27, it is a win-win situation for all parties as compared to before the 1st of January 2017.

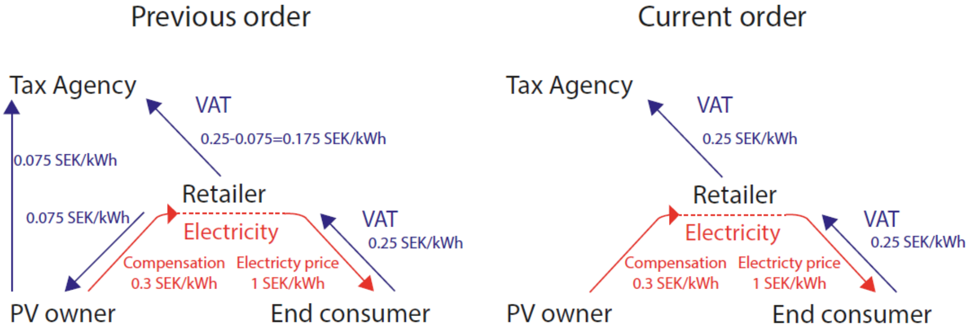

Figure 27: Illustration of the revenue and VAT streams for the excess electricity for a private PV owner before and after the 1st of January 2017.

3.3.5 Tax credit for micro-producers of renewable electricity

The 1st of January 2015, an amendment to the Income Tax Act was introduced [61]. 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 section 7.2), the grid benefit compensation (see section 3.3.6) and revenues for selling renewable electricity certificates and guarantees of origins (see section 3.2.3 and 3.3.7). 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 that 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 60 699 micro-producers of renewable electricity received a total 150 844 066 SEK for excess electricity fed into the grid in 2020. This amount is based on 228 552 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 per micro-producer with a capacity of less 100 amperes was thereby 3 765 kWh in 2020, as summarized in Table 27.

Table 27: Statistics about tax credit for micro-producers of renewable electricity.

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	5 391	11 421 003	19 035 005	3 531
2016	8 161	19 545 400	32 575 667	3 992
2017	12 138	30 068 341	50 113 902	4 129
2018	20 350	57 098 546	95 164 243	4 676
2019	40 442	102 164 634	170 274 390	4 210
2020	60 699	150 844 066	228 551 615	3 765
Total	-	**371 141 990**	**595 714 822**	-

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 (which corresponds to the 100-ampere limit of the tax reduction) in the green electricity certificate system. In total there was 297 664 kW of systems with a power less than 69 kW by 2020-12-31. Of this power 292 090 kW was PV, and the rest was 2 313 kW wind, 2 267 kW hydro and 995 kW biofuel or peat system [52]. If one uses this relationship, a rough estimation is that 364 192 055 SEK of the total 371 141 990 SEK has been paid to PV system owners through the tax credit for micro-production system until the end of 2020. 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.

3.3.6 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 loss reduction in the grid that the excess electricity entails [62]. The compensation varies between different grid owners and grid areas and is typically between 0.02 and 0.10 SEK/kWh.

3.3.7 Guarantees of origin

Guarantees of origin (GOs), were introduced in Sweden on December 1st 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 type 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.

Table 28: Statistics about solar guarantees of origin [50]**.**

Year	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	568 832	1 467 852	317 189	29 499
2019	166 670	894 568	1 527 014	526 292	976 716	51 935
2020	272 646	943 181	1 383 593	373 746	927 148	68 924

A utility company that wants to sell, for example, electricity from PV can do so 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 nullify them when the supplier sells the electricity to the end customer.

The GO act (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 [63]. Thus, 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 28. In 2017 a lot of solar GOs was imported to Sweden, and in 2018 a lot of them was exported. 2019 and 2020 once again saw an increase in imported solar GOs, along with a three-fold increase in nullification from the year before.

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 were generally traded in Europe for 33 €-cents/MWh in 2020, which would translate to the value of around 0.0033 SEK/kWh. However, some Swedish utilities buy solar GOs issued in Sweden from small-scale PV owners for a much higher price.

From the first of October 2021, GOs can solely be issued for the electricity that reaches the grid supported by the grid concession. Previously it could also be issued for electricity in a grid without support of grid concession.

3.4 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.

In 2019, in an effort to modernize the permit processes connected to the electrical grid, a consultation document was produced in which a number of legislative changes were proposed. The body considering the permit processes suggests an exemption from the grid concession (a permit to operate electrical lines, issued by the Energy markets Inspectorate (Ei)) for local low-voltage grids, established between buildings within the property [64]. The reason for this is the increasing interest for micro production of renewable electricity and energy storage, and that the process to share named electricity within a properly should be facilitated. The European Union package Clean Energy for All Europeans also pushes EU Member States to enable self-consumption and to establish simplified authorisation procedures for installations and access to the grid [65]. However, the consultation document highlights that an alternative to allowing local low-voltage grids is to establish a more flexible billing and taxing system, to enable sharing electricity between buildings without being subjected to double taxes and grid fees [64]. No legislative changes have yet been made, but the topic is expected to be taken up for discussion in the Swedish Parliament in the near future.

3.5 Tenders, auctions & similar schemes

There were no national or regional tenders or auctions in 2020 in Sweden. However, commercial PPAs for PV exists in Sweden.

3.6 Utility-scale measures including floating and agricultural PV

There were no specific national or regional subsidies for utility-scale PV in Sweden in 2020. The support and measures accessible for utility-scale PV are the general support schemes of the direct capital subsidy that expired mid 2020 (see section 3.2.1) but with a cap of 1.2 million SEK per system which lowers the benefits of utility-scale centralized PV parks, the green electricity certificate system (see section 3.2.3) and the guarantees of origin system (see section 3.3.7).

3.6.1 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 [66].

3.7 Social Policies

There were no social policy measures directed to PV in Sweden in 2020.

3.8 Retrospective measures applied to PV

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

3.9 Indirect policy issues

3.9.1 Rural electrification measures

There were no rural electrification measures in Sweden in 2020.

3.9.2 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 permits in general. Some installations still require building permits, and that is when the one of following situations applies [67]:

- 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.

3.9.3 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 [53];

- 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 3.9.6) or any other public support. Eligible costs are the costs of installing electrical energy storage systems, such as batteries, cabling, control systems, smart energy hubs and installation work. The subsidy is only granted to individuals with a maximum of 60 % of the eligible costs, but no more than 50 000 SEK [53].

For other end consumers 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 installed in 2016 are entitled to apply for the subsidy. The budget for the storage subsidy program was 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. In 2019, the program was prolonged to include projects either paid for or started up until December 31st, 2020.

Starting January 1st, 2021, the subsidy program is replaced by the joint green tax deduction for solar PV, storage systems and charging points for electrical vehicles for private persons. The tax deduction is designed for energy efficiency measures for private households and is explained further in section 3.2.4. The total granted and disbursement of funds as of the end of 2020 was 112 632 919 SEK and 59 570 855 SEK, respectively. Since projects initiated in 2020 and completed before June 30th, 2021, are eligible for support within the program, some more disbursements of the fund are to be expected in 2021.

To conclude the subsidy program's relevance for solar PV, or rather its contribution to make solar storage systems financially viable, the share of storage of the projects that have received the subsidy that have a PV system is investigated. This is done by studying the application forms of the approved projects that has received funding by the end of 2020, provided by the Swedish Energy Agency. Out of the 1433 unique systems that were granted funding for projects completed before the end of 2020, only one (1) system has no solar PV installed. Another three systems have a combination of PV and an additional electricity production unit. What type of micro production these villa systems have were not specified in their respective application form. The support system can thus be considered to have contributed to additional storage of self-produced PV electricity in Sweden.

3.9.4 Future aggregated grid subscriptions

From 2021 it will be possible to subscribe for aggregated grid contracts for connection points in areas where Svenska Kraftnät previously refused increased grid connection capacities. The prerequisite is that there are connection agreements for the points and that it is technically possible to connect them. An aggregated subscription means that the grid customer is given the opportunity to transfer power between the different connection points that are included in the aggregated subscription. These can be used to alleviate the situation in areas where there is a lack of grid capacity. The change is being implemented in the existing tariff structure to be able to facilitate the rapidly emerging markets relatively quickly.

3.9.5 Curtailment policies

There were no rules when it comes to curtailment of renewable electricity in Sweden in 2020.

3.9.6 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 [68].

The ROT-tax deduction in 2020 was 30 % of the labour cost and of maximum 50 000 [68] 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 2020. If it can be proved that the labour costs constitute a higher proportion than 30 %, the total deduction then consequently becomes higher.

The upside of the ROT-tax deduction scheme is that there is no queue, and that the PV owner can be sure of receiving this subsidy. Historically, some homeowners have installed 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 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 2 912 416 929 SEK has been disbursed from 2009 to the end of 2020 (see section 3.2.1). 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 2015–2020 granted a total support of 29 163 257 SEK to PV systems (see section 3.2.2). 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 renewable electricity certificate system and had at the end of 2020 received a total of 753 925 certificates over the years (see section 3.2.3). 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 2020 becomes 63 467 446 SEK [50]. The renewable 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.

Finally, a rough estimation is that a total of 364 192 055 SEK (see section 3.3.5) has been paid to small scale PV system owners through the tax credit for micro-producers of renewable electricity subsidy under 2015–2020. This subsidy financed by the Swedish state budget.

Adding all the above subsides the Swedish PV market had at the end of 2020 in total received about 3 511.77 million SEK in direct subsidies.

4 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 339 companies that sold and/or installed PV modules and/or systems in the Swedish market (see section 4.6) in 2020. In addition, the author was also aware of 45 consultancy firms working with different aspects of PV in Sweden (see section 4.7).

With regards to the upstream industry there were 2 active module producers in Sweden in 2020 (see section 4.3), even if the production volumes were small, and 14 companies active in manufacturing of production machines or balance of systems equipment (see section 4.4). Furthermore, the author was aware of 11 companies that can be classified as R&D companies, or companies that had R&D divisions in Sweden (see section 4.5) in 2020.

Unfortunately, there is a trend of fewer and fewer upstream PV industry companies in Sweden. Several Swedish module manufacturers shut down or went bankrupt around 2010-2012, namely ArticSolar, Eco Supplies, Latitude Solar, PV Enterprise and REC Scanmodule. In recent years several Swedish start-ups, R&D companies and manufacturers of BoS products have been forced to close down, e.g. Optistring Technologies AB (in 2017), Box of Energy AB (in 2018), Sol Voltaics AB (2019), Solibro Research AB (in 2019), Solar Wave (in 2019), and Solarus Sunpower AB (in 2020).

As illustrated by Figure 28 and Table 29 the number of active companies and organisations have been increasing steadily since 2010. In addition to the increasing number of active companies seen in the figure and listed in the table, an additional of 148 companies and organisations have under the period 2010–2020 withdrawn from the sector due to either; changes in business focus, controlled closure of business or bankruptcy. Consequently, the total turnover of active companies have been much higher than Figure 28 and Table 29 show.

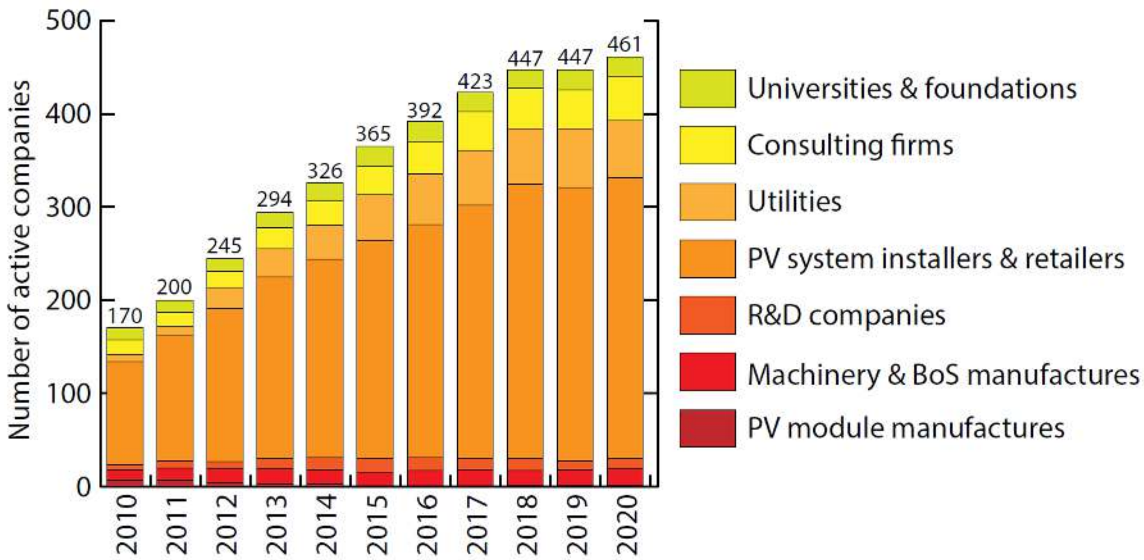

Figure 28. Evolution of the number of active companies in the Swedish PV sector (known to the authors).

Table 29: Evolution of the number of active companies in the Swedish PV sector (known to the authors).

Year	PV module manu-facturers	Machinery and balance of systems manu-factures	R&D companies	PV system installers and retailers	Utilities	Consulting firms	Universities foundations and educations companies
2010	7	11	5	111	8	15	13
2011	7	13	8	134	10	15	13
2012	4	15	8	164	23	17	14
2013	3	16	11	195	30	23	16
2014	3	15	13	213	36	26	20
2015	1	15	14	234	49	30	22
2016	1	16	14	250	55	34	22
2017	1	17	12	272	59	41	21
2018	2	15	13	294	60	43	20
2019	2	16	10	293	63	42	21
2020	2	17	11	301	62	47	21

4.1.1.1 Svensk Solenergi

Svensk Solenergi is a trade association which, with about 265 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 limited. However, the organisation is growing, and the activity is increasing.

4.2 Production of feedstocks, ingots and wafers

Sweden did not produce any feedstock or wafers in 2020 and there are currently no plans for this kind of production in the future.

4.3 Production of photovoltaic cells and modules

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

In the beginning of 2011, there were five module producers in Sweden that fabricated modules from imported silicon solar cells. In the acceleration of PV module price reductions on the world market in 2011 and 2012 the Swedish module manufacturers struggled (along with the rest of the module production industry) and at the end of 2012 only SweModule AB of the Swedish companies remained in business. In 2015 also SweModule was filed for bankruptcy, and there is no longer any large-scale module production in Sweden. Renewable Sun Energy Sweden AB, who bought the production equipment and the brand SweModule produced 0.6 MW_p of commercial modules as part of their product development in 2020. Furthermore, CIGS thin film equipment manufacturer Midsummer AB inaugurated a BIPV production line in Sweden in October 2019 and produced about 0.6 MW_p BIPV modules last year. In total 1.18 MW_p of modules where therefore produced in Sweden in 2020. However, both SweModule and Midsummer has announced plans to produce larger quantities in 2020. Total PV cell and module manufacturing together with production capacity information is summarised in Table 30 below.

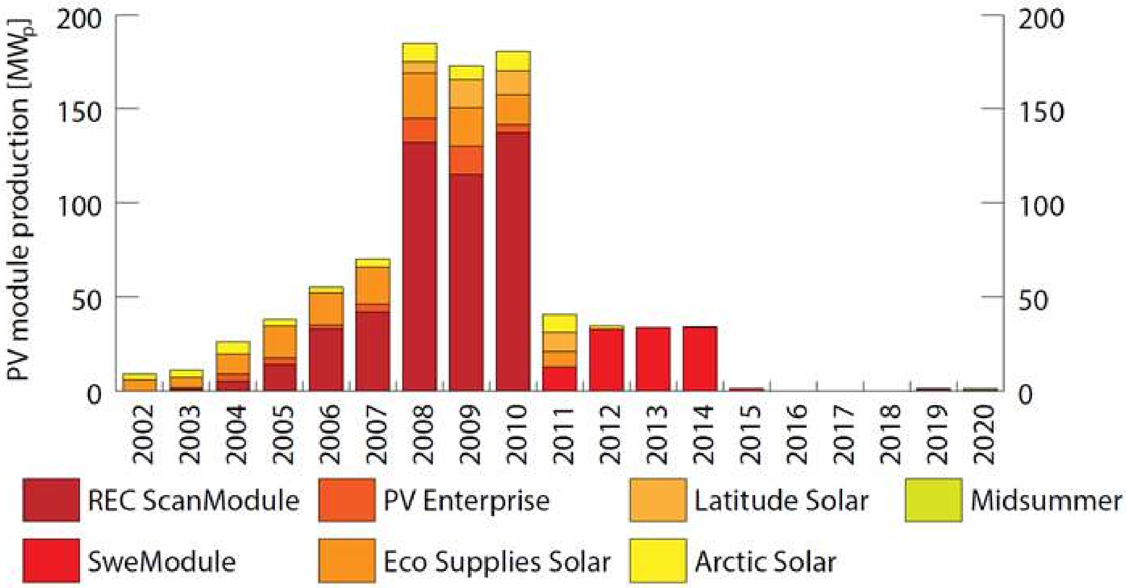

Figure 29: Yearly PV module production in Sweden over the years.

Table 30. PV cell and module production and production capacity information for 2020.

Cell/Module Manufacturer	Technology	Total Production [MW]		Maximum Production Capacity [MW/yr]	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
SweModule	Mono-Si	-	0.60	-	150
Thin film manufacturers					
Midsummer	BIPV CIGS	0.58	0.58	5	5
Cells for concentration					
None	-	-	-	-	-
Totals		**0.58**	**1.18**	**5**	**155**

4.3.1.1 Midsummer AB

Midsummer is a supplier of equipment (further described under the section 4.4.1.8) for manufacturing of CIGS thin film flexible solar cells as well as a developer, producer and installer of solar roofs. They sell integrated solar roofs with a focus design and with 90 % lower CO2-emissions compared to conventional panels according to a third party verified LCA. Today they have three products: Midsummer SLIM — long CIGS modules integrated directly onto regular standing seam metal roofs, Midsummer WAVE — flexible solar panel that follows the wave shape of Sweden's most popular roof tiles and Midsummer BOLD — 60-cell thin film CIGS solar panels for applications on membrane and metal roofs. The main market for SLIM and WAVE is the residential single-family home market. Typically, Midsummer BOLD modules are installed on factories and warehouses which usually can't handle the weight of conventional panels. Another popular market is that for sport halls and arenas. Midsummer SLIM and Midsummer WAVE are focused on the residential market.

Midsummer also has a sheet metal production line which they ramped up under 2019. The thin film solar panels as well as the production of sheet metal, with or without solar cells, for roof applications takes place in Järfälla. They are now aiming to expand from the local production in Järfälla, Sweden to multiple facilities in Europe.

4.3.1.2 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 500 MW, 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. Under 2016, 2017 and 2018, small quantities of approximately 100, 250 and 500 modules respectively were produced to test the equipment. In 2019, the company produced about 3 000 modules and in 2020 approximately 2000 modules, which was sold mainly to the Swedish and African PV market.

4.3.1.3 Windon AB

Windon was started in 2007 after a year of product development of different PV equipment. In 2011 Windon became an OEM by producing PV modules with its own brand in SweModules production facility in Glava, Sweden. Since the closure of the production facility in Glava in 2015, the company first moved their OEM production of modules to a factory in Poland, but since the beginning of 2017 almost all of Windons modules are produced on two production lines in a facility in northern Italy by Windon's own staff. For 2020 Windon plans to expand their module production by also producing some quantities in Latvia in addition to the production in Italy. In addition to the module production the company also produces mounting material and inverters (see section 4.4.1.14).

4.4 Manufacturers and suppliers of other components

4.4.1.1 ABB

ABB is a leading global technology company that energizes the transformation of society and industry to achieve a more productive, sustainable future. By connecting software to its electrification, robotics, automation and motion portfolio, ABB pushes the boundaries of technology to drive performance to new levels. With a history of excellence stretching back more than 130 years, ABB's success is driven by about 110,000 talented employees in over 100 countries.

ABB's Electrification business offers a wide-ranging portfolio of products, digital solutions and services, from substation to socket, enabling safe, smart and sustainable electrification. Offerings encompass digital and connected innovations for low- and medium-voltage, including EV infrastructure, modular substations, distribution automation, power protection, wiring accessories, switchgear, enclosures, cabling, sensing and control.

4.4.1.2 CC90 Composite AB

CC90 Composite's patented product CC90 UNUM is a mounting system for solar panels. Its rails and brackets are made of composite. To obtain a durable, time-saving, and easy installation, several parts are mounted with a click function. The mounting system can be used on both tile and metal roofs. The company was founded in 2019 and is based in Västerås, Sweden.

4.4.1.3 Checkwatt AB

Checkwatt AB is a R&D intense company providing solutions for a 100% renewable energy system. Data acquisition from sensors and through integration with other systems is a core part of the business. Sensors include but are not limited to electricity meters, irradiance and temperature sensors. System integration is made with devices and servers of technology providers (inverters, EV chargers, etc) as well as with electricity market stakeholder and grid operators. More than 4500 solar PV systems are in the system, sending minute data in near real-time.

Through a high density of accurate data and innovative algorithms, their service called 'virtual irradiance sensor' can provide the benefits of a real physical irradiance sensor without the need of purchasing and installing one. Another relatively new service involves control of distributed flexibility such as battery storage systems, hybrid solar PV inverters and EV chargers. This energy market role is called aggregator or BSP (Balancing Service Provider).

4.4.1.4 Comsys AB

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 LED lighting systems, servers, routers etc. Comsys 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 to run servers and lighting systems directly on DC current without conversions, thereby reducing the losses significantly.

Comsys has installed the DC power system in more than 30 data centres and commercial buildings since 2011. In addition, Comsys installs DC micro-grids that can go into island mode at the event of a power outage, which is a unique feature. Most PV inverters only do "power injection" to an already available power grid, which means that in a grid black-out situation, the PV systems stops producing energy and does not act as a power backup system.

The production of the components occurs at two locations in Sweden, Malmö and Söderhamn.

4.4.1.5 CW Lundberg Industri AB

CW Lundberg Industri have a long experience in roof safety. The company is based in Mora, Dalarna County, and has been on the PV market since 2016. Amongst their products are a variety of components and services in roof construction and safety, like roof ladders and support rails. They also give lessons in roof safety for companies in the industry. Connected to solar energy, they manufacture mounting brackets for PV and solar thermal panels, on which the panels are mounted directly. Thereafter, they can be mounted as they are on sheet metal roofs or on other suppliers' rail system for other roof types.

4.4.1.6 Ferroamp Elektronik AB

Ferroamp was founded in 2010 and has developed the EnergyHub system. The modular 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 measures 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. During 2019 the company supplied its DC grid technology for the world's largest DC powered office building in Gothenburg including 180 kW PV, 230 kWh energy storage, 100 kW HVAC system and 1 500 luminaires all powered by 380/760 VDC.

In 2014 Ferroamp reached a milestone as they started the shipment of their 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 2018, Ferroamp won the 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 flows. Ferroamp currently has 60 such DC grids in operation in Sweden. In 2020 Ferroamp won the Intersolar Award for its generic string optimizer solution that allows solar cells to be integrated directly into various DC systems such as public transport systems, ships or EV charging stations. The company has installed over 2 500 systems to date ranging from small residential systems to larger commercial facilities with integrated PV solar up to 1 000 kW and Energy Storage of 700 kWh.

4.4.1.7 MAPAB

MAPAB (Mullsjö Aluminiumprodukter AB) manufacture 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.

4.4.1.8 Midsummer AB

Midsummer is a supplier of equipment for manufacturing of CIGS thin film flexible solar cells as well as a developer, producer and installer of thin film solar panels (further described under the section 4.3.1.1). Midsummer was founded in 2004 by people with a background from the optical disc manufacturing equipment and the photo mask industry. The head office is 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 30 % of a corresponding crystalline silicon module. Midsummer's equipment customers are thin film solar cell manufacturers all over the world. Midsummer other machine product is the UNO, a research tool for universities and institutions focused on sputtering and solar panel research, the latest machine was sold to University of New South Wales in Australia in December 2020.

In 2016-2020 Midsummer, has secured multiple orders for their DUO thin-film solar cell sputtering tool from Asia, Russia and Europe. Midsummer's customers are mainly focusing on the BIPV-market and especially the roof-top segment.

4.4.1.9 Nilar AB

Nilar, founded in 2000, is a company within the stationary electrical energy storage sector. They currently have over 100 patents and manufacture high-tech batteries on an industrial scale. The first scalable and fully automated production line was implemented in 2014, during 2018 they commercialized their second-generation battery. Today, they have nearly 200 employees located in Sweden and the US. They produce their solutions locally in the company's factory in Sweden. The target markets for their products are home and small-scale storage, smart grid infrastructure, and commercial and industrial support. Nilar produce fully recyclable batteries both when it comes to chemistry and design, free of cadmium, mercury and lead. The patented Nilar Hydride® battery is based on a bi-polar design, where cells are laid horizontally and stacked on top of one another to gain space efficiency. By placing their flat cells in a layered structure in their building block the battery packs that can be varied in sizes and opens up for easy assemble and as well as disassemble at end of life.

Nilar, together with Ferroamp, has developed a complete solution that integrates energy storage with power electronics which facilitates both installation and utilization of the systems. Nilar also works closely with Enequi. Enequi's technology works by harvesting the energy when it's available either from PV or at a low cost from the grid. The energy is then stored in the built-in Nilar battery packs that can allocate and manage the total energy needs of the property.

During 2019 Nilar launched an energy storage solution to meet the growing demands from the residential market. During 2020 this solution has been widely distributed throughout Scandinavia and Europe. The cabinet is powered by a 6 kWh of Nilar Hydride® batteries. It allows the user to take full advantage of peak shaving and time shifting applications. During 2020, Nilar delivered more than 450 systems to their customers

4.4.1.10 Northvolt

Northvolt was founded in 2016, and is establishing its position as a European supplier of sustainable, high-quality battery cells and systems, by creating a European supply system of production facilities:

- Northvolt Labs, the demonstration line and research facility outside Västerås, Sweden, started its production in 2019 and will ramp up to 350 MWh of battery capacity per year. A pilot plant for recycling will be established during 2020.
- Northvolt Battery Systems Jeden, located in Gdansk, Poland, builds battery modules and energy storage solutions. It started production in 2019 and is ramping up capacity to 10,000 modules/year initially.
- Northvolt Ett, the company's first Gigafactory is being constructed in Skellefteå, Sweden, and will serve as Northvolt's primary production site, hosting active material preparation, cell assembly, recycling and auxiliaries. Large-scale production will begin in 2021. Ramping up to full capacity, Northvolt Ett will produce at least 32 GWh of battery capacity per year. An application for an environmental permit has been made that would allow for the expansion to 40 GWh per year.
- Northvolt Zwei, the second Gigafactory, will be established in Salzgitter, Germany. Construction will begin in 2021. The facility is scheduled to start manufacturing battery cells for Volkswagen from late 2023 or early 2024.

4.4.1.11 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. Since 2015, they are also manufacturing and selling aluminium profiles for BIPV.

4.4.1.12 Sluta Gräv AB

Sluta gräv AB is a company that specializes develop and manufacture ground screws. The screws are designed in Helsingborg, Sweden, and produced in Asia. ground screws work in the same way as a concrete plinth but speed up the construction process where you need ground foundation and traditionally use concrete. Their product is used for centralised PV systems and they also offer mounting racks.

4.4.1.13 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 other parts of Scandinavia.

4.4.1.14 Windon AB

Windon AB has developed their own mounting materials which they produce in the Swedish town Tranås. Originally, it was only a ground mounted mounting system suitable for Windons own module brand. But in 2019, Windon also developed and started to produce roof mounting systems, which are compatible with many different module brands. The aluminium profiles for Windon’s mounting systems are produced by an OEM contract with SAPA in Vetlanda, while all the sheet metal and steel details are produced by Windon in Tranås.

In 2014 Windon also started to develop inverters with an individual capacity range of 1–20 kW_p. The manufacturing of inverters started in 2016. Approximately 300 units were sold in 2016, 300 in 2017, 700 in 2018 and 700 in 2019. The parts for the inverters come from all over the world but are assembled at an OEM 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.

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

4.5.1.1 Dyenamo AB

Dyenamo offers chemical components, manufacturing equipment and test 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 optimize device-chemistry, processes and/or strategic decision-making. Dyenamo is part of the ESPRESSO and UNIQUE consortia, two European R&D initiatives dedicated to perovskite solar cells.

4.5.1.2 Eltek Valere AB

Delta Electronics is a global company with Taiwanese roots that develops, produces and markets energy solutions within the Renewable Energy, Telecom and Data Centre Energy, Railway & Metro, Power Utilities, EV Charging market segments.

The company has multiple development centers around the world and its Eltek product line is developed in Norway. Delta Electronics benefits from large scale sourcing, manufacturing, distribution, and sales in order to best serve customers worldwide.

4.5.1.3 Epishine

Epishine was founded 2016 with the aim to commercialize organic polymer solar cells. They are a spin-off from Linköping University based on decades of research resulting in process break-troughs that they think is part of the tipping point for printed OPV, where global research simultaneously has proven interesting performance and life-length.

Their first manufacturing site in Linköping focuses on small modules optimized for indoor ambient lighting, targeting the growing number of battery-driven wireless products, specifically the IoT-market where Epishine initially focuses on replacing batteries in low power devices such as sensors and consumer electronics.

The manufacturing process, although on a small scale, is constructed as a roll-to-roll process with a conscious focus on establishing manufacturing methods that can be scaled up to larger formats in the next step that will target the BIPV-market.

4.5.1.4 Evolar AB

Evolar AB was established late 2019 by founders earlier active in and founders of the Solibro group, which Swedish company went into bankruptcy the same year. The business idea is to develop and go to market with a unique technology for perovskite tandem solar cells with a premium conversion efficiency, PV Power Booster. The business model is based on sales of equipment for manufacturing tandem solar cells. In December 2020 the company closed an agreement with Magnora ASA, a venture capital company listed on the Oslo stock exchange, and received funding giving Magnora an ownership of 28.4%. The agreement gives Magnora options to achieve a higher ownership rate. The company had 6 employees at the end of 2020 (currently 12), acquired Solibros former lab and pilot production facilities 2020 and has ambitious plans to make a successful market entry within the nextcoming years. The technology for adding a perovskite solar cell layer can be combined with most primary cell technologies.

4.5.1.5 Exeger Operations 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 has addressed this problem and working on dye-sensitized solar cells suitable for mass production. Exeger have had a DSC technology screen-printing production line since in 2014. Since then, Exeger have been building the world's largest DSC production plant located in Stockholm. In this production facility Exeger can print lightweight flexible solar cells that can be integrated into products such as consumer electronics, IoT and automobile integrated photovoltaics, building integrated and applied photovoltaics.

The first commercial products to hit the market will be the JBL Reflect Eternal headphone, a self-charging headphone made by Harman Group (part of the Samsung family), and a smart helmet to enhance consumer safety developed together with POC, a leading manufacturer of helmets, eyewear, body armor and apparel. In 2019 SoftBank invested another USD 10M investment into Exeger. The Swedish pension company AMF have invested EUR 26.2 million and energy company and Fortum invested EUR 5.2 million in the Swedish Deep Tech company who is to revolutionize the way to power your electronic devices.

4.5.1.6 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 usage. The current focus is design of manufacturing processes, establishment of industrial partnerships and product development together with pilot customers.During 2020 Peafowl Solar Power started collaborating with several companies to test if their solar cells can power different devices (from dynamic glass to indoor sensors).

4.5.1.7 Samster AB

Samster has developed a "Cold PVT" which is a panel that supplies both electrical and thermal energy. The product consists of solar thermal pipes under a regular PV module and is specially made for operating at cold temperature. Samster is using commercial PV modules and the thermal parts are produced separately. Samster is responsible for development, assembly and sales. The Cold PVTs are optimal for boosting and rescuing geothermal heating systems. At the same time as the hybrids deliver more electric power due to cooling, they also lower the electricity consumption and prolongs the life span of the geothermal heat pump.

4.5.1.8 Solartes AB

Solartes, founded in 2020, is a R&D company that develops transparent plastics that capture and store energy from the sun during the day and release heat after sunset. By integrating the Solartes material, windows, blinds or shutters can be designed that contribute to passive dynamic insulation, reducing temperature fluctuations in the building. Solartes predict that over the course of one day, a 4 mm thin, transparent Solartes panel will store as much thermal energy as a 2.5 cm thick wall of concrete.

4.5.1.9 SolTech Energy Sweden AB

Stockholm based Soltech Energy Sweden is listed on Nasdaq First North Growth Market and develops and sells three different proprietary BIPV products besides standard solar energy products. Their 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 Soltech Sales & Support, Swede Energy, NP-Gruppen Soldags, Merasol, Takorama, Takrekond, Din Takläggare, Annelunds Tak and Ljungs Sedum. 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 solar as a service. The company's business within this area is in China, where they sold and installed about 176 MW until the end of 2020 through their joint venture company ASRE.

4.5.1.10 Sticky Solar Power AB

Sticky Solar Power (formerly known as JB EcoTech) is a Swedish developer and supplier of innovative solar photovoltaic technology solutions. The company is based in Stockholm and was founded in 2012. Their product is a cell interconnection and string production technology that avoids lead, decreases silver consumption, lowers cost, increases throughput, and minimizes factory footprint. The technology has been developed by Sticky Solar Power since 2012 and is currently undergoing final industrialization ahead of commercial launch.

4.5.1.11 Swedish Algae Factory AB

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, due to its light trapping and light manipulating properties.

Under 2017 the company started product testing together with partners to further test this material's ability to enhance the efficiency of silicon solar panel by being incorporated into coatings in and on silicon solar panels, reaching an enhancement of 5 % 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) and concluded in 2019 in an article a potential of over 38 %. In 2018 Swedish Algae Factory built a large pilot facility with a yearly production capacity of 300 m2 diatoms in Kungshamn, Sweden. In 2020 the company started to build a commercial production plant with a capacity of up to 3000 m2, which is planned to be finalized early 2022.

Meanwhile they are developing the material for two use cases in the industry. One is to use their material in PV modules during the actual production of the modules. The other is to offer the material for retrofit coatings on top of the glass of already installed modules, as a way of increasing the performance of old modules.

4.6 Installers, retailers and wholesalers of PV systems

The list below contains all the companies that were known to the author at the time of writing that either sold and/or installed PV modules and/or systems in Sweden in 2020. If the reader knows of any other active company, please contact the author at: johan.lindahl@ieapvps.se

24 Volt	2electrify AB	7 Energy AB
Affärsverken Karlskrona AB	Agronola	Ahlströms Solutions AB
Air By Solar Sweden AB	Aktiv Sol i Nöbbele AB	Albinsons Energicenter AB
Alcasol Nordic AB	Aldu Solenergi AB	Alfa SolVind i Skåne AB
Alight AB	AM Villabutiken	APM Avesta Persienn & Markis
Apptek Teknik Applikationer AB	Aprilice AB	Atlas Solenergi AB
Attemptare AB	Awimex International AB	Baltic Suntech AB
BayWa r.e. Scandinavia AB	Be-Lo Elektriska AB	BeGreen Sweden 2020-35 AB
Better Solar Nordic A/S	Bevego Byggplåt & Ventilation AB	Bixia AB
BLS Energy AB	Brael Norden AB	Braxel Solutions AB
Bredsands El & Solteknik AB	Brion Solenergi AB	C4 Elnät AB
Cardipoint AB	Caverion Sverige AB	Ce-Ce Elservice AB
Cell Solar Nordic AB	Co2Pro AB	Comne Work AB
Consize AB	Dalakraft AB	Dalarnas Solcellsmontage AB
Dalasolenergi AB	Dalaträhus Energi AB	Dalhem Sol AB
Delabglava AB	DJs Sol & Energiteknik AB	DT Micro Computer Systems AB
E.ON Energilösningar AB	Ecoklimat Norden AB	EcoKraft Sverige AB
Effecta Energy Solutions AB	Ekologisk Energi Vollsjö	El & Energi i Skåne AB
El & Projektering AB	El av Sol Nordic AB	El-agenten i Skillingaryd AB
El-B-man El o Energiteknik	Electrotec Energy AB	Elektra AB
Elektriker'N Jimmy Wilhelmsson AB	Elektroline i Kungsbacka AB	Elians Group AB
Elkatalogen i Norden AB	Elkontakten i Ale AB	Elteknik i Bräcke AB
Elterm i Alingsås AB	EMG Energimontagegruppen AB	Enequi AB
Energi & Innovation i Norden AB	Energi Solvind ESV AB	Energibyggarna i Väst AB
Energi-Center Nordic AB	EnergiEngagemang Sverige AB	Energiförbättring Väst AB
Energihem i Sverige AB	Energihuset i Vimmerby AB	Energiprojekt Stockholm AB
Energiteknik i Kungälv AB	Energy Effective Solutions AB	Enkla Elbolaget i Sverige AB
Enstar AB	Ergus El-Konsult	Erikas Tak & Bygg AB
Erntec AB	Etab energi AB	ETC El
ETC Elproduktion i Katrineholm AB	European Energy Sverige AB	Everöds Elbyrå AB
EWF ECO AB	EWS GmbH & Co. KG	Extra Arbetskraft i Uppland AB
Falu Solenergi AB	Falun Energi & Vatten AB	Fasadsystem i Stenkullen AB
Fire Mountain AB	Flens Solel AB	Forsbergs VVS & Energiteknik AB

Fortum Markets AB	Free Energy Sverige AB	Freebo AB
Friendly Power AB	Fronius Danmark Aps	Fueltech Sweden AB
Futura Energi AB	Future Energy Sweden AB	Fyrfasen Energi AB
Fyrstads El AB	Garo Elflex AB	GFSol AB
Gislaved Energi AB	Gisle Innovations AB	Gosol Energi AB
Gotlands Elförsäljning AB	Gridcon Solcellsteknik AB	GruppSol AB
Grön Sol AB	Guld Sol byggen AB	Gävle Energi AB
Göteborg Energi AB	Helio Solutions AB	Helios El & Solkraft AB
Hero Solkraft AB	Herrljunga Elektriska AB	HESAB
Highlands International AB	Holje-El AB	HPSolartech AB
HS Energi & Klimat AB	HS-Solteknik AB	Hybrida E-mobility AB
Höjentorps Solenergi AB	IBC Solar AB	Idola Solkraft AB
IKEA	Implementa Sol AB	Indsol Group AB
INKA Energi	Isorent AB	Iq Energi
J.E. Nordins El AB	JN Solar AB	JoDatec HB
Johanneshovs El AB	JSS Tjänst AB	Jämtkraft AB
Jönköping Energi AB	Jöta El AB	Kalmar Energi Försäljning AB
KAMA Fritid AB	Kjells Elektronik & Digital-Tv Center AB	Klimatprojekt i Mälardalen
Knuttes El AB	Kopernicus AB	Kostal Solar Electric GmbH
Kraftpojkarna AB	Kraftringen Energi AB	Krannich Solar AB
Kretsloppsenergi Kummelnäs AB	Krylbo Elmontage AB	Kungälv Energi AB
K-Utveckling Engineering AB	Lambertsson Sverige AB	Laxviks El och Solpanel AB
Lego Elektronik AB	LEVA i Lysekil AB	Levins Elektriska AB
Lorex AB	Luleå Energi AB	Lundgrens El AB
Lundgrens Elektriska AB	MagnusEnergy	MeraSol AB
Miljö & Energi Ansvar Sverige AB	Miljö- VVS- & Energicenter AB	Modern Miljöteknik i Varberg AB
Monier Roofing AB	MR Service & Teknik AB	Mälar Bygg & Montageservice AB
MälarEnergi AB	Mölndal Energi AB	NaturWatt AB
Newel AB	NIBE Energy Systems WFE AB	Nirosys AB
Nordens Solvärme AB	Nordh Energy Solar AB	Nordic Energy Partner AB
Nordic Solar Sweden AB	Nordisk System Teknik AB	Nordpolen Energi AB
Northern-Nature-Energy	Nossebro Energi Försäljnings AB	NP Gruppen AB
Orust Engineering	OTM Eko Energi AB	Otovo AB
Paneltaket AB	Parkys Solar AB	Penthon Installation AB
PFA Solteknik AB	PiteEnergi AB	PMC El AB
PPAM Solkraft AB	Prolekta Gotland AB	Rexel Sverige AB
Rigora AB	RK Sol & Energiteknik AB	RoslagsSOL-Forslund & Co AB
Rustabo Sverige AB	Rågård rör och teknik AB	S:t Eriks AB
Sala-Heby Energi	Samvets Elteknik AB	Sandhult-Standareds Elektrisk Ek. För.
Save-by-Solar Sweden AB	SEBAB AB	Sell Power Nordic AB
Senergia AB	Sesol AB	SEVAB Strängnäs Energi AB
SHS Gruppen AB	Signalmekano AB	Simply Solar AB
Skellefteå Kraft AB	Skånska Energi AB	Smart Solar Norden AB
Sol & Byggteknik i Grythyttan AB	Solandia AB	Solar Invest AB
Solar Supply Sweden AB	SolarClarity Group	SolarEdge Technologies Sweden AB
Solarenergy Scandinavia AB	Solarfuture i Sverige AB	Solarisenergi i Visby AB
Solarit AB	Solaritet AB	Solarlab Sweden HB
Solarwork Sverige AB	Solcellsbyggarna Boxholm AB	Soldags i Sverige AB
Solect Power AB	Solelexperten Umeå AB	Solelgrossisten AB
Solenergi Göteborg AB (installation)	Solenergi i Nynäshamn AB	Solenergi Norr AB

Solenergi Partner SP AB
Solenergi Sverige AB
Solenergimontage i Sverige AB
Solenergispecialisten i norden AB
SolensEnergi i Skåne AB
Solexperterna Värmland AB
Solfabriken Ugglum AB
Solfamiljen AB
Solgruppen Norden AB
Soliga Energi AB
Solinnovation i Värnamo AB
Soliva Sverige AB
Solkompaniet Sverige AB
Solkraft EMK AB
Solkraft i Viby AB
Solkraftcenter Sverige AB
Sollentuna Energi & Miljö AB
Sollux AB
SolNord AB
Solorder AB
Solortus AB
Solsystem Sverige AB
Solteamet i Västerbotten AB
Soltech Sales & Support AB
Solverket Alfa AB
Solvio AB
SolviQ Sverige AB
Solvision AB
Spindel AB
Stockholm Exergi AB
Storuman Energi AB
Sun Energy Nordic AB
Sun of Sunne
Sun4energy AB
Sunavia AB
SUNBEAMsystem Group
Suncellhouse Solenergi AB
SunDoSparks
SunnyFuture AB
Sunroof AB
Sunsolutions by Telecontracting AB
Sunwind Gylling AB
Sustainable and Natural AB
Susen AB
SVEA Renewable Solar AB
Svenska Solcellsanläggningar AB
Svenska Solenergigruppen AB
Svenska Solpanelmontage AB
Svenskt Byggmontage AB
Svesol Värmesystem AB
Swede Energy Power Solutions AB
Swedensol Energi AB
Switch Nordic Green AB
Sydpumpen AB
Södra Hallands Kraft Ek. För.
Södra Solmontage AB
Söne El AB
Takläggarna I Mälardalen AB
Takorama AB
Takrekond i Småland AB
Teknisk Fastighetsservice AB
Tekniska Verken i Linköping AB
Telge Energi AB
Tellux AB
Tranås Energi AB
Trollhättan Energi AB
Tröingebergs EL&VVS AB
Täta Tak Entreprenad Sverige AB
Umeå Energi AB
Upplands Energi Produkt & Miljö AB
Utellus AB
Valk Solar Systems Nordics
VallaCom AB
Vancos Munka Ljungby AB
Varberg Energi AB
Varmitek Energisystem AB
Vattenfall AB
Veosol Teknik AB
Viessmann Värmeteknik AB
Villavind AB
Vimmerby Energi & Miljö AB
Visionsteknik i Norr AB
Vårgårda Solenergi AB
Värmekällan Väst AB
West El AB
Wettersol AB
Windforce Airbuzz Holding AB
Windon AB (försäljning)
WOJAB AB
Yokk Solar AB
Zenitec Sweden AB
Öresundskraft Marknad AB
Östgöta Solel AB

4.7 Consultancy firms

The list below contains all the consultancy companies that were known to the author at the time of writing that offered different services with regards to PV in Sweden in 2020. In additions to these companies several of the companies listed as installers and retailers of PV systems also have consultancy sections and offers. If the reader knows of any other active company than in the list below, please contact the author at: johan.lindahl@ieapvps.se

Act Management AB
AddSolar
Advokatforman Lindahl
AFRY Group Sweden AB
Aktea Energy AB
Andersson & Hultmark AB
Becquerel Sweden AB
Bengt Dahlgren AB
Bjerking AB
Bodecker Partners AB
Creative Networks Consulting X AB
Elkatech AB
Emulsionen Ekonomiska Förening
Enable Energy Sve AB
Energibanken
Enklare Husliv BIM AB
Esam AB
Fasadglas Bäcklin AB (konsult)
Fenix Solar AB
Franzén Energiteknik AB
Gagnar AB
Hemsol AB
IATEK
Incoord Installationscoordinator AB
Ingenjörsfirman Flemming Åkesson AB
JB EcoTech AB
M2 Bioenergi AB
Norconsult AB
Paradisenergi AB
PE Teknik och Arkitektur AB
Profu AB
Ramböll Sverige AB
Redlogger AB
Rejlers Sweden AB
Shortcut Street AB
Solcellskollen AB

Solelsbyggarna Tribera AB	Solisten	Sunwide
Sustainable Business Partner AB	Sweco Systems AB	Watt-s
White Arkitekter AB	WSP Sverige AB	Åkerby Solenergi
Act Management AB	AddSolar	Advokatforman Lindahl
AFRY Group Sweden AB	Aktea Energy AB	Andersson & Hultmark AB
Becquerel Sweden AB	Bengt Dahlgren AB	Bjerking AB

5 HIGHLIGHTS OF R&D

5.1 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 31: 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 2020
Center of Molecular Devices	Dye-sensitized, perovskite and quantum dot solar cells	30
Chalmers, Chemical physics	Surface physics and catalysis by advanced calculation methods	1
Chalmers, Chemistry and Biochemistry, Abrahamsson Research Group	Photocatalytic conversion of CO_2 with light	2
Chalmers, Chemistry and Biochemistry, Albinsson Research Group	Technology for down and up conversion of sunlight	6
Chalmers, Chemistry and Chemical Engineering	Organic solar cells	2
Chalmers, Material Physics	Battery material research	15
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	6
Chalmers, Technology Management and Economics	Business models for PV deployment	5
Dalarnas University, Center for Solar Research	System research, PV and heat pump smart systems, micro-systems and smart grid business models	8
Karlstad University, Characterizing and Modeling of Materials	Multi crystalline silicon solar cells	7
Karlstad University, Molecular Materials for Electronics	Polymer-based and perovskite solar cells	6
KTH Royal Institute of Technology, Applied Thermodynamics and Refrigeration	PV system in Swedish housing associations and PV with heat pumps	1
KTH Royal Institute of Technology, Concentrating Solar Power and Techno-economic Analysis	Techno-economic analyses, design and experimental verification for CSP	7
KTH Royal Institute of Technology, Material and Nanophysics	Direct III-V/Si heterocycle for solar cells and silicon-based tandem cell	6

Linköping University, Biomolecular and Organic Electronics	Plastic solar cells	10
Linköping University, Organic Electronics	Solar heat-charged super capacitor as energy storage	2
Luleå University of Technology, Electric Power Engineering	Stochastic planning of smart electricity distribution networks, PV electricity quality and reliability from a grid perspective	2
Luleå University of Technology, Experimental Physics	New nanomaterials for third generation solar cells	8
Lund University, Chemical Physics	Dye-sensitized, plastic and quantum dot solar cells, along with semiconductor nanowires and organometal halide perovskites	15
Lund University, Energy and Building Design	Social issues with regards to solar energy, urban planning and building design	2,5
Lund University, International Environmental Institute	Social studies of private persons barriers and motives for PV investments	3
Lund University, Nanolund	Tandem transitions in nanowire solar cells and perovskites on nano wires	5
Lund University, Polymer and Materials Chemistry	Nano-structured materials for higher PV efficiency	2
Lund University. Centre for analysis and synthesis	Iron based solar cells and iron complexes as photosensitizers in solar cells	18
Mid Sweden University, Electronic Construction	Development of converters and supercapacitor, and grid stabilization studies	6
Mid Sweden University, Fibre Science and Communication Network	Lithium-ion batteries and super capacitors	10
Mälardalen University, Future Energy Center	PV in agriculture and the built environment, PV modelling software	5
RISE, Research Institute of Sweden AB	Testing of PV components, systems and batteries, BIPV and micro-grid research etc.	23
RISE 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
University of Gävle, Energy Systems and Building Technology	PV system operation and performance of PVT receivers	3
Uppsala University, Built Environment Energy Systems	PV grid integration studies and modelling of; PV systems, building systems, self-consumption and solar-powered transports	5
Uppsala University, Solid State Electronics	CIGS and CZTS thin film solar cells and materials	20
Uppsala University, Ångström Advanced Battery Centre	Li-ion batteries and different battery chemistries with high energy density	88

5.2 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).

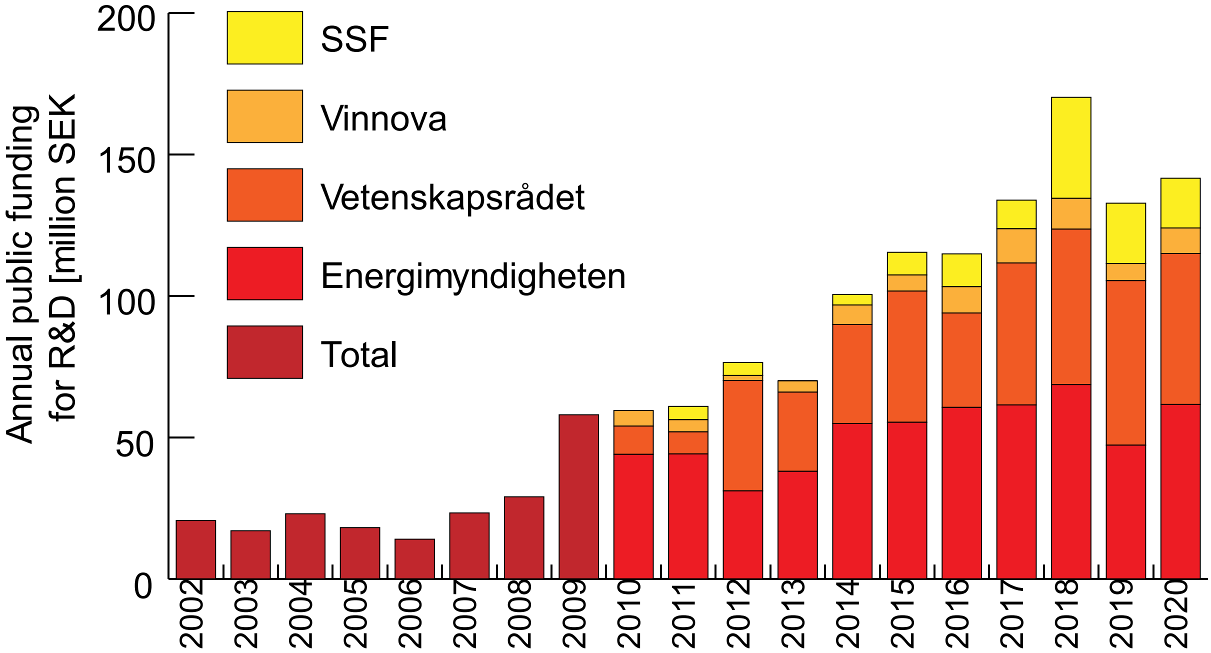

Figure 30. Annual public funding for PV related research in Sweden

Note that the difference in funds dedicated to PV research from Vinnova appears smaller for 2019 compared to last year's Swedish National Survey Report. This is, however, not a trend of declining research funding, but rather a result of a changed methodology when manoeuvring Vinnova's internal database to access the information. The new methodology that has been applied for 2020 and retrospectively for 2019.

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 is increasing 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 summarized in Figure 31 and By summarizing the labour places related to the actual Swedish PV market, i.e. PV system installers and retailers, utilities, consulting firms, real estate owners and building companies, and divide it with the annual installed PV capacity, one can get an estimation of how many labour places that is

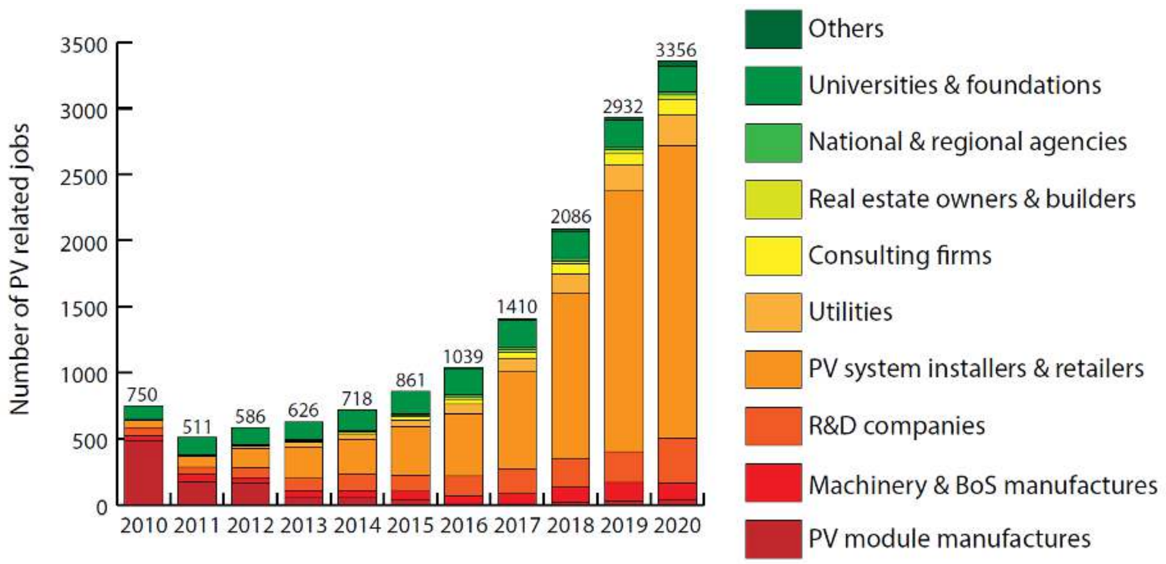

Figure 31: Estimated total full-time jobs within the Swedish PV industry over the years.

created per installed PV capacity. As Table 33 shows, the estimated number of created labour places per installed MW was 6.5 in 2020. A clear trend of fewer and fewer created labour places per installed MW can also be seen, which cannot be explained by changes in general system sizes (as Table 6 shows). The reason is probably that the companies are becoming bigger and more effective in their marketing and installation processes. The decreasing created labour places is probably one of the reasons for the declining PV prices in Sweden (See section 2.2).

Table 32 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.

By summarizing the labour places related to the actual Swedish PV market, i.e. PV system installers and retailers, utilities, consulting firms, real estate owners and building companies, and divide it with the annual installed PV capacity, one can get an estimation of how many labour places that is created per installed PV capacity. As Table 33 shows, the estimated number of created labour places per installed MW was 6.5 in 2020. A clear trend of fewer and fewer created labour places per installed MW can also be seen, which cannot be explained by changes in general system sizes (as Table 6 shows). The reason is probably that the companies are becoming bigger and more effective in their marketing and installation processes. The decreasing created labour places is probably one of the reasons for the declining PV prices in Sweden (See section 2.2).

Table 32: Estimated PV-related full-time labour places in 2020.

Market category	Number of full-time labour places
PV module manufacturers	32
Machinery and balance of systems manufactures	134
Research and development companies	339
PV system installers and retailers	2212
Utilities	232
Consulting firms	118
Real estate owners and building companies	33
National and regional agencies	28
Universities, foundations and educations companies	191
Others	37
Total	**3356**

Table 33: Estimated number of yearly full-time labour places created per installed PV capacity.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
PV market related labour places	59	89	174	286	323	450	598	897	1494	2281	2596
Annual installed capacity [MW]	2.3	4.0	7.9	18.9	34.4	48.0	60.3	85.7	157.2	281.8	400.1
Labour places created per MW	**25.2**	**22.1**	**22.2**	**15.2**	**9.4**	**9.4**	**9.9**	**10.5**	**9.5**	**8.1**	**6.5**

6.2 Business value

In Table 34 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 34: Rough estimation of the value of the PV business in 2020 (VAT is excluded).

Sub-market		Capacity installed in 2020 [MW]	Average price [SEK/W]	Market value
Off-grid		1.61	27.0	~ 43 million SEK
Grid-connected distributed	Residential	184.43	12.9	~ 2 379 million SEK
	Commercial	168.85	11.9	~ 2 009 million SEK
	Industry	4.82	11.2	~ 54 million SEK
Grid-connected centralized		40.37	6.9	~ 279 million SEK
Value of the Swedish PV market 2020				**~ 4 764 million SEK**

7 INTEREST FROM ELECTRICITY STAKEHOLDERS

7.1 Structure of the electricity system

In Sweden electricity is transported from the major power stations to the regional electricity grids (40–130 kV) via the national grid (220 kV and 400 kV). From the regional grids, electricity is transported via local, low voltage 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 in 2017 [69] and 152 grid owners in Sweden in 2020. However, the Swedish grid market is dominated by Vattenfall, E.ON and Ellevio that covers about 52 % of all customers. The retail market is dominated by three companies; Vattenfall, Fortum and E.ON, which together have about 56 % of all customers.

7.2 Interest from electricity utility businesses

Several utility companies started marketing small turnkey PV systems suited for roofs of residential houses in 2012. The utility companies that the author is aware of that offered these kinds of turnkey PV systems in 2020 were: Affärsverken Karlskrona, Arvika Kraft, Axpo Sverige, Bixia, Borlänge Energi, Borås Elhandel, C4 Elnät, Dalakraft, E.ON Energilösningar, Ellevio, Enkla Elbolaget i Sverige, Eskilstuna Strängnäs Energi & Miljö, ETC El, Falkenberg Energi, Falun Energi & Vatten, Fortum Markets, Fyrfasen Energi, Gislaved Energi, GodEl i Sverige, Gotlands Elförsäljning, Gävle Energi, Göteborg Energi, Halmstads Energi och Miljö, Herrljunga Elektriska, Jämtkraft, Jönköping Energi, Kalmar Energi Försäljning, Karlstads Energi, Kraftringen Energi, Kungälv Energi, LEVA i Lysekil, Luleå Energi, MälarEnergi, Mölndal Energi, Nossebro Energi Försäljnings, Pite Energi, Sala-Heby Energi, Sandhult-Standareds Elektrisk Ekonomiska förening, SEVAB Strängnäs Energi, Skellefteå Kraft, Skånska Energi, Sollentuna Energi & Miljö, Statkraft Financial Energy, Stockholm Exergi, Storuman Energi, Switch Nordic Green, Södra Hallands Kraft Ekonomiska förening, Sölvesborg Energi, Telge Energi, Tekniska Verken i Linköping, Trollhättan Energi, Tranås Energi, Uddevalla Energi, Umeå Energi, Upplands Energi Produkt & Miljö, Utellus, Varberg Energi, Vattenfall, Vimmerby Energi & Miljö, Västra Orust Energitjänst Ekonomiska förening, Växjö Energi and Öresundskraft Marknad. These utility companies are also listed as retailers of PV systems in section 4.6. Most of these utilities 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, as 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.

Since 2014 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 3.2.3) and the maximum

1.2 million SEK 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 have built PV parks over 1 MW_p are Mälarenergi, Arvika Kraft, C4 Energi, Varberg Energi, ETC El, Kalmar Energi, Luleå Energi, Göteborg Energi, Affärsverken, Vallebygdens Energi and Jämtkraft.

7.3 Interest from municipalities and local governments

As can be seen in Figure 4 and Figure 5 there are some municipalities in Sweden that stand out in installed PV in total and by capita. Important factors for the high local PV diffusion rates are in general peer effects [70] 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 [71]. 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. Other local initiatives that have influenced the adoption of PV are seminars and information meetings arranged by local actors. One example to highlight is the Swedish Energy Agency financed information campaign for residential PV adoption that occurred in Sweden in 2017, in which 41 % of Sweden's municipalities participated and led to a positive effect on PV adoption rates [72].

Some Swedish municipalities and local government have introduced ambitions goal for PV. Examples are:

- In Örebro County, the goal is to produce 150 GWh of PV electricity by 2030, which would correspond to about 4 percent of the county's electricity use [73].
- 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 [74].
- In the municipality of Linköping, the City Council formulated a goal in 2018 that PV electricity should have reached a penetration level of 5 % in 2025 and at least 20 % in 2040.
- The municipality of Helsingborg has set an ambition that local production of solar power corresponds to 10 percent of electricity demand in 2035 [75].
- Kristianstad's goal is for the municipal group to produce 2 GWh of solar energy per year in 2020, and 40 GWh per year in the municipality by 2030 [76].

Another activity several municipalities have implemented is the fabrication of so called "sun maps" to help potential stakeholders in PV to easier assess the potential for their roof. 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; Ale, Alingsås, Borlänge, Borås, Botkyrka, Danderyd, Ekerö, Eskilstuna, Eslöv, Falkenberg, Falun, Forshaga, Gävle, Göteborg, Haninge, Helsingborg, Huddinge, Håbo, Härnösand, Härryda, Höganäs, Hörby, Höör, Järfälla, Kalmar, Karlshamn, Karlskrona, Karlstad, Katrineholm, Kramfors, Kristianstad, Kumla, Köping, Landskrona, Lidingö, Lidköping, Linköping, Ljungby, Lomma, Ludvika, Luleå, 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, Ängelholm, 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.

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.

8 HIGHLIGHTS AND PROSPECTS

8.1 Highlights

Despite the COVID-19 pandemic, the positive PV market development in Sweden continued in 2020, as the annual market grew with 42 % to a yearly installed power of 400 MW. As a result, Sweden passed the GW-threshold, as the cumulative installed capacity at the end of 2020 amounted to 1 107 MW. The market is still dominated by residential roof-mounted systems for single-family houses and roof-mounted systems on commercial buildings. However, a clear trend of increasing capacity additions from centralized PV parks was noted for 2020.

The PV system prices continued to decrease. For PV systems on single family houses, the average price decrease was around 1–2 % in 2020, depending on size range. For PV systems on multi-family houses, the corresponding price drop averaged to 6–15 %, for PV systems on commercial buildings it was 10–13 % depending on size and for centralized ground mounted PV parks about 15 %.

The major policy change in 2020 that affect the Swedish PV market was the stop for new applications in the capital subsidy system by July 7th, 2020. For private persons, this marked the end of a more than 10-year long support program for PV. Instead, the capital subsidy is replaced by a green tax deduction, starting in 2021. For municipalities and companies, a total of SEK 260 million has been set aside for the capital subsidy program in 2021. It is not possible to apply for the funds for new projects, but support can be disbursed to those who have applied before July 7th, 2020. The support level is 10 percent for these projects.

On the industry side, there was barely any module production in Sweden. Some Swedish companies focusing on new PV technologies or balance of system components continued to develop in a healthy way, while others were forced to liquidate their business. Furthermore, the Swedish PV industry is becoming increasingly diversified every year, with more and more actors with other core businesses, such as utilities and real estate owners, taking interest in the PV technology.

8.2 Prospects

In the very short term, the Swedish PV market is facing the uncertainty on how the market segments of large residential systems on multi-family houses, commercial buildings, industry buildings and centralized PV parks will react to the new situation with no direct support available. Even if it has been the long-term goal of the industry to become independent of the good will of politicians to continue to support the market through the state budget funds, the situation is new and it can take some time for customers in these market segments to get used to the subsidy free market conditions. For the private person residential segment of single-family houses, the situation will also be novel as of 2021. The direct capital subsidy was replaced by a green tax deduction by the 1st of January 2021. The reports from the market so far is that the simplified procedure for the customer of this policy change has been received well, with accelerating interest and investments in the single-family houses market segment in 2021.

In the medium term, it is expected that the Swedish PV market continues to grow. The introduction of the tax credit for micro-producers in 2015, 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 quite good for homeowners and small companies to invest in PV. 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 differently defined in different laws [61][62]. Another suggested regulatory change is that property owners should be allowed to build small micro grids that connect different buildings within their premises [64].

Large centralized PV parks have been a marginal occurrence in Sweden until now. This market segment is, however, expected to grow a lot in the coming years, as they now seem economically viable 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. In October 2016, the Swedish Energy Agency presented 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 [77]. Furthermore, the goal of the broad political agreement of The Swedish Energy Commission that Sweden shall have a 100 % renewable electricity consumption by 2040 [78] forebodes a policy framework in which PV should be able to flourish.

9 APPENDIX I - DATA SOURCES AND THEIR LIMITATIONS

Several data sources are used in the collection of the statistics presented in this report, all of which have their respective advantages and disadvantages. In the following section, these are discussed to provide an overview of the statistical situation on the Swedish photovoltaic market.

9.1.1 Surveys to grid operators regarding grid-connected PV capacity

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. The accuracy of the grid connected capacity is therefore judged to be high. That methodology has, however, 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 exclusively based on the yearly collection of the sales statistics by the Swedish representatives in IEA PVPS task 1. 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.

For 2016 and 2017 weighted average number between the sales statistics and the statistics from the grid operators has been used due to uncertainties about the quality of the grid operators' statistics these years. For a more detailed description see the 2018 version of National Survey Report of PV Application in Sweden [2].

Additionally, the grid operators are not always notified if a PV system's capacity is increased after the original grid connection. This is, however, presumed to only cause a small possible deviation, but cannot be quantified at present.

9.1.2 Off grid sales statistics

Data for off-grid PV systems are by definition impossible to get from the grid operators. The information about 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. Off-grid systems older than 20 years are assumed to have been decommissioned by now and are therefore withdrawn from the cumulative sales statistics to obtain the total off-grid capacity in Sweden. The companies that have contributed off-grid data for 2020 are listed in section 4.6. Older Swedish National Survey Reports list the active companies for the sales statistics for their respective year. The accuracy of the off-grid capacity is judged to be much lower than for the grid connected capacity.

9.1.3 Labour places

As in the case of off-grid installations, the data collection of labour places is 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. This methodology provides no exact measure on the amount of labour places, nor does aim to do so. It is rather an effort to provide a representational picture on the development and the direction in which the market is heading. If the company representative is not contactable, the information is retrieved from open-source registers of companies' key figures of annual reports and company information.

The data collection is thereby limited to the IEA APVPS Task 1 representative's insight of the market and ability to detect new market actors.

9.1.4 Database of the Swedish direct capital subsidy

To obtain market segmentation, there is another data source in addition to the surveys sent to grid operators regarding grid-connected PV capacity, discussed in 9.1.1. In the database of the Swedish direct capital subsidy (see section 3.2.1) all PV systems that have been granted support from the start of the subsidy programme in 2009 until now are recorded. By cross-referencing between this database and Sweden's national business directory, a business sector can be assigned to each system owner. By doing this, the database can be divided into centralized, industry, commercial or residential systems. It is also possible to sort the PV systems based on if they were 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 and systems on schools just to mention a few.

A problem with the database of the Swedish direct capital subsidy is however that a lot of systems have been recorded in an incorrect way, for example with the wrong power rating, granted subsidy, or organization. When it is obvious that the information has been recorded incorrectly, these systems have manually been removed for the analysis within this report.

9.1.5 PV system prices

When it comes to PV system prices, there are two different data sources. One is the yearly sales survey that 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 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 2018–2020 numbers, the reported prices have not been weighted (as the collection of installation data from the installation companies ended after 2017) and the reported prices are a regular average.

The other source for system price statistics is the database of the Swedish direct capital subsidy, see above. So, since 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.

9.1.6 Cesar

Cesar is Sweden's accounting system for electricity certificates and guarantees of origin. In Cesar, plant owners are given their respective electricity certificates based on the registered plants' reported electricity production. In Cesar, the account holders electronically transfer their electricity certificates and guarantees of origin to the person they have agreed to sell the certificates to. Also, it is in Cesar that electricity certificates are annulled for fulfilment of quota obligations.

In Cesar, one can also find the statistics that is collected and presented in section 3.2.3. The Swedish Energy Agency is responsible for managing and developing the electricity certificate system in Sweden and since January 1st, 2015, they have also been responsible for Cesar. The authors see no concern in using this data base to collect information on the renewable electricity certificate system in Sweden.

9.1.7 Jordbruksverket

To obtain statistics on the direct capital subsidy for renewable energy production in the agriculture industry, an extract from the Swedish Board of Agriculture's (Jordbruksverket) register has been requested. The authors see no concern in using their internal data base to collect information and no direct obstacles have appeared in the processing of named data.

9.1.8 Tax credit for micro-producers

The Swedish Tax Agency (Skatteverket) is consulted when examining the tax credit for micro-producers of renewable electricity. They provide the number of control entities that have eligible for the tax credit, as well as the amount that has been paid. Since the intention is to obtain the total amount that has been disbursed in tax credits and between what amount of system owners, the methodology for data collection is considered satisfactory and without major challenges. However, some simplifying assumptions are made when the share of systems that receive the tax credit is calculated. This is explained in section 9.1.8.

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