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
2021

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, 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, SolarPower Europe, the Smart Electric Power Alliance (SEPA) and the Solar Energy Industries Association and the Solar Energy Research Institute of Singapore 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 2021. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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COVER PICTURE

Building integrated PV roof (3 MW_{DC} / 3 MW_{AC}) in Knivsta, Sweden, manufactured by Midsummer AB.

Foto: Johan Lindahl

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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 2021 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2021, 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 a feed-in premium scheme, that add value for the excess electricity, has until now been crucial for this business model to work in Sweden. However, as of 2022 no subsidies exist except for the private domestic PV market segment. About 52 % of the installed grid-connected PV power are residential systems, 33 % are installed on commercial buildings, 4 % on public buildings and 3 % on industrial buildings and sites. So far only 8 % of the grid-connected market are ground-mounted centralized PV parks, and by international standards the parks are relatively small in size. But the interest and activity in this market segment has increased a lot in 2021 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 499.7 MW was installed in 2021, out of which 497.8 MW was grid-connected, as shown in Figure 1 and Table 2. This means that the annual Swedish PV market grew with 25 % compared to the 400.1 MW that was installed in 2020.

Of the grid-connected PV capacity installed in 2021, 52.3 MW is estimated to be centralized PV parks and 445.5 MW distributed PV systems for primary self-consumption. By that, the annual market of centralized PV in Sweden grew with about 14 % and the distributed annual market by 26 % as compared with 2020, when approximately 46.0 MW of centralized and 352.5 MW of distributed PV was installed.

Sweden has a stable off-grid PV market. In 2017–2019, about two MW per year of off-grid applications were sold. In 2020 the annual off-grid market decreased slightly to 1.6 MW but grew again in 2021 to 1.9 MW.

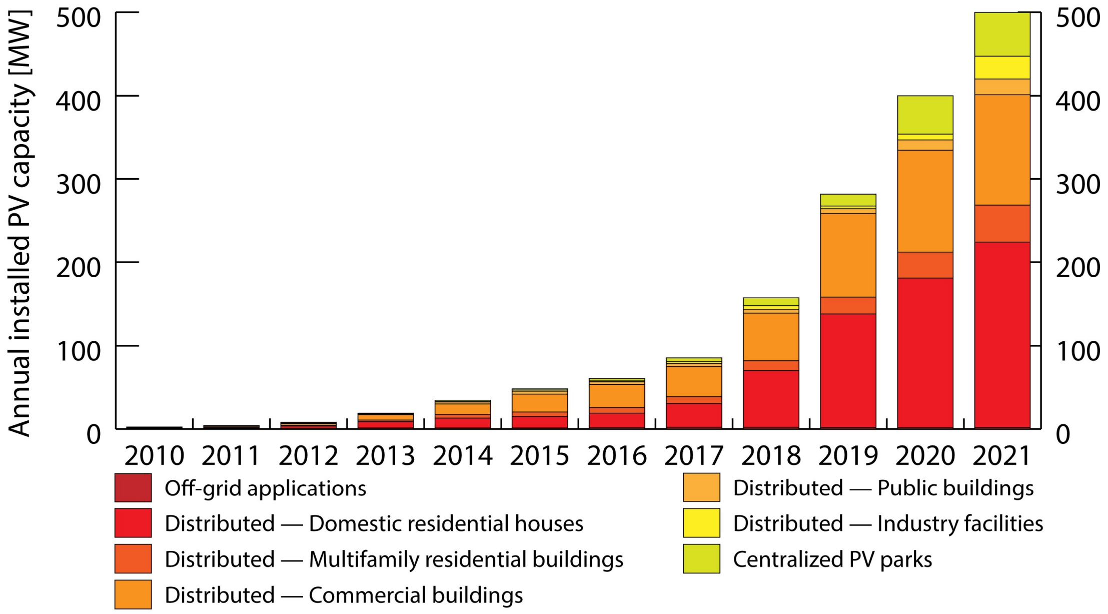

Figure 1: Annual installed PV capacity in Sweden

Table 1: Annual PV power installed during calendar year 2021.

		Installed PV capacity in 2021 [MW]	AC or DC
PV capacity	Off-grid	1.891	DC
	Decentralized	445.51	AC
	Centralized	52.26	AC
	Total	499.66	AC

Table 2: PV power installed during calendar year 2021.

			Installed PV capacity [MW]	Installed PV capacity [MW]	AC or DC
Grid-connected	BAPV	Residential	445.51	266.82	AC
		Commercial		132.56	AC
		Public		18.83	AC
		Industrial		27.30	AC
	BIPV	Unknown (Included in BAPV)			
	Utility-scale	Ground-mounted	52.26	52.26	AC
		Floating		0	AC
		Agricultural		0	AC
Off-grid		Residential	1.61	0.93	DC
		Commercial		0.14	DC
		Mobile applications		0.82	DC
Total			499.66		AC

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	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 2021 was 1 587.2 MW, according to the grid operators. Out of this capacity, about 133.8 MW is estimated to be centralized PV and 1 453.3 MW to be distributed. In addition, a total of 21.8 MW of off-grid PV applications have been sold in Sweden since 1993, wherein 18.9 MW is estimated to still be in operation.

By adding the off-grid and the grid-connected PV capacities together, a total of 1 606.1 MW of electricity producing PV power by the end of 2021 is estimated to up and running, illustrated in Figure 2 and summarized in Table 4. The total installed PV capacity grew by 45 % in 2021, which is in line with the development over the five previous years, where the total market grew by 57 % (2020) 66 % (2019), 59 % (2018), 47 % (2017) and 49 % (2016).

The strong overall growth in the last decade 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 7.1) and an ongoing reformation work from the Government to simplify the rules for micro-producers (see section 3.3).

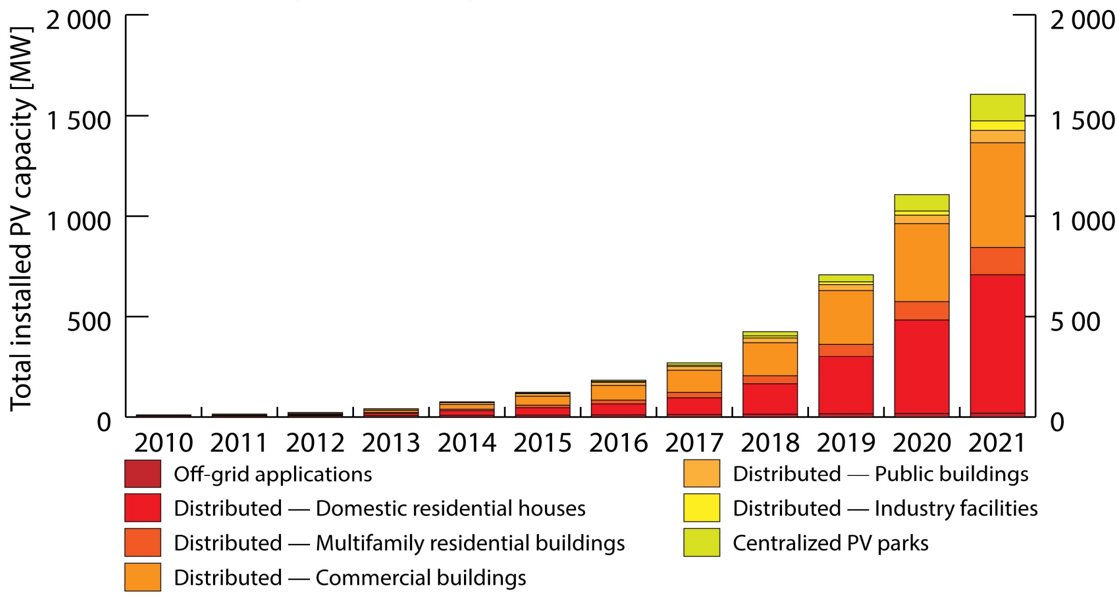

Figure 2: Total installed PV capacity in Sweden.

In total there were 92 359 grid-connected PV systems in Sweden by the end of 2021. The number of off-grid systems is unknown. A majority of the grid-connected PV systems, 80 207, are small systems below 20 kW. 12 093 are in between 20 kW – 1000 kW and 59 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 59 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 2021. 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 2021, Sweden had 92 359 grid-connected PV system, and the corresponding average system size was about 17.2 kW. That is a relatively small system size, which 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	0.28	14.53
2012	6.38	14.92	0.89	22.19
2013	7.31	32.14	1.37	40.82
2014	8.20	63.81	2.95	74.95
2015	9.16	109.19	4.30	122.64
2016	10.43	165.17	7.12	182.73
2017	12.27	244.18	11.64	268.10
2018	14.09	390.15	20.09	425.14
2019	15.82	655.86	35.07	706.75
2020	17.20	1 007.82	81.58	1 106.60
2021	18.89	1 453.33	133.84	1 606.06

Table 5: Other PV market information.

<table>
<tr><td colspan="2"></td><td colspan="2">2021</td></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>80 207</td></tr>
<tr><td>20 kW – 1000 kW</td><td>12 093</td></tr>
<tr><td>Above 1000 kW</td><td>59</td></tr>
<tr><td>Total</td><td>92 359</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	2021
Number of systems	10 006	15 298	25 486	43 944	65 819	92 359
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	17.2
Average size per system for the annual market [kW]	17.3	17.3	17.6	15.7	17.7	18.7

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 2021, 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 2021, 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]	789.55	675.28	122.38
Total number of grid-connected PV systems according to the grid operators collected by the Swedish Energy Agency [#]	80 207	12 093	59

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.

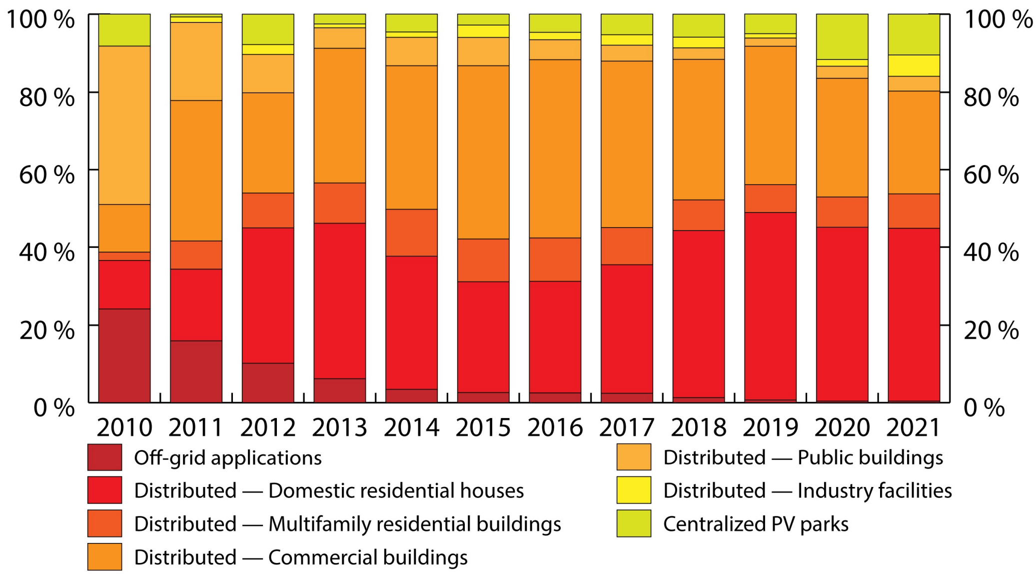

Figure 3: Various market segments share of the annual installed PV capacity in Sweden. Based on statistics from the capital subsidy database.

Clearly, the biggest market segments in Sweden have been residential domestic 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 historic policy structure in Sweden.

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 2020 basically. 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 38 commissioned PV parks in Sweden that with a capacity of above 0.5 MW known to the authors. Besides those mentioned, the authors are aware of additional plans for several larger PV parks. It appears 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.

The increase of the industry segment in 2021 can partly be explained by the increase of the energy tax threshold from 255 kW to 500 kW that took place the July 1st, 2021 (see section 3.3.2), which made it economical more feasible to install larger systems. In addition, a few ground-mounted PV parks, built next industry facilities, was commissioned in 2021. These are counted as industry systems and not centralized PV parks (even if they are ground-mounted parks) as the electricity is generated in primary for self-consumption on the site.

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 3.2.4), 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 2019 these municipalities were Ale, Arjeplog, Arvidsjaur, Borgholm, Haparanda, Hultsfred, Norberg, Skellefteå, Sorsele, Storuman, Surahammar, Åmål and Överkalix.

In 2021, no confidentiality hindered the reporting of installed PV power in any municipalities.

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 Uppsala and Linköping were in the top at the end of 2021 with 58.4, 41.7 and 40.7 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 municipality the recent years.

Taking the lead from last year's leader Strängnäs, Skurup was the top municipality in 2021 with regards to installed PV capacity per capita. Skurup is a rather small municipality with 16 322 inhabitants, which with 19.5 MW installed PV capacity results in the top score of 1189.5 W/capita. Sweden's largest PV park (18 MW) was installed in Skurup by E.ON in 2021, and even though it was officially commissioned in 2022, it was probably connected and registered already in the end of 2021 [3]. Second on the list is Sjöbo with 992.0 W/capita, holding its position from 2020. 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 MWp installed. This PV Park was extended to 18 MW in 2020, giving it the top ranking again in 2021. Borgholm is the municipality with third most PV capacity installed per capita, with 581.0 W/capita.

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 shows. The value of the PV electricity is also higher in SE4 and SE3, as the average market value between 2014 and 2021 (see section 2.6 for further explanation and discussion) of PV in these bidding areas was 382.9 and 352.9 SEK/MWh respectively, as compared to 318.5 and 319.5 in SE2 and SE1 respectively.

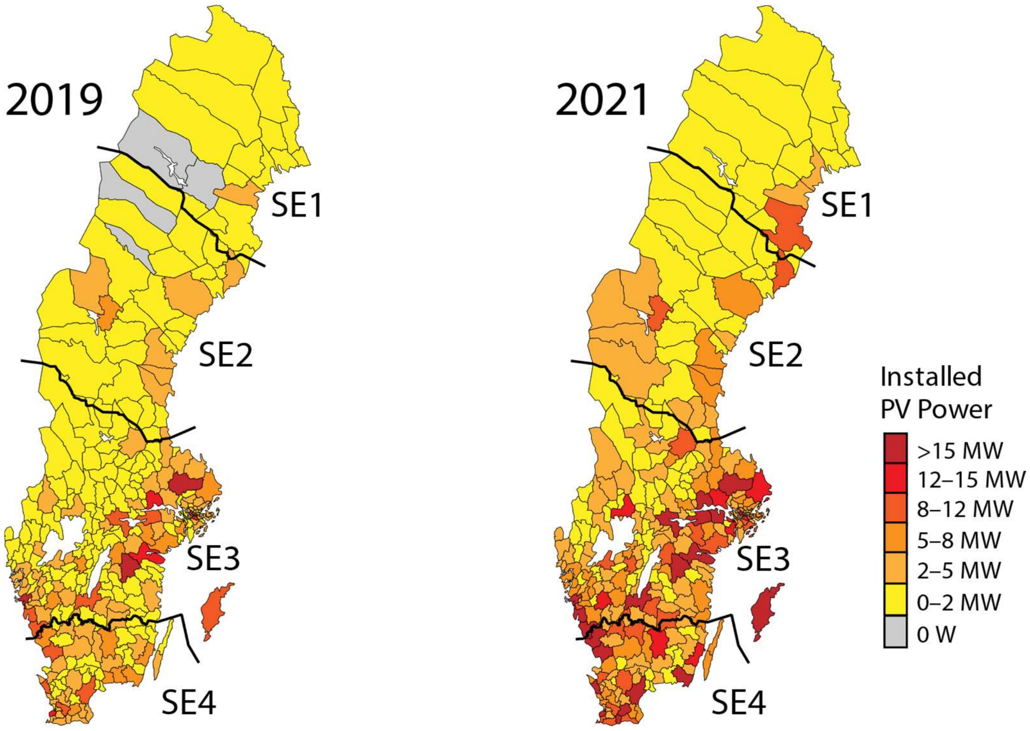

Figure 4: Total power of the PV systems in each of Sweden's municipalities. For some municipalities data from the green electricity system has been used instead of grid operators' data due to confidentiality reasons.

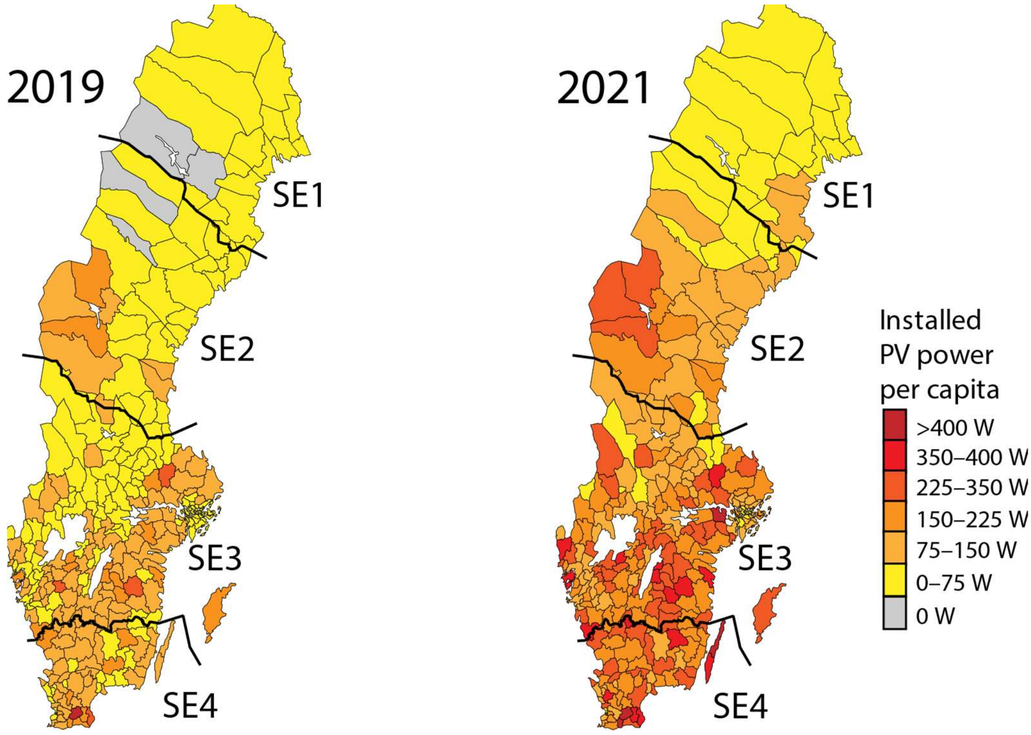

Figure 5: Total power of the PV systems per capita in each of Sweden's municipalities. For some municipalities data from the green electricity system has been used instead of grid operators' data due to confidentiality reasons

1.6 Key enablers of PV development

1.6.1 Other technologies

For the last six years, the survey sent 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 21.5 MWh was installed in 2021, an increase of 74 % compared to the 12.4 MWh installed in 2020, 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 influences 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.

The battery capacity of the electrical cars in Sweden was 7377 MWh in the end of 2021 [5]. If one adds the total battery capacity of stationary grid connected batteries connected to PV systems installed between 2016 and 2021 the total battery capacity at the end of 2020 became 7 425 MWh.

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
2021	16 086 kWh	5 413 kWh	21 499 kWh

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 6, indicating a strong majority of 80 % of the respondents want more investments in PV in Sweden, which makes the PV technology by far the most popular electricity production technology in that aspect.

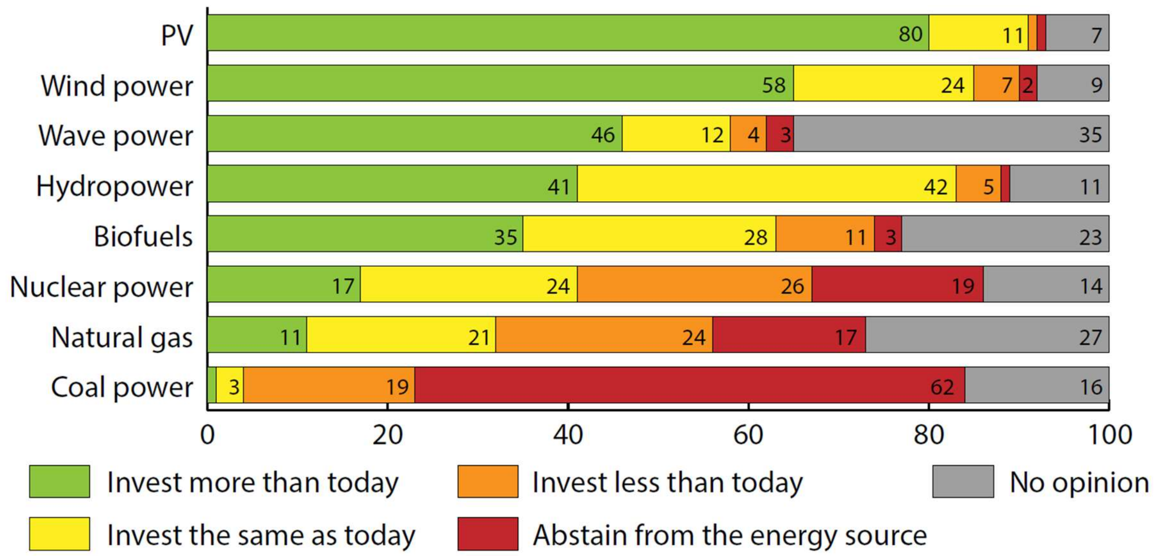

Figure 6: The public opinion in Sweden about different electricity production technologies in 2020.

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 have 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 transmission system operator (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 border 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 [7].

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 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 [8][9][10][11], which can increase the internal congestion in Sweden [8]. 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 [11]. 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 1.4.

In Figure 7, the Swedish electricity production in 2021 is presented. The electricity production data used in Figure 7 and Figure 8, along with Table 9, were retrieved from Svenska Kraftnät [12], but with complementary data from SCB [13] with regards to the fuels used in the Swedish CHP power plants. The total power generation in Sweden was 165.8 TWh in 2021, while the electricity consumption was 139.8 TWh. In total, Sweden imported 8.3 TWh and exported 33.9 TWh.

As can be seen in Figure 8, 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.

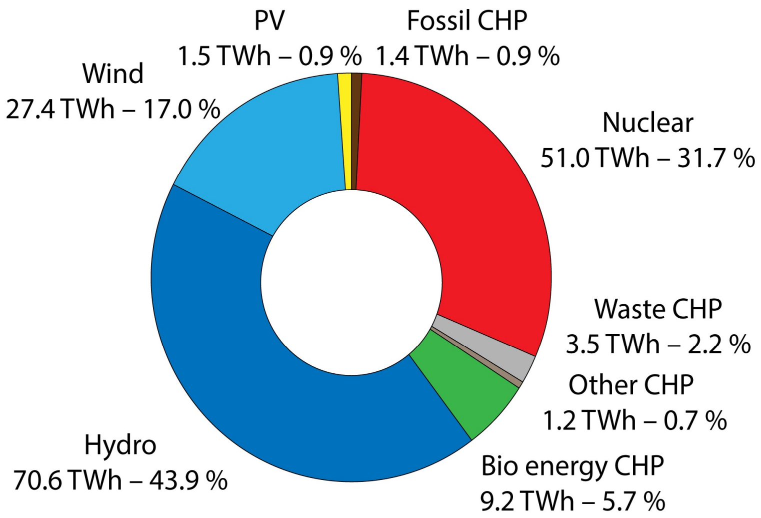

Figure 7. Total electricity production in Sweden in 2021.

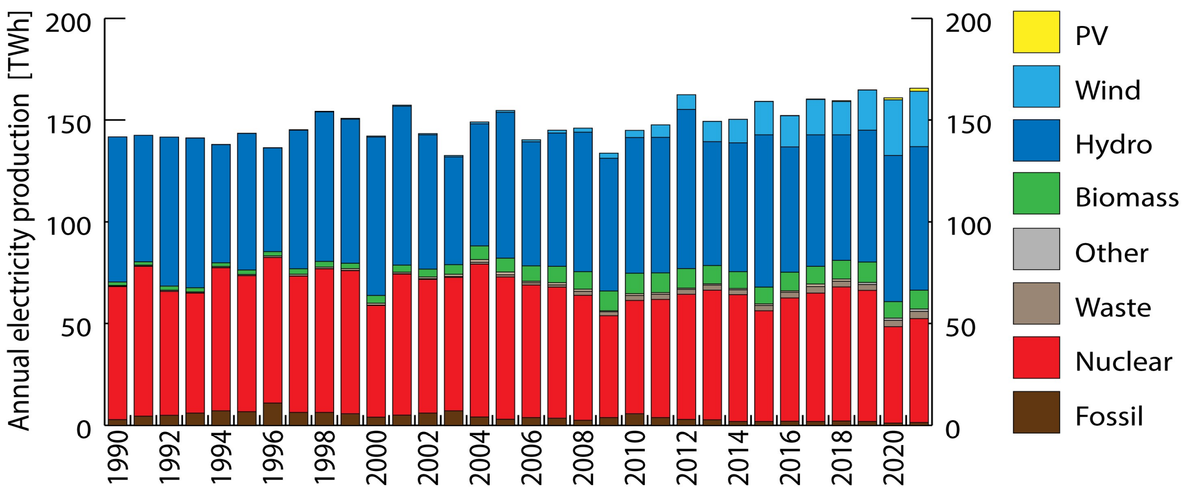

Figure 8. Total annual electricity production in Sweden between 1990 to 2021.

Table 9. PV power and the broader national energy market.

	Data	Year
Total power generation capacities [MW]	43 669	2021
Total renewable power generation capacities (including hydropower) [MW]	33 699	2021
Total electricity demand [TWh]	139.8	2021
New power generation capacities installed [GW]	2 614	2021
New renewable power generation capacities (including hydropower) [GW]	2 530	2021
Estimated total PV electricity production (including self-consumed PV electricity) in [GWh]	1118	2021
Total PV electricity production as a % of total electricity consumption	1 %	2021
Average yield of PV installations [kWh/kW$_p$]	950	2021

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 [14]. 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 2021, however, the price survey shows an increase in price for the first time since the data collection started. A slight increase in prices for 2021 has been documented in several sources, amongst them IEA PVPS Task 1 global Trends report [15] and international spot market prices [16]. This increase is assigned to conjunctural effects of the COVID-19 pandemic, which resulted in disrupted value chains, higher polysilicon prices and shipment costs globally. This development also affected Sweden.

In addition to the collected sales statistics, which should be read as the module price to the end customer, the result of an Swedish 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 in 2020 [17]. 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
2021	3.5	7.0	4.6

2.2 System prices

Sweden has experienced a large decrease in PV system prices since 2010, especially before 2013, as Figure 7 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 historic trend of decreasing yearly full-time labour positions per installed MW is illustrated in Table 33. The decreasing trend in labour places per MW is probably one of the reasons for the declining PV prices in Sweden since companies are becoming bigger and more effective in their marketing and installation processes. This can be applied to all years except the 2021 development that can be explained by major events following the COVID-19 pandemic and the subsequent supply constraints, see sections 2.2.4 and 6.1.

The maturing of the Swedish PV market and the increasing competition is a factor likely pushing down the prices of Swedish PV systems. Table 32 further corroborates this, as in 2010 the authors of the Swedish NSR's were aware of 111 active companies that sold and/or installed modules or PV systems in Sweden. In the end of 2021, the corresponding figure had gone up to 308.

2.2.1 Estimated PV system prices by the sales statistics

The price information from the sales surveys is presented in Figure 7 and Table 11. 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 below.

Compared to previous years of collecting sales statistics, the installation and sales companies have reported difficulty to generalise prices on a yearly basis. The reason for this is that the last year have demonstrated an increased hardware price volatility, which translates to the end customer system prices.

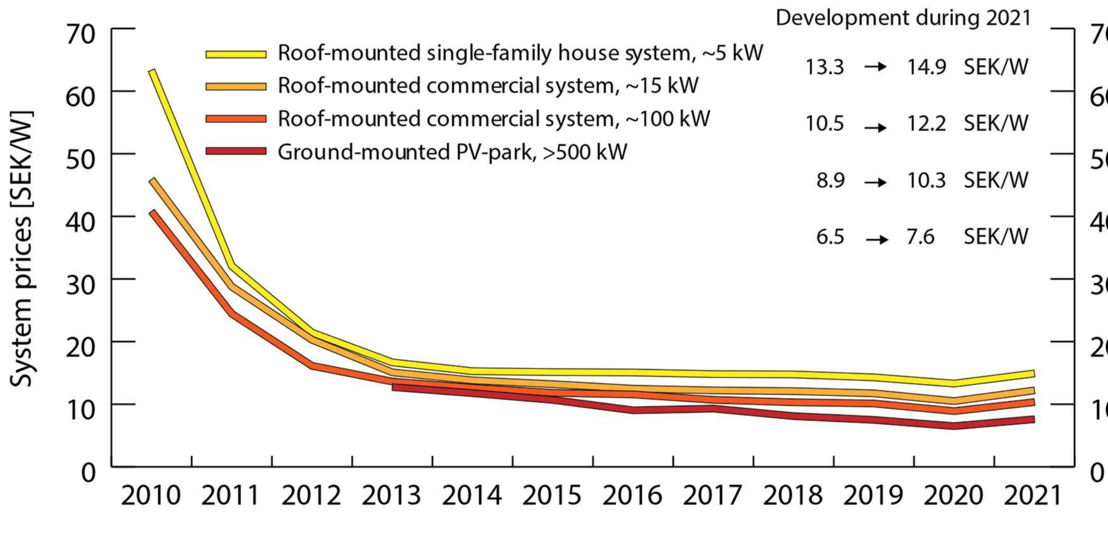

Figure 7: Historic development of the weighted average typical prices for turnkey photovoltaic systems (excluding VAT), reported by Swedish installation companies.

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
2021	14.91	12.21	10.34	7.60

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. As explained in 3.2.1 and 9.1.4, the number of systems in the data base is lower this year compared to previous years. This is because investment support was closed for new applications in 2020. The decrease is evident in Table 12 and 13, as they also list how many systems that the presented average prices have been derived from, for the reader to get a sense of relevance of the average price presented. Concretely, it means that the number of systems on which the price information is based has dropped and thus also the statistical certainty.

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, etc. 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 >44 SEK/W_p or low <4 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 the residential sector the size ranges are 5–10 kWp and 10–20 kWp 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 8 and Table 12.

Table 12: Average prices for turnkey grid-connected residential PV systems (excluding VAT) from the

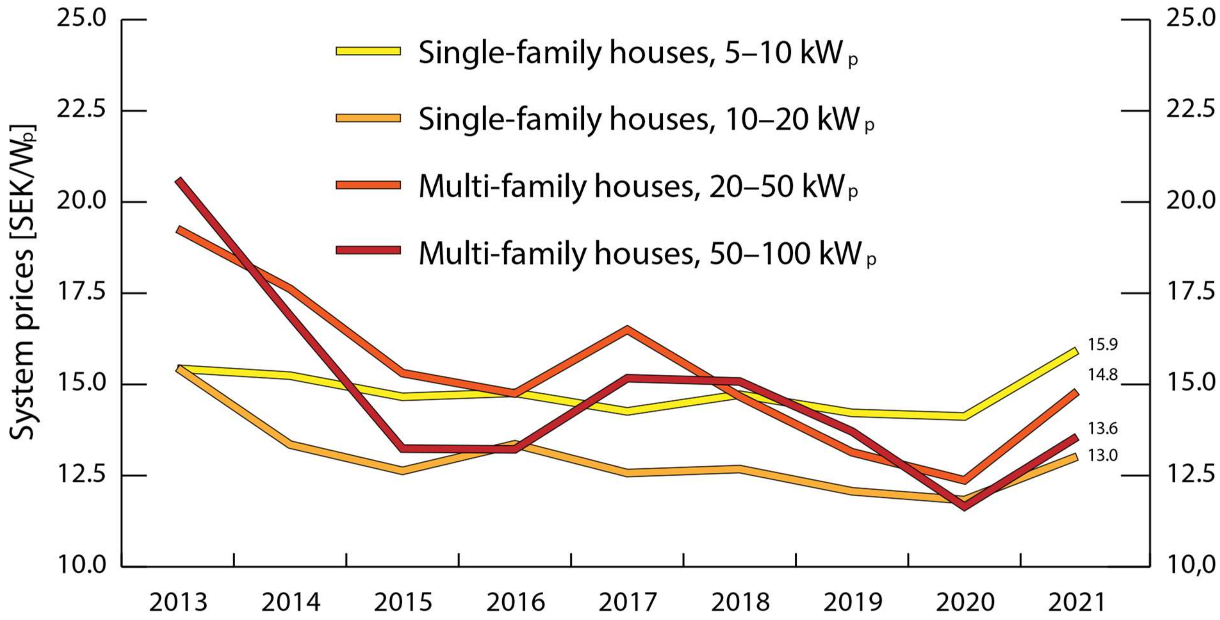

Figure 8: Average prices for turnkey grid-connected residential PV systems (excluding VAT) from the database of the direct capital subsidy programme.

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
2021	15.93	221	13.02	332	14.81	116	13.56	101

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 9 and Table 13. The reason for choosing 255 kW_p as the upper boundary for the largest commercial systems is due to the former limit for tax legislation in place (see section 3.3.2), while the limit was increased to 500 kW_p in 2021, it has been kept to 255 kW_p for consistency reasons.

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.

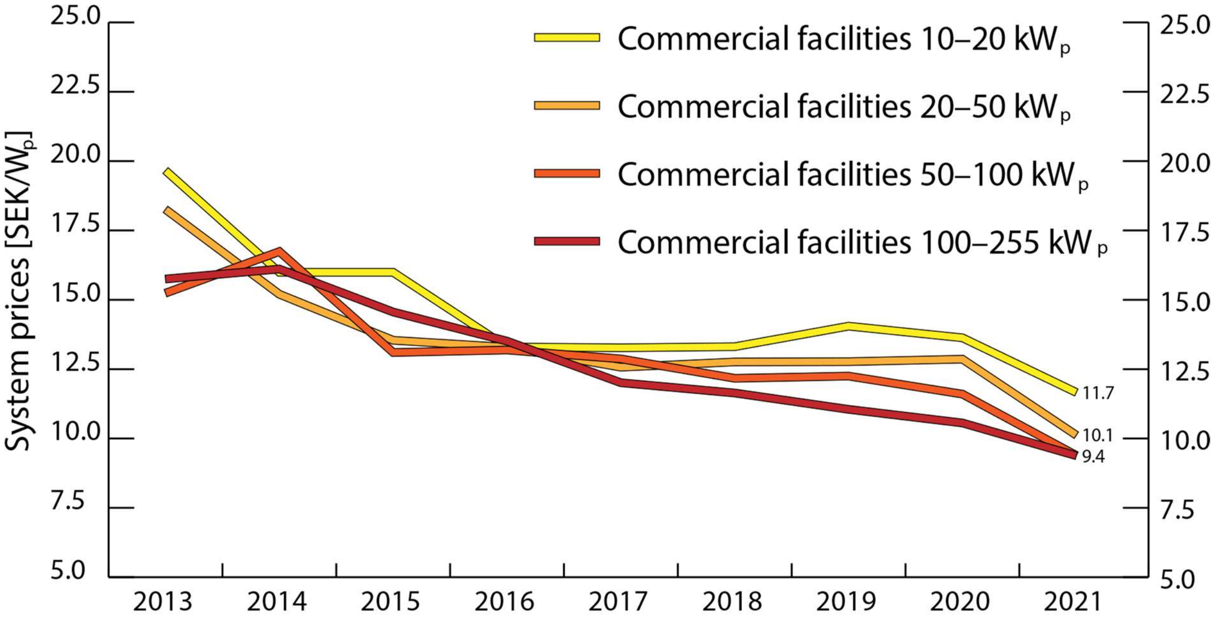

Figure 9: Average prices for turnkey grid-connected commercial PV systems (excluding VAT) from the database of the direct capital subsidy programme.

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
2021	11.66	122	10.12	263	9.39	125	9.38	128

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 [17]. This will translate to the category "single-family houses/small buildings (småhus)".

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 [18]. The cost structures presented in Table 14, and Figure 11 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 to 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.

The results, presented in Figure 11, 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/kW_p, respectively.

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 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**	-	

A standardized supplier cost structure for a 10 kW_p system, presented in Figure 11, 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 was 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.

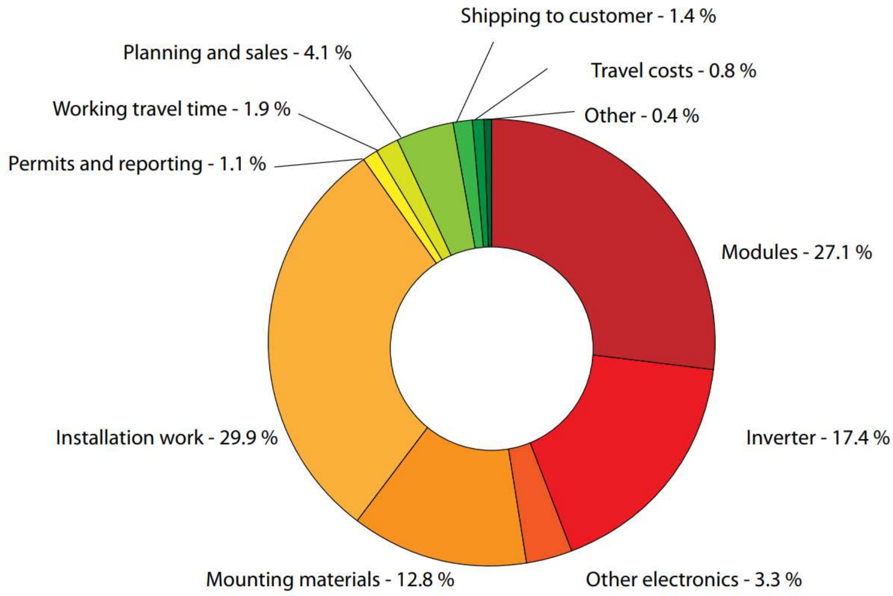

Figure 10: The supplier cost structure for a typical Swedish grid-connected roof-mounted residential PV system in 2020. The total price was 11.70 SEK/W_p.

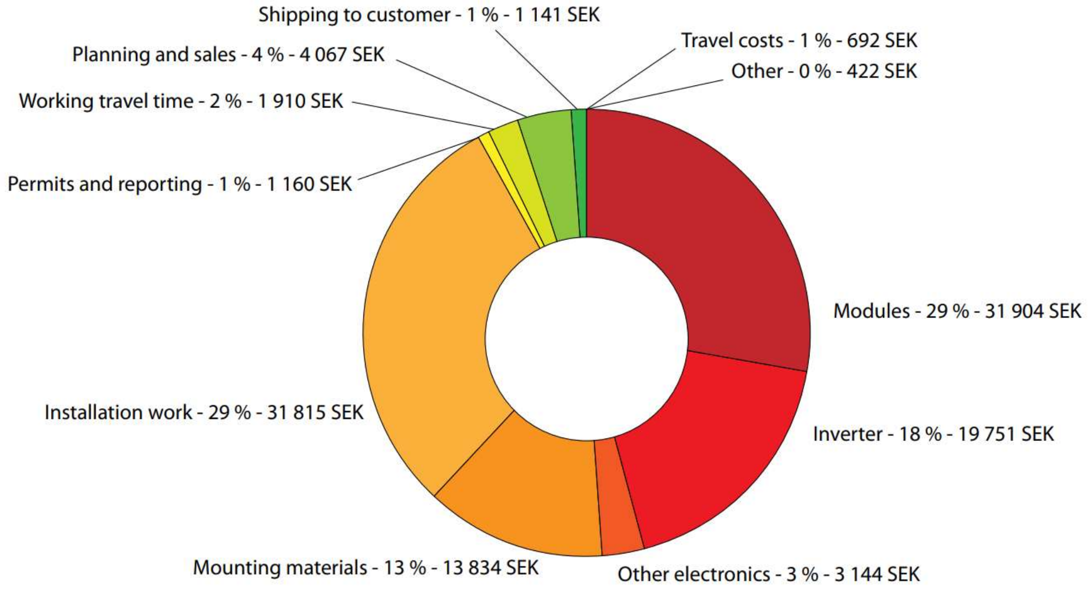

Figure 11: The supplier cost structure for a typical Swedish grid-connected roof-mounted residential PV system (10 kW_p) in 2020. The total price was 109 840 SEK.

2.2.4 PV system price discussion

As mentioned in the introduction to this section, prices have decreased significantly in all market segments over the past decade, as can be seen in Figure 9 to 11. During the years before 2021, the price had started to stabilize. Despite that, prices went down between 1–15% in 2020, depending on the segment. This trend, however, was broken in 2021 with price increases in all segments according to the sales survey, and for residential systems according to the database of the direct capital subsidy programme, while the prices for commercial systems continued to go down in 2021.

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 increased in 2021, with around 6 % according to the installers and 13 % according to direct capital subsidy programme, to reach an average between 14.9 SEK/W_p or 15.9 SEK/W_p. The price of somewhat larger PV systems on residential single-family houses of about 10–20 kW_p increased with about 10% from 11.83 to 13.02 SEK/Wp (see Table 12). For residential PV systems on multi-family houses the prices went up with 20 % and 16 % in 2021, to 14.8 SEK/W_p and 13.6 SEK/W_p, within the size ranges of 20–50 kW_p and 50–100 kW_p respectively.

Contrary to the development for residential PV systems, the statistics in the database for the capital subsidy programme indicates a price decrease for commercial PV systems in 2021. The smallest commercial size segment, 10–20 kW_p, experienced price reductions of 14 % according to the subsidy programme database. The steepest price drop was recorded for commercial facilities of size 20–50 kW_p, from 12.86 SEK/W_p in 2020 to 10.12 SEK/W_p in 2021, corresponding to a 21.3 % decrease. Lastly, the data base show average prices of 9.4 SEK/W_p for systems of both sizes 50–100 kW_p and 100–255 kW_p on commercial facilities, corresponding to a price decrease of 19 % and 11 %, respectively. However, the survey results show a price increase at around the same level as residential installations for commercial PV systems. Numerically, the price for roof-mounted PV systems on commercial buildings increased with 16 % for ~100 kWp systems, to 10.3 SEK/Wp, and 16 %, to 12.2 SEK/Wp, for ~15 kWp systems according to installation companies (see Table 11).

Historically, the installation companies seem to have estimated typical system prices lower than the average in the direct capital subsidy programme database. This year, the opposite trend can be read, with higher prices reported in the survey. This can either be interpreted as that the installers answering the survey are more sensitive to the price changes and overestimate the yearly average development. Another explanation could be that in the database of the direct capital subsidy programme, a few outlier systems are noted for all categories, which can pull the average prices in either direction. Lastly, a possible reason is that the capital subsidy programme statistics are based on the commissioning date, while the sales statistics are based on date of the sale.

The reason for the opposite trend for commercial PV systems compared to residential in the capital subsidy programme is not entirely clear. As the segment generally include PV systems of larger size than the residential, longer design and sales processes could be a reason for the price development to be lagging in the capital subsidy program. Another reason could indeed be that the commercial PV market segment in Sweden did not suffer from price increases to the same extent as the residential market segment.

For centralized utility scale PV parks, where the typical price increased with 17 % from 6.5 SEK/W_p to 7.6 SEK/W_p (see Table 12). Table 15 summarizes the PV system prices in 2021. 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.	24–29
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.	11–17
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.	5–8
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) was to 0.00 % during the entire 2021 [19]. Changes in interest rate by the central bank have a direct impact on the market rates, which therefore have been quite low in 2021. The cost of capital for a PV system was consequently low in 2021.

In Table 16 the average nominal mortgage rate in 2021 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 deriving the levelized cost of electricity (LCOE) of Swedish centralized PV parks [20] present average weighted average cost of capital (WACC) for industrial and ground-mounted installations, which have been used in Table 16. However, the reader should not that the interest rates since 2021 in general have increased, and higher values are reasonable to assume for 2022 and onwards.

Table 16: PV financing information in 2021.

Different market segments	Loan rate [%]
Average rate of loans – residential installations [21]	1.5 %
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 2.90 % 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 2.15 % and a repayment period of up to 10 years [24][25]. A third example is Vattenfall, that in collaboration with Handelsbanken, offer a solar loan at an interest rate of 1.9 % [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 2021 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]. With a population of 10 452 326 people at the end of 2021, the population density of Sweden is therefore low with about 25.7 inhabitants per km², but with a much higher density in the southern part of the country [29]. About 88% of the population live in urban areas [30].

Table 18: Country information.

Retail Electricity Prices for a household (range)	1.5–4.8 SEK/kWh (including grid charges and taxes)
Retail Electricity Prices for a commercial company (range)	0.9–2.17 SEK/ kWh (including grid charges and taxes)
Retail Electricity Prices for an industrial company (range)	0.8–1.1 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 [31], due to its (1) *high operational reliability* - the delivery security was 99.987 % in 2020 [32], (2) *high electrification level* – 100 % of total population have access to electricity [33], and (3) *low greenhouse gas emissions* – emissions from fossil fuels associated with the domestic electricity production, in 2021 was 1.4 TWh, which corresponds to 0.9 % of the total Swedish electricity production of 165.8 TWh [34].

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.

2021 was a year with record-high electricity prices in Sweden. The annual average was the highest recorded and even the average price per week, day and hour were on peak levels. The main reason was the high natural gas prices in Europe, and coupled with a substantial deficit in the hydrological balance, it negatively affected the usual Nordic resilience to high electricity prices from central Europe. Since the Swedish electricity mix is characterized by a large share of hydropower while having problems with power congestions, large variations between the bidding areas appear [35]. Opposite to 2021, Sweden experienced low electricity prices in 2020, with a 73% decrease from 2019. The national yearly average electricity price was 0.63 SEK/kWh on the Swedish electricity market in 2021, which is a 554% increase compared to the 2020 average of 0.11 SEK/kWh.

In 2021, the spot prices were quite volatile over the year, with remarkably high prices, as Figure 12 and 15 illustrates. The yearly average ended up at 0.432 in SE1, 0.433 in SE2, 0.672 in SE3 and 0.819 in SE4. Up until 2020, there was only a very small price difference between the areas, which 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 1.3). However, if the price difference between the different price areas will be in the same order of magnitude as in 2020 and 2021 in the future, this could affect the distribution of PV in Sweden.

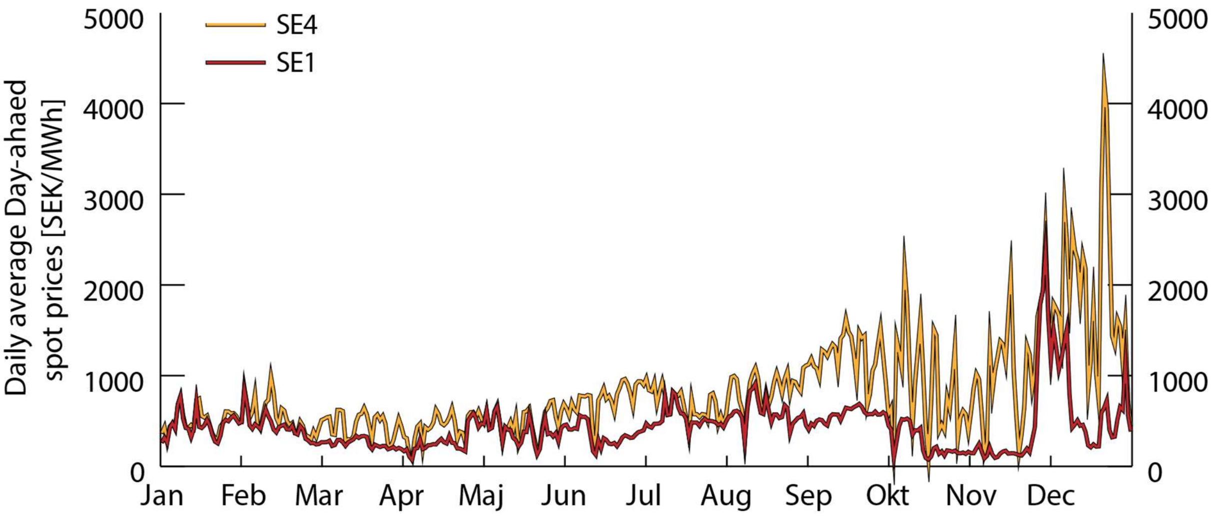

Figure 12: Daily average day-ahead spot prices in area 1 (Luleå) and area 4 (Malmö) in 2021.

Looking back at the last seven years, the spot prices have varied substantially in Sweden, as Figure 13 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 [36][37][38][11]. 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.

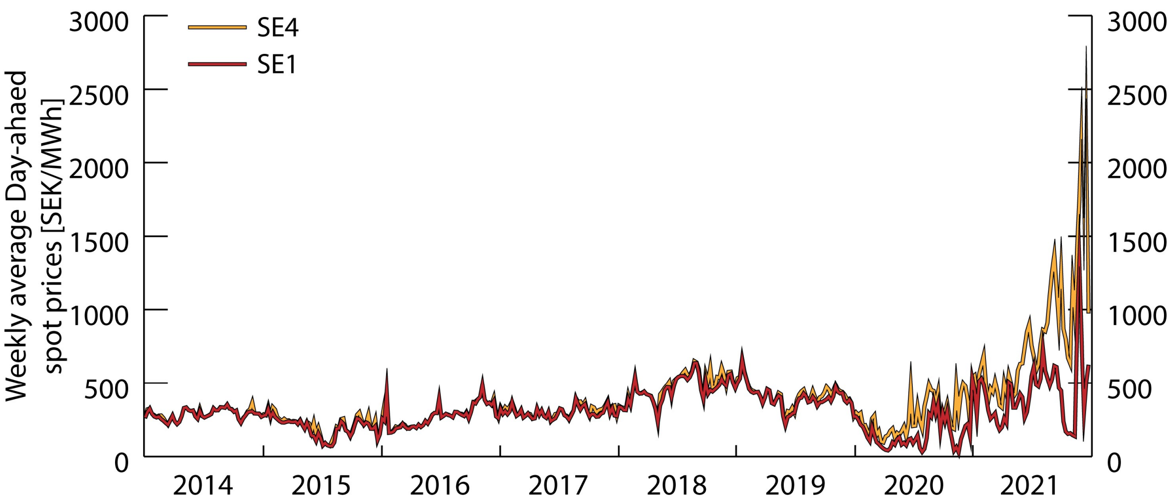

Figure 13: Weekly average day-ahead spot prices in area 1 (Luleå) and area 4 (Malmö) in 2014–2021.

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 7.7 SEK/MWh higher and 2.2 SEK/MWh lower than the average spot prices in Sweden during 2014 to 2021 in SE1 and SE4, respectively. The highest market value was achieved in 2021, which was also the year with highest electricity prices in this period in Sweden.

From Table 19, 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. 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, while 2021, the opposite occurred with value factor was above 1.0 in SE1 and SE2, but below 1.0 in SE3 and SE4.

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 SEK/MWh, and corresponding value factor for the major electricity generation technologies in Sweden from 2014 to 2021 in each of the price areas. Nuclear power only appears in SE3 since all active reactors during 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	-	1,068	1,049	0,976	0,980	-
	2015	188,4	211,4	201,9	224,1	-	0,951	1,068	1,020	1,132	-
	2016	279,6	288,5	268,0	272,7	-	1,016	1,049	0,974	0,991	-
	2017	308,1	314,4	290,0	295,7	-	1,037	1,058	0,976	0,995	-
	2018	489,7	473,6	443,8	444,1	-	1,077	1,042	0,976	0,977	-
	2019	389,7	433,7	386,6	417,5	-	0,972	1,082	0,964	1,041	-
	2020	151,8	161,6	135,6	161,0	-	1,010	1,075	0,902	1,071	-
	2021	443,6	477,9	361,4	438,7		1,026	1,106	0,836	1,015	
	Average	**319,5**	**332,6**	**295,8**	**316,8**	-	**1,020**	**1,066**	**0,953**	**1,025**	-
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	483,5	455,8	433,8	447,3	-	1,064	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	-
	2021	439,3	451,4	343,2	460,2	-	1,015	1,043	0,793	1,063	-
	Average	**318,5**	**320,5**	**290,0**	**321,7**	-	**1,016**	**1,028**	**0,934**	**1,040**	-
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	481,0	439,4	434,9	450,6	452,4	1,051	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
	2021	592,0	707,0	593,7	815,7	683,1	0,881	1,053	0,884	1,215	1,017
	Average	**352,9**	**360,7**	**328,6**	**384,0**	**353,2**	**1,018**	**1,022**	**0,932**	**1,076**	**0,997**
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	508,5	430,9	445,2	462,2	-	1,067	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	-
	2021	718,4	880,5	703,2	991,9	-	0,877	1,075	0,859	1,212	-
	Average	**382,9**	**389,3**	**349,4**	**415,0**	-	**1,017**	**1,006**	**0,913**	**1,059**	-

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 [39].

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 14 illustrates the evolution of the average electricity price for the average end consumer over the years [34]. In Figure 15, the variable part of the electricity price, which is what can be saved if the micro-producer replaces purchased electricity with self-generated PV electricity, is illustrated. Furthermore, the value of the excess electricity is shown for two base cases with the Nord Pool spot price as a base compensation offered by electricity trading utility companies (see section 7.1), energy compensation from the grid owner (see section 3.3.6), the tax credit system (see section 3.2.4) and with and without the green electricity certificate, since few PV owners are using the green electricity certificate system (see section 3.2.3).

It is 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.

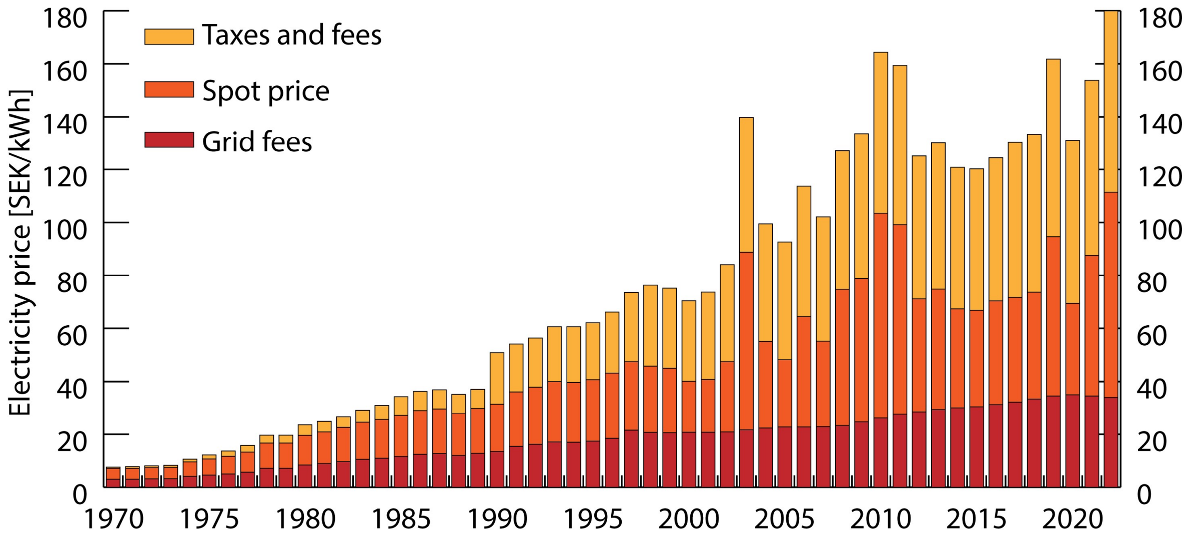

Figure 14: Evolution of the average electricity price (in January) for private end consumer with a single-family house with electric heating.

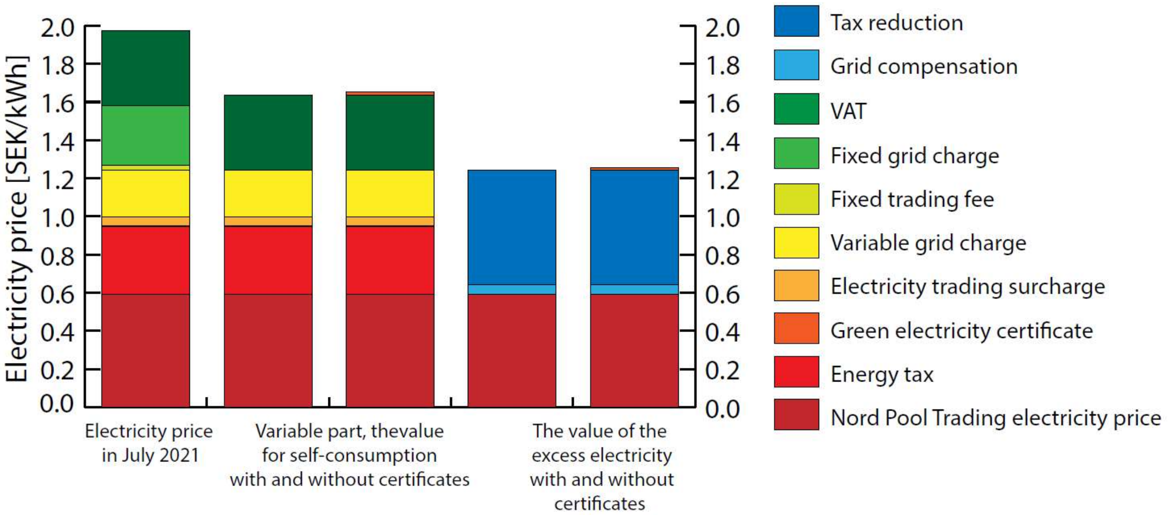

Figure 15: The lowest available electricity price for a typical house with district heating in Stockholm with an annual electricity consumption of about 10 000 kWh/year, a 16-ampere fuse and Vattenfall as the grid owner in July 2021. Furthermore, the compensation for the excess electricity, with and 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 16 [40].

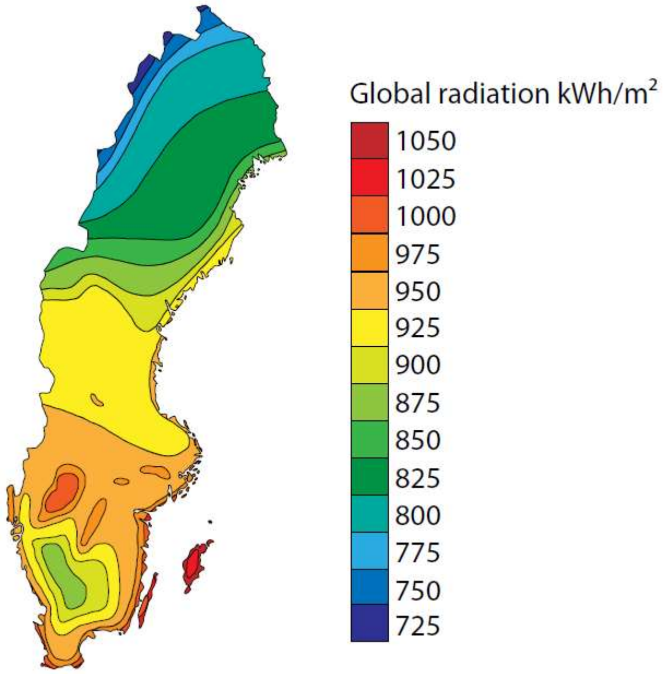

Figure 16: Average global solar radiation in Sweden in one year.

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 2021 annual average accumulated global radiation reached 976.6 kWh/m² [40]. This is quite a normal value and is well below the historic record of 1050.6 kWh/m^2 in 2018, as illustrated in Figure 17, when long periods of anticyclone weather (where barometric pressure is high) over Scandinavia gave very sunny weather during May and July.

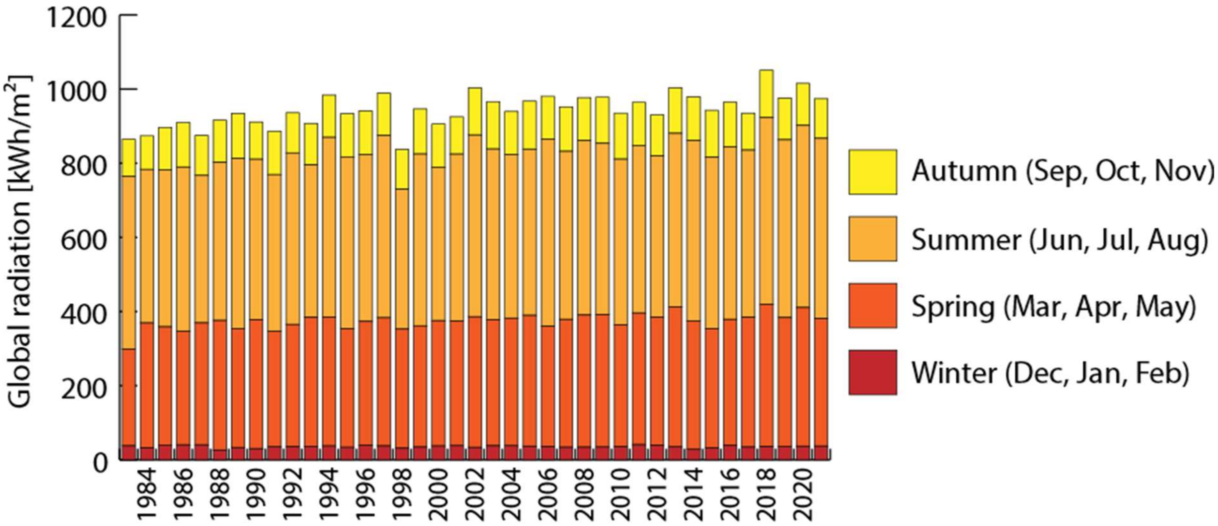

Figure 17: The annual average accumulated global solar radiation in Sweden between 1984 and 2021.

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 simplify, 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 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 [41]. 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 [41] 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 [41]**.**

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 15 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.

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[2]	-	Yes[2]	-	Yes[2]	-
Green certificates	Yes	-	Yes	-	Yes	-
Renewable portfolio standards with/without PV requirements	-	-	-	-	-	-
Income tax credits	Yes[3]	-	(Yes)[3]	-	-	-
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] Eligible for residential projects completed before June 30th, 2021, and non-residential projects completed no later than September 30th, 2021.
[3] 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 direct capital subsidy was active between 2009 and 2021 in its latest form. Prior to that, there was a support for energy efficiency in public premises, where PV was included as eligible investments that could be applied for.

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 [42]. As presented in Table 22, it has since then been modified several times and the support level has been decreased as the market grew and prices fell. The program was extended several times and more money was allocated over time, as Figure 18 shows.

Table 22: Summary of changes in the direct capital subsidy ordinance, support level and duration [43].

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

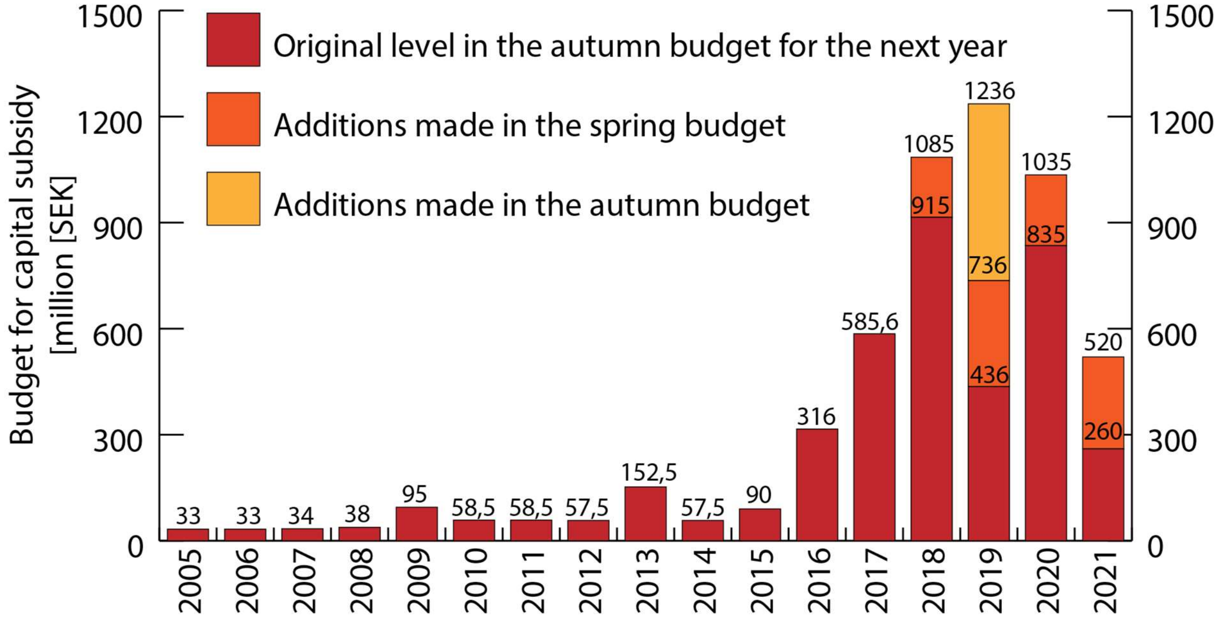

Figure 18: The annual budget of the direct capital subsidy program.

Since its introduction, the interest in the capital subsidy program has always been greater than the budget allocated. When the support was introduced the 1st of July 2009, there had been a gap since the 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 [43]. 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 [43]. 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. 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 [43][44][45].

	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	213.39	138.79	50.93	57.27
2017				585.6	307.58	235.71	76.81	83.61
2018	30%			1085	959.02	601.56	164.92	155.16
2019	20%			1236	579.19	676.53	283.26	279.89
2020	20%			1035	993.15	840.12	303.52	398.45
2021	20%[3]			520	128.04	633.13	159.78	497.77
Total	-	-	-	**5485.10**	**3 788.63**	**3 545.40**	**1116.84**	**1587.17**

[1]Extract from Boverket's database 2022-08. 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.

[3]No new applications are accepted in 2021.

Since the start of the first program in 2006 until the end in 2021, 3788.63 million SEK had been granted and 3 545.40 million SEK had been disbursed [45]. This capital has supported a total installation of 1116.84 MW_p so far. This means that the average subsidy for all PV systems since 2006 to 2021 has been 3.2 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, 3.7 SEK/W_p I 2019 and 3.3 SEK/W_p in 2020.

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 it was 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 [46]. For private persons, this marked the end of a more than 10-year long support program for PV. Instead, the capital subsidy was 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 2020 [47]. This was a measure to meet the need for possible project time extensions due to the COVID-19 pandemic. For municipalities and companies, a total of SEK 260 million was set aside in the budget for the capital subsidy program in 2021, eligible for projects completed no later than September 30th, 2021. The support level was 10 % for these projects. After recognizing that 9 000 private individuals in the queue for approval of already installed projects would suffer from the sudden termination, SEK 260 million was added in the spring budget for projects eligible for support according to the abovementioned criteria [48].

Adding to the applications from companies and municipalities, the applications from private individuals that meet the criteria above could not start to be processed earlier than 1 December 2021. The evaluation process is expected to continue well into 2022, explaining the apparent lag in disbursements.

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 [49].

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) [49].

The support level of this direct capital subsidy is higher than in the previously active 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 [50].

Until the end of 2021, the program has granted and disbursed support to 193 PV projects with a total capacity of 8 785 kW for a total amount of 33 542 362 SEK, in accordance with Table 24. On December 22, 2020, the government decided on a proposal to alter the Swedish rural development program for 2014-2022 and submitted it to the European Commission. The reason for the decision was that the original rural development program for 2014-2020 was extended and new funds were added for 2021-2022. The European Commission subsequently approved on the proposed program changes 22 April 2021, marking the date of closing for new applications in the direct capital subsidy program for renewable energy production, as it was not included in the prolonged plan. There are no plans to re-open the subsidy program, but support could possibly be applied for through a capital subsidy program for investments in agriculture, horticulture, and reindeer farming, as it includes support for energy efficiency measures.

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

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	11.7
2021	32	4 379 105	1 907	11.7
Total	193	33 542 362	8 785	12.1

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 [51]. 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 [52].

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, primarily due to the rapid deployment of wind power, the goal was reached already in March

2021 [53][54]. 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 11th, 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 [55].

In 2021, the average price for a certificate decreased drastically to 18.9 SEK/MWh from the average price of 69.6 SEK/MWh in 2020, 120.7 SEK/MWh in 2019 [56], and the quota obligation was decreased to 25.5% from the 26.3% that was set for 2020, which was in turn decreased from 30.5 % in 2019 [57]. The established trend in the level of the quota duties is summarized in Figure 19 and the price trend in Figure 20.

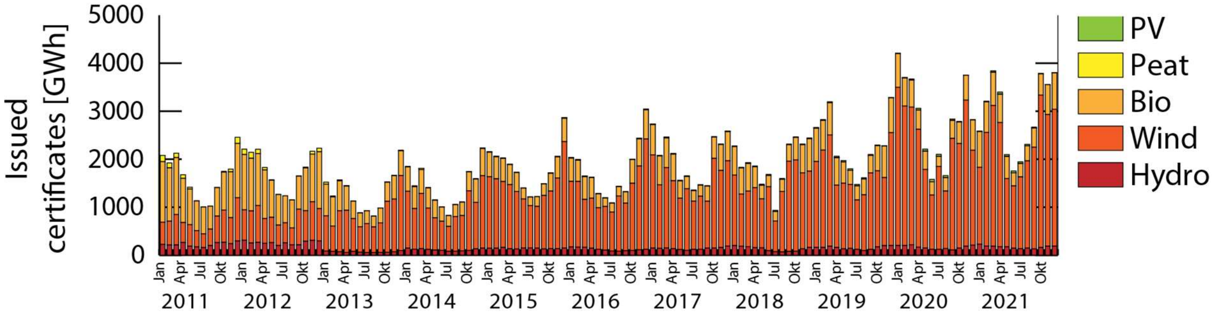

Figure 21: The allocation of renewable electricity certificates to different technologies [56]

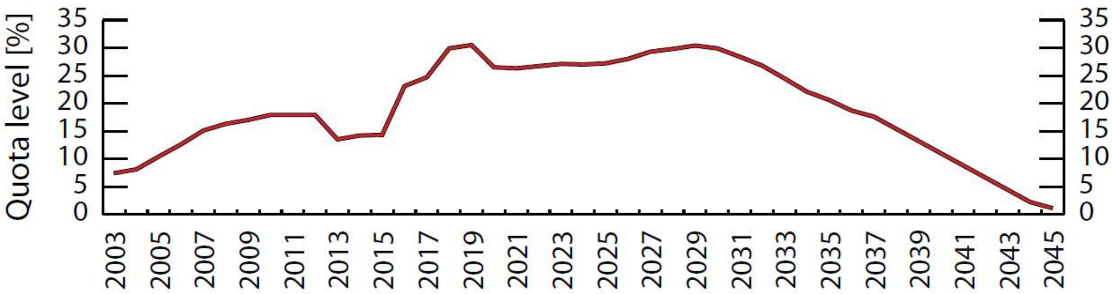

Figure 19: The quota levels in the renewable electricity certificate system [52].

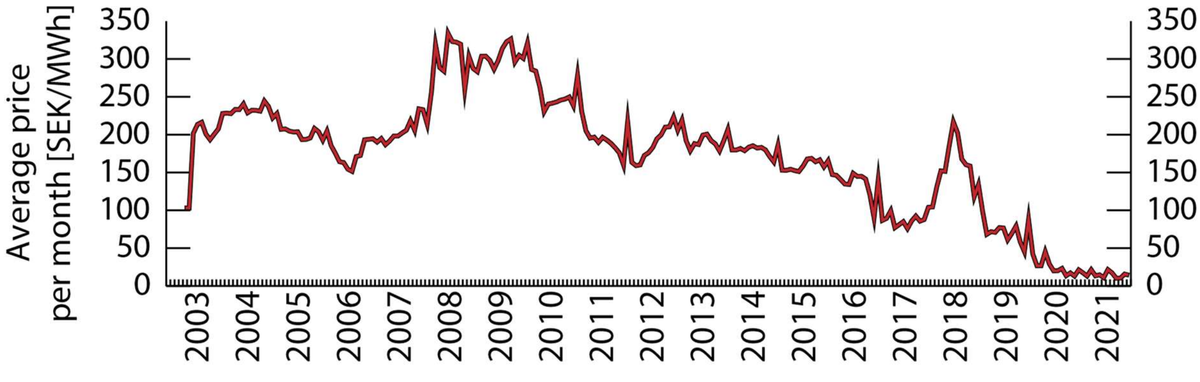

Figure 20: The price development of the renewable electricity certificates [56].

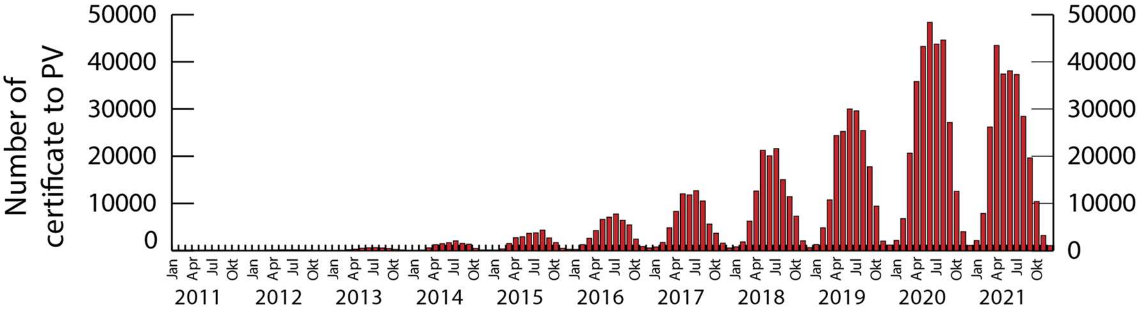

Figure 23: Renewable electricity certificates issued to PV produced electricity [56].

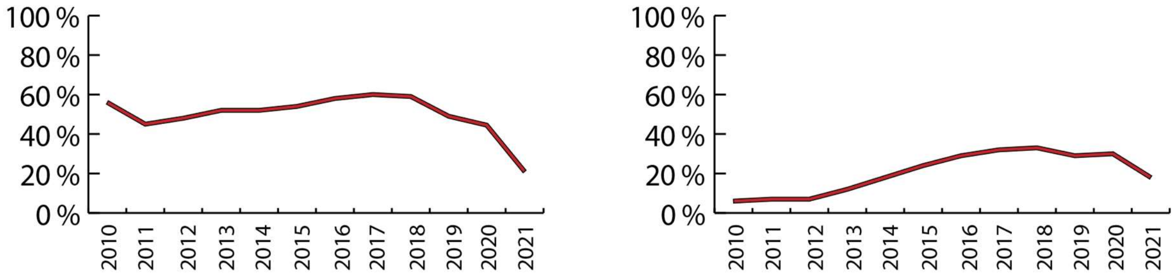

Figure 22: (a) Percentage of the installed PV power in Sweden that is approved for renewable electricity certificates. (b) Allocated certificates to PV electricity divided by the theoretical yearly PV production [56].

Until 2005 there were no PV systems in the electricity certificate system [58]. 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 21, most of the certificates has gone to wind and biomass power, which produce more in the winter months.

Following the amendment stating that no power production constructed after 2021 would be eligible for certificates, the Swedish Parliament agreed that owners of a certificate trading account will be charged an annual administrative fee of 200 SEK, starting July 1st, 2021 [59]. This meant that for owners of smaller PV system, many of the villa system owners, it would no longer be profitable to be part of the renewable electricity certificate system. To avoid the account fee, PV system owners needed to close their electricity certificate account before May 31st, 2021, and by doing that, the facilities approval for electricity certificates is revoked. This explains the drastic decrease in systems approved for electricity certificates in the end of 2021 and the decreased number of issued certificates to PV, in Table 25: Statistics about PV in the electricity certificate system The fact that only larger PV systems are still profiting from the electricity certificate system is clearly demonstrated in table 25, as the average system size more than doubled when 67% of the PV systems withdrew their participation in the program.

255 206 certificates were issued to PV in 2021 [50]. This is only about 18 % of the theoretical production of 1 586 MW × 900 kWh/kW ≈ 1427.4 GWh from all grid-connected PV systems in Sweden. The reader should note that the calculation above is very simplified, especially since the whole cumulative grid-connected PV power at the end of 2021 was not up and running throughout the whole year. 334.0 MW of PV power was accepted in the certificate system at the end of 2021 [58], making it 21 % of the total installed PV grid connected capacity. The steep decrease in Figure 22a and 25b can be explained by the low certificate price and the expiration of the program combined with the introduction of an administrative yearly fee for all PV system owners taking part in the system.

Table 25: Statistics about PV in the electricity certificate system [56][58].

	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
2021	6 615	333 954 kW	50.5 kW	255 206 MWh	764 kWh/kW

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

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) [42] for private persons, the subsidy for storage of self-produced electricity (2016:899) [60] and the subsidy for private installations of charging points for electric vehicles (2017:1318) [61]. 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 designed 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 reduce the price for the house owner already on the invoice, and the system suppliers will report the deducted amounts to the tax authorities [17].

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 [62]. This means that the direct capital subsidy for private individuals of 20 percent of the total cost was replaced by a support of 15 % of 97 % total system cost, which equals 14.55% percent, by 2021. The advantage of the tax reduction for green technology, as compared to the former direct capital subsidy, is that there is no limiting budget, and thus no queue in this system as everyone who meets the requirements can take advantage of the tax deduction directly at the investment time.

3.2.5 BIPV development measures

There were no specific BIPV measures in Sweden in 2021.

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 conducted, 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 2021.

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 + 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…)	Tax reduction for green technology
	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 500 kW_p 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 0), 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 0.006 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 [63]. The latest increase occurred the first of January 2021 when the energy tax was increased from 0.353 SEK/kWh (excluding VAT) to 0.356 SEK/kWh. The exception is some municipalities in northern Sweden where the energy tax now is 0.260 SEK/kWh (excluding VAT) [64]. 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 2021, see Figure 14.

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 July 1st 2021, can be can be summarized as [65]:

- A solar electricity producer that owns one or more PV systems whose total power amounts to less than 500 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 500 kW_p or more, but where all the individual PV systems are smaller than 500 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 500 kW_p pays the normal energy tax of 0.356 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 500 kW_p.

The current legislation has the effect that few PV systems over 500 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 technical potential of PV systems on large industrial properties currently is unexploited. When it comes to systems smaller than 500 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 500 kW_p is exceeded remains.

However, it is only since July 1st, 2021, that the limit has been 500 kW_p. Before that, PV system owners had to pay energy tax on self-consumed electricity produced by systems larger than 255 kW_p. The former limit actively hindered the market development in the industrial and large commercial segments. The limit-increase was welcomed by the Swedish industry, even though many advocates for the limit be completely abolished, amongst them the Swedish solar trade association [66].

Another positive prospect in this matter is that the government has declared their purpose to remove the 0.006 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 [67].

3.3.3 Deduction of the VAT for the PV system

Sweden has a non-deductible VAT for permanent residences [68]. However, homeowner's associations or property owners are granted the right of deduction for VAT for a roof-mounted PV systems as long as the acquisition is attributable to the association's or company's VAT liable sales of surplus electricity. This position, published in November 2020 by the Swedish Tax Agency, replaced the former position from 1 March 2018 [69], as it was legally tried in case 6174-18 of the Swedish Supreme Administrative Court [70].

Before that, only if all generated electricity was delivered to an electricity supplier, and the PV system was therefore exclusively used in economic activity, deduction of the VAT for the PV system was allowed. Worth noting is that it was crucial for the case that a roof mounted PV system is not a part of the permanent residence. Consequently, this does not necessary apply to building-integrated PV.

To summarize, a homeowner's association or property owner may deduct VAT on the investment, operation and preparation of a PV system corresponding to the proportion of electricity that will be sold to the electricity grid [71].

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 0). If the total annual renumeration from the property (including other revenue streams than selling excess electricity) 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 24). If the total annual sales do not exceed 30 000 SEK the PV system owner are exempted from VAT [72].

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 would be an exceptionally large PV system size for a regular homeowner.

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 24, it is a win-win situation for all parties as compared to before the 1st of January 2017.

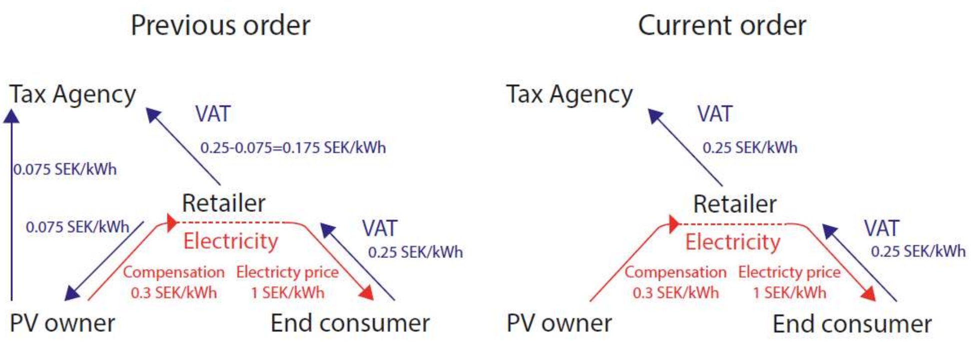

Figure 24: Illustration of the revenue and VAT streams for the excess electricity for a private PV owner before and after the 1st of January 2017.

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 [73]. 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 7.1), 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 3.3.6). 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 76 370 micro-producers of renewable electricity received a total 385 556 429 SEK for excess electricity fed into the grid in 2021. This amount is based on 385 556 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 5 049 kWh in 2021, 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	56 188	183 883 925	306 473 209	5 454
2021	76 370	231 333 857	385 556 429	5 049
Total	-	**635 515 706**	**1 059 192 845**	-

These numbers contain, not only PV, but all small-scale renewable production. Historically, the share of technologies of systems with a production capacity below 69 kW (which corresponds to the 100-ampere limit of the tax reduction) in the green electricity certificate system has been studied to get an estimation of the share of PV in the tax reduction. This methodology generated 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. However, as explained in section 3.2.3, few incentives remain for residential PV system owners to be registered for green certificates in 2021, which eliminates the possibility for that estimation.

Both in 2020 and 2019, 98 % of the capacity of systems below 69 kW were PV in the green electricity certificate system, and the corresponding number for 2018 was 96 %. There is therefore reason to believe that the share of PV would have been around that level also in 2021, if were not for the changes in the system. A level of 98 % PV among the micro-produced electricity would result in 622 805 392 SEK has been paid to PV system owners through the tax credit for micro-production system until the end of 2021.

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 necessitates [74]. 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 [56]**.**

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
2021	316 475	518 255	969 157	201 969	952 894	111 143

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 [75]. 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, and has remained a trend since then. Except for 2018, the export of GOs has been markedly larger than the import into Sweden since the introduction of the GO act in 2017, along with a continuous increase in nullifications compared 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 55 €-cents/MWh in 2021, which would translate to the value of around

0.0055 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.

3.3.8 Feed-in subscriptions for micro-producers

There is an ongoing process to abolish the requirement that homeowners must be net-consumer on yearly basis for free feed-in subscription towards the grid owner. In December 2021, the Swedish Government proposed the legislative alteration through a proposal referred to the Council on Legislation for consideration (*"lagrådsremiss*"). The Council on Legislation agreed with the government's proposed amendment, announced February 15th, 2022 [76]. The exemption enters into force July 1st, 2022 [77].

In practicality, the decision enables small electricity producers, who are net producers of electricity, to feed electricity to the grid with no additional grid fee. This could in turn stimulate the distributed PV market segment by removing the hindering criteria of yearly net-consumption, improving the economic calculation of large private PV systems.

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), regulated in the *IKN-ordinance* [78] for local low-voltage grids, established between buildings within the property or between buildings and facilities that individually also have one connection to the public electricity grid [79]. 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 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 [80].

On October 28th 2021, the Government decided on an exception to the IKN Ordinance in line with the consultation document's suggestion, that gained legal power on January 1st 2022 [78] [81]. Due to the phrasing of the exemption, it is not entirely uncomplicated to predict the extent to which the decision applies. For example, the regulation mentions that the internal low voltage grids shall constitute a complement to the public grid and that it shall be spread over a limited area. How these two criteria should be implemented practically can be interpreted differently. To reach certainty, it must be legally tried by the Energy markets Inspectorate (Ei), which is handled through so-called binding replies ("*bindande besked*"). Due to the processing time to receive such binding reply, at the time of writing the report, there is still no case-law in the matter.

3.5 Tenders, auctions & similar schemes

There were no national or regional tenders or auctions in 2021 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 2021. 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 that expired 31st December 2021 (see section 3.2.3) and the guarantees of origin system (see section 3.3.6). This means that from 2022 onwards, the utility scale segment is developing under unsubsidised market conditions in Sweden. Even if there are no subsidies in Sweden, the centralized market segment is thriving and competitive [20].

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 [82].

3.7 Social Policies

There were no social policy measures directed to PV in Sweden in 2021.

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 2021.

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 [83]:

- 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 introduced a direct capital subsidy for energy storage owned by private households in 2016. The subsidy was given for energy storages that fulfil these criteria [60];

- 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 subsidy was only granted to individuals with a maximum of 60 % of the eligible costs, but no more than 50 000 SEK [60].

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 (See section 0).

To conclude the 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 Aggregated grid subscriptions

Since January 1st, 2021, it is possible to subscribe for aggregated grid contracts ("*summaabonnemang*") 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 [84].

3.9.5 Curtailment policies

There were no rules when it comes to curtailment of renewable electricity in Sweden in 2021.

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 [85].

The ROT-tax deduction in 2021 was 30 % of the labour cost and of maximum 50 000 [85] 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 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 3 545 404 848 SEK has been disbursed from 2009 to the end of 2021 (see section 3.2.1). This system is financed by the Swedish state budget and the money is distributed by the 21 county administrations. While the system has been closed for new applications, further disbursements are expected at least throughout 2022.

In addition, the direct capital subsidy for renewable energy production in the agriculture industry program granted a total support of 33 542 362 SEK to PV systems has during 2015–2021 (see section 0). 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 2021 received a total of 1 009 131 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 2021 becomes 67 411 530 SEK [56]. 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 622 805 392 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 2015–2021. This subsidy financed by the Swedish state budget.

Adding all the above subsides, the Swedish PV market received approximately a total of 4 411.70 million SEK in direct subsidies at the end of 2021.

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 308 companies that sold and/or installed PV modules and/or systems in the Swedish market (see section 4.3.1.1) in 2021. In addition, the author was also aware of 51 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 2021 (see section 4.3), even if the production volumes were small, and 19 companies active in manufacturing of production machines or balance of systems equipment (see section 4.4). Furthermore, the authors were 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 2021.

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 25 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 164 companies and organisations have under the period 2010–2021 withdrawn from the sector due to either; changes in business focus, controlled closure of business or bankruptcy. Consequently, the total turnover of active companies has been much higher than Figure 25 and Table 29 show.

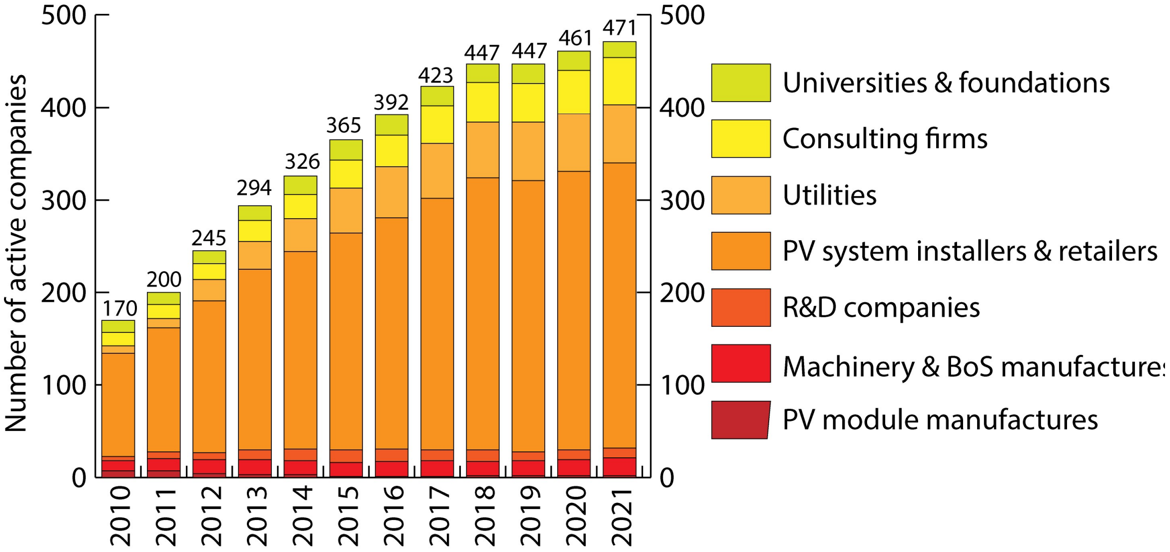

Figure 25. Evolution of the number of active companies in the Swedish PV sector (known to the authors).

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
2021	2	19	11	308	63	51	17

4.1.1.1 Svensk Solenergi

Svensk Solenergi is a trade association which, with about 290 professional members, represent both the Swedish solar energy industry and market as well as research institutions active in the solar energy field.

4.2 Production of feedstocks, ingots and wafers

Sweden did not produce any feedstock or wafers in 2021 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 1.2 MWp BIPV modules last year. In total 1.8 MW_p of modules where therefore produced in Sweden in 2021. However, both SweModule and Midsummer has announced plans to produce larger quantities in 2022. Total PV cell and module manufacturing together with production capacity information is summarised in Table 30 below.

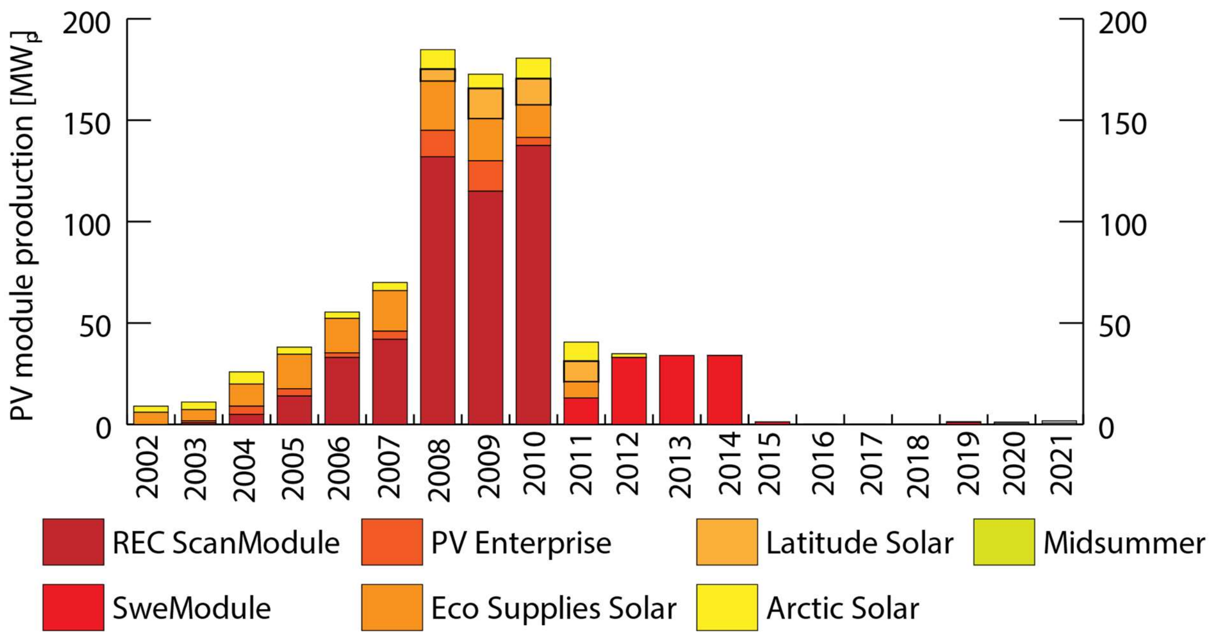

Figure 26: Yearly PV module production in Sweden over the years.

Table 30. PV cell and module production and production capacity information for 2021.

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	1.20	1.20	5	5
Cells for concentration					
None	-	-	-	-	-
Totals		**1.20**	**1.80**	**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 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 and 2021 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. 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 4.4.1.13).

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 90 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 4 000 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 starting from 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 2016-2019 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 approximately 250 employees located in Sweden. 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.

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 began in 2021. The facility is scheduled to start manufacturing battery cells for Volkswagen from late 2023 or early 2024.

4.4.1.11 Sluta Gräv AB

Sluta gräv AB is a company that specializes in development and manufacture of groundscrews. The screws are designed in Helsingborg, Sweden. Sluta Gräv operate on a global basis via a partner network and have business in 12 market. Groundscrews is a modern ground foundation and has it clear advantage compared to concrete. Faster installation and with a re-usable and recyclable product that has 60% lower CO_2 emission than comparable concrete foundation makes the groundscrew a better sustainable alternative. Sluta Gräv Groundscrew can be used for centralized PV systems and Sluta Gräv also offer an own mounting racks system.

4.4.1.12 Weland Stål AB

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

4.4.1.13 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 aluminum 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 kWp. 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 is a highly specialized chemical company providing state-of-the-art materials for research and industrialization. Since 2011, we manufacture and sell high-quality speciality chemicals in our facilities in Stockholm. We pave the way for industry and research organizations to access the latest findings in chemistry-based cleantech energy conversion, particularly in the fields of dye-sensitized solar cells, perovskite solar cells and solar fuels.

4.5.1.2 Delta Electronics (Sweden) AB

Delta Electronics is a global developer and manufacturer of switching power supplies, thermal management systems and solutions in the areas of Telecom Energy, Data Centre Infrastructure, Renewable Energy, EV Charging, Industrial Automation, Building Automation and Display and Monitoring Solutions.

It has close to 200 sales offices, R&D centres and manufacturing facilities around the world. Its major brands include Delta, Eltek, Vivotek and Loytec.

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

The business model is based on sales of turnkey fabs for manufacturing perovskite 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%.Based on the agreement Magnora has increased its ownership to the current 50%. The company had 19 employees at the end of 2021 (currently 25), operates a 2500 sqm facility in Uppsala with R&D labs and a pilot manufacturing plant and has ambitious plans to make a successful market entry shortly. The PV Power Booster technology for adding a perovskite solar cell layer can be combined with most primary cell technologies.

4.5.1.5 Exeger Operations AB

Exeger is a Swedish company with a solar cell technology that converts all forms of light into electrical energy. The material, Powerfoyle, is a fully customizable solar cell. With its superior design properties, it can be integrated seamlessly into any electronic device such as consumer electronics or Internet of Things (IoT).

Commercially available products are Urbanista Los Angeles, Urbanista Phoenix, adidas Headphones RPT 02-SOL, Blue Tiger Solare, POC Omne Eternal and Spåra Hund.

Powerfoyle enhances products it is integrated into with extended or even unlimited battery life.

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 SolTech Energy Sweden AB

Stockholm based Soltech Energy Sweden is listed on Nasdaq First North Growth Market and has over 70 000 shareholders. Soltech is a total supplier of energy and solar cell solutions. With oversight over the entire value chain, from development to installation, they can transform all types of properties to more sustainable and self-sufficient energy producers.

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 217 MW until the end of 2021 through their joint venture company ASRE.

4.5.1.9 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.

4.5.1.10 Swedish Algae Factory AB

Swedish Algae Factory was founded in 2016 around the discovery of the light manipulating traits of the microalgae group diatoms. The nanostructured silica shells of diatoms can trap light efficiently and manipulate shorter wavelengths of light to longer wavelengths of light. The company has developed an algae cultivation and wastewater treatment system from which they harvest these silica shells from the algae. The organic algae biomass that is left after the extraction of the silica shell, could be utilized in several applications such as for feed production or energy and organic fertilizers. In late 2016 the company started to test the silica shells ability to enhance the efficiency of solar panels. Initial lab tests showed that the nanostructured silica material could enhance the efficiency of silicon solar panels with over four relative percentage, due to its light trapping and light manipulating properties.

The company has 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 has also validated the potential of the material to enhance the efficiency of DSSC (dye sensitized solar cell). This research was published in 2020. Since 2018 Swedish Algae Factory has operated a pilot facility with a yearly production capacity of 30 kg of this material. In late 2020 the company started to build a commercial production plant with a yearly production capacity of 700 kg, which is planned to be finalized early 2022.

The technology is primarily targeting two use cases in the industry. One is to use the 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 2021. If the reader knows of any other active company, please contact the author at: amelia.oller@ieapvps.se.

24 Volt
2electrify AB
7 Energy 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
Alstra Nordic AB
AM Villabutiken
APM Avesta Persienn & Markis
Apptek Teknik Applikationer AB
Aprilice AB
Armatec AB
Atlas Solenergi AB
Attemptare AB
Awimex International AB
Baltic Suntech AB
Baxi AB
BayWa r.e. Scandinavia AB
BeGreen Sweden 2020-35 AB
Be-Lo Elektriska AB
Benny Gruvesäter Teknik
Better Energy Sweden AB
BLS Energy AB
Brael Norden AB
Braxel Solutions AB
Bredsands El & Solteknik AB
Brion Solenergi AB
Cardipoint AB
Caverion Sverige AB (norr)
Ce-Ce Elservice AB
Cell Solar Nordic AB (1komma5)
Forsbergs VVS & Energiteknik AB
Free Energy Sverige AB
Freebo AB
Friendly Power AB
Fronius Danmark Aps
Fueltech Sweden AB
Futura Energi AB
Fyrstads El AB
GFSol AB
Gisle Innovations AB
Gosol Energi AB
Gridcon Solcellsteknik AB
Guld Sol byggen AB
Heat-On AB
Helio Solutions AB
Helios El & Solkraft AB
Hero Solkraft AB
HESAB
Highlands International AB
Holje-El AB
HPSolartech AB
HS Energi & Klimat AB
HS-Solteknik AB
Hybrida E-mobility AB
Hyssna Solvärme AB
Höjentorps Solenergi AB
IBC Solar AB
Idola Solkraft AB
IKEA
Implementa Sol AB
Indsol Group AB
INKA Energi
Iq Energi
Isorent AB
J.E. Nordins El AB
JN Solar AB
JoDatec HB
Sesol AB
SHS Gruppen AB
Signalmekano AB
Simply Solar AB
Smart Solar Norden AB
Sol & Byggteknik i Grythyttan AB
Solar Invest AB
Solar Supply Sweden AB
Solar Teknik Solfångare SV 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
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

Co2Pro AB
Comne Work AB
Consize AB
Creative Networks Constructions X AB
Creative Networks Solutions X AB
Dalarnas Solcellsmontage AB
Dalasolenergi AB
Dalaträhus Energi AB
Dalhem Sol AB
Delabglava AB
DJs Sol & Energiteknik AB
DT Micro Computer Systems 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 Solar AB
Elektriker'N Jimmy Wilhelmsson AB
Elektroline i Kungsbacka AB
Elians Group AB
Elkatalogen i Norden AB
Elkontakten i Ale AB
Elterm i Alingsås AB
Eltjänst i Falköping AB
EMG Energimontagegruppen AB
Enequi AB
Energi & Innovation i Norden AB
Energi Solvind ESV AB
Energibyggarna i Väst AB
Energi-Center Nordic AB
Energicompagniet Sverige AB
EnergiEngagemang Sverige AB
Energiförbättring Väst AB
Energihem i Sverige AB
Energihuset i Vimmerby AB
JSS Tjänst AB
Jöta El AB
KAMA Fritid AB
Kjells Elektronik & Digital-Tv Center AB
Klimatprojekt i Mälardalen
Knuttes El AB
Kopernicus AB
Kostal Solar Electric GmbH
KP Energy AB
Krannich Solar AB
Kretsloppsenergi Kummelnäs AB
Krylbo Elmontage AB
K-Utveckling Engineering AB
Lambertsson Sverige AB
Laxviks El och Solpanel AB
Lego Elektronik AB
Levins Elektriska AB
Lorex AB
Lundgrens El AB
Lundgrens Elektriska AB
MagnusEnergy
Miljö & Energi Ansvar Sverige AB
Miljö- VVS- & Energicenter i Östergötland AB
Modern Miljöteknik i Varberg AB
Monier Roofing AB
Mälar Bygg & Montageservice i Stockholm AB
Neolar AB
Newel AB
Nexion Enertech AB
NIBE Energy Systems WFE AB
Nirosolar AB
Nordens Solvärme AB
Nordh Energy Solar AB
Nordic Energy Partner AB
Nordic Solar Sweden AB
Nordisk System Teknik AB
Nordpolen Energi AB
Nordströms Elektriska Byrå AB
Northern-Nature-Energy
NP Gruppen AB
Solkompaniet Sverige AB
Solkraft EMK AB
Solkraft i Viby AB
Solkraftcenter Sverige AB
Sollux AB
SolNord AB
Solorder AB
Solortus AB
Solsystem Sverige AB
Solteamet i Västerbotten AB
Soltech Energy Solutions 1988 AB
Soltech Sales & Support AB
Solverket Alfa AB
Solvio AB
SolviQ Sverige AB
Solvision AB
Spindel AB
Sun Energy Nordic AB
Sun Of Sunne AB
Sun4energy AB
Sunavia AB
SUNBEAMsystem Group
Suncellhouse Solenergi AB
SunDoSparks
Sunna Group AB
SunnyFuture AB
Sunroof AB
Sunsolutions by Telecontracting Scandinavia AB
Sunwind Gylling AB
Susanna — Sustainable and Natural AB
SVEA Renewable Solar AB
Svenska Solcellsanläggningar AB
Svenska Solenergigruppen AB
Svenska Solpanelmontage AB
Svenskt Byggmontage AB
Svesol Värmesystem AB
Swedensol Energi AB
Sydpumpen AB
Södra Solmontage AB
Söne El AB
Tadastro AB

Energiprojekt Stockholm AB
Energiteknik i Kungälv AB
Energiverkstan 2030
Energy Effective Solutions i Mälardalen AB
Enerparc AG
Enstar AB
Ergus El-Konsult
Erikas Tak & Bygg AB
Erntec AB
Esdec Sverige
Etab energi AB
ETC Elproduktion i Katrineholm AB
Euronom Group AB
European Energy Sverige AB
Everöds Elbyrå AB
EVI Heat AB
EWF ECO AB
EWS GmbH & Co. KG
Extra Arbetskraft i Uppland AB
Falu Solenergi AB
Fasadsystem i Stenkullen AB
Fire Mountain AB
Flens Solel AB
Orust Engineering
OTM Eko Energi AB
Otovo AB
Paneltaket AB
Parkys Solar AB
Penthon Installation AB
PFA Solteknik AB
PMC El AB
PPAM Solkraft AB
Prolekta Gotland AB
Raymond Solar 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
Samvest Elteknik AB
Save-by-Solar Sweden AB
Schletter Solar GmbH
SEBAB AB
Sell Power Nordic AB
Senergia AB
Takorama AB
Takrekond i Småland AB
Teknisk Fastighetsservice i Norrland AB
Tellux AB
Thermotech Scandinavia AB
Tröingebergs EL&VVS AB
Täta Tak Entreprenad Sverige AB
Valk Solar Systems Nordics
VallaCom AB
Vancos Munka Ljungby AB
Varmitek Energisystem AB
Veosol Teknik AB
Viessmann Värmeteknik AB
Villavind AB
Visionsteknik i Norr AB
Vårgårda Solenergi AB
Värmekällan Väst AB
Wettersol AB
Windforce Airbuzz Holding AB
Windon AB (försäljning)
WOJAB AB
Yokk Solar AB
Zenitec Sweden 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 2021. 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: amelia.oller@ieapvps.se.

Act Management AB
Advokatfirman Lindahl
Advokatfirman Vinge
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
Drivkraft Andrén EF
Elkatech AB
Emulsionen Ekonomiska Förening
Enable Energy Sve AB
Energianalys i Alingsås AB
Energibanken
Enklare Husliv BIM AB
Esam AB
Fasadglas Bäcklin AB
Fenix Solar AB
Franzén Energiteknik AB
Gagnar AB
Grön Sol AB
Hemsol AB
IATEK
Incoord Installationscoordinator AB
Ingenjörsfirman Flemming Åkesson
Mark-Man AB
JB EcoTech AB
M2 Bioenergi AB
Maple Energy 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
Åkerby Solenergi
Solelsbyggarna Tribera Net AllFiber
Bredbandskonsult AB
Solisten David Larsson AB
Sunwide
Sustainable Business Partner Scandinavia AB
Sweco Systems AB
Vinnergi AB
Watt-s
White Arkitekter AB
WSP Sverige 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 2021
Center of Molecular Devices	Dye-sensitized, perovskite and quantum dot solar cells	27
Chalmers, Architecture and Civil Engineering - Works with Architecture	Roof renovation with PV	0.5
Chalmers, Chemistry and Biochemistry, Abrahamsson Research Group	Photocatalytic conversion of CO_2 with light	1
Chalmers, Chemistry and Biochemistry, Albinsson Research Group	Technology for down and up conversion of sunlight	6
Chalmers, Chemistry and Chemical Engineering	Organic solar cells	3
Chalmers, Material Physics	Battery material research	21
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, Electrical Engineering	Studies and modelling of PV systems integrated to the grid and simulations of the campus system	1
Chalmers, Technology Management and Economics	Business models for PV deployment	10
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	1
Karlstad University, Molecular Materials for Electronics	Polymer-based and perovskite solar cells	7
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	8

KTH Royal Institute of Technology, Electric Power Systems	Power grid control at coordinated input of PV electricity	1
KTH Royal Institute of Technology, Material and Nanophysics	Direct III-V/Si heterocycle for solar cells and silicon-based tandem cell	6
Linköping University, Biomolecular and Organic Electronics	Plastic solar cells	10
Linköping University, Organic Electronics	Solar heat-charged super capacitor as energy storage	7
Luleå University of Technology, Electric Power Engineering	Stochastic planning of smart electricity distribution networks, PV electricity quality and reliability from a grid perspective	3
Luleå University of Technology, Experimental Physics	New nanomaterials for third generation solar cells	5
Lund University, Chemical Physics	Dye-sensitized, plastic and quantum dot solar cells, along with semiconductor nanowires and organometal halide perovskites	10
Lund University, Energy and Building Design	Social issues with regards to solar energy, urban planning and building design	4
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	3
Lund University, Polymer and Materials Chemistry	Nano-structured materials for higher PV efficiency	11.5
Lund University. Centre for analysis and synthesis	Iron based solar cells and iron complexes as photosensitizers in solar cells	19
Mid Sweden University, Electronic Construction	Development of converters and supercapacitor, and grid stabilization studies	4
Mid Sweden University, Fibre Science and Communication Network	Lithium-ion batteries and super capacitors	8.5
Mälardalen University, Future Energy Center	PV in agriculture and the built environment, PV modelling software	7
RISE, Research Institute of Sweden AB	Testing of PV components, systems and batteries, BIPV and micro-grid research etc.	24.5
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	0.5
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	7
Uppsala University, Material Science and Engineering - Solar Cell Technology	CIGS and CZTS thin film solar cells and materials	22
Uppsala University, Ångström Advanced Battery Centre	Li-ion batteries and different battery chemistries with high energy density	95

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).

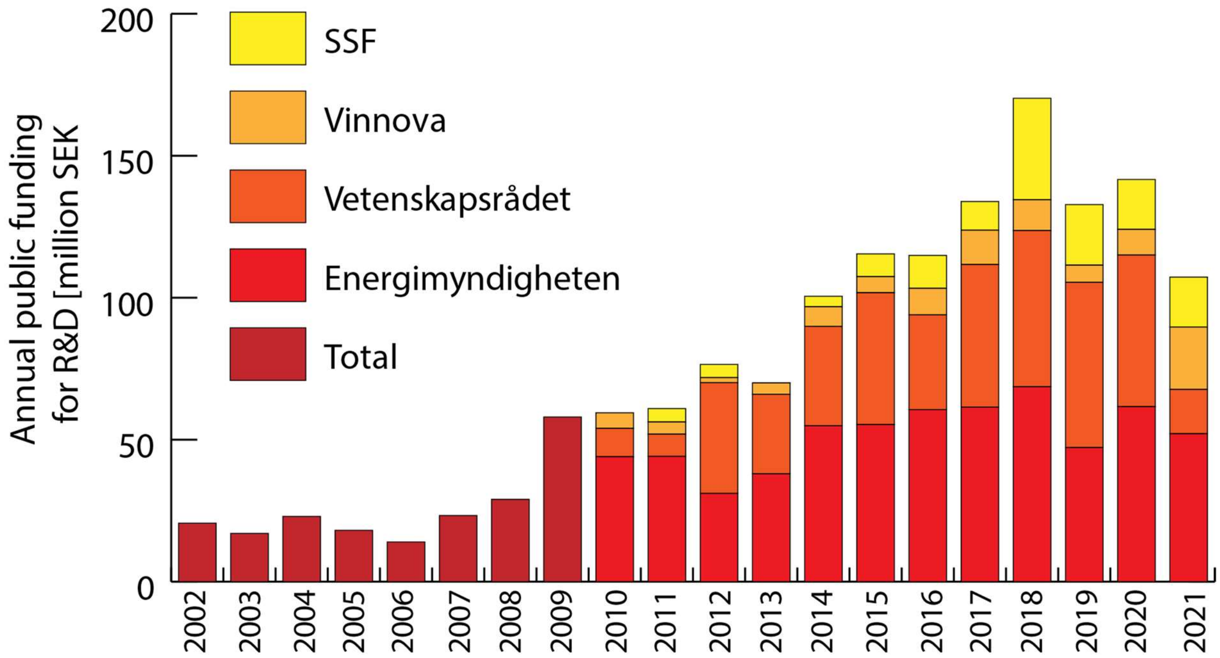

Figure 27. Annual public funding for PV related research in Sweden

Note that the difference in funds dedicated to PV research from Vinnova appears smaller for 2019 compared to the Swedish National Survey Report published in 2020. 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 2021, 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 full-time equivalent (FTE) 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, with 1 098 out of the 1 370 new FTEs created in 2021 being in that segment, according to the survey (See 9.1.3). The growing market in turn 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 FTEs summarized in Figure 28 and Table 32 is an assembly of all the reporting stakeholders' estimations over how many FTEs the Swedish PV market employs at their company. The figures are therefore just estimations.

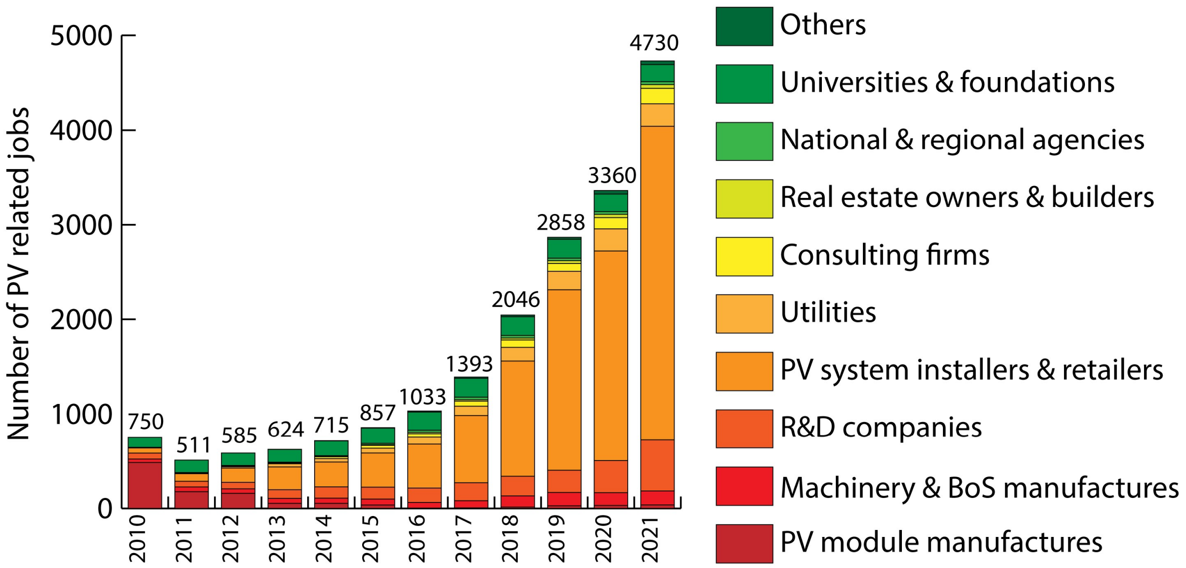

Figure 28. The historic development of PV related full-time equivalents in Sweden.

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 dividing 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 and 7.6 in 2021.

The years prior to 2021 demonstrated a clear trend of fewer and fewer created labour places per installed MW, 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 that is shown for the same period (See section 2.2). Just as with the PV system price development, the opposite trend can be detected for 2021, with an increase with 1.1 FTE per installed MW. While there can be many explanations for this development, it is likely connected to the turmoil caused by the covid-19 pandemic, with effects like longer project times and supply chain issues. This could have impeded the market development, pushing commissioning of PV systems to 2022 instead of 2021, without affecting the companies' staffing.

Table 32: Estimated PV-related full-time equivalents in 2021.

Market category	Number of full-time equivalents
PV module manufacturers	37
Machinery and balance of systems manufactures	148
Research and development companies	539
PV system installers and retailers	3 317
Utilities	237
Consulting firms	163
Real estate owners and building companies	39
National and regional agencies	31
Universities, foundations and educations companies	181
Others	38
Total	**4 730**

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	2021
PV market related labour places	59	89	174	286	323	450	598	897	1494	2281	2596	3756
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	499.7
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**	**7.6**

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 1.3) and typical prices within those segments (see section 0).

Table 34: Rough estimation of the value of the PV business in 2021 (VAT is excluded).

Sub-market		Capacity installed in 2021 [MW]	Average price [SEK/W]	Market value
Off-grid		1.89	27.5	~ 52 million SEK
Grid-connected distributed	Residential	292.82	14.3	~ 4 187 million SEK
	Public	16.19	12.7	~ 244 million SEK
	Commercial	107.88	10.2	~ 1 100 million SEK
	Industry	28.62	9.1	~ 260 million SEK
Grid-connected centralized		52.26	7.2	~ 376 million SEK
Value of the Swedish PV market 2021				**~ 6 220 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 [86] 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. 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.

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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 2021 were:

Affärsverken Karlskrona, Arvika Kraft, Axpo Sverige, Bixia, Borlänge Energi, Borås Elhandel, C4 Elnät, Dalakraft, E.ON Energilösningar, Ellevio, Energi Försäljning Sverige, 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, Jönköping Energi, Kalmar Energi Försäljning, Karlstads Energi, Kraftringen Energi, Kungälv Energi, LEVA i Lysekil, Luleå Energi, MälarEnergi, Mölndal Energi, Nossebro Energi Försäljnings, Nybro Energi, PiteEnergi, Sala-Heby Energi, Sandhult-Standareds Elektrisk Ekonomiska förening, SEV Strängnäs Energi, Skellefteå Kraft, Skånska Energi, Sollentuna Energi & Miljö, Statkraft Financial Energy, Stockholm Exergi, Storuman Energi, 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, Varberg Energi, Vattenfall, Vimmerby Energi & Miljö, Växjö Energi and Öresundskraft Marknad .

At least one utility company, Umeå Energi, also offer leasing of PV system to private individuals.

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 subsidy (see section 3.2.1), both closed for new applications in 2021. 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 Affärsverken, Arvika Kraft, Bixia, C4 energy, EON, ETC El, Göteborgs Energi, Jämtkraft, Jönköping Energi, Kalmar Energi, Luleå Energi, Mälarenergi, Vallebygdens Energi and Vattenfall.

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 [87] 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 [88]. 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 [89].

Some Swedish municipalities and local government have introduced ambitious 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 [90].
- 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 [91].
- 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 [92].
- 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 [93].

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 2021, with 499.7 MW installed. This corresponds to a market growth of 25 %, compared to the 400.1 MW that was installed in 2020. While the centralized PV market grew with 14%, the Swedish PV market is still dominated by residential roof-mounted systems for single-family houses and roof-mounted systems on commercial buildings.

However, the pandemic has likely impacted other parts of the PV market, with prices being particularly affected. 2021 shows a clear trend break in the reported prices for residential PV systems, with prices comparable to 2018 levels reported by PV installers and suppliers. The price statistics for commercial systems are more ambiguous, but still show signs of increased prices. It is the first time since the data collection started that such price increases have been documented, and the development is mostly assigned to global hardware supply chain constrains and increased material prices. Additionally, the number of full-time equivalents of PV-related jobs per installed MW of PV capacity also rose for 2021, which has a connection to the soft cost of PV system prices.

Regarding policy development, new non-residential systems in Sweden are entering a non-subsidies policy environment after the end of 2021. The system for green electricity certificates closed for new systems commissioned after 2021, and the capital subsidy program was closed for new applications already in mid-2020. This leaves the centralized, commercial, public and industry segments relying on market incentives such as utilities buying PV electricity above spot-market price and guarantees of origin as possibilities for extra revenues. Generally, self-consumption business models and corporate PPAs are driving the PV market development in Sweden. For private individuals, the tax reduction for green technology, starting 2021, has become the most impactful support system, adding to the tax credit for micro-producers for electricity fed into the grid by PV systems under 69 kW_p of size. An exemption from the general grid-rules will allow for renewable energy sharing between buildings starting 2022, which is expected to stimulate the multi-family house PV segment, as it allows for collective self-consumption.

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 short term, lingering turmoil and supply chain constraints from COVID-19 and geopolitical events are causing uncertainty on the Swedish PV market, impeding the possible market growth otherwise accelerated by the high electricity prices. The lack of direct support for non-residential PV system might also hamper development slightly in the very short term. 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 has been novel as of 2021. 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 and onwards.

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 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. The introduction of internal low-voltage grids for energy sharing is well awaited by the industry and a first step in allowing collective self-consumption. Future steps to align with EU-regulation awaits and should enable more possibilities for jointly acting self-consumers or even energy communities.

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. Developers are currently struggling with extensive permitting processes, which creates a barrier for rapid growth in this segment. Whether this is a short-term problem caused by inexperience of such processes in the deciding institutions or whether it is a long-term problem for the industry remains to be seen.

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. Furthermore, the direct capital subsidy has now been closed, and a lot of in capacity is missing in this database, especially for the year 2021. Hence, the segmentation results should be viewed as estimates calculated by the authors.

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 2018–2021 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.

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.

10 REFERENCES

[1] Energimyndigheten, “Nätanslutna solcellsanläggningar,” 2022. [Online]. Available: https://www.energimyndigheten.se/statistik/den-officiella-statistiken/statistikprodukter/natanslutna-solcellsanlaggningar/.
[2] M. Warneryd and K. Karltorp, “The role of values for niche expansion: The case of solar photovoltaics on large buildings in Sweden,” *Energy. Sustain. Soc.*, vol. 10, no. 1, 2020, doi: 10.1186/s13705-020-0239-7.
[3] EON Energidistribution, “E.ON har anslutit Sveriges största solcellspark utanför Skurup.” [Online]. Available: https://www.eon.se/artiklar/anslutning-av-sveriges-stoersta-solcellspark.
[4] B. Nykvist and M. Nilsson, “Rapidly falling costs of battery packs for electric vehicles,” *Nat. Clim. Chang.*, vol. 5, no. 4, pp. 329–332, 2015, doi: 10.1038/nclimate2564.
[5] Power Circle, “Elbilsstatistik,” 2021. [Online]. Available: https://www.elbilsstatistik.se/elbilsstatistik.
[6] E. Jönsson and S. Holmberg, “Åsikter om energi och kärnkraft — Den svenska miljö-, energi- och klimatopinionen (MEK),” Göteborg, 2021.
[7] L. Nohrstedt, “Mer förnybar el — då sjunker stamnätets kapacitet,” *Ny Teknik*, p. 6, 2020.
[8] J. Egerer, F. Kunz, and C. von Hirschhausen, “Development scenarios for the North and Baltic Seas Grid - A welfare economic analysis,” *Util. Policy*, vol. 27, pp. 123–134, 2013, doi: 10.1016/j.jup.2013.10.002.
[9] B. Zakeri, V. Virasjoki, S. Syri, D. Connolly, B. V. Mathiesen, and M. Welsch, “Impact of Germany’s energy transition on the Nordic power market – A market-based multi-region energy system model,” *Energy*, vol. 115, pp. 1640–1662, 2016, doi: 10.1016/j.energy.2016.07.083.
[10] B. Zakeri, J. Price, M. Zeyringer, I. Keppo, B. V. Mathiesen, and S. Syri, “The direct interconnection of the UK and Nordic power market – Impact on social welfare and renewable energy integration,” *Energy*, vol. 162, no. 2018, pp. 1193–1204, 2018, doi: 10.1016/j.energy.2018.08.019.
[11] Å. G. Tveten, J. G. Kirkerud, and T. F. Bolkesjø, “Integrating variable renewables: the benefits of interconnecting thermal and hydropower regions,” *Int. J. Energy Sect. Manag.*, vol. 10, no. 3, pp. 474–506, 2016, doi: 10.1108/IJESM-08-2014-0006.
[12] Svenska Kraftnät, “Elstatistik - Statistik hela landet per månad, 2021,” 2021. [Online]. Available: https://www.svk.se/om-kraftsystemet/kraftsystemdata/elstatistik/.
[13] Statistikmyndigheten SCB, “Bränsleförbrukning för elproduktion i Sverige efter produktionsslag och bränsletyp. År 1990–2021,” 2022. [Online]. Available: https://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__EN__EN0105/BrforelAR/. [Accessed: 04-Jun-2022].
[14] European Commission, “The European Union´s measures against dumped and subsidised imports of solar panels from China,” 2015.
[15] G. Masson *et al.*, *Trends in photovoltaic applications 2022*. Photovoltaic Power Systems Technology Collaboration Programme (IEA PVPS) Task 1, 2022.
[16] PV Insight, “Price download,” 2022. [Online]. Available: http://pvinsights.com/index.php. [Accessed: 30-Sep-2022].
[17] A. Oller Westerberg and J. Lindahl, “Kostnadsstruktur för svenska villasystem,” *Energiforsk*, 2020, doi: 10.13140/RG.2.2.16091.69923.
[18] J. Lindahl and C. Stoltz, “National Survey Report of PV Power Applications in Sweden 2017,” Stockholm, 2018.
[19] Sveriges Riksbank, “Repo rate, deposit and lending rate,” 2021. [Online]. Available: https://www.riksbank.se/en-gb/statistics/search-interest--exchange-rates/repo-rate-deposit-and-lending-rate/.
[20] J. Lindahl, D. Lingfors, Å. Elmqvist, and I. Mignon, “Economic analysis of the early market of centralized photovoltaic parks in Sweden,” *Renew. Energy*, vol. 185, pp. 1192–1208, 2022, doi: 10.1016/j.renene.2021.12.081.
[21] Statistikmyndigheten SCB, “Bolåneräntor till hushåll fördelat på räntebindningstid,” 2019. [Online]. Available: https://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__FM__FM5001__FM5001C/RantaT04N/.

[Accessed: 12-Mar-2022].
[22] Swedish Financial Benchmark Facility, “Information Portal — STIBOR Statistics Averages,” 2021. [Online]. Available: https://swfbf.se/sfbf-benchmarks/rates/.
[23] Sparbanken Syd, “Solcellslån.” [Online]. Available: https://www.sparbankensyd.se/lana/solcellslan. [Accessed: 23-Aug-2022].
[24] Swedbank, “Sollån — lån på solpaneler och solceller,” 2021. [Online]. Available: https://www.swedbank.se/privat/privatlan-och-krediter/energilan/sollan.html. [Accessed: 03-Jun-2022].
[25] SEB, “Lån till köp av solceller,” 2022. [Online]. Available: https://seb.se/privat/lana/privatlan-och-krediter/lan-till-kop-av-solceller. [Accessed: 19-Aug-2022].
[26] Vattenfall, “Delbetala dina solceller,” 2022. [Online]. Available: https://www.vattenfall.se/solceller/solcellspaket/delbetalning/. [Accessed: 22-Aug-2022].
[27] Statistikmyndigheten SCB, “Land- och vattenareal i kvadratkilometer efter region, arealtyp och år.” [Online]. Available: https://www.scb.se/hitta-statistik/statistik-efter-amne/miljo/markanvandning/land-och-vattenarealer/. [Accessed: 13-Mar-2022].
[28] Statistikmyndigheten SCB, “Preliminär befolkningsstatistik per månad 2021,” 2022. [Online]. Available: https://www.scb.se/hitta-statistik/statistik-efter-amne/befolkning/befolkningens-sammansattning/befolkningsstatistik/. [Accessed: 26-Feb-2022].
[29] Statistikmyndigheten SCB, “Befolkningstäthet i Sverige.” [Online]. Available: https://www.scb.se/hitta-statistik/sverige-i-siffror/manniskorna-i-sverige/befolkningstathet-i-sverige/. [Accessed: 10-Jun-2022].
[30] Statistikmyndigheten SCB, “Markanvändning - Tätorter.” [Online]. Available: https://www.scb.se/hitta-statistik/statistik-efter-amne/miljo/markanvandning/tatorter/. [Accessed: 08-Jun-2022].
[31] World Economic Forum, “Fostering Effective Energy Transition — 2020 edition,” 2020.
[32] Energimarknadsinspektionen, “Leveranssäkerhet i Sveriges elnät 2020 — Statistik och analys av elavbrott,” 2020.
[33] The World Bank, “Databank - Sustainable Energy for all,” 2021. [Online]. Available: https://datacatalog.worldbank.org/search/dataset/0041706. [Accessed: 30-Sep-2022].
[34] Energiföretagen, “Energiåret — årsstatistik,” 2021. [Online]. Available: https://www.energiforetagen.se/globalassets/energiforetagen/statistik/energiaret/2021/energiaret_2021_220413.pdf.
[35] E. Rydegran, “Elåret 2021 – från rekordlågt till rekordhögt elpris,” *Energiföretagen*, no. December 2021, 2021.
[36] L. Hirth, “Market value of solar power: Is photovoltaics costcompetitive?,” in *IET Renewable Power Generation*, 2015, vol. 9, no. 1, pp. 37–45, doi: 10.1049/iet-rpg.2014.0101.
[37] L. Hirth, “The market value of variable renewables — The effect of solar wind power variability on their relative price,” *Energy Econ.*, vol. 38, no. 2013, pp. 218–236, 2013, doi: 10.1016/j.eneco.2013.02.004.
[38] J. López Prol, K. W. Steininger, and D. Zilberman, “The cannibalization effect of wind and solar in the California wholesale electricity market,” *Energy Econ.*, vol. 85, p. 104552, 2020, doi: 10.1016/j.eneco.2019.104552.
[39] D. Lingfors, M. Åberg, and J. Widén, “Effekt- och elprisscenarier vid hög andel solel i det svenska elsystemet,” 2019.
[40] SMHI, “Klimatindikator — globalstrålning,” 2021. [Online]. Available: https://www.smhi.se/klimat/klimatet-da-och-nu/klimatindikatorer/stralning-1.17841.
[41] “El från nya anläggningar,” *Energiforsk*, 2021. [Online]. Available: https://energiforsk.se/media/30796/el-fra-n-nya-anla-ggningar-energiforskrapport-2021-714.pdf.
[42] Sveriges Riksdag, *Sveriges Riksdag, Svensk författningssamling — Förordning (2009:689) om statligt stöd till solceller*. .
[43] Energimyndigheten, “Förenklad administration av solcellsstödet — ER 2018:19,” Eskilstuna, 2018.
[44] Boverket, A. Carlsson, U.-C. Götherström, A. Lindén, and J. Molinder, “Utformningen reducerade effekterna — Boverkets utvärdering av OFFrotstödet,” Karlskrona, 2009.
[45] Boverkets statistiksystem, “Stöd för installation av solceller — månadsrapport tom 2021,” 2021. .
[46] Regeringskansliet, “Färdigställandetiden förlängs för solcellsstödet,” 2020. .
[47] Infrastrukturdepartementet, *Förlängt stöd för installation av solceller för kommuner och företag*, no. november 2021. 2022.
[48] Infrastrukturdepartementet, “Ny version : Medel avsätts i vårbudgeten till solcellsstödet.” [Online].

Available: https://www.regeringen.se/pressmeddelanden/2021/04/medel-avsatts-i-varbudgeten-till-solcellsstodet/.
[49] Jordbruksverket, “Investeringsstöd till förnybar energi.” [Online]. Available: https://nya.jordbruksverket.se/stod/fornybar-energi/investeringsstod-for-fornybar-energi. [Accessed: 12-May-2022].
[50] I. Norberg *et al.*, “Solel i lantbruket — Realiserbar potential och nya affärsmodeller,” Uppsala, 2015.
[51] Energimyndigheten, “Elcertifikatsystemet — ett stödsystem för förnybar elproduktion,” Eskilstuna, 2012.
[52] Sveriges Regering and Norges Regering, *Avtal mellan konungariket Sveriges regering och konungariket Norges regering om ändring av avtal om en gemensam marknad för elcertifikat*. 2015.
[53] Infrastrukturdepartementet, “Elcertifikatsystemet – Det svenska stoppdatumet den 31 december 2021 står fast.” [Online]. Available: https://www.regeringen.se/pressmeddelanden/2021/06/elcertifikatsystemet--det-svenska-stoppdatumet-den-31-december-2021-star-fast/.
[54] Energimyndigheten, “Kontrollstation för elcertifikatsystemet 2023,” 2022. [Online]. Available: https://www.regeringen.se/49ee7d/contentassets/8281cd75aa844bcbaa4cff0c3d4dce78/er-2022_09_arkiv.pdf. [Accessed: 13-Sep-2022].
[55] Sveriges Riksdag, “Elcertifikat – stoppregel och kontrollstation 2019 Innehållsförteckning,” 2021.
[56] Energimyndigheten, “Cesar — Sveriges kontoföringssystem för elcertifikat och ursprungsgarantier,” 2022. [Online]. Available: https://cesar.energimyndigheten.se/default.aspx. [Accessed: 17-Jun-2022].
[57] Energimyndigheten, “Kvotnivåer.” [Online]. Available: http://www.energimyndigheten.se/fornybart/elcertifikatsystemet/kvotpliktig/kvotnivaer/. [Accessed: 19-Jun-2022].
[58] Energimyndigheten, “Godkända anläggninar i elcertifikatsystemet.” [Online]. Available: http://www.energimyndigheten.se/fornybart/elcertifikatsystemet/marknadsstatistik/. [Accessed: 19-Jun-2022].
[59] Infrastrukturdepartementet, “Nya kvoter och avgifter inom elcertifikatsystemet.” [Online]. Available: https://www.energimyndigheten.se/nyhetsarkiv/2021/nya-kvoter-och-avgifter-inom-elcertifikatsystemet/.
[60] Sveriges Riksdag, *Svensk författningssamling — Förordning (2016:899) om bidrag till lagring av egenproducerad elenergi*. Sweden, 2018.
[61] Sveriges Riksdag, *Svensk författningssamling — Förordning (2017:1318) om bidrag till privatpersoner för installation av laddningspunkt till elfordon*. Sweden, 2017.
[62] Skatteverket, “Så fungerar skattereduktion för grön teknik,” 2021. [Online]. Available: https://www.skatteverket.se/privat/fastigheterochbostad/gronteknik/safungerarskattereduktionenforgronteknik.4.676f4884175c97df4192870.html. [Accessed: 15-Apr-2022].
[63] Energikommissionen, B. Diczfalusy, A. Steen, G. Andrée, and C. Hellner, “Kraftsamling för framtidens energi — SOU 2017:2,” Stockholm, 2017.
[64] Konsumenternas Energimarknadsbyrå, “Höjd energiskatt från 1 januari 2021.” [Online]. Available: https://www.energimarknadsbyran.se/nyheter/nyhetsarkiv/2020/hojd-energiskatt-fran-1-januari-2021/.
[65] Sveriges Riksdag, *Utökad befrielse från energiskatt för egenproducerad el*. 2020.
[66] K. Lundin, “Efter elchocken – nu bygger svenskarna solceller i rekordfart,” *Dagens Industri*, 2021.
[67] Finansdepartementet, “Ytterligare utvidgning av skattebefrielsen för egenproducerad el,” *Skatte- och tullavdelningen*, 2018.
[68] Skatteverket, “Rättslig vägledning: Stadigvarande bostad.” [Online]. Available: https://www4.skatteverket.se/rattsligvagledning/edition/2017.6/323873.html.
[69] Skatteverket, “Rättslig vägledning: Avdragsrätt för mervärdesskatt vid inköp och installation av en solcellsanläggning för mikroproduktion av el.” [Online]. Available: https://www4.skatteverket.se/rattsligvagledning/368691.html?date=2018-03-01.
[70] Högsta förvaltningsdomstolen, *HFD 2019 ref. 50 (Mål nr. 6174-18, 6175-18 & 6177-18)*. 2019.
[71] Skatteverket, “Rättslig vägledning: Avdragsrätt vid inköp och installation m . m . av en solcellsanläggning för mikroproduktion av el ; mervärdesskatt.” [Online]. Available: https://www4.skatteverket.se/rattsligvagledning/386073.html?date=2020-11-09.
[72] Sveriges Riksdag, *Svensk författningssamling — Mervärdesskattelag (1994:200)*. Sweden, 1994.
[73] Sveriges Riksdag, *Svensk författningssamling — Inkomstskattelag (1999:1226)*. Sweden, 1999.
[74] Sveriges Riksdag, *Svensk författningssamling — Ellag (1997:857)*. Sweden, 1997.
[75] Energimyndigheten, *Statens energimyndighets föreskrifter om ursprungsgarantier för el*, no. june 2017.

Sweden, 2017.
[76] Lagrådet and Infrastrukturdepartementet, “Beslut: Genomförande av elmarknadsdirektivet när det gäller nätverksamhet,” pp. 1–14, 2022.
[77] Skatteverket, “Rättslig vägledning: Mikroproduktion av förnybar el (kompletterande information),” 2022. [Online]. Available: https://www4.skatteverket.se/rattsligvagledning/edition/2022.3/329337.html#h-Vem-kan-fa-skattereduktion.
[78] Infrastrukturdepartementet, *Förordning (2007:215) om undantag från kravet på nätkoncession enligt ellagen (1997:857)*. Sveriges Riksdag, 2007.
[79] S. O. Utredningar, “Moderna tillståndsprocesser för elnät — SOU 2019:30,” Stockholm, 2019.
[80] S. Hunkin and K. Krell, “Renewable energy self-consumption — A Policy Brief from the Policy Learning Platform on Low-carbon economy,” 2020.
[81] Energimarknadsinspektionen, “Undantag från kravet på nätkoncession - IKN,” 2022. [Online]. Available: https://ei.se/bransch/koncessioner/undantag-fran-kravet-pa-natkoncession---ikn#h-Attansokaombindandebeskedomundantagfrankravetpakoncession.
[82] Sveriges Riksdag, *Svensk författningssamling — Fastighetstaxeringslag (1979:1152)*. Sweden, 1979.
[83] Boverket, “Solfångare och solcellspaneler,” *PBL kunskapsbanken*. [Online]. Available: https://www.boverket.se/sv/PBL-kunskapsbanken/lov--byggande/anmalningsplikt/byggnader/andring/sol/.
[84] Svenska kraftnät, “Tariff , prislistor , avtal och abonnemang.” [Online]. Available: https://www.svk.se/aktorsportalen/anslut-till-transmissionsnatet/transmissionsnatstariffen/tariff-prislistor-avtal-abonnemang/.
[85] Skatteverket, “Så här fungerar rot- och rutavdraget.” .
[86] Energimarknadsinspektionen, “Ny modell för elmarknaden,” Eskilstuna, 2017.
[87] A. Palm, “Peer effects in residential solar photovoltaics adoption — A mixed methods study of Swedish users,” *Energy Res. Soc. Sci.*, vol. 26, pp. 1–10, 2017, doi: 10.1016/j.erss.2017.01.008.
[88] A. Palm, “Local factors driving the diffusion of solar photovoltaics in Sweden: A case study of five municipalities in an early market,” *Energy Res. Soc. Sci.*, vol. 14, pp. 1–12, 2016, doi: 10.1016/j.erss.2015.12.027.
[89] A. Palm and B. Lantz, “Information dissemination and residential solar PV adoption rates: The effect of an information campaign in Sweden,” *Energy Policy*, vol. 142, p. 111540, 2020, doi: 10.1016/j.enpol.2020.111540.
[90] Region Örebro län and Länsstyrelsen Örebro län, “Energi- och klimatprogram för Örebro län 2017–2020,” 2017.
[91] Uppsala kommun, “Miljö- och klimatprogram 2014–2023,” 2015. [Online]. Available: https://www.uppsala.se/kommun-och-politik/publikationer/2014/miljo--och-klimatprogram/.
[92] Helsingborgs stad, “Klimat- och energiplan för Helsingborg 2018–2024,” 2018.
[93] Kristianstads Kommun, “Klimat- och energistrategi — Kristianstads kommun,” 2018.

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