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
2023

Swedish Energy Agency

What is IEA PVPS TCP?

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The Technology Collaboration Programme (TCP) was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of 6.000 experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the TCP's within the IEA and was established in 1993. The mission of the programme is to "enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems." In order to achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct 'Tasks,' that may be research projects or activity areas.

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

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What is IEA PVPS Task 1?

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation. An important deliverable of Task 1 is the annual "Trends in photovoltaic applications" report. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the country National Survey Report for the year 2023. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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COVER PICTURE

Residential PV system with all-black panels and EV charging in Varberg, southwestern Sweden. Photo credit: Svea Solar.

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1 INSTALLATION DATA

The photovoltaic (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. PV installations are included in the 2023 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2023, 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, with approximately 300 kW installed that year. Before that, only a few grid-connected systems were installed annually, and the Swedish PV market primarily consisted of a small but stable off-grid sector, catering mainly to holiday cottages, marine applications, and caravans. This domestic off-grid market has remained relatively stable over the years.

However, since 2007, the annual installation of grid-connected capacity has surpassed that of off-grid capacity. The grid-connected market is predominantly comprised of distributed roof-mounted systems installed by homeowners, companies, municipalities, farmers, and other entities. Right from the beginning, the Swedish distributed market has been driven by the self-consumption business model due to the absence of feed-in tariffs. To support this business model, capital subsidies and a feed-in premium scheme, which adds value to excess electricity, have been vital. However, as of 2023, subsidies are now exclusively allocated to the distributed PV market segment, predominantly benefitting private installations.

On the other hand, the centralized PV sector is comparatively small on a global scale. However, there has been a notable increase in interest and activity in recent years within the centralised PV park market segment. Although the capacity additions from PV parks remain limited, this trend is anticipated to continue, resulting in a growth in both the quantity and size of centralized PV parks in the coming years.

1.2 Annual installed PV capacity

The installation rate of PV continues to increase rapidly in Sweden. In 2023, a total of 1600.9 MW of grid-connected capacity was added, as illustrated in Figure 1 and Table 1. This translates to a notable 101% market growth compared to the 796.6 MW installed in 2022.

Among the grid-connected PV capacity added in 2023, approximately 67.6 MW is estimated to be centralised ground-mounted PV parks, while 1533.3 MW comprises distributed PV systems primarily installed for self-consumption. Consequently, the annual centralised PV market in Sweden grew by 82%, whereas the distributed market expanded by 102% compared with 2022, when approximately 37.2 MW of centralised and 759.4 MW of distributed PV was installed.

As mentioned in the past section, Sweden has a small but steady off-grid PV market. Between 2017 and 2019, approximately 2 MW per year were sold for off-grid applications. In 2020, the annual off-grid market slightly decreased to 1.6 MW but rebounded in 2021 to 1.9 MW. Collection of off-grid capacity through sales statistics has not been within the scope of the two last National Survey Report, but it's reasonable to estimate that it remains consistent with recent years and 1.5 MW_p of new off-grid capacity is estimated for 2022 and 2023 respectively.

Worth noting is that, with the discontinuation of the capital subsidy program (See previous Swedish National Survey Reports) and the gradual phasing-out of the electricity certificate system (See Section 3.2.1), replicating the past market segmentation — which was based on the databases of these two subsidy programmes — of the Swedish installed capacity is no longer viable. This shift is clearly reflected in the data portraying the yearly installed capacity, as shown in Figure 1 and Table 2.

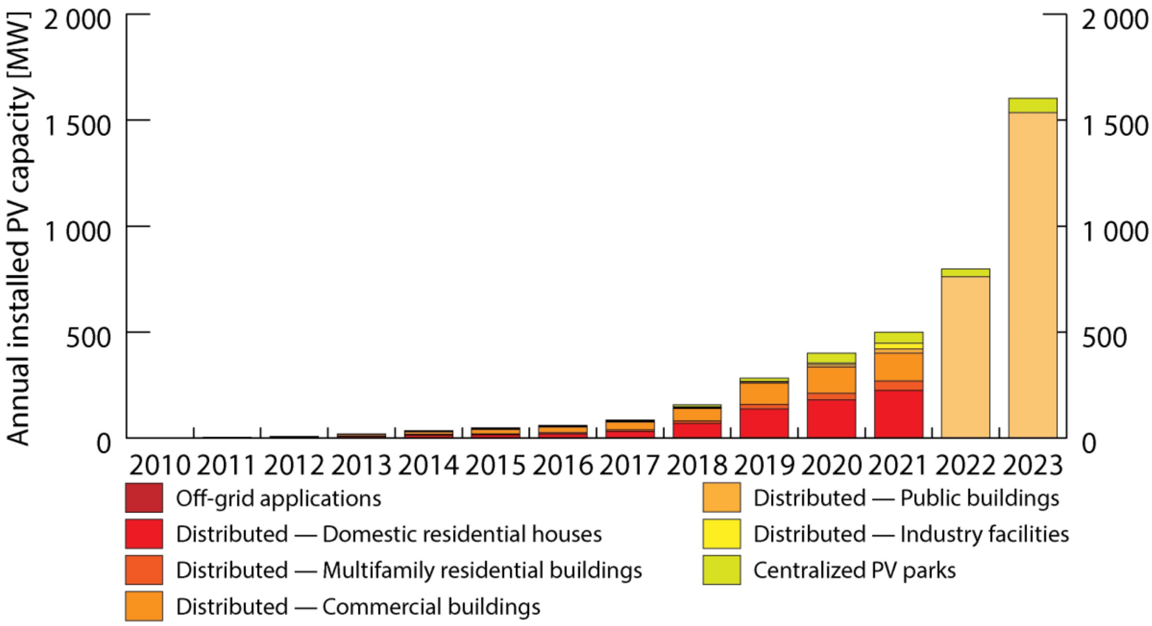

Figure 1: Annual installed PV capacity in Sweden.

Table 1: Annual PV power installed during calendar year 2023.

		Installed PV capacity in 2023 [MW]	AC or DC
PV capacity	Off-grid	1.50	DC
	Decentralised	1533.3	AC
	Centralised	67.6	AC
	Total	1602.4	AC

Table 2: PV power installed during calendar year 2023.

			Installed PV capacity [MW]	**Installed PV capacity [MW]**	**AC or DC**
Grid-connected	BAPV	Residential	1 533.3	-	AC
		Commercial		-	AC
		Public		-	AC
		Industrial		-	AC
	BIPV	Unknown (Included in BAPV)			
	Utility-scale	Ground-mounted	67.6	67.6	AC
		Floating		0	AC
		Agricultural		0	AC
Off-grid		Residential	1.5	-	DC
		Commercial		-	DC
		Mobile applications		-	DC
Total			1 602.4		AC

Table 3: Data collection process

Is the data reported in AC or DC?	The reported data is in AC and the data is not reconstructed to DC in this report. Studies have shown that the Swedish PV parks commissioned in 2019 and 2020 that use a configuration with regular modules and a fixed south tilt have an AC/DC ratio between 0.77-1 [1]. For the residential segment, the background data of a cost break-down study of Swedish BAPV systems on single-family houses installed in 2020 [2] show an average AC/DC ratio of 0.96.
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 before 2022)
Link to official statistics	Swedish Energy Agency – Statistics
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 2023 was 3 975.6 MW according to the grid operators. Out of this capacity, about 238.7 MW is estimated to be centralised PV and 3 736.9 MW to be distributed. In addition, a total of approximately 23.5 MW of off-grid PV applications is estimated to have been sold in Sweden between 1992 and 2023, of which 19.6 MW is assumed to still be in operation.

By adding the off-grid and the grid-connected PV capacities together, a total of 3 995.2 MW of PV capacity is estimated to up and running in Sweden by the end of 2023, illustrated in Figure 2 and summarised in Table 4. The total installed PV capacity grew by 67% in 2023, which is a high increase considering the increasing total volumes, but still in line with the development over the five previous years, where the total market grew by 49 % in (2022), 45 % (2021), 57 % (2020), 66 % (2019), and 59 % (2018).

The strong overall growth in the last decade started with the introduction of the direct capital subsidy system (see previous Swedish National Survey Reports) 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), a growing interest from utilities (see 7.2) and the tax credit for micro-producers (see section 3.3.5). During the past three years, the tax deduction for green technology (see section 3.2.2) has been contributing to stimulating the residential PV market. Additionally, in 2023, the support within that subsidy system for batteries is estimated to also have had a positive impact on residential PV installations.

Just as for Figure 1, the discontinuation of the capital subsidy program (See previous Swedish National Survey Reports) and the gradual phasing-out of the electricity certificate system (See Section 3.2.1), do not allow for the same market segmentation for 2022 and 2023 as for previous years in Figure 2.

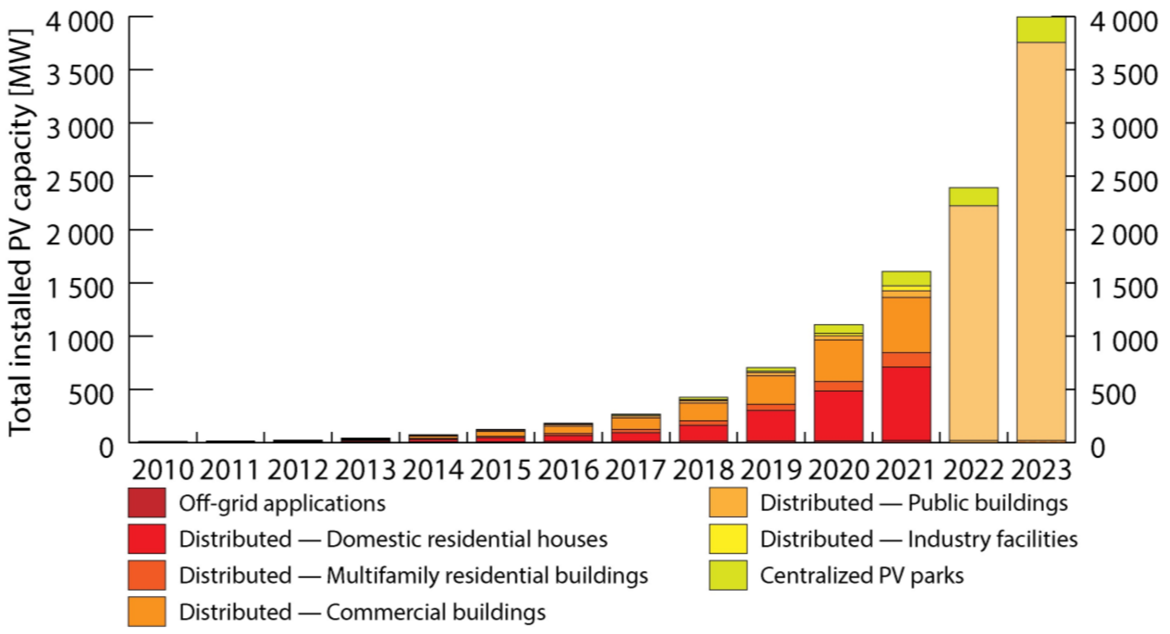

Figure 2: Total installed PV capacity in Sweden.

Table 4: The cumulative installed PV power in 3 sub-markets. Note that no new sales statistics on off-grid capacity was collected for 2022 nor 2023, but instead an estimate of a 1.5 MW annual market is used.

Year	Off-grid [MW]	Grid-connected distributed [MW]	Grid-connected centralised [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	74.96
2015	9.16	109.19	4.30	122.65
2016	10.41	165.17	7.12	182.70
2017	12.21	244.18	11.74	268.13
2018	13.99	390.15	20.09	424.23
2019	15.65	655.86	35.07	706.58
2020	15.38	1007.82	81.58	1104.78
2021	17.10	1453.33	133.84	1604.27

2022	18.34	2203.59	171.05	2392.98
2023	19.60	3736.90	238.68	3995.18

In total, there were 251 626 grid-connected PV systems in Sweden by the end of 2023. The number of off-grid systems is unknown. A majority of the grid-connected PV systems, 228 262, are small systems below 20 kW. 23 265 are in between 20 kW – 1000 kW and 99 systems are above 1 MW according to the official statistics (summarised in Table 5).

However, the official statistics count everything behind one single connection point to the grid as one system. Several of the centralised PV parks built in Sweden have multiple 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 99 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 2023. The number of systems at the end of each year, and the corresponding average system size are presented in Table 6.

As seen at the end of 2023, Sweden had an average PV system size of about 15.8 kW. This relatively small system size illustrates that the Swedish PV market mainly consists of small, distributed PV systems. Beginning in 2022 and continuing through 2023, there was a clear break in the trend of continuous growth in average system size, especially notable in the annual average shown in Table 6. While the annual average is slightly larger in 2023, at 15.4 kW compared to 14.4 kW in 2022, it is still considerably smaller than the 18.4 kW average in 2021. This indicates a faster expansion of the market for small distributed PV in Sweden compared to the segment of larger decentralized and centralized PV systems.

Some developers working on centralized projects have reported experiencing delays, suggesting a potential time lag before these projects, previously announced for 2022 and 2023, will be connected to the grid. However, for 2023, it is more likely that it was a very strong year for residential PV, rather than a bad year for centralized PV, which is reflected in the decreased average size.

In the next couple of years, it is likely that the upward trend will return, driven by the commissioning of centralized PV parks and possibly a decrease in residential systems due to several factors, such as changes to the tax deduction for green technology (see section 3.2.2), lower electricity prices, periods of higher interest rates, and increased inflation. Another explanation could be that the spike in interest due to high energy prices during the energy crisis in 2022 was more quickly addressed by private individuals and other actors in smaller PV market segments, as these projects can be developed faster.

Table 5: Other PV market information.

			2023
Number of PV systems in operation in Sweden	Grid-connected PV	Under 20 kW	228 262
		20 kW – 1000 kW	23 265
		Above 1000 kW	99
		Total	**251 626**
	Off-grid PV		Unknown
Decommissioned PV systems during the year [MW]		248 kW of off-grid system is estimated to have been decommissioned	
Repowered PV systems during the year [MW]		Unknown	

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	2022	2023
Number of systems	10 006	15 298	25 486	43 944	65 819	92 358	147 690	251 626
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	17.1	16.1	15.8
Average size per system for the annual market [kW]	17.3	17.3	17.6	15.7	17.7	18.4	14.4	15.4

1.4 PV market segments

The official statistics provided by grid operators and collected by the Swedish Energy Agency only classify PV system sizes (power) into three ranges: 0–20 kW, 20–1000 kW, and >1000 kW. Table 7 summarises the total installations at the end of 2023 based on this data source.

Table 7: Total installations of grid-connected PV capacity and number of systems at the end of 2023, according to the grid operators[3].

	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]	2 400.9	1 308.8	263.3
Total number of grid-connected PV systems according to the grid operators collected by the Swedish Energy Agency [#]	228 262	23 265	99

Prior to 2022, it was possible to assess more detailed market segmentation based on the former Swedish subsidy programme databases, that were available for 2009–2021. The Swedish direct capital subsidy maintained a comprehensive database of all PV systems that have received support since the subsidy program's inception in 2009 until its termination in 2020/2021. By cross-referencing this database with Sweden's national business directory, each system owner could be assigned a specific business sector, allowing for the division of the database into centralised, industry, commercial, or residential systems (as explained in section 9.1.4). By analysing the annual installed PV capacity for each market segment and comparing it to the total installed PV capacity, an estimate of the market share of each segment in annual installations could be made. The historical development of these shares is presented in Figure 3. No similar breakdown can be made for 2022–2023 as this subsidy programme has been terminated, and the years are therefore missing in the figure below.

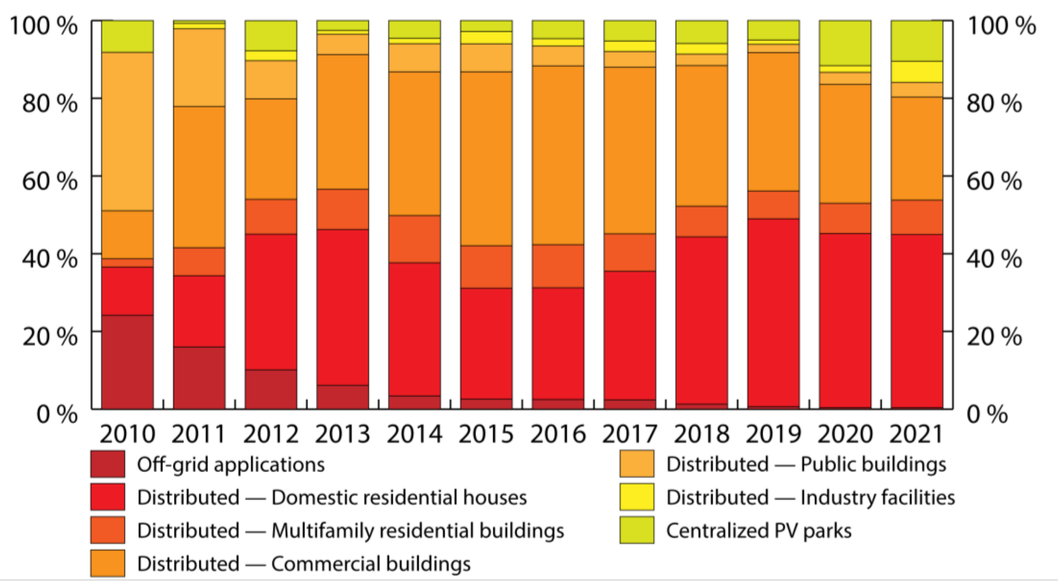

Figure 3: Various market segments share of the annual installed PV capacity in Sweden between 2010–2021 based on statistics from the capital subsidy database.

It is evident that residential single-family houses and commercial facilities have consistently been the largest market segments in Sweden. Although detailed segmentation data for 2022 and 2023 is unavailable, Table 7 illustrates that systems below 20 kW constitute most of the Swedish PV market. This is primarily due to that the self-consumption business model is easy to implement in these building types. In the same way, the relatively low market shares of other segments such as centralised PV parks, industry, and residential multi-family houses can be attributed to historical policy structures in Sweden.

Regarding the centralised market segment, as of the end of 2023, the authors are aware of 58 commissioned PV parks in Sweden with a capacity exceeding 0.5 MW. The underdevelopment of centralised PV parks in Sweden until today, in comparison to many other countries, can be attributed to limited support schemes until 2020. The two available support schemes were the renewable electricity certificate system (as described in section 3.2.1) and a maximum subsidy of 1.2 million SEK per system from the direct capital subsidy program (see previous National Survey Reports). However, it is expected that this market segment will experience significant growth in the coming years, as business models, electricity market development, and technology development are making these systems profitable in Sweden without any state subsidies, for example thanks to business models such as power purchase agreements (PPAs) (see section 2.7) and PV cooperative models (see section 2.4). More and more companies, including engineering, procurement, and construction (EPC) companies that have previously focused on continental Europe, are getting involved in developing solar PV parks in Sweden.

The recent increase in the industry segment can be attributed to two factors. Firstly, the energy tax threshold was raised from 255 kW to 500 kW on July 1st, 2021 (see section 3.3.2), which made it more economically feasible to install larger systems. This change encouraged industries to invest in PV installations to meet their energy needs. Additionally, a few ground-mounted PV parks have been commissioned near industrial facilities. Although these parks are considered industry systems, they are not classified as centralised PV parks (even if they are ground-mounted) since the electricity generated primarily serves self-consumption on-site.

Residential multi-family houses face a general obstacle due to current tax laws, making it complex to self-consume PV electricity within individual apartments. Typically, each apartment has its own meter and contract with the grid operators, while the entire multi-family house has a separate meter and contract for electricity consumed in common areas such as elevators, laundry rooms, and lighting. Under this arrangement, the PV electricity generated by a system on the building can only be utilised for common area consumption.

If the owner of the multi-family house wishes to sell PV electricity to the apartments, they become a retailer of electricity and must adhere to the associated regulations, including the Swedish energy tax, which is applied to the electricity even if it remains within the building. Consequently, achieving a high degree of self-consumption in multi-family houses with this arrangement becomes challenging. Moreover, the value of excess electricity exported to the grid diminishes if the fuse capacity exceeds 100 amperes (see *section 3.3.5*), making it difficult to achieve profitability for such installations.

However, it is possible to achieve tax-free self-consumption of PV electricity within the apartments if the entire multi-family building, including the individual apartments, shares a single meter and contract with the grid operator. This arrangement requires that the electricity consumption within the apartments is included in the general rent. The owner of the multi-family house can decide whether the residents should pay a fixed price for the electricity regardless of their consumption or handle the metering of electricity consumption themselves and adjust the monthly rent based on individual electricity consumption. The latter solution is becoming increasingly common in Sweden, but the overall complexity and cost of switching meters involved in transitioning to this arrangement is one of the reasons for the low installation numbers for multi-family houses.

As of January 1st, 2022, it has been allowed to establish low-voltage ground cables (microgrids) between buildings for energy sharing [4]. This allows for self-consumption of energy within multiple neighbouring buildings. However, it should be noted that self-consumption within individual apartments still necessitates the aforementioned solutions. Despite the need for some more time to accumulate the necessary knowledge and understanding of this exception to the grid regulation, it is anticipated that this policy shift will stimulate the multi-apartment market segment.

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 the municipality level. The expansion of PV takes place at different speeds in Sweden's municipalities. When it comes to the total most installed PV capacity, Gothenburg, followed by Uppsala and Linköping were at the top at the end of 2023 with 133.9, 76.9, and 76.8 MW, respectively. This top 3 ranking remained unchanged from 2022.

Similar to last year, but with a different individual order, the top 3 municipalities in terms of watts of PV capacity installed per capita are Borgholm, Sjöbo, and Skurup, with 1635.7 W/capita (total 17.6 MW), 1585.6 W/capita (total 30.8 MW), and 1576.4 W/capita (total 26.6 MW), respectively. This is not a coincidence, as these three municipalities are located in the southern parts of Sweden, where most PV capacity is installed. Additionally, two of them are home to two of Sweden's largest centralised PV parks, Martin & Serveras Solpark in Skurup with 18 MW and Sparbanken Skånes Solcellspark in Sjöbo with 17.8 MW. Though initially the largest in Sweden upon completion, both of these PV parks have since been surpassed, now ranking fourth and fifth respectively. The current leaders are the Kungsåra PV Park (22 MW) in Västerås, HSB Sörmland PV Park (21 MW) in Strängnäs, and Parks and Resorts PV Park (20 MW) in Nyköping. For several years, the typical scale of the largest PV parks in Sweden has ranged from 15 to 20 MW, but this is anticipated to increase soon. As of the first half of 2024, the authors are aware of two PV parks that has entered the construction phase: one in Hallstavik with a planned capacity of 64 MWp (expected commissioning in 2024) and another in Hultsfred with a planned capacity of 100 MWp (anticipated commissioning in early 2025). While, to the best of the authors' knowledge, Borgholm doesn't have any PV parks, it is a municipality with a high density of vacation homes and therefore a substantial summer population which makes residential and commercial PV an interesting investment.

The Swedish electricity market is from the first of November 2011 divided into four bidding areas by the decision of the Swedish National Grid (Svenska Kraftnät). 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 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 more densely populated municipalities.

1.6 Key enablers of PV development

1.6.1 The public opinion about PV

The overall public sentiment towards PV technology in Sweden is highly positive. According to a recent bi-annual survey [5] conducted by the SOM Institute, where respondents were randomly selected and asked about their preferences for energy source investments over the next 5–10 years, a large majority of 77% expressed a desire for increased investments in PV technology in Sweden. This places PV technology at the forefront as the most preferred electricity production technology or source among the surveyed population, as well as the least disliked.

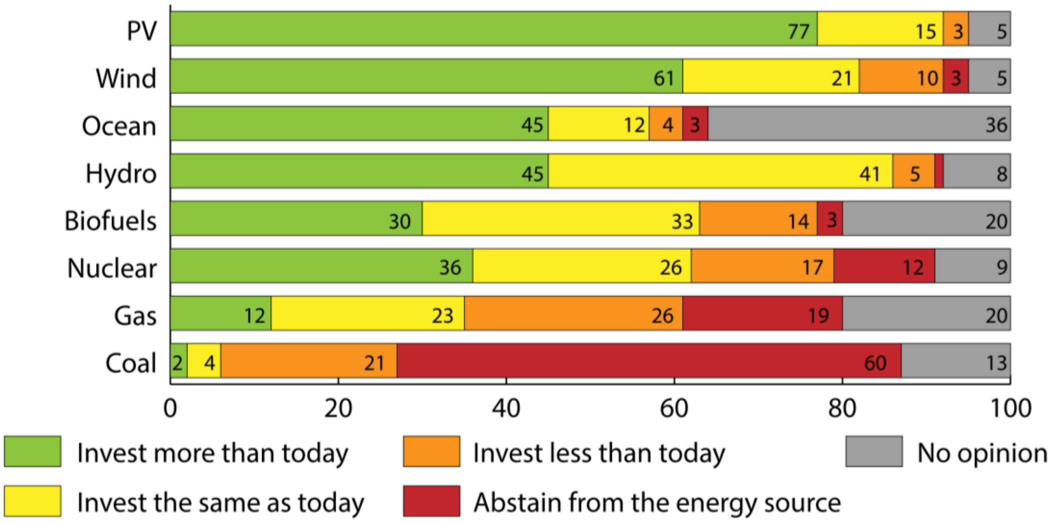

Figure 4: The public opinion in Sweden about different electricity production technologies in 2023.

The fact that the Swedish PV market mainly consist of distributed PV installations, thus driven by self-consumption, is closely linked to its high acceptance rate. While some developers have encountered local opposition during PV park development, it has not significantly impeded the rollout of PV projects. This opposition often stems from two main motives: (1) "Not In My Back Yard" (NIMBY) resistance from residents who wish to preserve the scenic countryside, and (2) national concerns regarding maintaining agricultural land for food production autonomy.

Local Swedish authorities and grid operators have not been prepared for the sudden surge in interest from farmers seeking to lease their land for PV park projects, leading to lengthy permit processes for such projects, especially on agricultural land. However, many PV parks have been successfully constructed on less valued land types, such as industrial sites near major highways, former landfills, and grassy areas close to airports. These projects have generally encountered minimal social opposition, instead garnering positive reception from local communities who view the repurposing of such land for renewable energy production as beneficial [6].

Additionally, a common practice for PV parks in Sweden is to be named after the entity purchasing the electricity through the PPA. This underscores the close connection between the PV park and the sustainability initiatives of the companies and the positive PR value that the PV parks bring — an example of the high social acceptance of solar PV in Sweden.

1.7 PV in the broader Swedish power system

As mentioned in Section 1.5, the Swedish power system has been organised into four bidding areas (SE1–SE4) by the Swedish National Transmission System Operator (Svenska Kraftnät) since November 1st, 2011. This decision was made to address an electricity supply-demand imbalance: northern Sweden has an excess of electricity production, while southern Sweden faces higher demand than production. This disparity led to transmission capacity issues, prompting the delineation of bidding area boundaries at grid congestion points. The purpose of these four bidding areas is to pinpoint regions in Sweden where grid expansion is necessary and where increased electricity production can alleviate consumption demands, thus reducing the need for long-distance electricity transport.

In recent years, significant changes in Swedish power production include the expansion of wind power, the shutdown of two nuclear reactors (Ringhals 2 in December 2019 and Ringhals 1 in December 2020), and the closure of the last coal power plant in 2020.

In 2023, Sweden's electricity consumption, excluding losses, was the lowest since the start of the Swedish Energy Agency’s and SCB’s time series in 1990. In parallel, the total electricity production decreased, but still resulting in a surplus for the year. Sweden imported 7.3 TWh, including transit, and exported approximately 35.8 TWh, also including transit. This signifies an increased import by about 19% and a decrease in exports by approximately 9% compared to 2022. Consequently, Sweden maintained a net electricity export of 28.5 TWh. Norway stands as the primary source of electricity imports for Sweden, while the primary export market remains Finland. Throughout the year, total electricity production was approximately 163 TWh, while electricity consumption amounted to 135 TWh. This reflects a decrease in production by around 4% and a decrease in consumption by about 2% compared to 2022.

In Figure 5, the Swedish electricity production in 2023 is presented. The electricity production data used in Figure 5 and Figure 6, along with Table 8, were retrieved from Svenska Kraftnät [7], but with complementary data from Swedenergy [8] with regards to the fuels used in the Swedish CHP power plants.

As can be seen in Figure 6, Swedish electricity has historically been produced by technologies that have a low CO_2

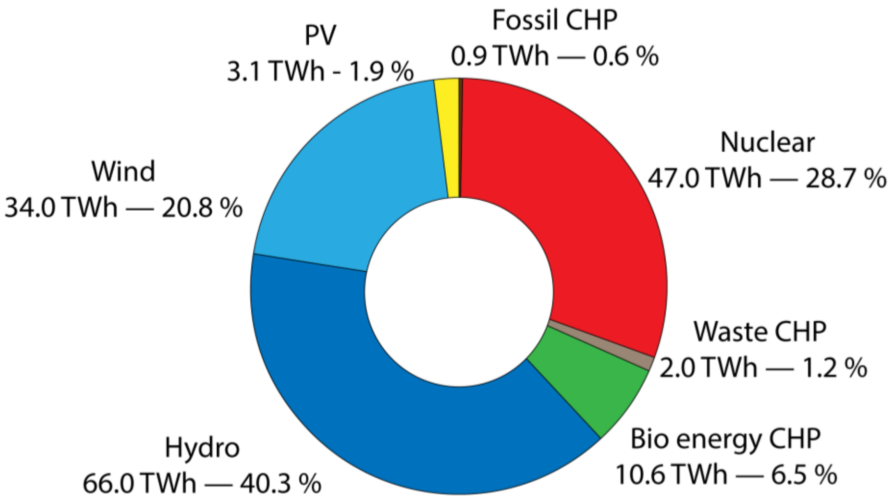

Figure 5. Total electricity production in Sweden in 2023.

footprint. This along with the comparably 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.

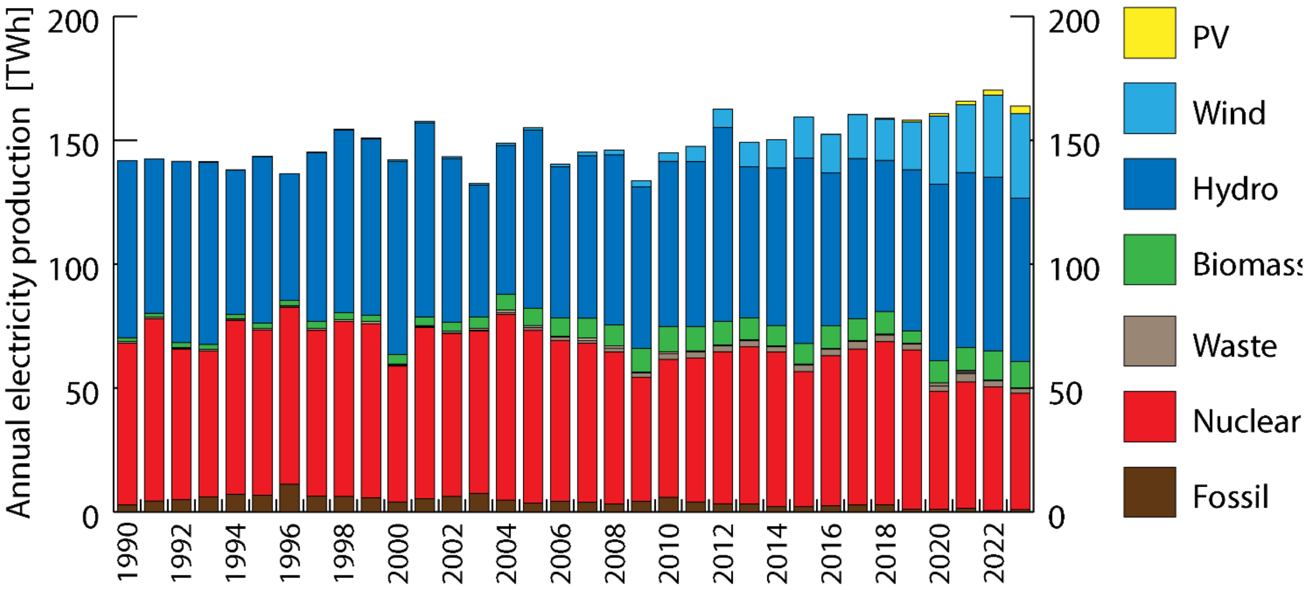

Figure 6. Total annual electricity production in Sweden between 1990 to 2023.

Table 8. PV power and the broader national energy market.

	Data	Year
Total power generation capacities [MW]	50 211	2023
Total renewable power generation capacities (including hydropower) [MW]	36 641	2023
Total electricity demand [TWh]	134.6	2023
New power generation capacities installed [MW]	3 372	2023
New renewable power generation capacities (including hydropower) [MW]	3 293	2023
Estimated total PV electricity production (including self-consumed PV electricity) in [GWh]	3 098	2023
Total PV electricity production as a % of total electricity consumption	1.9 %	2023
Average yield of PV installations [kWh/kW$_p$]	950	2023

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

Module prices in Sweden are closely tied to the global module market. In the period from 2008 to 2013, there was a significant drop in PV module prices in Sweden due to the growing domestic market, which enabled retailers to import larger quantities, and due to the general global price decline closely tied to the advancements in mass-production of PV modules and technology development which led to the use of less material and energy per kW_p of PV capacity. However, between 2013 and 2016, the decline in prices was more gradual. This stability in module prices was primarily attributed to the introduction of import duties on Chinese PV modules and cells by the European Commission in 2013 [14]. These measures included the establishment of a minimum import price (MIP), which meant that silicon modules could not be imported into the European Union at a price lower than 0.56 €/W_p, approximately equivalent to 5.2 SEK/W_p.

Following the removal of these duties, many Swedish retailers reduced module prices for Swedish installation companies by 20–30%. As a result, the average typical module price for end consumers decreased by 14 % in 2018, followed by a 4 % decline in 2019 and a further 7 % drop in 2020 (see Table 9).

Starting 2021, the price survey indicated a notable increase in prices, marking the first such increase since data collection began. These price hikes were observed across various sources, primarily attributed to supply chain constraints, as reported in the IEA PVPS Task 1 Global Trends report [9]. Throughout 2022, global prices for polysilicon, wafers, and cells remained consistently high or continued to rise for most of the year. There was a dip in the final weeks of the year, influenced by factors such as production expansions and the global and Chinese New Year.

The trend of declining prices continued throughout the entirety of 2023, particularly in the second half of the year. After several years of tension in material and transport costs, module prices plummeted. This phenomenon was not unique to Sweden but rather a trend that contributed significantly globally to the competitiveness of PV systems, even though electricity prices decreased after the historical peaks in 2022. As in earlier developments, the Swedish PV market pricing remained closely linked to global trends. This steep cost decrease is attributed to several factors, primarily an oversupply in the manufacturing industry since the increases in the global module manufacturing capacity, predominantly in China, have not been matched by as large of an increase in deployments [10].

Table 9: 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
2022	2.6	7.8	5.6
2023	1.7	5.6	3.1

2.2 System prices

Just as for PV modules, Sweden has witnessed a substantial reduction in PV system prices since 2010, particularly before 2013, as demonstrated in Figure 7. This decline can be attributed to two primary factors. Firstly, the prices of modules and balance of system (BoS) equipment have decreased in the global market. Secondly, the expansion of the Swedish market has provided installation firms with a more consistent flow of orders and an opportunity to optimise the installation process, thereby reducing both labour and overhead costs. Companies have grown and become more efficient in their marketing and installation processes. Since 2013, the price decline has continued, but in a more modest rate, which holds for all years except 2021 and partly 2022. The unique circumstances of 2021 and 2022 can be linked to major events stemming from the COVID-19 pandemic and subsequent supply constraints, as detailed in sections 2.2.3.

The further maturation of the Swedish PV market and increasing competition are factors that likely exert downward pressure on the prices of Swedish PV systems. The increase in the market and the maturation that it indicates, combined with the low prices of modules and the overall improving availability of hardware, contributed to the decline in system prices. Additionally, the alleviation of issues that had increased prices in 2021 and 2022 led to a significant decrease in system prices in 2023. This decline, as reported in the sales statistics from the 2023 survey, has brought prices back on the same projected trajectory as before the disruption.

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 10. The methodology for collecting the price statistics is explained in section 9.1.5 and the price development is discussed in section 2.2.3 below.

In comparison to the early years of collecting sales statistics, installation and sales companies have found it challenging to provide generalised price trends on an annual basis for 2021 – 2023. This difficulty arises from the increased hardware price volatility experienced in recent years and to the increasing diversification in offers to end customers. This includes a wider variety of sizes, technologies, and other options available in the market.

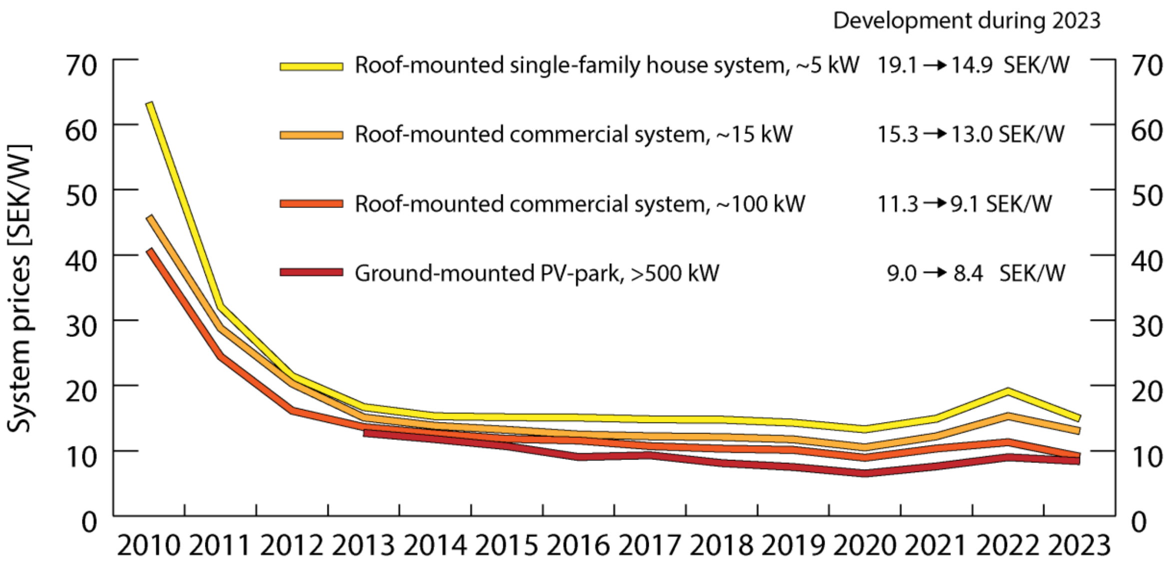

Figure 7: Historic development of the weighted average typical prices for turnkey photovoltaic systems (excluding VAT), reported by Swedish installation companies.

Table 10: 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 centralised PV** Grid-connected, ground-mounted, centralised 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
2022	19.12	15.34	11.32	9.01
2023	14.88	13.04	9.11	8.38

2.2.2 Cost breakdown of residential PV systems

In addition to the PV system prices extracted from the sales statistics, a study on Swedish grid-connected roof-mounted residential PV systems was conducted in 2020 [2]. This will translate to the category "Domestic residential houses" in Figure 3.

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 [11]. The cost structures presented in Table 11, and **Error! Reference source not found.** 8 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 focus 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 in the database of the Swedish direct capital subsidy, the profit margin seems to be about 10 %. In addition, the end customer also pays 25 % in VAT for the system.

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

The results, presented in Figure 8, 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 11: Cost breakdown for a grid-connected roof-mounted residential PV system 2020 in SEK/W_p. The table presents a supplier cost structure excluding VAT and profit margins.

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

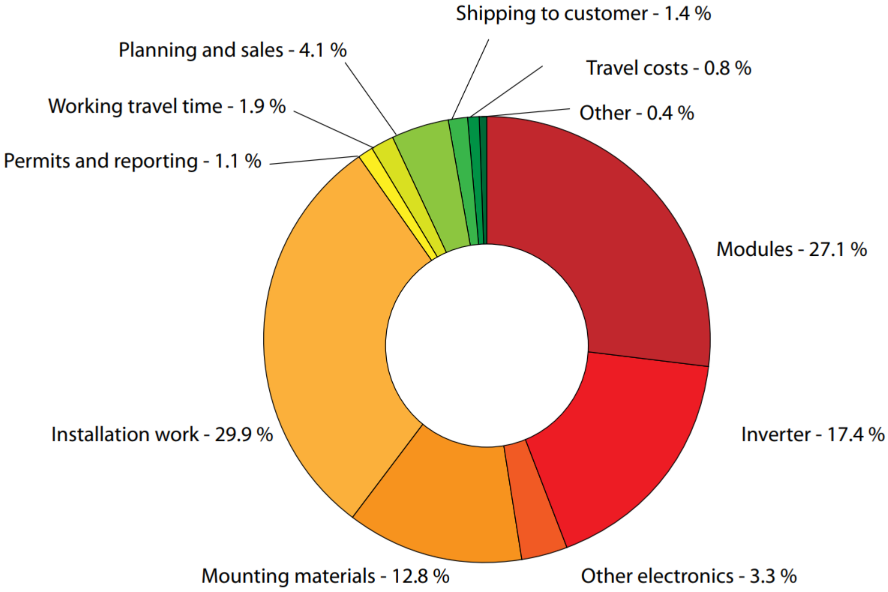

Figure 8: The supplier cost structure for a typical Swedish grid-connected roof-mounted residential PV system in 2020. The total price was 11.70 SEK/W_p.

There have been some significant changes in the Swedish residential PV market between 2020 and 2023, for example, the size of the annual market and the number and size of companies working with PV system installations. With the termination of the capital subsidy program, there is less data available to evaluate the recent market trends. According to 2023 sales statistics, the system prices for residential PV systems (although smaller than the ones in the cost structure breakdown) are still above 2020 levels, while the module prices are below 2020 levels. Although there are margins and internal pricing strategies that prevent the spot market prices from directly translating to residential customer prices, it is possible that the cost breakdown study is becoming outdated.

To the authors' knowledge, no similar breakdown has been made for other market segments.

2.2.3 PV system price discussion

As mentioned in the introduction to this section, prices in all market segments have significantly decreased over the past decade. Before 2021, prices had started to stabilize, with reductions ranging from 1% to 15% in 2020, depending on the segment. However, this trend was disrupted in 2021 and 2022, as indicated by the sales survey, which reported price increases across all segments.

Before 2022, the capital subsidy program database provided a valuable resource for analysing system prices, but it is no longer available as the program has been terminated. Consequently, the price survey now stands as the sole source for Swedish PV system prices. Historically, installation companies tended to estimate typical system prices lower than the average in the direct capital subsidy program database during periods of declining prices. Conversely, their estimates were higher than the prices recorded in the subsidy database for 2021. This disparity could be attributed to a few possible factors. It may reflect that the survey respondents are more attuned to price changes and tend to overestimate yearly average trends. Alternatively, the presence of outlier systems in the subsidy database for all categories could influence average prices in different directions. Lastly, it's worth noting that the capital subsidy program statistics are based on commissioning dates, whereas sales statistics are based on the date of the sale. While there is no data available for 2022 or 2023 other than the sales survey, these trends can be relevant to keep in mind when valuing the price development trends.

Just as the global trends show, the constraints in the supply chains that increased prices in 2021 and 2022 were alleviated in 2023, and instead, module prices decreased significantly due to an over capacity in the PV module manufacturing industry. Additionally, the installation companies and wholesalers reported a good availability of hardware which contributed to the price development. These factors likely led to the decline in prices in 2023, which in relative terms are very notable between the years. Going back to the price trend witnessed before the price increase, it instead shows that 2023 is almost back on the same trajectory as before the price increase.

In numerical terms, the survey results revealed that small residential systems experienced the highest price decrease in 2023, falling from 19.1 SEK/W to 14.9 SEK/W, marking a 22 % decrease. This means that prices returned to 2021 levels, which was the first year that increases were recorded in the Swedish PV system sales survey. Small commercial systems decreased by 15 %, from 15.3 SEK/W to 13.0 SEK/W. Larger commercial systems decreased by 20 %, from 11.3 SEK/W to 9.1 SEK/W, which is even below 2021 levels. Ground-mounted parks decreased from 9.0 SEK/W to 8.4 SEK/W, corresponding to a 7 % decrease.

Another note is that the market segment sizes presented in the survey may no longer represent the overall Swedish market. Residential systems are now typically larger than 5 kW, commercial systems often exceed 15 kW and are closer to 100 kW, and ground-mounted parks are often larger than 500 kW. While the prices are presented normalised to SEK/W, it's essential to consider the impact of scale on the economics of PV systems, as discussed in the cost structure breakdown. To be able to compare the prices and keep the consistency, however, it is considered necessary to keep the size ranges as is for the PV system price survey.

Table 12 summarises the PV system prices in 2023. The price ranges presented are appraisals made by the authors and are based on data from the installer and retailers' surveys.

Table 12: Estimated turnkey PV system prices of different typical PV systems in 2023 based on sales statistics.

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.	20–27
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.	11–19
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.	6–11
Industrial BAPV >250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected industrial buildings, warehouses, etc.	5–11
Small centralised PV 1-20 MW	Grid-connected, ground-mounted, centralised 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.	5–9
Large centralised PV >20 MW	Grid-connected, ground-mounted, centralised 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

Like many economies globally, the Swedish economy encountered some instability characterized by high inflation during 2023, prompting the central bank (Riksbanken) to raise the interest rate (styrräntan) from 2.5 percent to 4.0 percent. This was done to stabilise the rate towards the inflation rate target of 2 percent within a reasonable timeframe. After tightening the monetary policy throughout the year, the Board of the central bank chose to keep the interest rate unchanged at the year's final policy meeting. These central bank interest rate changes directly influenced market rates, resulting in a notable increase in the cost of capital in Sweden during 2023.

In Table 13, the average nominal mortgage rate for residential installations in 2023 has been used. For commercial installations in Sweden, a realistic nominal loan rate has been reported to be the STIBOR rate plus 450 basis points (bps). However, it's important to note that since interest rates have been on the rise since 2022, readers should consider the loan rates as estimates and note that they have not been stable throughout 2023.

Table 13: PV financing information in 2023.

Different market segments	Loan rate [%]
Average rate of loans – residential installations [12]	4.8 %
Average rate of loans – commercial installations [13]	6.5 %
Average nominal cost of capital – industrial and ground-mounted installations	6.5 %

Several commercial banks have introduced specialised "solar loans" aimed at individual homeowners with single-family houses. As far as the authors are aware, the first loan explicitly designed for PV installations in Sweden was launched by Sparbanken Syd in 2019. Currently, individuals looking to invest in PV systems can secure a loan of 250,000 SEK at a variable interest rate of 6.99% (as of 2024) with a repayment period of up to 10 years [23]. Other examples include Swedbank and SEB, both offering "solar loans" of up to 350,000 SEK at a variable interest rate of 6.15% and 6.40% in 2024 and a repayment period of up to 10 years [24][25]. Another option is Vattenfall, which, in partnership with Handelsbanken, provides a solar loan at an interest rate of 6.06% [26].

2.4 Specific investments programs

As early as 2009, Sweden's first PV cooperative, Solel i Sala & Heby ekonomisk förening, was formed. This cooperative entered into a FiT agreement with the local utility company Sala-Heby Energi, purchasing the electricity generated by the cooperative's PV systems. Since its inception in 2009, this cooperative has successfully built six systems with a combined capacity of 599 kW_p. Other notable PV cooperatives with co-owned PV systems include Solel i Bergslagen ekonomisk förening, operating four systems totalling 166 kW_p. Another example is Zolcell 1:1, that managed two systems totaling 27 kW_p that closed operations in 2023, citing more efficient solar investment options available in Sweden today compared to 2013 when they were founded. They also referenced already achieving their vision of 1 W/capita of solar PV capacity in the county (Jämtland) long before their closure.

The PV cooperative business model has evolved over the years and has also been adopted by utility companies involved in the construction of large PV parks or systems. This model allows private individuals or companies to purchase shares in the cooperative, where each share represents a certain yearly production or compensation. The cooperative then deducts this from the share owners' electricity bills or provides it as monetary compensation. Examples of this model include the 1 MW_p park with solar tracking located outside Västerås, jointly managed by utility company Mälarenergi and KP (formerly Kraftpojkarna). Another example is the Törneby driftförening Ek. Förening cooperative initiated by Kalmar Energi, which installed a crowdfunded 600 kW_p system on the roof of a local farm called Nöbble Gård. Following the success of Nöbble Gård, Kalmar Energi embarked on building a PV park near Kalmar Airport on behalf of the cooperative, developed in stages of 750 kW_p each, with the first completed in 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, constructed a PV park with a total capacity of 530 kW_p on a former landfill near Helsingborg. Another PV Park cooperative, Karlskrona Solpark drift Ek. Förening, was initiated by utility Affärsverken. Their initial stage of a 0.6 MW_p crowd-funded PV park was completed in April 2019, followed by a second stage of another 0.6 MW_p completed in October 2019. Jämtkraft, a utility company, also established Östersunds Solpark Drift Ek. Förening, which owns a 3 MW_p PV park located outside Östersund, commenced in late 2019. Additionally, local utilities Tranås Energi and C4 Energi have initiated similar cooperatives: Bredstorp Sol Ek. Förening and Solpunkten Kristianstad Ek. Förening, respectively. As of 2024, these two cooperatives operate PV parks with capacities of 1.2 MW_p and 4 MW_p outside Tranås and Kristianstad, respectively.

Table 14: 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 organisation financing	No

2.5 Additional Country information

Sweden is a country in northern Europe. With a land area of 407 272 km² [14]. Sweden is the fifth largest country in Europe. With a population of 10 551 707 people at the end of 2023, the population density of Sweden is quite low with about 25.9 inhabitants per km², but with a much higher density in the southern part of the country [15]. About 88% of the population lives in urban areas [16].

Table 15: Country information in 2023.

Retail Electricity Prices for a household (range) [17]	1.9–5.2 SEK/kWh (including grid charges and taxes)
Retail Electricity Prices for a commercial company (range)	1.1–2.6 SEK/ kWh (including grid charges and taxes)
Retail Electricity Prices for an industrial company (range)	0.8–2.2 SEK/kWh (including grid charges and taxes)
Liberalisation of the electricity sector	Sweden currently has one of the most liberalised and top ranked electricity systems in the world [18], due to its (1) *high operational reliability* - the delivery security was 99.986 % in 2022 [19], (2) *high electrification level* – 100 % of the total population have access to electricity [20], and (3) *low greenhouse gas emissions* – emissions from fossil fuels associated with the domestic electricity production, in 2023 was approximately 1.0 TWh, which corresponds to 0.6 % of the total Swedish electricity production of 163.3 TWh [21].

2.6 Electricity prices

With the record-high prices in 2022, the electricity spot price in 2023 was comparatively low. What stands out the most for the Swedish electricity market was the occasional very low or negative prices. During five percent of all hours in the year, negative electricity prices occurred, which has previously been rare. The lowest measured electricity spot price during the year is the same for all regions, namely -0.69 SEK/kWh.

Another general trend in 2023 was that price fluctuations were larger than they typically are, with high electricity prices at the beginning and end of the year and lower prices in between. The average day ahead spot prices in the four Swedish electricity areas – Luleå (SE1), Sundsvall (SE2), Stockholm (SE3), and Malmö (SE4) – varied between 0.46 and 0.74 SEK/kWh. The price was the same in all Swedish electricity areas for 61 percent of all hours in the year, but on average, the electricity price in the south was 0.15 SEK/kWh higher than in the central and 0.29 SEK/kWh higher than in the north. During the first half of December, the high spot price levels also spread to the northern parts of the country. Many factors coincided with low temperatures and increased demand. It involved limitations in nuclear power, ice formation in several rivers simultaneously, weak winds, and ice formation in wind power.

The highest day ahead spot electricity price in 2023 was 2.95 SEK/kWh and was recorded in SE4. However, it is low compared to the highest day ahead spot electricity price in 2022 at 8.51 SEK/kWh in both southern and central Sweden.

Since the introduction of electricity areas on November 1st, 2011, there has been an average spot price difference between north and south of 0.05 SEK/kWh. After that, four nuclear reactors have been shut down, which has partly resulted in an increased deficit in the south and partly in a limitation of transmission capacity to the south. These consequences have led to prices in the south being more affected by the electricity price on the European continent.

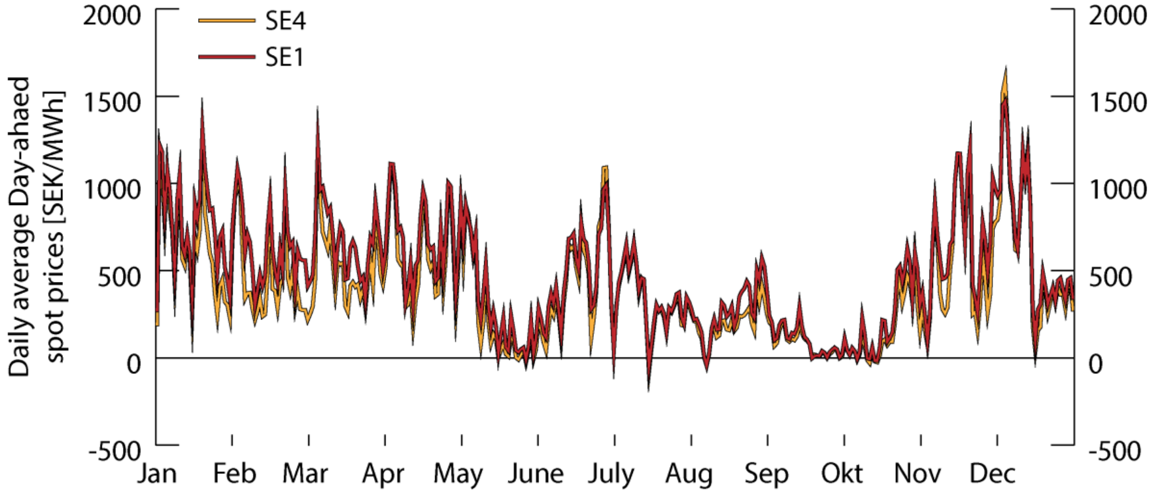

Figure 10: Daily average day-ahead spot prices in area 1 (Luleå) and area 4 (Malmö) in 2023.

2.7 Merchant PV / PPA / CPPA

Sweden, being a primarily distributed market, is driven mainly by the self-consumption business model. However, this model is only allowed for systems smaller than 500 kWp and for on-site consumption (see section 3.3.2). Since the termination of the Capital Subsidy Program (see earlier National Survey Reports) and the halt of new systems in the program for renewable electricity certificates in 2021 (see section 3.2.1), roof-mounted systems above 500 kWp and PV parks are being developed without subsidies. While there exist other setups, PPAs have become the main business model for these systems.

In Sweden, the most common practice is as-produced contracts, where the off-takers simply purchase the electricity when it is produced, and they are financially designed as contracts for difference (CFD). On the pricing side, more creative and dynamic mechanisms are becoming increasingly popular, but a fixed price seems to be the most common, with a contract period of ten year. Guarantees of origin (see section 3.2.3) are typically included in the price. This is a significant motivation for entering into a PPA since it guarantees the availability and the price for the number of years the PPA is set for. Companies want to ensure access to guarantees of origin for their sustainability reporting and to demonstrate that they are actively contributing to the green transition.

As mentioned in Section 1.6.1, the electricity off-taker is usually a commercial actor who also communicates positively about the effort.

2.8 Global solar radiation

The total amount of solar radiation that hits a horizontal surface is called 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 of the globe, and the season of the year. The distribution of annual average global radiation over Sweden is presented in Figure 11 [22].

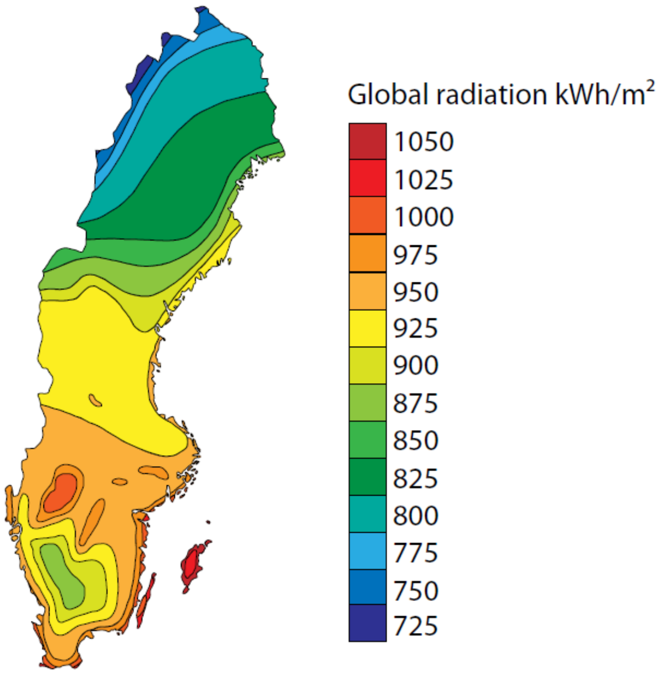

Figure 11: Average global solar radiation in Sweden in one year.

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, and a similar trend is seen in large parts of Europe. In 2023, annual average accumulated global radiation reached 1 005.3 kWh/m² [22]. This is quite a normal value and is well below the historic record of 1 050.6 kWh/m^2 in 2018, as illustrated in Figure 2, when long periods of anticyclone weather (where barometric pressure is high) over Scandinavia resulted in very sunny weather during May and July.

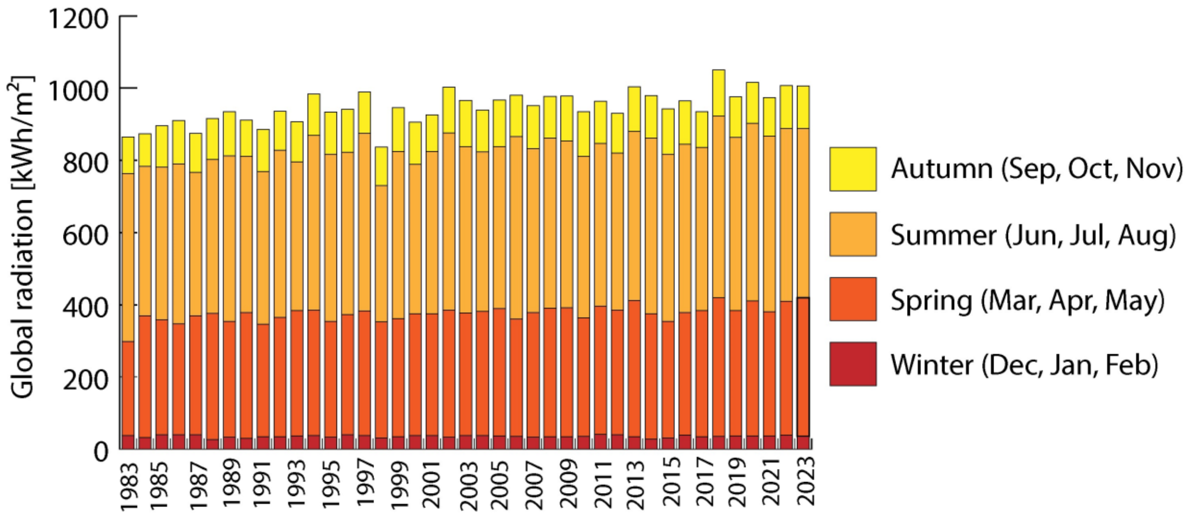

Figure 12: The annual average accumulated global solar radiation in Sweden between 1983 and 2023.

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

Table 16: Summary of PV support measures.

Category	Residential		Commercial + Industrial		Centralised	
Measures in 2023	**On-going**	**New**	**On-going**	**New**	**On-going**	**New**
Feed-in tariffs	-	-	-	-	-	-
Feed-in premium (above market price)	Yes	-	(Yes)[1]	-	-	-
Capital subsidies	-	-	-	-	-	-
Green certificates	Yes[2]	-	Yes[2]	-	Yes[2]	-
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)	-	(Yes[4])	-	-	-
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 systems completed before December 31st, 2021.
[3] Feed-in premium is compensated as income tax credits. It is the same system.
[4] Micrografts for sharing and storage of electricity have been allowed since January 1st, 2022, but there is no true collective self-consumption model.

3.1 National targets for PV

Sweden does not have an official target for PV installations.

3.2 Direct support policies for PV installations

3.2.1 The renewable electricity certificate system

The renewable electricity certificate system operates on the principle that producers of renewable electricity receive government-issued certificates for each MWh of renewable electricity they generate. Meanwhile, certain players on the electricity market have a quota obligation, meaning they must purchase certificates corresponding to a set share of the electricity they sell or consume. These certificates provide extra income to producers alongside their electricity sales revenue. Ultimately, the cost of these certificates is passed on to electricity consumers, affecting their electricity prices.

Eligible energy sources for certificates include wind, small hydropower, some biofuels, solar PV, geothermal energy, wave, and peat in power generation. Each production facility can earn certificates for up to 15 years, with a cutoff in 2035.

The quota-bound stakeholders are:

1. Electricity suppliers
2. Electricity consumers using more than 60 MWh annually from a plant with over 50 kW_p capacity
3. Electricity consumers using imported or Nordic power exchange-purchased electricity
4. Producers commercially annually supplying more than 60 MWh of electricity to a grid without grid concession (nätkoncession), if it's used by consumers on the same grid
5. Electricity-intensive industries registered by the Swedish Energy Agency.

The system began in Sweden in 2003 to boost renewable electricity use. Initially, the goal was to increase annual renewable energy production by 17 TWh by 2016 compared to 2002 levels. In 2012, Sweden and Norway established a joint certificate market with a target of increasing renewable electricity production by 26.4 TWh between 2012 and 2020. This common market allows the trading of both Swedish and Norwegian certificates to meet quotas [23]. In March 2015, Sweden and Norway increased their combined goal to 28.4 TWh by 2020, funded primarily by Swedish consumers [24]. Additionally, in 2017, the system was extended until 2030 with an additional 18 TWh of renewable electricity, gradually increasing by 2 TWh each year from 2022 to 2030 [25]. Due to rapid wind power expansion, this goal was reached in March 2021 [26].

To prevent certificate prices from plummeting and adversely affecting early investors, the Swedish government made changes in November 2020. It was decided that power production constructed after 2021 would no longer be eligible for certificates, and the system's termination was advanced to 2035 from the previous 2045 end date [27]. This transition means that some PV systems in Sweden still benefit from the certificate system, but it is gradually being phased out.

In 2023, the average price was 9.24 SEK/MWh, which is similar to the average certificate price of 9.10 SEK/MWh in 2022. Before this, there were two dramatic price decreases: 2021's value of 18.9 SEK/MWh, down from the previous year's average of 69.6 SEK/MWh, and even more so from 2019's 120.7 SEK/MWh [28]. The quota obligation was reduced to 25.1%, following an increase to 26.2% in 2022, which had interrupted the downward trends of 25.5% in 2021, 26.3% in 2020, and 30.5% in 2019 [29].

Until 2005, there were no PV systems included in the electricity certificate system [30][31]. However, as indicated in Table 17, the number of approved PV installations has grown steadily over the years, with a majority of the number of approved plants in the certificate system now being PV systems. Nevertheless, these PV systems account for only a small fraction of the total installed power and generated certificates.

After the amendment stipulating that no power production constructed after 2021 would qualify for certificates, the Swedish Parliament introduced an annual administrative fee of 200 SEK for owners of certificate trading accounts, effective from July 1st, 2021 [32]. This change rendered participation in the renewable electricity certificate system unprofitable for owners of smaller PV systems, including many villa owners. To avoid the account fee, PV system owners had to close their electricity certificate accounts before May 31st, 2021, resulting in the revocation of the approval of their systems for electricity certificates. This explains the significant drop in systems approved for electricity certificates at the end of 2021, along with the reduced number of certificates issued to PV systems, as seen in Table 17. It's evident in Table 17 that only larger PV systems continue to benefit from the electricity certificate system, as the average system size more than doubled when 67% of the PV systems withdrew their participation in the program between 2020 and 2021.

224 318 certificates were issued to PV in 2023 [31]. This is only about 6 % of the theoretical production of 3 973 MW × 900 kWh/kW ≈ 3 575.7 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 2023 was not up and running throughout the whole year. 321.7 MW of PV power had been accepted in the certificate system at the end of 2023 [30], making it 8 % of the total installed PV grid-connected capacity.

Table 17: Statistics about PV in the electricity certificate system [33][30]**.**

	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
2022	6 279	338 442 kW	53.9 kW	248 072 MWh	733 kWh/kW
2023	5 301	321 682 kW	60.7 kW	224 318 MWh	697 kWh/kW

In summary, the current form of the renewable electricity certificate system has primarily benefited larger PV systems and parks constructed before the close of 2021. Neither currently nor historically has it offered substantial support to smaller PV systems Sweden.

3.2.2 Tax reduction for green technology

The 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) [34] for private persons, the subsidy for storage of self-produced electricity (2016:899) [35] and the subsidy for private installations of charging points for electric vehicles (2017:1318) [36]. It is often referred to as the *green deduction*.

The support system 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 3.9.4. This means that instead of the system owner applying for the economic support and handling the process — as was the case with the capital subsidy program it replaced — the tax deduction reduces the price for the house owner already on the invoice, and the system suppliers will report the deducted amounts to the tax authorities [2].

This system provides a percentual tax deduction for the hardware and installation costs of the three energy efficiency measures for private house owners. PV installations are offered a 20 % deduction, while batteries and charging points for electric vehicles get a 50 % tax deduction. This deduction can be made by private individuals 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 regular 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 [37]. The support can logically only be given if the system owners have paid enough tax to deduct.

Table 18 confirms the clear development of the market segment for domestic grid-connected PV installations in Sweden, which was presented in Table 2 and Table 5. They highlight that in 2023, there was a notable increase in the installation of small-scale PV systems, primarily in residential (or rather systems ≤20 kW). Additionally, the data extracted from the database for the tax reduction program for green technology for private individuals indicate a significant adoption of residential solar batteries in Sweden in 2023. The fact that the batteries are residential solar batteries is supported by that eligibility for the tax deduction for a storage system requires the individual to have renewable electricity production to charge the battery. Swedish PV installers report that interest in batteries has been enormous in 2023, so much so that it is a defining factor for the year's trends. This interest helped drive the solar PV business, and the attractive tax deduction for batteries, combined with variable electricity prices and support grid support services available via aggregators, likely made 2023 the year many individuals in Sweden saw it as a rational investment to pair their PV systems with a battery.

During the initial two years of the implementation of the green tax deduction, it was predominantly utilized for EV chargers, as indicated by the numbers of individuals in the scheme using it for EV chargers. However, in 2023, there was a decline in the system for EV chargers, with a 14% reduction in the number of deductions and a corresponding 19% decrease in the deducted funds. A contrasting trend is observed for solar PV and storage systems. In 2023, the majority of homeowners used the tax deduction for solar PV systems, marking a 105% increase in the number of private individuals utilizing the system and a 155% increase in the deducted funds. Particularly noteworthy is, however, the rise in the usage of the deduction for storage systems, witnessing a 198% increase in the number of private individuals in the system and a corresponding 217% increase in the deducted funds between 2022 and 2023. This significant surge in popularity for storage systems was already evident between 2021 and 2022, with a 557% increase, albeit from a lower level.

The fact that most funds are deducted in the tax scheme for PV installations can be attributed to both the high number of individuals benefiting from the tax deduction and its inherently higher capital investment compared to EV chargers. Regarding batteries, it is probable that the installations closely mirror the total number of storage systems installed by private individuals in Sweden. Unfortunately, due to the sole consideration of costs in this system, there is a lack of collected information on battery capacity or other interesting statistical data.

Table 18: Statistics about the tax reduction for green technology [38]**.**

	Number of buyers of PV systems that received the green deduction				Total amount deducted inside the green deduction system [SEK, thousands]				Average amount of tax deduction per buyer of green technology [SEK, thousands]			
	Solar PV	**EV Chargers**	**Storage systems**	**Total**	**Solar PV**	**EV Chargers**	**Storage systems**	**Total**	**Solar PV**	**EV Chargers**	**Storage systems**	**Total**
2021	22 234	54 119	2 167	73 1611	473 251	577 766	65 456	1 116 473	21.4	10.6	30.1	15.3
2022	59 457	95 059	14 319	145 941[1]	1 297 096	1 013 147	452 907	2 763 150	22.0	10.7	31.0	18.8
2023	122 162	81 573	42 632	200 648[1]	3 303 308	820 475	1 435 812	5 559 594	27.4	10.1	33.4	28.1

[1] Since the same buyer can use the green deduction for several green technologies, the total number of buyers is lower than the sum of the buyers having used the green deduction for each green technology.

Considering that the green deduction accounted for 14.6% (97% of 15%) of the total investment for a residential PV system in 2021 and 19.4% (97% of 20%) in 2022 and 2023, we can estimate that approximately 3.3 billion SEK was invested in the private residential PV sector in 2021, 6.7 billion SEK was invested in 2022, and 17.0 billion SEK was invested in 2023. It is however important to note that there are simplifications to this estimate. Firstly, for the deduction to apply, the PV system owner must have paid sufficient taxes to cover the full deduction. Therefore, the actual deducted amount may be less than the full 14.6% or 19.4% of the total investment. While most private individuals are likely eligible for the full deduction, there could be exceptions. Secondly, since there is a maximum deduction limit of 50 000 SEK within the program, it's possible that the ROT-deduction is used instead of the green deduction when installing multiple green technologies, especially since PV has a lower deductible share than EV chargers and storage systems. Lastly, there might be special cases where the total cost of the PV installation alone exceeds the total deductible amount. This would apply to systems with a total cost of 257 732 SEK, which is higher than a typical system cost for a standard 10 kW building applied turnkey PV system on a villa. However, the explanation for the higher cost could be that it includes several larger systems, building-integrated PV systems and installations in remote areas.

The green deduction has generally been well-received by both the installers and the buyers of PV systems in Sweden. However, the Swedish Solar Association has highlighted an issue with regard to that the system is tied to the year breaks and only validates deductions after the final invoice has been paid. According to the Swedish Solar Association, it's common to request a portion of the payment in advance as a security measure for both completed and future work, ranging from 10 to 80 percent. Not seldom, the final invoice covers only the labour and materials related to the final electrical work. However, the green deduction is only approved by the Swedish Tax Agency once the installation is finished and fully paid, typically on the final invoice. When all partial payments occur in the same year, this does not cause any issues. However, problems arise when partial payments span across two years, with the breaking point on January 31st. In such cases, customers can only claim the green deduction for the partial payments made in the final year. The extent of this issue, however, remains unknown to the authors at the time of writing. In early 2024, the Swedish department of finance released a memorandum for public consultation, proposing changes to the rules concerning this issue [39]. The proposed amendment aims to better accommodate advance payments and the legislative change is suggested to take effect at the next fiscal year transition — consequently, it would apply immediately to projects with advance payments made in 2024 and finalized by 2025.

In late 2023, another concern emerged that could impact the residential PV and solar battery market in Sweden. It concerns the eligibility to claim a green deduction for a battery utilized for purposes other than enhancing self-sufficiency in self-produced renewable electricity. Examples of alternative uses include spot price arbitrage (where the battery is charged from the grid during off-peak hours and discharged during peak hours), peak shaving, and participation in grid and frequency support service markets. This issue became apparent following a discussion in late 2023 and a clarification by the tax authorities in early 2024. The clarification stipulates that the battery must be connected to a grid-connected system that produce renewable electricity and that the battery should be used for self-consumption. Now, it explicitly states that for the tax deduction to be granted, the installed batteries must be used exclusively, or predominantly, for storing self-generated electricity for household consumption at a later time [37].

Although there haven't been specific studies conducted on the usage and business models for solar storage in Sweden, the emergence of aggregation services and virtual power plant offerings shows that utilizing batteries for support services is popular. Depending on whether the eligibility criteria for the green tax deduction will be modified, there could be a potential slowdown in the deployment of batteries. Homeowners must in turn choose between participating in system services or claiming the green tax deduction, which would invariably increase the payback period for a system. The Swedish Solar Association advocates for lowering the support limit for batteries to a level closer to that of PV systems (20% instead of the current 50%) while allowing system owners to retain control over the battery's usage [40].

3.2.3 Guarantees of origin

Guarantees of origin (GOs) were introduced in Sweden on December 1st, 2010, as electronic documents that certify the source of electricity. For each MWh of electricity they generate, electricity producers receive a guarantee from the Government. These GOs can then be sold in an open market, typically to utility companies interested in selling a specific type of electricity. Utilities purchase GOs corresponding to the amount of electricity they intend to sell. It's important to note that applying for guarantees of origin is still a voluntary process.

Once the electricity supplier has acquired GOs and sold electricity to a customer, the GOs are "nullified," meaning they are no longer valid. This nullification process ensures that the amount of electricity sold from a particular source matches the amount of electricity produced from that same source.

A utility company looking to sell electricity generated from, for example, solar PV can handle it in two ways. They can either nullify guarantees of origin from their own PV system or purchase guarantees of origin from a PV system owner and nullify them when selling the electricity to their end-customers.

On June 1st, 2017, changes were made to the GO act (2010:601) and regulation (2010:853) to empower the Swedish Energy Agency to issue guarantees of origin for electricity that can be transferred to another EU Member State [41]. Consequently, the Swedish GO system has been aligned with the EECS standard.

According to Svensk Kraftmäkling (SKM), the largest brokerage firm in the Nordic electricity market, the price development of Solar GOs during 2023 began at historically high levels, €8.6, as a result of the historically high prices in 2022 which, in turn, was due to the very negative hydrological balance in the Nordic countries and the gas crisis in Europe. The situation normalized during the spring of 2023 and the price trend was broken to note prices as low as €1.25 at the end of the year. Still, only small volumes are being traded in the market, which is due to buyers of the larger new solar parks entering the system also wanting the origin guarantee when forming their PPAs. The previous premium that solar guarantees of origin had compared to the benchmark Nordic hydro is now negligible.

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.

Table 19: Statistics about solar guarantees of origin [33]**.**

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
2022	383 928	967 315	2 376 906	120 393	2 881 142	115 057
2023	404 099	567 518	1 256 963	137 908	972 134	232 123

3.2.4 BIPV development measures

In 2023, Sweden did not have any specific measures in place for BIPV. However, with the inauguration of the government in October 2022, they included a commitment in their political manifesto ('Tidöavtalet') [42] to assess the current necessity of building permits for BIPV. The rules of building permits only apply to a limited number of BIPV installations and do not represent a widespread concern within the BIPV sector in Sweden.

3.3 Self-consumption measures

Self-consumption of PV electricity is allowed in Sweden, and it is the primary business model that is driving the market. Numerous utilities provide a range of agreements for surplus electricity generated by micro-producers.

Since the spring of 2014, an ongoing discourse has unfolded regarding the applicable tax regulations for micro-producers. Consequently, there have been several amendments to various tax laws during this period. This section outlines some specific tax regulations that have an impact on self-consumption and micro-producers in Sweden.

Table 20: Summary of self-consumption regulations for small private PV systems in 2023.

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 100 A and maximum 30 MWh/year for the tax credit. 2.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 imposed both on the production and consumption of electricity. Taxes related to electricity production include property taxes (refer to section 3.6.1), taxes on fuels, and emissions taxes.

When it comes to electricity consumption, the primary taxes are the energy tax on electricity and the value-added tax (VAT). In 2023, the manufacturing and agriculture industries paid an energy tax of 0.006 SEK/kWh. The energy tax rate for residential customers has been incrementally raised in recent years after the Swedish Energy Commission's decision (as discussed in section 3.1) to eliminate the specific tax on nuclear energy and finance it through a higher energy tax [43].

The most recent increase took effect on January 1, 2023, raising the energy tax from 0.360 SEK/kWh (excluding VAT) to 0.392 SEK/kWh. However, some municipalities in northern Sweden have a lower energy tax rate of 0.296 SEK/kWh (excluding VAT) [43]. Additionally, a 25% VAT is added on top of the energy tax.

3.3.2 Energy tax on self-consumption

There has been an ongoing modernisation 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 summarised as [44]:

- 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 are installed.
- A solar producer that owns several PV systems, whose 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 are installed.
- A solar producer that owns a PV system larger than 500 kW_p pays the normal energy tax of 0.392 SEK/kWh on the self-consumed electricity used within the same premises as where the PV system is installed, but 0.006 SEK/kWh in energy tax for the self-consumed electricity from the other systems if they are less than 500 kW_p.

With the current legislation, there's a constraint on the construction of self-consumption PV systems exceeding 500 kW_p in Sweden. This is primarily due to the full energy tax applied to self-consumed electricity, which limits the profitability of such systems. Consequently, the untapped technical potential of large industrial properties for PV systems remains.

For systems smaller than 500 kW_p, the main economic hurdle for real estate owners planning to deploy multiple small PV systems has been alleviated by this legislation. However, the administrative burden of measuring and reporting self-consumed electricity still applies if the total power exceeds 500 kW_p. It's worth noting that it has only been since July 1st, 2021, that this limit has been at 500 kW_p. Prior to that, PV system owners had to pay energy tax on self-consumed electricity generated by systems larger than 255 kW_p. The previous limit especially impeded market growth in the industrial and large commercial sectors. The increase in the limit was well-received by the Swedish PV sector, although many advocates for its complete removal, including the Swedish Solar Association [45]. There's a positive development in this regard as the government has expressed its intent to eliminate the 0.006 SEK/kWh energy tax for real estate owners with multiple small systems. They plan to do this by submitting a state aid notification to the EU Commission [46], thus removing the administrative barrier.

3.3.3 Deduction of the VAT for the PV system

Sweden has a non-deductible VAT for permanent residences [47]. However, homeowner’s associations or property owners are granted the right of deduction for VAT for 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 [48], as it was legally tried in case 6174-18 of the Swedish Supreme Administrative Court [49].

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 necessarily apply to building-integrated PV.

To summarise, 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 [50].

3.3.4 VAT on the revenues of the excess electricity

A PV system owner that sells the excess electricity will receive compensation from the electricity trading utility company and from the grid owner (see section 3.11). If the total annual remuneration from the property (including other revenue streams than selling excess electricity) exceeds 80 000 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 13). If the total annual sales do not exceed 80 000 SEK for three consecutive years, the PV system owner is exempted from VAT [51].

At a reimbursement from a utility company of 0.5 SEK/kWh, 160 000 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 320 kW_p. Hence, as a general rule of thumb, the 80 000 SEK limit corresponds to PV systems of 275–400 kW_p, which would be an exceptionally large PV system size for a regular homeowner.

The limit of 80 000 SEK was implemented the 1st of January 2022 and is considered an improvement for the Swedish PV market. Before 2022, the limit was 30 000 SEK, as the start of the new tax-system for PV, which was implemented January 1st, 2017. Before that, 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 of 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 13, it is a win-win situation for all parties as compared to before the 1st of January 2017.

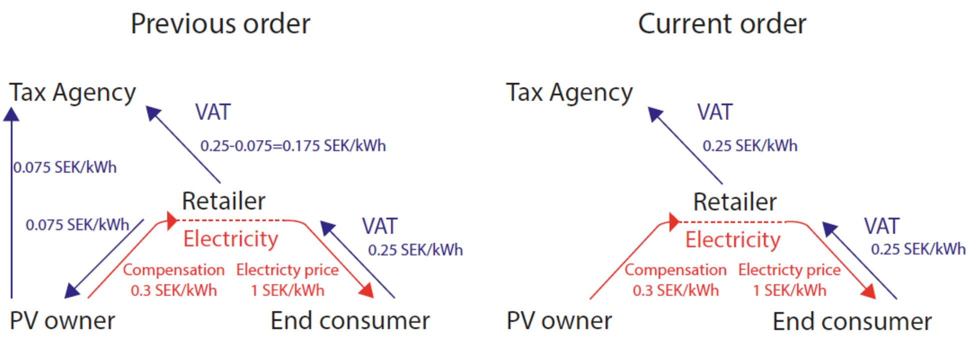

Figure13: Illustration of the revenue and VAT streams for the excess electricity for a private PV owner before and after the 1st of January 2017.

3.3.5 Tax credit for micro-producers of renewable electricity

On the 1st of January 2015, an amendment to the Income Tax Act was introduced [52]. 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 exceeds 100 amperes at the connection point,
- notify the grid owner that renewable electricity is produced at the connection point.

The tax reduction is determined by the number of kWh that a system feeds into the grid at the connection point during a calendar year. However, there are some limitations: the tax credit cannot exceed the number of kWh purchased in the same year, and it is capped at a maximum of 30,000 kWh annually.

The grid owner is responsible for measuring the electricity fed into and out of the connection point throughout the year, and this data is transmitted to the Swedish Tax Agency (Skatteverket). Subsequently, the tax reduction is incorporated into the income tax return information, which must be submitted to the Swedish Tax Agency in May of the following year.

The tax credit, amounting to 0.60 SEK per kWh, is an additional benefit received on top of other compensations for surplus electricity. These other compensations include renumeration provided by electricity retailers (refer to section 7.2), grid benefit compensation (refer to section 3.11), and earnings from the sale of renewable electricity certificates and guarantees of origin (refer to sections 3.2.1 and 3.2.3). Even if it is a tax credit system, it functions as a feed-in-bonus for surplus electricity. However, unlike some other European countries with feed-in-premiums or feed-in-tariffs, the Swedish tax credit system does not guarantee the specific number of years the tax credit system will be in place. This means that the additional earnings a micro-producer gains from the tax credit system when feeding electricity to the grid can be subject to political decisions, potentially leading to changes in the amount or even withdrawal of the tax credit.

According to the Swedish Tax Agency, a total of 194 042 micro-producers of renewable electricity collectively received 586 545 555 SEK for the excess electricity they supplied to the grid in 2023. This calculation is based on the 1 003 677 MWh of excess electricity reported by grid operators to the Swedish Tax Agency. On average, micro-producers with a capacity of less than 100 amperes contributed with 5 172 kWh of electricity to the grid in 2023, as summarised in Table 21. The reader should note a slight variation in the figures compared to last year's report, which applies retroactively to all years. This is because the Swedish Tax Agency now provides a statistics portal where updated statistics can be accessed, making retroactive adjustments possible [53].

Table 21: 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	5 166	10 766 633	18 427 927	3 567
2016	7 847	18 643 902	31 724 664	4 043
2017	11 940	29 296 615	49 529 912	4 148
2018	20 764	57 519 609	97 496 756	4 695
2019	36 777	103 021 980	174 643 281	4 749
2020	56 279	182 182 571	307 848 693	5 470
2021	79 976	246 258 662	417 293 238	5 218
2022	130 085	415 027 942	705 946 552	5 427
2023	194 042	586 545 555	1 003 677 331	5 172
Total	-	**1 649 263 469**	**2 806 588 354**	-

These numbers include all small-scale renewable energy production, not just PV systems. 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 systems in the tax reduction payouts. This method provided only a rough estimate because the total electricity produced annually, and the self-consumption ratio, vary among different renewable energy technologies and individual systems. However, as explained in section 3.2.1, there are few incentives for residential PV system owners to register for green electricity certificates in 2022, rendering this estimation unfeasible.

In both 2020 and 2019, 98% of the capacity for systems below 69 kW in the green electricity certificate system consisted of PV systems, while the corresponding figure for 2018 was 96%. Therefore, it's reasonable to assume that the share of PV remains at a similar level in 2023.

3.4 Collective self-consumption, community solar and similar measures

Collective self-consumption from a PV system within an apartment building is permitted in Sweden as long as all the apartments share the same grid subscription. Many housing companies and housing societies are opting for this approach. In this setup, the standard practice is for the entire apartment building to have a single electricity contract with the utility. The electricity costs are typically either included in the rent or the housing company/society measures and bills electricity consumption internally.

To modernise the legislation around electricity grids, an exception to the IKN Ordinance became legally effective on January 1st, 2022 [4][54]. This exception allows property owners to set up low-voltage microgrids for sharing and storing renewable electricity. However, due to the wording of the exemption, it is not entirely straightforward to predict the scope of its application and how it aligns with the rules concerning the tax on self-consumed electricity for larger systems. For instance, the regulation states that the internal low-voltage grids should serve as a supplement to the public grid and be confined to a limited area. The practical implementation of these criteria can be subject to different interpretations. To obtain clarity, the Energy Markets Inspectorate (Ei) must legally assess the matter through what is known as binding replies *("bindande besked").*

Virtual self-consumption where the electricity is transferred through a grid that is covered by a grid concession is currently not allowed [55].

There is currently no well-defined implementation of energy communities in Sweden, or at least no clear definition that fosters widespread adoption in society. According to the definitions in the European directives (Directive 2018/2001 [56] on the promotion of the use of energy from renewable sources and Directive 2019/944 [57] on common rules for the internal market for electricity), there are few to no energy communities in Sweden [55]. In 2024, the Government tasked the Swedish Energy Agency with investigating the conditions for energy communities and the potential need for enabling measures [58].

3.5 Tenders, auctions & similar schemes

There were no national or regional tenders or auctions in 2023 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 2023. The historical support and measures accessible for utility-scale PV have been the general former support schemes — 1) the direct capital subsidy that expired mid-2020 but with a cap of 1.2 million SEK per system which lowers the benefits of utility-scale centralised PV parks [59], 2) the green electricity certificate system that expired 31st December 2021 (see section 3.2) and 3) the guarantees of origin system (see section 3.2.3). This means that from 2022 onwards, the utility-scale segment is developing in unsubsidised market conditions in Sweden. Even if there are no subsidies in Sweden, the centralised market segment is competitive [60].

3.6.1 Property taxes

Power generation facilities in Sweden are charged with a general industrial property tax. Today, PV technology is not defined as a 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 buildings” and taxed them as industrial units. Currently, the property tax of an industrial unit represents 0.5 % of the assessed value of the facility [61].

3.7 Social Policies

There were no social policy measures directed to PV in Sweden in 2023.

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 2023.

3.9.2 Exemption for building permits for solar energy systems

As of 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 one of following situations applies [62]:

- 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 is of national interest to 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 Curtailment policies

There were no rules when it came to the curtailment of renewable electricity in Sweden in 2023.

3.9.4 ROT tax deduction

The ROT program is an incentive program for private individuals who buy services from the construction industry in Sweden. The program is in the form of tax credits. ROT is a collective term for measures to renovate and upgrade existing buildings, mainly residential properties. Reparations, maintenance, conversions and extensions are counted as ROT work and are therefore tax deductible, provided that such work is carried out in close connection to a residence that the client owns and in which he or she lives (or if it is a second home, like a vacation house [63]).

The ROT-tax deduction in 2023 was 30 % of the labour cost and of maximum 50 000 [63] for the installation of a PV system. The requirements are that the house is older than five years, and that the owner has not used the green tax deduction for the same service. Installation and replacement of solar panels are entitled to 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 2023. If it can be proved that the labour costs constitute a higher proportion than 30 %, the total deduction then consequently becomes higher.

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. These two subsidy systems were financed by the Swedish state budget and the money was distributed by the 21 county administrations.

Secondly, 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 during 2015–2021. This system was 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 2023 received a total of 1 481 521 certificates over the years (see section 3.2). By taking the monthly average prices for the certificates and multiplying these prices with the number of certificates that have been issued to PV in each month the total support to PV by the end of 2023 becomes 72 171 258 SEK [33]. 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.

On addition, a rough estimation is that a total of 1 522 544 652 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 during 2015–2023.

Lastly, for the tax deduction for green technology, about 5 179 000 000 SEK has been allocated between 2021–2023 for PV systems. These subsidies are financed by the Swedish state budget.

Adding all the above subsides, the Swedish PV market have throughout the years received approximately a total of 10 353 million SEK in subsidies at the end of 2023.

3.11 Grid integrations policies

3.11.1 Grid connection policies

The standard procedure for grid connection involves notifying the grid owner well in advance of installing a PV system. The grid company must then specify the requirements for the installation. After installation, the electrical company must submit a final report to the grid company and conduct a system inspection [64]. The grid company then replaces the electricity meter — at no cost — with a new meter that can measure surplus electricity fed into the grid. All feed-in is measured hourly and self-consuming customers that want to measure all electricity produced, including self-consumption, need to cover the cost of installing a separate meter.

The Swedish Energy Market Inspectorate (Ei) has examined grid connections for small-scale systems in several cases and determined that distributed system operators (DSO) shall connect micro-production PV systems to the grid at no additional cost, even if the grid needs to be reinforced. However, if the PV system requires a larger fuse than the existing one, the grid company has the right to charge a connection fee for the fuse upgrade. This can result in high costs and in some cases as the grid may need to be adjusted to the fuse. The PV system owner has the right to request a review of the connection terms beforehand and in case of disputes regarding the fee, the PV system owner or the grid company can turn to Ei for review.

For centralised PV systems, grid reinforcement may be necessary, which can be costly and complex [65]. No data is available for the cost of grid-connection for centralised PV in Sweden in 2023. However, an economic study of six PV parks commissioned in 2019–2020 in Sweden, shows that the grid connection costs varied significantly between projects and across different grid owners, with connection costs ranging from 9 615 €/MWp to 56 662 €/MWp, with an average of 29 596 €/MWp [1].

3.11.2 Grid access policies

3.11.2.1 Grid benefit compensation

A micro-producer is entitled to reimbursement from the grid operator for the electricity that is fed into the grid. The electricity producer is entitled to compensation when supplying electricity equivalent to the production facility's contribution to reduced costs for the grid company. In simplified terms, the compensation should be calculated based on the difference between the grid company's cost when the production facility is connected to the grid compared to the hypothetical equivalent cost if the production facility was not part of the network [40]. The compensation varies between different grid owners and grids.

3.11.2.2 Feed-in subscriptions for micro-producers

The 1st July, 2022 , the Swedish Government removed the requirement for homeowners to be annual net consumers to qualify for a free feed-in subscription towards the grid owner in the legislation [66]. However, as of March 2023, the Swedish Energy Markets Inspectorate (Ei) released an assessment indicating that reducing the grid fee for smaller production facilities is not in compliance with the EU's electricity market regulation. This regulation specifies that all grid users, including producers, should bear their own costs. Consequently, following this assessment, the exception was immediately revoked. EU law takes precedence over national laws in member states, and as a result, owners of smaller production facilities should not receive a reduced grid fee [67].

3.11.2.3 Aggregated grid subscriptions

Since January 1st, 2021, it has been 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 [68].

4 INDUSTRY

The Swedish PV industry mainly contains of small to medium size installers and retailers of PV modules or systems. In 2021, the author was aware of 308 companies that sold and/or installed PV modules and/or systems in the Swedish market. While no survey has been sent out to the industry in 2022 or 2023 and therefore the same exercise of collecting companies has not been performed, there is reason to believe that the downstream industry of installers and retailers is growing steadily in Sweden.

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).

On the other hand, there is news of a new module manufacturer in northern Sweden, Nordcell Group AB, which plans to set up a 1.2 GW module manufacturing capacity. They aim to start operations in mid-2025 and provide modules for the residential, commercial and utility segments of the PV market [69].

4.1 Production of feedstocks, ingots and wafers

Sweden did not produce any feedstock or wafers in 2023. The only plan known to the authors is that the aforementioned new company, Nordcell Group AB, has a mission to build a vertically integrated production facility in Sweden covering all primary stages of solar panel production, including silicon, ingot, and wafer production [69].

4.2 Production of photovoltaic cells and modules

Module manufacturing is defined as the industry where the process of the production of PV modules (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 assembled modules from imported silicon 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 European 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 around 0.6 MW_p of commercial modules as part of their product development in 2023.

Furthermore, in October 2019, CIGS thin film equipment manufacturer Midsummer AB established a cell and module production line in Järfälla, Sweden, where they produced approximately 1.3 MWp of cells and panels in 2023.

Midsummer also operates an Italian subsidiary called Midsummer Italia, founded in 2020 to establish a factory there. In the fall of 2021, the Italian Ministry of Economic Development and the Italian investment institution Invitalia announced they would support the construction of a 50 MW factory with a grant for the project of nearly 22m€. By the end of 2023, Midsummer announced the shipment of the final Swedish-produced machines for thin-film PV manufacturing to Bari, Italy, signalling a production start during 2024 [70].

In July 2023, the EU Innovation Fund selected Midsummer for a grant of approximately 32.3 m€ to establish a new 200 MW factory in Flen, Sweden. Production is scheduled to start in the first quarter of 2026, following preparatory activities in 2025 such as equipment installation, functionality testing, factory certification, and staff training [71].

Total PV cell and module manufacturing, along with production capacity information, is summarized in Table 22.

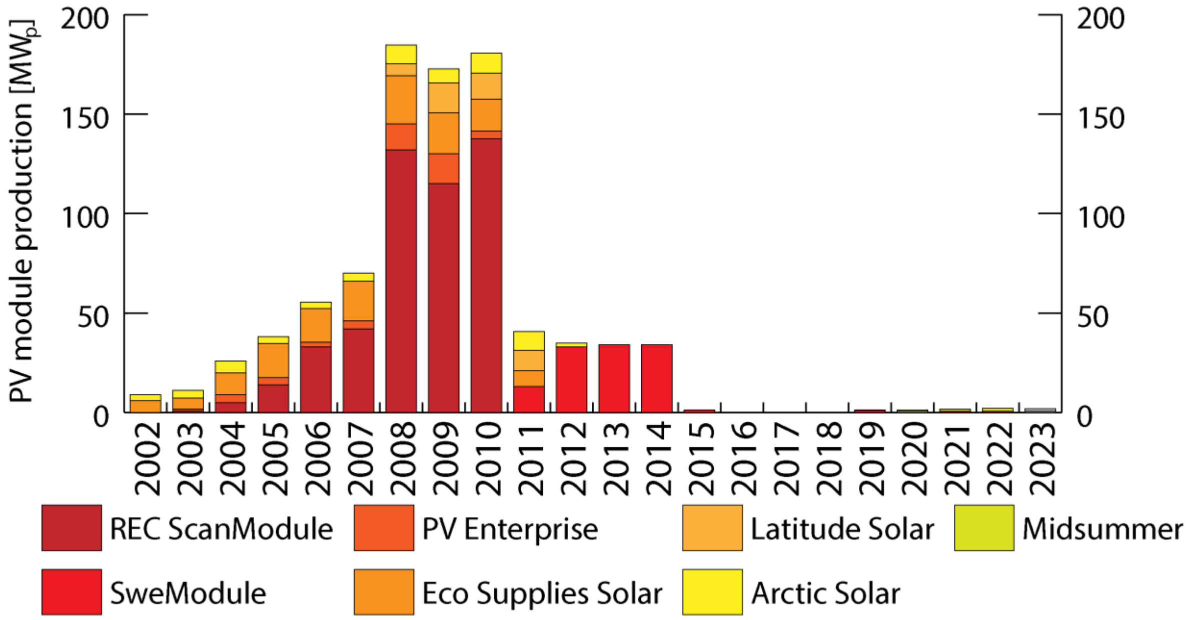

Figure 14: Yearly PV module production in Sweden over the years.

Table 22. PV cell and module production and production capacity information for 2023.

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	1.30	1.30	5	5
Cells for concentration					
None	-	-	-	-	-
Totals		**1.30**	**1.90**	**5**	**155**

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.

There is a center of excellence focused on increasing the use of solar power in Sweden, called the Solar Electricity Research Centre Sweden (SOLVE) [72]. It conducts research and promotes sustainable solutions for integration in buildings, land, and the energy system. SOLVE fosters strong partnerships between researchers and industry actors to support the growth of PV markets and disseminate research-based knowledge. It prioritizes the education of engineers and PhD students with industry connections, ensuring sustainable growth in the solar sector. SOLVE is a collaboration among five Swedish universities, one institute, and nearly 50 public and private organizations involved in solar PV development in Sweden and Northern Europe.

Furthermore, some smaller groups focus on PV systems, Agrivoltaics, and PV in energy system-oriented research.

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 organisations 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).

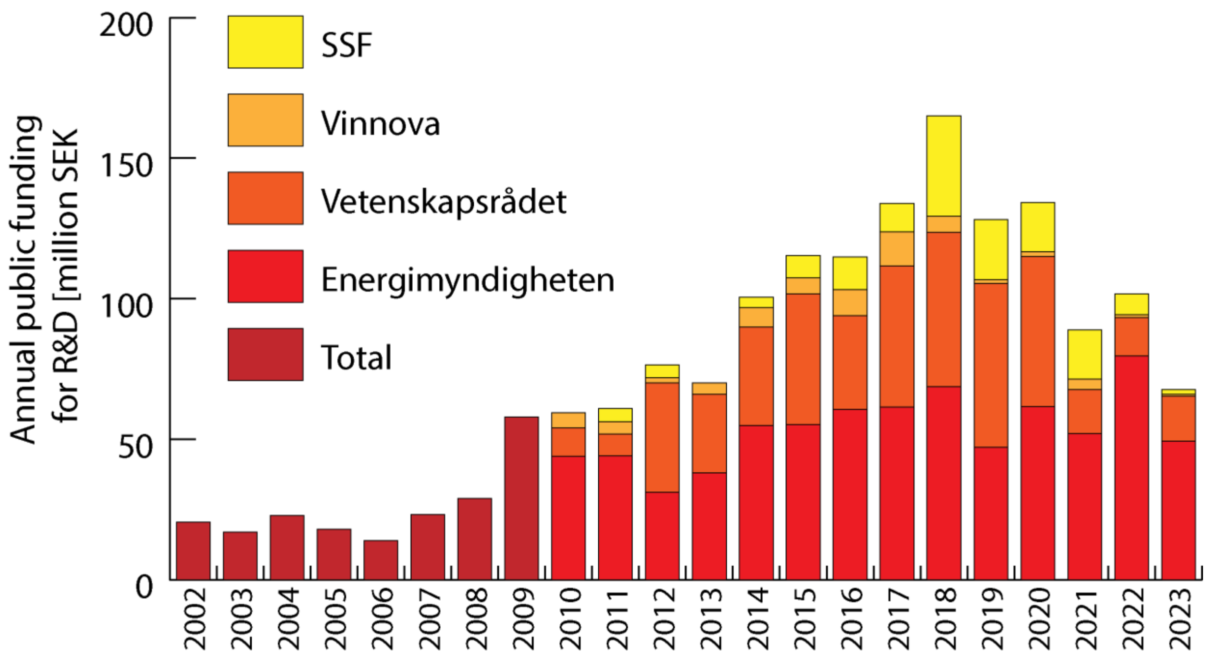

Figure 15. Annual public funding for PV related research in Sweden

Compared to 2022 and the earlier years for which this development has been tracked, 2023 stands out as a year with lower funding. However, the reader should note that the funding figures from Vinnova for 2018–2022 have been retroactively modified due to a new methodology applied starting in 2023. Therefore, these figures will differ from those presented in earlier national survey reports. In any case, the trend from Vinnova, like that of the other funders apart from the Swedish Research Council, shows a decline in disbursed funds.

At the Swedish Energy Agency, which is generally the largest public funder of PV research, funding is lower in 2023 because the program “El från solen” (*Electricity from the sun*) [73][74] is coming to an end. This program has been merged with several other technology-specific programs into "Framtidens elsystem" (*The Future's Electricity System*) [75]. There are fewer and fewer ongoing projects in "El från solen", and the program is set to conclude in December 2024. Meanwhile, payments from other programs at the Swedish Energy Agency remained at the same level as in 2022.

6 PV IN THE ECONOMY

6.1 Labour places

With the bankruptcy and shutdown of several of the Swedish PV module factories in 2010 and 2011 the number of full-time equivalent (FTE) jobs in the Swedish PV module production industry decreased dramatically. However, the number of people involved in selling and installing PV systems is increasing as the Swedish PV market grows. The growing market in turn leads to an increased involvement from utility companies, consulting firms, and real estate owners. In many companies and research institutes, several people work only partly with PV-related duties.

In previous Swedish National Survey Reports from 2010 to 2021 [76], a survey was conducted to gather information on employment opportunities across various parts of the solar PV market. These reports highlighted the described decline in PV module manufacturing jobs, and the parallel growing job market for installers and salespeople, as installations increased, and the Swedish market matured and became more complex. The surveys also showed a relatively stable number of jobs for machinery and BoS manufacturers, R&D companies, national and regional agencies, universities, and foundations. There was moderate growth in the job market during these years for consulting firms, real estate owners, builders, and other workplaces indirectly connected to the PV market and its installed capacity.

The discontinuation of these surveys has made it impossible, to estimate the number of jobs directly attributable to the PV market in Sweden.

One indicator can be derived from the green tax deduction (see 3.2.2 Tax reduction for green technology), which reports the number of unique installers who have submitted data to the tax deductions scheme and thus were involved in residential PV installations each year. As previously explained, not all new residential PV systems in Sweden necessarily use the green tax deduction, but the logical conclusion, given the ease of obtaining the tax reduction, is that most do take advantage of it. Therefore, the number of active companies invoicing private customers for PV systems in Sweden is likely close to this figure. Additionally, there are probably subcontractors not captured in this data, and the number is difficult to estimate.

Over the three full years that the support has been in place, there has been a clear increase, from 1 279 unique companies in 2021, to 2 457 companies in 2022, and 3 948 companies in 2023 [53]. This suggests that there are likely many more installers and retailers today than during the survey period, and the same likely applies to the number of jobs, despite significant variation in the size of installation companies in Sweden. There are several very large companies operating in all market segments in Sweden and throughout Europe, as well as many small companies that offer PV installations as part of their general electrician services. Therefore, it is not possible to directly translate the number of unique companies reporting control data and acting as suppliers of residential PV systems into an estimated number of full-time labour places associated with it.

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 (Ei) is the regulatory authority over the electricity market. Since the grid is a monopoly, there is only one network owner in each area that is licensed.

The base price of the electricity is daily set by the Nordic electricity retailing market, Nord Pool. Electricity trading companies then use this price as basis for their pricing in the competition for customers. The Swedish electricity market was deregulated in 1996, which resulted in that the customers could change their electricity supplier more easily.

There are more than 150 grid owners in Sweden. However, the Swedish grid market is dominated by Vattenfall, E.ON and Ellevio that covers about 60 % of all customers. The retail market is dominated by three companies; Vattenfall, Fortum and E.ON.

7.2 Interest from electricity utility businesses

Several utility companies started marketing small turnkey PV systems suited for roofs of residential houses already in 2012 and it is still a common occurrence in 2023.

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 the demand that the micro-producer is a net consumer of electricity during the 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 centralised PV parks. 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 by 2023 are to the authors' knowledge 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 stated in section 1.5, 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 [77] 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 [78]. 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 [79].

Some Swedish municipalities and local governments have introduced ambitious goals 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 [80].
- The municipality of Uppsala that has set a goal to have approximately 30 MWp of PV by 2020 and about 100 MWp by 2030 [81].
- 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 [82].
- 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 [83].

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.

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 levels. With support from the Swedish Energy Agency (Energimyndigheten), they coordinate national projects with the municipality's energy and climate advisors.

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

In 2023, the Swedish solar PV market experienced a record-breaking year, reaching a gigawatt market for the first time. Much of this growth in annual installations could be attributed to the high volume of requests for residential PV systems that installers received during the period of high electricity prices in 2022, many of which were completed in 2023. With an addition of 1600 MW in 2023, the previous market record from 2022 was more than doubled. This also means that 40% of the PV capacity in Sweden at the end of the year was installed in 2023.

In definite terms, the grid-connected Swedish solar market grew by 101%, from 796.6 MW in 2022 to 1600.9 MW in 2023. The largest growth was seen in small PV systems (below 20 kW), with 1533.3 MW added in 2023, a 102% increase compared to the 759.4 MW added in 2022. Confirming this trend, data from the tax deduction subsidy for green technologies for private individuals showed a 155% increase in invested funds and a 105% increase in the number of individuals who made use of the support for PV systems. Additionally, there was a significant 217% increase in investments in solar batteries, corresponding to a 198% increase in individuals using the tax deduction for battery energy storage systems. This marks 2023 as the year when batteries entered the market more notably. For a long time, it was not cost-effective for homeowners to invest in batteries, and the sales of PV systems with batteries were reported as scarce. 2023 saw a shift where it became more economically beneficial. Incentives contributing to this trend include volatile electricity prices, the tax deduction for green technology, and improved home energy management systems and aggregator services that allow participation in support services. However, the exact number of stand-alone batteries or their total capacity in Sweden remains unknown as no official data collection or reporting is conducted.

The market for centralized PV grew by 82% in 2023, with 67.6 MW added compared to 37.2 MW installed in 2022. Despite this growth, there remains a large pipeline of projects and PV parks in active development, many of which are significantly larger than the largest PV parks in 2023. Obtaining a grid connection is generally considered a bottleneck for the development of PV parks in Sweden, along with securing proper permits and conducting alternative land evaluations if the PV park is to be built on agricultural land. Despite the increased interest in ground-mounted PV parks, the Swedish PV market is still dominated by residential roof-mounted systems for single-family houses and roof-mounted systems on commercial buildings.

2023 was also defined by lower overall prices on hardware, especially PV modules and power electronics, and good overall availability. This contrasted sharply with 2020–2022 when global prices were high due to the COVID-19 pandemic, the Russian invasion of Ukraine, and supply chain issues. However, reports towards the end of 2023 indicated a lower market interest in new investments and a decline in new sales compared to 2022, largely due to the general economic situation in Sweden and the world throughout the year. As a result, private individuals and companies may have become more cautious and not as willing to make large new investments in their homes or buildings. Compared to last year, when suppliers were overwhelmed with incoming requests, Sweden may now be moving towards a plateau after several years of significant market growth.

Small residential systems saw the highest price decrease in 2023, dropping from 19.1 SEK/W to 14.9 SEK/W, marking a 22% decrease. Small commercial systems decreased by 15%, from 15.3 SEK/W to 13.0 SEK/W, larger commercial systems decreased by 19%, from 11.3 SEK/W to 9.1 SEK/W, and ground-mounted parks decreased from 9.0 SEK/W to 8.4 SEK/W, corresponding to an 8% decrease. Generally, price volatility in the Swedish PV market makes it increasingly challenging for the installers to determine a typical yearly price in the survey. The termination of support policies makes it difficult to assess market segmentation development in Sweden past 2021 with great detail since the capital subsidy database has been a valuable resource for that purpose.

In policy terms, 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 purely 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 in 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 below 69 kW_p. An exemption from the general grid rules allowed for renewable energy sharing between buildings in micro grids, starting in 2022. While the extent to which this has been established is not known, it is expected to stimulate the multi-family house PV segment, as it allows for collective self-consumption.

On the industry side, there is still minimal module production in Sweden after several manufacturers closed down in the 2010s. However, some Swedish companies focusing on new PV technologies or Balance of System components continued to develop healthily. There has also been news about potential new PV industry deployment, with plans for new PV module manufacturing in Sweden involving both thin-film and silicon technologies. Furthermore, the Swedish PV downstream industry is becoming increasingly diversified every year, with more actors from other core businesses, such as utilities and real estate owners, showing interest in PV technology.

8.2 Prospects

Several factors are negatively affecting both the Swedish private and commercial sectors' willingness to invest in solar PV in the short term, such as high interest rates and, consequently, the high cost of capital, the state of the Swedish economy, and global geopolitical events. This is likely to slow down deployment. The trend of declining purchase orders and requests that became noticeable by mid-2023 is confirming this development. However, lower hardware prices and the high availability of PV modules and other components can counteract some of this effect and help solar PV remain competitive despite low electricity prices.

In the medium term, it is expected that the Swedish PV market will continue to grow. The introduction of the tax credit for micro-producers in 2015, the tax deduction for green technology for private individuals in 2021, the launch of an information platform by the Swedish Energy Agency, and increased activity from utilities have created favourable conditions for homeowners and small companies to invest in PV. The introduction of internal low-voltage grids for energy sharing was highly anticipated by the sector building new apartment complexes and represents a first step in enabling collective self-consumption. Future steps to align with EU regulations are awaited and should enable more possibilities for jointly acting self-consumers and energy communities.

Extending this trend, in the longer term, there is no reason to believe that the market will not recover from the current slowdown. With the tax deduction for green technology, solar batteries with smart management are now becoming profitable investments for private individuals and these prosumers can play a crucial role in the future, more decentralized, energy system. The definition and formation of rules for private battery owners receiving the green tax deduction will likely impact the speed of development in this market segment.

Large, centralized PV parks have been rare in Sweden until recent years. This market segment is, however, expected to grow significantly in the coming years, as PV parks now seem economically viable without subsidies. Developers are currently struggling with extensive permitting processes, which create a barrier to rapid growth in this segment. In recent years, developers of PV parks in other European countries have been attracted to Sweden as a relatively untapped market and as a gateway to other Nordic countries. More than before, PV park owners and developers are joining forces to advocate for better conditions, such as streamlined permitting processes and improved procedures for obtaining grid connections. The PV parks that are already in mature development are now much larger than the 20 MW that has been the size limit up until now. Solar PV parks being rolled out above 100 MW do not seem far away, which will likely allow PV parks in Sweden to gain market share more quickly in terms of the total market.

In summary, there may be some hurdles in the short term, but in the long term, the Swedish PV market is well-positioned for growth. Overall, there is a growing interest in PV in Sweden, and the public is very positive about the technology.

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 [84]. 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 [85].

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 are listed in the older Swedish National Survey Reports 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.

No collection of off-grid statistics has been collected for 2022 or 2023 and the number for 2022 and 2023 is therefore an estimate made by the authors of the report.

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.

No collection of labour places statistics was made for 2022 and the number for 2022 is, therefore, an estimate made by the authors of the report, and no estimate could be made in 2023, as is explained in Section 6.1.

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 older Swedish National Survey Reports) 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 centralised, industry, commercial or residential systems.

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 organisation. 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. The fact that no new systems are added makes it impossible to use the database of the Swedish direct capital subsidy as a source for segmentation after 2021.

9.1.5 PV system prices

When it comes to PV system prices, the yearly survey that goes out to the Swedish installers and retailers is the source used 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 2018–20223 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.

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.

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 Tax credit for micro-producers & Tax deduction for green technology

Statistikportalen, the data base managed by the Swedish Tax Agency (Skatteverket) is used for examining the tax credit for micro-producers of renewable electricity and the tax deduction for green technology. 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 3.3.5.

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