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 FINLAND

2019

LUT University

What is IEA PVPS TCP?

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

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

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

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What is IEA PVPS Task 1?

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation. An important deliverable of Task 1 is the annual "Trends in photovoltaic applications" report. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the country National Survey Report for the year 2019. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

Authors

- **Main Content:** Jero Ahola
  - **Data:** The Energy Authority, Motiva, Statistics Finland, Heat Pump Association of Finland, The Finnish Information Centre of Automobile Sector, The Wind Power Association of Finland, Fingrid.
- **Analysis:** Jero Ahola

COVER PICTURE

Jero Ahola, taken at the technology tour in IEA Exco Meeting in Helsinki on May 8th 2019.

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ACKNOWLEDGEMENTS

1 INSTALLATION DATA

The PV power systems market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W or more. A PV system consists of modules, inverters, batteries and all installation and control components for modules, inverters and batteries. Other applications such as small mobile devices are not considered in this report.

For the purposes of this report, PV installations are included in the 2019 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2019, although commissioning may have taken place at a later date.

1.1 Applications for Photovoltaics

For a long time, the PV market in Finland has been concentrated on small off-grid systems. There are more than half a million summer cottages in Finland, and more than 50 000 of them are electrified with an off-grid PV system capable of providing energy for lighting, refrigerators and consumer electronics. Since 2010, the number of grid-connected PV systems has started to increase. Currently, the market of grid-connected systems significantly outnumbers the market of off-grid systems. The grid-connected PV systems are mainly roof-mounted systems for public and commercial buildings, agricultural sites and individual houses. The largest individual solar PV plant in Finland is a 6 MW ground-mounted system, which is constructed on an industrial site in Nurmo. The majority of systems are built for self-consumption of PV electricity, since there is no economic potential for utility-scale PV systems for grid electricity generation yet. However, solar PV is currently in Finland the second least cost option for new electric power generation after wind power.

1.2 Total photovoltaic power installed

The Energy Authority (www.energiavirasto.fi) collects the official data of grid-connected PV electricity in Finland from the grid companies on yearly basis. The results of the survey are published on late June. The total installed PV capacity is estimated to be approximately 214 MW by the end of the year 2019 with an increase of 80,7 MW from the year 2018 (Tables 1 & 2). Of the total capacity, 203 MW (197 MW of PV plants with P < 1 MW, and a 6 MW PV plant in Nurmo) is grid-connected and 11,3 MW off-grid installations. The distribution of installed capacity in 2019 in the categories of residential, commercial and industrial installations is uncertain. However, according to interviews of two major PV system providers in Finland, it can be estimated that around 45 % of the capacity is covered by residential, 30 % commercial and 25 % industrial installations. This is used as a basis of the division presented in Table 2. Information about the data collection process is given in Table 3, about cumulative installed PV power in three sub-markets in Table 4, about other PV market information in Table 5, and about PV power in the broader national energy market in Table 6. The total number of PV power plants in Finland is estimated to be around 20 000 – 25 000.

Table 1: Annual PV power installed during calendar year 2019

		Installed PV capacity in 2019 [MW]	AC or DC
PV capacity	Off-grid	0,3	DC
	Decentralized	80,4	DC

	Centralized	0	DC
	Total	80,7	DC

*There is no data collected about the sales of off-grid systems. However, based on discussions with PV system provider the market in Finland is estimated to be around 300 kW on yearly basis.

Table 2: PV power installed during calendar year 2019

			Installed PV capacity [MW]	Installed PV capacity [MW]	AC or DC
Grid-connected	BAPV	Residential	80,4	36,2	DC
		Commercial		24,1	DC
		Industrial		20,1	DC
	BIPV	Residential	0		DC
		Commercial			DC
		Industrial			DC
	Utility-scale	Ground-mounted	0		DC
		Floating			DC
		Agricultural			DC
Off-grid		Residential	0,3	0,3	DC
		Other			DC
		Hybrid systems			DC
Total			80,7		DC

Table 3: Data collection process

If data are reported in AC, please mention a conversion coefficient to estimate DC installations.	Data are reported as DC.
Is the collection process done by an official body or a private company/Association?	Public body
Link to official statistics (if this exists)	Total installation data is collected by the Energy Authority, www.energiavirasto.fi
	The data are collected with a yearly survey to grid companies by the Energy Authority.

Table 4: The cumulative installed PV power in 4 sub-markets

Year	Off-grid [MW]	Grid-connected distributed [MW]	Grid-connected centralized [MW]	Total [MW]
2015	10*	10	0	20
2016	10,3*	27,1	0	37,4
2017	10,6*	69,8	0	80,4
2018	10,9*	122,6	0	133,5
2019	11,2*	203	0	214,2

*Mostly small off-grid PV systems in summer cottages, official statistics not available.

Table 5: Other PV market information

	2018
Number of PV systems in operation in your country	Estimate: 20 000-25 000, mostly grid-connected rooftop systems at domestic houses.
Decommissioned PV systems during the year [MW]	0
Repowered PV systems during the year [MW]	No data available
Total capacity connected to the low voltage distribution grid [MW]	Estimate: around 95 % of total capacity
Total capacity connected to the medium voltage distribution grid [MW]	No data available
Total capacity connected to the high voltage transmission grid [MW]	0

Table 6: PV power and the broader national energy market

	2018	2019
Total power generation capacities [GW]	17,6	17,7
Total renewable power generation capacities (including hydropower) [GW]	7,6	-
Total electricity demand [TWh]	87	86

Total energy demand [TWh]	383	377
New power generation capacities installed [GW]	-	-
New renewable power generation capacities (including hydropower) [GW]	Wind: 0,016 Hydro: 0,039, Bio: 0,201	Wind: 0,243
Estimated total PV electricity production (including self-consumed PV electricity) in [GWh]	88	150
Total PV electricity production as a % of total electricity consumption	0,1 %	0,2 %

*The power capacities are based on power plant registry of Finland, which includes all the power plants with nominal capacity of > 1 MW. The registry is maintained by the Energy Authority.

1.3 Key enablers of PV development

Information on key enablers of PV development is presented in Table 7.

Table 7: Information on key enablers

	Description	Annual Volume	Total Volume	Source
Decentralized storage systems [MWh]	Probably ~10			No official data available
Residential Heat Pumps [#]	air-to-air ; air-to-water ; exhaust heat pumps & ground source	98 000	1 000 000	Heat Pump Association of Finland (www.sulpu.fi)
Electric cars [#]	Battery electric vehicle (BEV) & Plug-in hybrid vehicle (PHEV)	PHEV: 11 609 BEV: 2 257	PHEV: 24 704 BEV: 4 661	The Finnish Information Centre of Automobile Sector (www.aut.fi)
Electric buses and trucks [#]		41	64	Statistics Finland (www.stat.fi)
Other				

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

Finland is a net-importer of PV modules. The modules are mainly imported from Eastern Asia. However, there is some module manufacturing capacity in Finland. The prices have declined from year 2018 due to a decrease in global market prices. The module prices presented in Table 8 give the price of multiple panels typically delivered as a part of a commercial or industrial rooftop PV system. The price data are given without VAT. The data were collected from PV system providers operating in Finland.

Table 8: Typical module prices for a number of years

Year	Lowest price of a standard module crystalline silicon	Highest price of a standard module crystalline silicon	Typical price of a standard module crystalline silicon
2014	0,65	1	0,85
2015	0,6	0,7	0,65
2016	0,5	0,65	0,55
2017	0,4	0,55	0,45
2018	0,25	0,35	0,3
2019	0,2	0,3	0,25

2.2 System prices

The turnkey price intervals (excluding VAT) collected from Motiva and two major PV systems providers operating in Finland are presented in Table 9. The prices represent the situation at the end of 2019. The prices do not include permitting cost; however, it may be a relevant system cost contributor only in residential rooftop installations (P < 10 kW). Especially, the amount of required installation work and materials varies in rooftop installations causing a spread of costs. Electricity utilities and retailers, such as local electrical installation companies, typically sell the household rooftop systems. Companies specialized for the planning and installing of PV systems provide typically the larger commercial and industrial systems. The average trends of system prices (excluding VAT) are illustrated in Table 10. Only some ground-mounted systems have been built with an investment support from the Ministry of Economic Affairs and Employment of Finland, but they are still smaller than 20 MW and are mainly designed for the self-consumption of electricity.

Table 9: Turnkey PV system prices of different typical PV systems

Category/Size	Typical applications and brief details	Current prices [€/W]
Off-grid Up to 5 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. Typically, PV systems that are installed in boats, caravans, summer cottages and include lead-acid or lithium-ion batteries.	3-5
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.	1,05-1,84
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.	0,8-1,05
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.	0,7-0,8
Industrial BAPV >250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected industrial buildings, warehouses, etc.	0,6-0,7
Small centralized PV 1-20 MW	Grid-connected, ground-mounted, centralized PV systems that work as central power station. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale.	No plants
Large centralized PV >20 MW	Grid-connected, ground-mounted, centralized PV systems that work as central power station. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale.	No plants, estimate 0,5-0,6

Table 10: National trends in system prices for different applications

Year	Residential BAPV Grid-connected, roof-mounted, distributed PV system 5-10 kW **[€/W]**	Small commercial BAPV Grid-connected, roof-mounted, distributed PV systems 10-100 kW **[€/W]**	Large commercial BAPV Grid-connected, roof-mounted, distributed PV systems 100-250 kW **[€/W]**	Small centralized PV Grid-connected, ground-mounted, centralized PV systems 10-20 MW **[€/W]**
2014	1,5-1,8	1,25-1,5	1,2	No estimate
2015	1,45-1,75	1,15-1,4	1,05-1,35	1,1-1,3*
2016	1,3-2	1,05-1,35	0,95-1,3	1-1,2*
2017	1,2-1,8	0,9-1,15	0,85-1,15	0,9-1,1*
2018	1,05-1,61	0,85-1,05	0,75-0,85	0,55-0,65*
2019	1,05-1,84	0,8-1,05	0,7-0,8	0,5-0,6*

*) There are no 10-20 MW ground mounted centralized PV systems in Finland. The given intervals are estimates given by PV system providers. The price estimate do not include transformers nor land construction work.

2.3 Cost breakdown of PV installations

The cost breakdown (VAT 0%) of a residential PV system in Table 11 was produced as follows. First, the system size was defined to be around 5 kW. Next, the component prices and the amount of installation work were discussed with PV system providers. Based on these discussions average case was defined. The cost of installation work to the employer was estimated to be 25 €/h*1.6 = 40 €/h. The amount of installation work including electrical installation was estimated to be 2 h/module (275 W). Even lower values, such as 1-2 h/module, were indicated in the discussions with a PV system provider. In the literature (Rutovitz, 2012), the employment of a PV installation was estimated to be 11 man-years/installed MW of PV. This values around 4 h/module for work. However, the year of the publication is 2012. Since then, the PV module power has increased and both mounting systems as well as working practices improved. However, there will be always working hours of installation staff that cannot be charged from customers. The fraction of planning, travel expenses and permitting was assumed to be 0.05 €/W for each component.

The profit margin was assumed to be 20 % of the whole system price. Residential PV system providers typically purchase the PV systems from wholesale instead of importing the systems themselves. In residential PV systems, the building permitting practices differ between municipalities. In the most progressive municipalities there are no building permitting requirements for residential rooftop systems. Some municipalities require an announcement and some a building permit depending on the system size and location. The VAT in Finland is 24 %.

So far, there are no utility-scale installations (P > 10 MW) in Finland. Thus, the cost breakdown is not given for a utility-scale PV plant.

Table 11: Cost breakdown for a grid-connected roof-mounted, distributed residential PV system of 5-10 kW

Cost category	Average [€/W]	Low [€/W]	High [€/W]
Hardware			
Module	0,3		
Inverter	0,15		
Mounting material	0,15		
Other electronics (cables, etc.)	0,05		
Subtotal Hardware	**0,65**		
Soft costs			
Planning	0,05		
Installation work	0,36		
Shipping and travel expenses to customer	0,05		
Permits and commissioning (i.e.	0,05		

cost for electrician, etc.)			
Project margin	0,29		
Subtotal Soft costs	**0,8**		
Total (excluding VAT)	**1,45**		
Average VAT	0,35		
Total (including VAT)	**1,8**		

(Rutovitz, 2012) Jay Rutovitz, Steve Harris, Calculating Global Energy Sector Jobs: 2012 Methodology, University of Technology Sydney, Australia, 2012.

2.4 Financial Parameters and specific financing programs

The parameters for different financing schemes for PV in Finland are presented in Table 13. The banks will usually finance residential rooftop PV systems with home loans. Thus, the interest rate of these loads is as low as 0–2 %. MuniFin is a funding organization for the Finnish public sector. It provides Green Bond loans and leasing for municipalities with interest rates around 1–2 % for PV system with the financing duration from 5 to 41 years. For private companies, the cost of loan is far higher than for house owners of municipalities.

Table 12: PV financing information in 2019

Different market segments	Loan rate [%]
Average rate of loans – residential installations	0–2 % can be financed with home loans
Average rate of loans – commercial installations	1–2 % loans and leasing for municipalities, higher for private-owned companies
Average cost of capital – industrial and ground-mounted installations	No information available

2.5 Specific investments programs

In Finland, there are several funding options for investments in PV plants or PV electricity (Table 14). Several companies offer the third-party ownership. The contract may include the selling of electricity from a rooftop PV plant to local consumption with a fixed price and fixed time (PPA). Panel rental services are provided for instance by energy companies like Helen. They offer their customers the rental of a PV panel at a fixed monthly price. The value of electricity produced by the panel is deduced from the energy bill of the customer. Energy valuation is based on the electricity market Nord Pool Finland area spot price. Several utilities provide different financing solutions for a PV system investment. There are also crowdfunding companies funding solar PV installations.

Table 13: Summary of existing investment schemes

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

2.6 Additional Country information

The Statistics Finland database was used as a source for electricity prices. Household electricity prices include transmission, distribution, electricity tax, levies and VAT (24 %) The prices are for September 2019. Commercial company and industrial company prices include transmission/distribution, electricity tax and levies. The class 1 electricity tax (2,253 €$_{cent}$/kWh VAT 0%) is assumed for households and commercial companies and class 2 (0,703 €$_{cent}$/kWh VAT 0%) for industrial manufacturing companies. The country information is presented in Table 15.

Table 14: Country information

Retail electricity prices for a household [€$_{cent}$/kWh]	13,9-21,9			
Retail electricity prices for a commercial company [€$_{cent}$/kWh]	11-12,3			
Retail electricity prices for an industrial company [€$_{cent}$/kWh]	7,4-9			
Population at the end of 2019	5 521 158			
Country size [km^2]	390 908			
Average PV yield in [kWh/kW]	800-950			
Name and market share of major electric utilities. In Finland, the electricity production and distribution businesses are separated into different companies.		Electricity production [%]	Share of grid Subscribers [%]	Number of retail customers [%]
	Caruna Oy	0	18,9	681 717
	Elenia Oy	0	11,9	429 354
	Helen Sähköverkko Oy	0	10,8	389 094

3 POLICY FRAMEWORK

This chapter describes the support policies aiming directly or indirectly to drive the development of PV. Direct support policies have a direct influence on PV development by incentivizing or simplifying or defining adequate policies. Indirect support policies change the regulatory environment in a way that can push PV development. An overview of active PV support measures is presented in Table 16.

Table 15: Summary of PV support measures

Category	Residential		Commercial + Industrial		Centralized	
Measures in 2019	**On-going**	**New**	**On-going**	**New**	**On-going**	**New**
Feed-in tariffs	-	-	-	-	-	-
Feed-in premium (above market price)	-	-	-	-	-	-
Capital subsidies	-	-	Yes	-	Yes	-
Green certificates	-	-	Yes	-	Yes	-
Renewable portfolio standards with/without PV requirements	-	-	-	-	-	-
Income tax credits	Yes	-	-	-	-	-
Self-consumption	Yes	-	Yes	-	-	-
Net-metering	-	-	-	-	-	-
Net-billing	Yes	-	Yes	-	-	-
Collective self-consumption and virtual net-metering	-	-	-	-	-	-
Commercial bank activities e.g. green mortgages promoting PV	-	-	Yes	-	Yes	-
Activities of electricity utility businesses	Yes	-	-	-	-	-
Sustainable building requirements	Yes	-	Yes	-	-	-
BIPV incentives	-	-	-	-	-	-

3.1 National targets for PV

There are currently no official national targets set for the solar PV capacity in Finland. However, in National Energy and Climate Plant of Finland PV capacity of 1200 MW at 2030 is estimated for the Finland (NCEP, 2019).

(NCEP, 2019) Finland's Integrated Energy and Climate Plan, 20.12.2019. Available at: http://julkaisut.valtioneuvosto.fi/handle/10024/161977

3.2 Direct support policies for PV installations

3.2.1 Capital subsidies for companies, communities and other organizations

The Ministry of Economic Affairs and Employment grants investment support/energy aid for the renewable energy production. This energy support is particularly intended for the promoting, introduction and the market launch of new energy technologies. In 2019, the Ministry has granted a 20 % investment subsidy of the total costs of grid-connected PV projects. Companies, communities and other organizations are eligible for the support. Business Finland (www.businessfinland.fi) evaluates the subsidy applications and makes the decisions. The investment subsidy has been probably the most effective tool to increase the number of commercial and industrial-size solar PV investments for self-consumption in Finland. However, its' significance is decreasing due decreasing subsidy level as well as decreasing PV system prices.

3.2.2 Guarantees of origin

Guarantees of origin are certificates, which guarantee that the sold electricity is produced from renewable energy sources. The electricity sales company marketing renewable energy has to be able to guarantee the origin of electricity. The nation-wide electric system operator Fingrid maintains the registry for the certificates. The system started on 1 January 2015. Guarantees of origin are granted as a blocks of MWhs. Hence, the system is not practical nor cost-efficient for residential solar PV.

3.2.3 BIPV development measures

There are currently no specific measures promoting the building of building-integrated solar PV systems. PV electricity can be used to improve the energy class of a building (e.g. BAPV or BIPV). There are two conditions: 1) PV systems have to be installed either on the building or on the same property and 2) only the proportion of electric energy that is used in the building can be taken into account. The sold electric energy does not affect the energy class.

3.3 Self-consumption measures

The self-consumption measures in Finland are presented in Table 17.

Table 16: Summary of self-consumption regulations for small private PV systems in 2019

PV self-consumption	1	Right to self-consume	Yes
	2	Revenues from self-consumed PV	Savings on the variable or fixed retail price of electricity from the grid.

	3	Charges to finance Transmission, Distribution grids & Renewable Levies	No
Excess PV electricity	4	Revenues from excess PV electricity injected into the grid	Yes, depends on contract: 1) Electrical energy price (typically SPOT)– commission 2) Fixed energy price
	5	Maximum timeframe for compensation of fluxes	Real-time, mostly measurement of energy from individual phases, hourly net metering will be regulated during 2020 and implemented by 2022.
	6	Geographical compensation (virtual self-consumption or metering)	On site only
Other characteristics	7	Regulatory scheme duration	Unlimited
	8	Third party ownership accepted	Yes
	9	Grid codes and/or additional taxes/fees impacting the revenues of the prosumer	German VDE-AR-N 4015 2018-11 grid code generally accepted, no additional requirements
	10	Regulations on enablers of self-consumption (storage, DSM…)	No
	11	PV system size limitations	Exemption of electricity tax, when When S_N < 100 kVA or E_a < 800 MWh/a. In addition, the maximum allowable size depends on the dimensioning of the electricity supply.
	12	Electricity system limitations	No
	13	Additional features	No

3.3.1 Support to PV electricity self-consumption

Self-consumption of PV electricity is allowed in Finland. However, the current net-metering scheme is real-time, and the majority of installed electricity meters do not either net-meter between phases. A regulation change enabling hourly-based net-metering for prosumers is currently prepared by the Government of Finland. The change be included in the regulation concerning the settlement and measurement of electricity supplies. The regulation change will be potentially accepted in 2020. There will be a transition period of two years to distribution companies to enable the hourly net-metering for prosumers.

In the case of individuals, both the consumption and generation of electricity are metered with the same energy meter owned by the electricity distribution company. Most electrical energy companies offer two-way electric energy contracts for the prosumers. Owning of a PV system is not regarded as a business activity (1535/1992, TVL). Individuals can produce electricity for their own household use without paying taxes. It is also considered that the occasional sales of the surplus electricity do not generate taxable income.

Electricity generation with the nameplate power of less than 100 kVA is exempted from the electricity tax. The tax exemption is also valid for larger plants (100 kVA–2 MVA), if the yearly electricity generation is less than 800 MWh. Thus, PV plants with an installed capacity of less than 900 kW are practically exempted of electricity tax.

3.4 Collective self-consumption, community solar and similar measures

The collective self-consumption of energy communities will be potentially enabled by a regulation change during the year 2020. It will make possible the collective self-consumption in multi-dwelling buildings, such as in apartment flats and row houses. The change will be included in regulation concerning the settlement and measurement of electricity supplies. There will be a transition period of two years to electricity distribution companies to make the required changes to their electricity measurement data collection systems.

3.5 Tenders, auctions & similar schemes

3.5.1 Renewable electricity feed-in premium

In autumn 2018 the Energy Authority arranged a technology neutral premium auction for new renewable electricity production including technologies: wind, solar, biomass, biogas and wave power. The premium will be paid for a 12 years and the total subsidised electricity production can be up to 1.4 TWh. Based on the auction seven wind power projects were selected. The average subsidy level of accepted bids was 2.5 €/MWh. Currently, there are no plans about further auctions in the future.

3.6 Other utility-scale measures including floating and agricultural PV

3.6.1 Capital subsidies for agricultural sector

For the agricultural sector, an investment subsidy is also available for renewable energy production from the Finnish Food Authority (www.ruokavirasto.fi). The subsidy was 40 % of the total investment costs in 2019 without VAT. The minimum applied subsidy has to be 7000 €. The investment subsidy decisions are made based on applications. Only the proportion of the investment used in agricultural production is eligible for investment support.

3.7 Social Policies

There are no this kind of support measures.

3.8 Retrospective measures applied to PV

There are no measures affecting negatively to the profitability to previously installed solar PV plants.

3.9 Indirect policy issues

3.9.1 Rural electrification measures

There are no such measures, as almost all permanently inhabited buildings are electrified already.

3.9.2 Support for electricity storage and demand response measures

There are no specific support schemes for energy storages. Instead, an energy investment subsidy of the Ministry of Economic Affairs and Employment, granted by Business Finland, can be applied also for energy storage projects. In order to be eligible for the support, the project has to include also renewable energy production. The Finnish electricity transmission system operator Fingrid has a marketplace for reserve and regulating power. For example, demand side management can participate in eight different marketplaces.

3.9.3 Support for electric vehicles (and VIPV)

The Finnish Transport and Communications Agency (www.traficom.fi) grants investment subsidy of 2000 € for individuals for buying a fully electric car. The car eligible to receive the support has to be for a personal use, and the total cost of the car, including VAT and vehicle tax, has to be less than 50 000 €. The investment subsidy is valid for the years 2018–21.

3.9.4 Curtailment policies

Currently, there is no curtailment policies in Finland.

3.9.5 Other support measures

Currently, there are few policy initiatives that might rapidly influence the PV installation rates in Finland. For consumers, the ongoing implementation of hourly net-metering and self-consumption for energy communities would potentially have further effects on the installation rates especially in residential sector. Especially, the latter will potentially increase both the number of installations and PV plant sizes especially in apartment flats and row houses.

3.10 Financing and cost of support measures

Financially, the main cost elements of PV support measures are investment subsidies granted by the Business Finland and the Finnish Food Authority, and tax breaks granted to individual persons for the PV system installation work. All the incentives are paid from state taxes. The direct cost of investment subsidies granted by Business Finland were 13.2 M€ for around 500 PV installations.

4 INDUSTRY

4.1 Production of feedstocks, ingots and wafers (crystalline silicon industry)

There is no manufacturing of silicon feedstock, ingots or wafers for solar PV in Finland (Table 18).

Table 17: Silicon feedstock, ingot and wafer producer's production information for 2019

Manufacturers	Process & technology	Total Production	Product destination	Price
None	Silicon feedstock [Tonnes]	0		
None	sc-Si ingots. [Tonnes]	0		
None	mc-Si ingots [Tonnes]	0		
None	sc-Si wafers [MW]	0		
None	mc-Si wafers [MW]	0		

4.2 Production of photovoltaic cells and modules

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

There are two companies owning a PV module manufacturing line in Finland, Valoe Oy (www.valoe.com) in Mikkeli and Salo Tech Oy (http://www.arevasolar.fi/fi/salosolar) in Salo. The modules produced by Valoe are of back contact type. Both companies produce c-Si modules. The total production capacity in 2019 was estimated to be 30 MW and the produced capacity around 7 MW in 2019. The total PV cell and module manufacture together with the production capacity information is given in Table 19 below.

Total PV cell and module manufacture together with production capacity information is summarised in Table 19 below.

Table 18: PV cell and module production and production capacity information for 2019

Cell/Module manufacturer	Technology (sc-Si, mc-Si, a-Si, CdTe, CIGS)	Total Production [MW]		Maximum production capacity [MW/yr]	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
Salo Tech Oy	Sc-Si/mc-Si		6		10*
Valoe Oy	Sc-Si/mc-Si		1*		20*
Thin film manufacturers					
None					
Cells for concentration					
None					
Totals			**7**		**30***

*The given numbers are estimates.

4.3 Manufacturers and suppliers of other components

The listing below covers the main companies manufacturing PV systems or related components in Finland. The list is not necessarily complete. Please contact the author of this report if something relevant is missing. The company listing will be updated for the report of year 2020.

Ampner Oy develops and manufactures high-power solar PV string inverters.

ABB Oy develops and manufactres special transformers, protective relays, contactors, as well as control, monitoring and automation products for electricity distribution grids are developed and manufactured in Vaasa.

Beneq Oy provides technology for ALD (Atomic Layer Deposition) that can be used both in crystalline and thin film solar cells.

Danfoss Oy is located in Vaasa, Lappeenranta and Tampere. It is a frequency converter manufacturer. It produces power electronics mainly for electric transport purposes.

Endeas Oy is located in Espoo. It provides solar photovoltaic measurement and simulation systems.

Ensto Oy manufactures different enclosing solutions such as combiner and junction boxes for solar PV applications.

Fimer Oy bought the solar PV inverter business from ABB in 2019. The R&D of solar PV inverters is continuing in Finland.

Finnwind Oy is located in Lempäälä. In addition to selling and planning turnkey PV systems, it sells and manufactures mounting systems for PV modules.

Glaston Oy is located in Tampere, and it delivers machines and services globally for the production off heat-treated glass for solar PV and CSP solutions.

GreenEnergy Finland Oy is located in Lappeenranta. It is a developer and manufacturer of systems for the optimization of self-consumption of PV electricity and electric energy storage systems. They also develop mounting systems for rooftop PV modules.

Luvata Oy manufactures copper-based flat wire used to connect silicon cells electrically and to carry current in crystalline silicon and thin-film photovoltaic modules.

Naps Solar Systems Oy manufactures complete off-grid PV systems consisting of solar modules, control units, batteries and all necessary accessories.

Orima Oy manufactures mounting systems for rooftop solar PV modules.

Ruukki Oy is currently a part of the steel company SSAB. It provides facade mounting systems for solar PV.

SOLA Sense Oy provides solutions for optimization and monitoring of solar power plants.

Wartsila Oy is located in Vaasa. The company develops and provides diesel/gas engine and solar PV hybrid power plants on a MW scale.

Yaskawa Oy is located in Vaasa and Lappeenranta. Its main products are generators and power electronics for wind turbines. However, they also provide inverters for utility-scale PV plants.

5 PV IN THE ECONOMY

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

5.1 Labour places

The estimated PV-related labour places in Finland in 2019 are presented in Table 20. There are no official figures available, and thus, the uncertainty in the estimates is high.

Table 19: Estimated PV-related full-time labour places in 2019

Market category	Number of full-time labour places
Research and development (not including companies)	100
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	150
Distributors of PV products	50
System and installation companies	200
Electricity utility businesses and government	50
Other	50
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	50
Total	**600**

5.2 Business value

The value of PV business in Finland in 2018 is estimated in Table 21. The uncertainties of the given estimates are at least ±20 %.

Table 20: Rough estimation of the value of the PV business in 2019 (VAT is excluded)

Sub-market	Capacity installed [MW]	Average price [€/W]	Value [€]	Sub-market [€]
Off-grid	0,3	4	1 200 000	1 200 000
Grid-connected distributed	80,4	1,1	80 400 000	88 440 000
Grid-connected centralized	0	0	0	0
Value of PV business in 2019				89 640 000

6 INTEREST FROM ELECTRICITY STAKEHOLDERS

6.1 Structure of the electricity system

Currently, the Finnish power system consists of power plants, the nationwide transmission grid, regional networks, distribution networks and electricity end-users. The Finnish power system belongs to the inter-Nordic power system together with power systems in Sweden, Norway and Eastern Denmark. In addition, there are direct-current transmission links from Finland to the Russian and Estonian power systems. These power systems are managed separately from the inter-Nordic power system. Correspondingly, the inter-Nordic power system is connected to Continental Europe by DC links.

The backbone of the Finnish power systems is the nationwide transmission grid. It is a high-voltage network, which covers the whole of Finland and consists of 4600 km of 400 kV lines, 2200 km of 220 kV lines, 7600 km of 110 kV lines and 116 substations. The largest power plants, industrial plants and regional electricity distribution networks are connected to the transmission grid. The transmission grid is managed by Fingrid. The State of Finland is the main owner of Fingrid with 53 % ownership. The transmission grid serves electricity producers and consumers enabling electricity trading at the inter-Nordic power system level. The majority of electricity consumed in Finland is transmitted through the transmission grid. In addition to the ownership, Fingrid is responsible for the system supervision, operation planning, balance services, grid maintenance, construction and development, and promotion of the electricity market. (Fingrid, 2020)

The electricity distribution networks, local and regional, are owned both by municipal and private utility companies. The number of distribution networks is 77. Each distribution system operator has a license to operate alone in a certain area. Being monopolies, their operation is monitored and regulated by the Energy Authority. The electricity trading companies are separated from the electricity distribution companies. The Finnish electricity market was deregulated in 1995. Each electricity consumer is free to select the electricity provider. Currently, all electricity users have remotely read hourly-basis electric energy meters. The hourly system price of electricity is formed day-ahead based on supply and demand in the Nordic power market Nord Pool. Because of bottlenecks in power transmission capacities, there are several price areas. Hence, the area prices may differ from each other.

(Fingrid, 2020) The Power System of Finland, available at: https://www.fingrid.fi/en/grid/power-transmission/electricity-system-of-finland/

6.2 Interest from electricity utility businesses

Several utility companies have started to sell and install turnkey PV systems as a product for residential houses and commercial buildings with different funding options. They either make the installations by themselves or have contracts with installation companies. The majority of utility companies have announced offers to buy surplus electricity from micro-PV plants. In general, the utilities pay the Nord Pool Spot Finland area price of the surplus electricity without VAT 24 %, which is roughly one-third of the retail electricity price.

6.3 Interest from municipalities and local governments

Several municipalities have installed PV systems of their own and are, for example, planning new housing areas so that roofs will be aligned towards south and there are no shadowing

obstacles. There is also a Finnish project Carbon Neutral Municipalities (http://www.hinku-foorumi.fi/en-US), which is coordinated by the Finnish Environment Institute. The municipalities involved in the project are committed to large CO2 emissions reductions. Tools for this are, for example, promotion of PV installations in the area of the municipality, removal of recognized regulatory barriers, provision of rooftop solar potential map services, and installation of PV systems on buildings owned by the municipality.

7 HIGHLIGHTS AND PROSPECTS

7.1 Highlights

- The grid-connected solar PV capacity in Finland increased around 60 % between the years 2018-2019 reaching the capacity of more than 200 MW.
- The number of grid-connected solar PV plants in Finland is between 20 000 – 25 000.

7.2 Prospects

Solar PV is profitable in Finland in buildings where majority of generated electricity can be used for the self-consumption. These are, for example, commercial buildings, offices, public buildings and agricultural buildings. In Finland, the utility-scale solar PV is currently the second least cost option for the new power generation after the wind power. Thus, we will potentially see also the first utility-scale solar PV plant in Finland within the coming years.

Currently the Finnish regulation is being adjusted to allow energy communities. This will improve the profitability of solar PV plants in multi-dwelling houses, such as apartment flats and row-houses. It will potentially increase the number of PV installations. With the same regulation adjustment, the status of individual prosumers will be improved from the current due to implementation of hourly electricity net-metering.