IEA INTERNATIONAL ENERGY AGENCY

LUT Lappeenranta University of Technology

IEA-PVPS

National Survey Report of Photovoltaic Applications in Finland 2017

PVPS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

Prepared by

Jero Ahola

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Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD) which carries out a comprehensive programme of energy co-operation among its member countries

The IEA Photovoltaic Power Systems Technology Collaboration Programme (IEA-PVPS) is one of the collaborative R & D agreements established within the IEA and, since 1993, its participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The participating countries and organisations can be found on the www.iea-pvps.org website.

The overall programme is headed by an Executive Committee composed of one representative from each participating country or organization, while the management of individual Tasks (research projects / activity areas) is the responsibility of Operating Agents. Information about the active and completed tasks can be found on the IEA-PVPS website www.iea-pvps.org

*Photo on the front cover of the report: solar power plant in Mikkeli, Finland; Etelä-Savon Energia Oy/Heidi Makkonen

Introduction

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 2017. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

The PVPS website www.iea-pvps.org also plays an important role in disseminating information arising from the programme, including national information.

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 2017 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2017, 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 a significant proportion 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 solar PV plant in Finland is a 3.6 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.

1.2 Total photovoltaic power installed

The official data of grid-connected PV electricity in Finland were collected from the grid companies by the Energy Authority. The total installed PV capacity was 80.4 MW by the end of the year 2017 with an increase of 43 MW from the year 2016 (Table 1). Of the total capacity, 69.8 MW is grid-connected and 10.6 MW off-grid installations. The distribution of installed capacity in the categories of residential, commercial and industrial installations is uncertain. However, according to an interview of a major PV installer in Finland, it can be estimated that around 30 % of the capacity is covered by residential, 35 % commercial and 35 % industrial installations. This is used as a basis of the division presented in Table 1. Information about the data collection process is given in Table 2, about PV power in the broader national energy market in Table 3, additional information in Table 4, and about cumulative installed PV power in four sub-markets in Table 5. The total number of PV power plants in Finland is estimated to be around 7000.

Table 1: PV power installed during calendar year 2017

AC			**MW installed in 2017**	**MW installed in 2017**	**AC or DC**
Grid-connected	BAPV	Residential	42.7	13	DC
		Commercial		14.9	DC
		Industrial		14.8	DC
	BIPV (if a specific legislation exists)	Residential	No legislation		DC
		Commercial			DC
		Industrial			DC
	Utility-scale	Ground-mounted	No utility solar PV power plants > 10 MWp in Finland		DC
		Floatting			DC

		Agricultural			DC
Off-grid		Residential (SHS)	0.3*		DC
		Other			DC
		Hybrid systems			DC
		Total	**43**		DC

*Mostly small off-grid PV systems in summer cottages, official statistics not available. It is estimated by a major PV installer in Finland that the capacity of domestic stand-alone PV systems sold yearly is around 300 kW.

Table 2: 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)	Collected by the Energy Authority, www.energiavirasto.fi
	The data are collected with a yearly survey to grid companies by the Energy Authority.

Table 3: PV power and the broader national energy market.

MW-GW for capacities and GWh-TWh for energy	**2017 numbers**	**2016 numbers**
Total power generation capacities (all technologies)	15.98 GW	16.21 GW
Total power generation capacities (renewables including hydropower)	N/A	N/A
Total electricity demand (= consumption)	85.5 TWh	85.1 TWh
Total energy demand (= final consumption)	377 TWh	378 TWh
New power generation capacities installed during the year (all technologies)		
New power generation capacities installed during the year (renewables including hydropower)	Wind power: +516 MW[1]	Wind power: +570 MW[2]

[1] Tuulivoimayhdistys, available at: http://www.tuulivoimayhdistys.fi/filebank/1014-STY_-_Vuosiraportti_2017_23_1_.pdf , accessed 12 June 2018.

[2] Tuulivoimayhdistys, available at: http://www.tuulivoimayhdistys.fi/tietoa-tuulivoimasta/tietoa-tuulivoimasta/tuulivoima-suomessa-ja-maailmalla/tuulivoima-suomessa , accessed 26 August 2017

Total PV electricity production in GWh-TWh	66 GWh	30 GWh
Total PV electricity production as a % of total electricity consumption	0.08 %	0.035 %

Table 4: Other information

	2017 Numbers
Number of PV systems in operation in your country (a split per market segment is interesting)	Total number approximately 7000. Mostly domestic roof-top systems
Capacity of decommissioned PV systems during the year in MW	potentially insignificant
Total capacity connected to the low voltage distribution grid in MW	~65 MW
Total capacity connected to the medium voltage distribution grid in MW	~5 MW
Total capacity connected to the high voltage transmission grid in MW	0

Table 5: The cumulative installed PV power in four sub-markets (MWp)

Year	Off-grid (including large hybrids)	Grid-connected distributed (BAPV, BIPV)	Grid-connected centralized (Ground, floating, agricultural…)	Other uses (VIPV, wearables…)	Total
1992					
…					
2015	10*	10	0	0	20
2016	10.3*	27.1	0	0	37.4
2017	10.6*	69.8	0	0	80.4

*Mostly small off-grid PV systems in summer cottages, official statistics not available. It is estimated by a major PV installer in Finland that the capacity of domestic stand-alone PV systems sold yearly is around 300 kW.

1.3 Key enablers of PV development

Information on key enablers of PV development is presented in Table 6.

Table 6: information on key enablers

	Description	**Annual Volume (Units)**	**Total Volume (Units)**	**Source**
Decentralized storage systems	~5 MWh			
Residential Heat Pumps		60 000	600 000	Heat Pump Association of Finland www.sulpu.fi
Electric cars (and light weight)		705	1449	Finnish Transport Safety Agency www.trafi.fi
Electric buses/trucks			12	
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 2016 due to a decrease in global market prices. The module prices presented in Table 7 give the price of multiple panels typically delivered as a part of a PV system. The price data are given without VAT. The data were collected from the main system providers operating in Finland.

Table 7: Typical module prices for a number of years

Year	1992			2014	2015	2016	2017
Standard module crystalline silicon price(s): Typical [€/W]				0.85	0.65	0.55	0.45
Lowest prices [€/W]				0.65	0.6	0.5	0.4
Highest prices [€/W]				1	0.7	0.65	0.55

2.2 System prices

The turnkey price intervals (excluding VAT) collected from three major PV systems providers operating in Finland are presented in Table 8. The prices represent the situation at the end of 2017. The prices do not include permitting costs; however, it is probably a relevant system cost contributor 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. The average trends of system prices (excluding VAT) are illustrated in Table 9. Only some ground-mounted systems have been built with an investment support, but they are still smaller than 10 MW.

Table 8: **Turnkey Prices of Typical Applications – local currency**

Category/Size	Typical applications and brief details	Current prices [€/W]
OFF-GRID Up to 1 kW (SHS)	Typically PV systems that are installed in boats, caravans, summer cottages and include lead-acid batteries.	5
OFF-GRID > MW scale	No MW-scale off-grid plants in Finland.	No plants
Grid-connected Rooftop up to 5-10 kW (residential BAPV)	Systems installed in grid-connected houses for self-consumption. These plants are typically roof-mounted.	1.2-1.8
Grid-connected Rooftop from 10 to 250 kW (commercial BAPV)	Systems installed to produce electricity for the self-consumption of commercial buildings, offices and public buildings.	0.9-1.15
Grid-connected Rooftop above 250 kW (industrial BAPV)	Systems installed to produce electricity for self-consumption in industrial sites or large commercial buildings.	0.85-1.15
Grid-connected Ground-mounted above 10 MW	Utility-scale PV plants that generate electricity to be sold in electricity markets. No > 10 MW plants installed in Finland yet. The numbers represent the estimated price window.	0.9-1.1
Other category (hybrid diesel-PV, hybrid with battery…)		No data

Floating PV		No plants
Agricultural PV		No data
Residential BIPV (tiles, or complete roof).		No data
Industrial BIPV		No data

Table 9: National trends in system prices (current) for different applications – local currency

Price €/Wp	2014	2015	2016	2017
Residential PV systems < 5-10 KW	1.5-1.8	1.45-1.75	1.3-2	1.2-1.8
Commercial and industrial BAPV	1.25-1.5	1.05-1.4	0.95-1.35	0.85-1.15
Ground-mounted > 10 MW	N/A	1.1-1.3*	1-1.2*	0.9-1.1*

*) There are no 10 MW ground-mounted PV plants in Finland. The given intervals are estimates given by PV installers.

2.3 Cost breakdown of PV installations

The cost breakdown (VAT 0%) of a residential PV system in Table 10 was produced as follows. First, the system size was defined to be close to 10 kW. Next, the component prices and the amount of installation work were discussed with system providers. Based on these discussions, the low-, average- and high-price cases were defined. The cost of installation work to the employer was estimated to be 23 €/h*1.5 = 35 €/h. The amount of installation work was estimated to be 2, 2.5 and 3 h/module depending on the case (low, average and high). Even lower values, such as 1–2 h/module, were mentioned in the discussions with a PV system provider, but they only cover the installation. In the literature[3], the employment effect of a PV installation was estimated to be 11 person-years/installed MW of PV. This values around 4 h/module for work. However, there will always be working hours of installation staff that cannot be charged directly from the customer and that are included in the customer acquisition work.

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, installation type and location. However, the general trend in Finland is that the costs of permitting are decreasing. The cost of announcement was estimated to be 400 € (average case) and 600 € for a building permit (high case). The profit was assumed to be 15 % both for the system components and work. 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 in Table 12.

2.3.1 Residential PV System < 5-10 kW

Table 10: Cost breakdown for a residential PV system – [€/W]

[3] Jay Rutovitz, Steve Harris, Calculating Global Energy Sector Jobs: 2012 Methodology, University of Technology Sydney, Australia, 2012.

Cost category	Average [€/W]	Low [€/W]	High [€/W]
Hardware			
Module	0.45	0.4	0.55
Inverter	0.18	0.15	0.21
Other (racking, wiring…)	0.19	0.13	0.27
Soft costs			
Installation	0.32	0.26	0.39
Customer Acquisition	0.15	0.15	0.15
Profit	0.11	0.09	0.14
Other (permitting, contracting, financing…)	0.04	0	0.07
Subtotal Hardware	1.14	0.94	1.42
Subtotal Soft costs	0.3	0.24	0.36
Total	1.45	1.18	1.78

2.3.2 Utility-scale PV systems > 10 MW

There are currently no PV plants with a capacity higher than 10 MW in Finland.

Table 11: Cost breakdown for an utility-scale PV system – [€/W]

Cost category	Average [€/W]	Low [€/W]	High [€/W]
Hardware			
Module			
Inverter			
Other (racking, wiring, etc.)			
Soft cost			
Installation Labour			
Customer acquisition			
Profit			
Other (contracting, permitting, financing etc.)			
Subtotal Hardware			
Subtotal - Soft cost			
Total Installed Cost			

2.4 Financial Parameters and specific financing programs

The parameters for different financing schemes for PV in Finland are presented in Table 12. 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[4] is a funding organization for the Finnish public sector. It provides loans and leasing for municipalities with interest rates around 1–2 % for PV system financing and leasing. For private companies, the cost of loans is far higher than for house owners of municipalities.

Table 12: PV financing scheme

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 companies
Average cost of capital – industrial and ground-mounted installations	Estimate not available

2.5 Specific investments programs

In Finland, there are several funding options for investments in PV plants or PV electricity (Table 13). The third-party ownership is offered by several companies. The contract may include the selling of electricity from a rooftop PV plant to local consumption with a fixed price and fixed time period (PPA). Panel rental services are provided for instance by energy companies like Helen and KSS Energia. 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 spot price. Several utilities provide financing for a PV system investment. There are also crowdfunding companies, such as Joukon voima and Solarvoima, which are also funding solar PV installations.

Table 13: Specific investment programs

Third Party Ownership (no investment)	Yes
Renting	Yes
Leasing	Yes
Financing through utilities	Yes
Investment in PV plants against free electricity	No
Crowdfunding (investment in PV plants)	Yes
Community solar	No
Other (please specify)	

2.6 Additional Country information

The Energy Authority was used as a source for the retail electricity prices[5]. Household electricity prices include transmission, distribution, electricity tax, levies and VAT. Commercial company and industrial company prices include transmission/distribution, electricity tax and levies. The class 1 electricity tax

[4] Municipality Finance, available at: https://www.munifin.fi/ , accessed 20 June 2018.

[5] Electricity prices, Energy Authority, www.energiavirasto.fi

(2.253 €cent/kWh VAT 0%) is assumed for households and commercial companies and class 2 (0.703 €cent/kWh VAT 0%) for industrial companies. The country information is presented in Table 14.

Table 14: Country information[6]

Retail Electricity Prices for a household (range)	12.4-19.5 €cent/kWh
Retail Electricity Prices for a commercial company (range)	9.9-10.6 €cent/kWh
Retail Electricity Prices for an industrial company (range)	7.5-7.7 €cent/kWh
Population at the end of 2017 (or latest known)	5 505 575
Country size (km^2)	390 903 km^2
Average PV yield (according to the current PV development in the country) in kWh/kWp	800-950 kWh/kWp
Name and market share of major electric utilities.	The largest electricity distribution companies, proportion of customers (total 3.4 million): Caruna Oy, 19%, Elenia Oy, 12 %, Helen Sähköverkko Oy, 11%

3 POLICY FRAMEWORK

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

3.1 Direct support policies for PV installations

There are currently no official national targets set for the solar PV capacity in Finland. An overview of active PV support measures is presented in Table 15.

3.1.1 New, existing or phased-out measures in 2017

3.1.1.1 Climate change Commitments

Finland is committed to COP21 targets. However, it has no impact on solar PV measures so far.

3.1.1.2 Description of support measures (excluding BIPV, VIPV and rural electrification)

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 promoting the introduction and market launch of new energy technologies[7]. So far, the Ministry has granted a 25 % investment subsidy of the total costs of grid-connected PV projects. Companies, communities and other organizations are eligible for the support.

Tax credit for prosumers

Individual persons may get a tax credit for the work cost component of the PV system. The sum is 45 % of the total work cost including taxes. The maximum tax credit for a person is 2400 €/a. It is subtracted directly from the amount of taxes that has to be paid. The tax credit can be applied only when the PV installation is made as a retrofit to an existing building.

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 net-meter between phases. The hourly-based net-metering for individual consumers is under active discussion, and will possibly be implemented later. 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. Several energy companies offer two-way electric energy contracts for the prosumers.

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 freed from the electricity tax.

Owning of a PV system is not regarded as a business activity (1535/1992, TVL)[8]. Individuals can produce electricity for their own household use without paying taxes. For individual persons, the income from the surplus electricity sales is considered personal income. However, an individual person is able to subtract the depreciation and yearly system maintenance costs from the sales income. As a result, in most cases there will be no income from a rooftop PV system.

[7] Energy Support from the Ministry of Economic Affairs and Employment, available at http://tem.fi/en/energy-aid, accessed 20 June 2018

[8] Income tax law, available at: http://www.finlex.fi/fi/laki/ajantasa/1992/19921535, accessed 20 June 2018

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 registry for the certificates is maintained by the nation-wide system operator Fingrid. The system started on 1 January 2015. Guarantees of origin are granted as a blocks of MWhs. Hence, the system is not practical for micro-generation.

3.1.1.3 BIPV development measures

There are no specific BIPV support measures in Finland. 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.

3.1.1.4 Utility-scale measures including floating and agricultural PV

For the agricultural sector, an investment subsidy is also available for renewable energy production from the Agency for Rural Affairs[9]. The subsidy was 40 % of the total investment costs in 2018. The investment subsidy decisions are made based on applications. Only the proportion of the investment used in agricultural production is eligible for investment support.

3.1.1.5 Rural electrification measures

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

3.1.1.6 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 can be applied also for energy storage projects. The Finnish transmission system operator Fingrid has a marketplace for reserve and regulating power. Currently, demand side management can participate in eight different marketplaces[10].

3.1.1.7 Support for electric vehicles (and VIPV)

The government of Finland grants an investment subsidy of 2000 € for individuals 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.

[9] The Agency for Rural Affairs, available: http://www.mavi.fi/en/Pages/default.aspx accessed 20 June 2018.

[10] Fingrid marketplaces, available: https://www.fingrid.fi/en/electricity-market/demand-side-management/market-places/ accessed 20 June 2018.

Table 15: PV support measures (summary table)

	On-going measures residential	Measures that commenced during 2017 - residential	On-going measures Commercial + industrial	Measures that commenced during 2017 – commercial + industrial	On-going measures Ground-mounted	Measures that commenced during 2017 – ground-mounted
Feed-in tariffs	No	No	No	No	No	No
Feed-in premium (above market price)	No	No	No	No	No	No
Capital subsidies	No	No	Yes/ Investment subsidy 25%/40% applicable	No	Yes/ Investment subsidy 25%/40% applicable	No
Green certificates	No	No	No	No	No	No
Renewable portfolio standards (RPS) with/without PV requirements	No	No	No	No	No	No
Income tax credits	Yes/ 45% of work component	-	No	No	No	No
Self-consumption	Yes	-	Yes	-	Yes	-
Net-metering	No	No	No	No	No	No
Net-billing	Yes	-	Yes	-	No	No
Commercial bank activities e.g. green mortgages promoting PV	No	No	Yes/ MuniFin, green bond	No	Yes/ MuniFin Funding, green bond	
Activities of electricity utility businesses	Yes	Yes	No	No	No	No
Sustainable building requirements	Yes / Improves building energy class	No	Yes / Improves building energy class	No	No	No
BIPV incentives	No	No	No	No	No	No
Other	No	No	No	No	No	No

3.2 Self-consumption measures

The self-consumption measures in Finland are presented in Table 16.

Table 16: Self-Consumption Schemes

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	No
Excess PV electricity	4	Revenues from excess PV electricity injected into the grid	Depends on contract: 1) Electrical energy price (typically SPOT)– commission 2) Fixed energy price
	5	Maximum time frame for compensation of fluxes	Real-time, hourly net metering under discussion
	6	Geographical compensation	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 grid code generally accepted, no additional requirements
	10	Regulations on enablers of self-consumption (storage, DSM…)	Unlimited
	11	PV system size limitations	When S_N < 100 kVA or E_a < 800 kWh/a, exemption of electricity tax
	12	Electricity system limitations	No
	13	Additional features	No

3.3 Collective self-consumption, community solar and similar measures

There are also some pilot projects where virtual metering is tested mainly in apartment buildings. However, there are no official measures for collective self-consumption yet. The implementation of virtual metering requires changes to the legislation, where the electricity tax and its payment is defined.

3.4 Tenders, auctions & similar schemes

No governmental auctions or tender schemes have been arranged for solar PV in Finland. The new support system for renewable electricity currently in the parliamentary process will also be applicable

to solar PV. It will be a premium-based PPA auction arranged by the State of Finland. The objective is to build new electricity production from renewable energy sources with a target of 1.4 TWh/a. The premium will be funded from the tax revenues. The auction will be arranged in autumn 2018. The duration of the premium will be 12 years.

3.5 Financing and cost of support measures

Financially, the main cost elements of PV support measures are investment subsidies granted by the Ministry of Economic Affairs and Employment and the Agency for Rural Affairs, and tax breaks granted to individual persons for the PV system installation work. All the incentives are paid from state taxes. With 42.7 MW of new grid-connected PV capacity installed in 2017, the cost of all PV support measures was approximately 10 M€.

3.6 Indirect policy issues

Currently, there are few policy initiatives that might rapidly influence the PV installation rates in Finland. For consumers, the potential implementation of hourly net-metering and virtual metering would potentially have further effects on the installation rates.

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 17).

Table 17: Production information for the year for silicon feedstock, ingot and wafer producers

Manufacturers (or total national production)	Process & technology	Total Production	Product destination (if known)	Price (if known)
None	Silicon feedstock	tonnes		
None	sc-Si ingots	tonnes		
None	mc-Si ingots	tonnes		
None	sc-Si wafers	MW		
None	mc-Si wafers	MW		

4.2 Production of photovoltaic cells and modules (including TF and CPV)

Module manufacturing is defined as the industry where the process of the production of PV modules (the encapsulation) is carried out. 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[11] in Mikkeli and SaloSolar[12] in Salo. The modules produced by Valoe are of back contact type. Both companies produce mc-SI modules. The total production capacity in 2017 was estimated to be 20 MW and the produced capacity around 5.5 MW in 2017. The total PV cell and module manufacture together with the production capacity information is given in Table 18 below.

Table 18: Production and production capacity information for 2017

Cell/Module manufacturer (or total national production)	Technology (sc-Si, mc-Si, a-Si, CdTe)	Total Production (MW)		Maximum production capacity (MW/yr)	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
1 Salo Solar Oy			4.5		estimate 10
2 Valoe Oy			1 (estimate)		estimate 10
TOTALS			**5.5**		**20**

[11] Valoe Oy, available at: http://www.valoe.com/ , accessed 18 June 2018

[12] SaloSolar Oy, available at: http://www.arevasolar.fi/fi/salosolar , accessed 18 June 2018

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 2018.

ABB Oy

In Finland, ABB is one of the largest companies investing in R&D. For solar PV systems, ABB develops and produces utility-scale PV inverters in Helsinki. Correspondingly, 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

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

Endeas Oy

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

Ensto Oy

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

Finnwind Oy

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

Glaston Oy

The company 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

GreenEnergy Finland 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.

Luvata Oy

Luvata 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

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

Nocart Oy

Nocart is a manufacturer of off-grid hybrid PV-Wind power systems; the company is located in Lahti. The core competence of the company lies in their own power-electronics-based system, which enables the interconnection and optimization of power plants, batteries and consumption.

Ruukki Oy

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

Sola Sense Oy

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

TheSwitch Oy

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

Danfoss Oy

Danfoss is located in Vaasa, Lappeenranta and Tampere. It is a frequency converter manufacturer. It produces power electronics mainly for electric transport purposes. For example, they have a 50 kW power module that can be applied in integrated PV and battery plants.

Wartsila Oy

Wartsila is located in Vaasa. The company develops and provides diesel/gas engine and solar PV hybrid power plants on a MW scale. Wartsila has a strong vision on 100 % renewable electricity system powered mainly by solar and wind.

5 PV IN THE ECONOMY

The volume of PV installations in Finland is still low, but it is growing rapidly, employing more people. There are several companies working with power electronics systems for solar PV. It is probably the most significant individual PV-related employer in companies. The tasks include R&D and manufacturing.

5.1 Labour places

The estimated PV-related labour places in Finland in 2017 are presented in Table 19. There are no official figures available, and thus, the uncertainty in the estimates is high.

Table 19: Estimated PV-related labour places in 2017

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
Total	600

5.2 Business value

The value of PV business in Finland in 2017 is estimated in Table 20. It was difficult to even roughly approximate the export value of PV products, and thus, no value is given. The uncertainties of the given estimates are at least ±20 %.

Table 20: Value of PV business

Sub-market	**Capacity installed in 2017 (MW)**	**Price per W** *(from table 7)*	**Value**	**Totals**
Off-grid domestic	0.3	5	1.5 M€	
Off-grid non-domestic	-	-	-	
Grid-connected distributed	42.7	1.2	51.2 M€	
Grid-connected centralized				
				52.7 M€
Export of PV products (estimate: utility-scale solar inverters, off-grid systems, switch gears, etc)				no estimate
Change in stocks held				-
Import of PV products				30 M€
Value of PV business				**82.7 M€**

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.[13]

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.[13]

The electricity distribution networks, local and regional, are owned both by municipal and private utility companies. The number of distribution networks is around 80. 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 (Energiavirasto). The electricity trading companies (about 60–70) 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, practically 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.

6.2 Interest from electricity utility businesses

Several utility companies have started to market and install turnkey PV systems as a product for residential houses and commercial buildings. They either make the installations by themselves or have contracts with installation companies. In June 2017, 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[14] 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

[13] The power system in Finland, available at: https://www.fingrid.fi/en/grid/electricity-system-of-finland/, accessed 25 June 2018.

[14] Nordpool spot prices, available at: http://www.nordpoolspot.com/Market-data1/#/nordic/table, accessed 25 June 2018

committed to large CO_2 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

Some highlights of year 2017 in Finland related to Solar PV are listed below.

- The grid-grid-connected PV capacity increased by approximately 150 % from the year 2016. The installed capacity is expected to double also in 2018.
- So far, the largest PV plant in Finland (P_n = 3.6 MW) was invested by Nurmon Aurinko Oy in Nurmo. It is a ground-mounted fixed-tilt PV system.
- The main grocery chains in Finland, S-Ryhmä, Kesko Oy and Lidl Oy, announced plans to install rooftop solar PV on their stores.
- Several municipalities have plans to install solar PV on public buildings.