IEA INTERNATIONAL ENERGY AGENCY

LUT Lappeenranta University of Technology

National Survey Report of PV Power Applications in FINLAND

2016

PVPS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

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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 - PAF Head Office, Åland Islands, Finland, 2016. The photo is owned by Naps Solar Systems Oy

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 2016. 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 system 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 2016 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2016, 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 is electrified with an off-grid PV system capable of providing energy for lighting, refrigerators and consumer electronics. The amount of off-grid PV capacity in Finland is estimated to be around 10 MW with a yearly increase of 0.3 MW. Since 2010, the number of grid-connected PV systems has slowly started to increase. Currently, the market of the grid-connected systems outnumbers the market of off-grid systems. The grid-connected PV systems are mainly roof-mounted systems for public and commercial buildings and individual houses. Almost all systems are built for self-consumption of PV electricity.

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 grid-connected PV capacity was 27 MW by the end of the year 2016 (Table 1). In addition to this, approximately 10 MW of off-grid capacity is installed mainly in summer cottages. 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 40 % of the capacity is covered by residential, 30 % commercial and 30 % 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.

Table 1: PV power installed during calendar year 2016.

AC			**MW installed in 2016**	**MW installed in 2016**	**AC or DC**
Grid-connected	BAPV	Residential	16.1	6.1*	DC
		Commercial		5*	DC
		Industrial		5*	DC
	BIPV (if a specific legislation exists)	Residential	0	N/A	DC
		Commercial		N/A	DC
		Industrial		N/A	DC
	Ground-mounted	cSi and TF	1	1	DC
		CPV			
Off-grid		Residential	0.3*	N/A	DC
		Other		N/A	

	Hybrid systems		N/A	
	Total	17.4		DC

*Estimates by major PV installers in Finland.

Table 2: Data collection process:

If data are reported in AC, please mention a conversion coefficient to estimate DC installations.	Data is 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
	Additional comments on market and data collection, especially the estimated accuracy of data.

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

MW-GW for capacities and GWh-TWh for energy	2015 numbers	2016 numbers
Total power generation capacities (all technologies)	16.75 GW[1]	16.21 GW[1]
Total power generation capacities (renewables including hydropower)	N/A	N/A
Total electricity demand (= consumption)	82.5 TWh[2]	85.1 TWh[3]
New power generation capacities installed during the year (all technologies)	N/A	N/A
New power generation capacities installed during the year (renewables including hydropower)	Wind power: 379 MW	Wind power: 570 MW[4]
Total PV electricity production in GWh-TWh	15 GWh	30 GWh
Total PV electricity production as a % of total electricity consumption	0.02 %	0.035 %

[1] Statistics Finland, available at: http://pxweb2.stat.fi/sahkoiset_julkaisut/energia2015/html/suom0002.htm , accessed 26 June 2017.

[2] Statistics Finland, available at: http://tilastokeskus.fi/til/ehk/2015/04/ehk_2015_04_2016-03-23_tie_001_fi.html, accessed 3 May 2016.

[3] Finnish Energy, available at: https://energia.fi/ajankohtaista_ja_materiaalipankki/materiaalipankki/energiavuosi_2016_sahko_sahkonkaytto_kaantyi_nousuun.html , accessed 26 August 2017

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

Table 4: Other information

	2016 Numbers
Number of PV systems in operation in your country (a split per market segment is interesting)	N/A
Capacity of decommissioned PV systems during the year in MW	N/A, probably insignificant
Total capacity connected to the low voltage distribution grid in MW	26.4
Total capacity connected to the medium voltage distribution grid in MW	0.7
Total capacity connected to the high voltage transmission grid in MW	0

Table 5: The cumulative installed PV power in four sub-markets.

Sub-market	1992	1993									2015	2016
Stand-alone domestic											10*	10.3*
Stand-alone non-domestic											N/A	N/A
Grid-connected distributed											10	26.4
Grid-connected centralized											0	0.7
TOTAL (MW)											20	37.4

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

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 and Germany. However, there is also some module manufacturing capacity in Finland. The prices have declined from year 2014 probably due to an increase in the sales volume in Finland. The module prices presented in Table 6 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 system providers.

Table 6: Typical module prices for a number of years.

Year	1992				2014	2015	2016
Standard module crystalline silicon price(s): Typical					0.85	0.65	0.55
Lowest prices					0.65	0.6	0.5
Highest prices					1	0.7	0.65

2.2 System prices

For the time being, the PV system market volume in Finland is small. Therefore, there are still variations in system prices (excluding VAT) in all categories. In addition, the amount of required installation work and materials varies in rooftop installations causing a spread of costs. The turnkey price intervals collected from three major PV systems providers operating in Finland are presented in Table 7. The prices represent the situation at the end of 2016. The prices do not include permitting costs; however, it is probably a relevant system cost contributor in residential rooftop installations (P < 10 kW). The average trends of system prices are illustrated in Table 8.

Table 7: **Turnkey Prices of Typical Applications – local currency.**

Category/Size	Typical applications and brief details	Current prices per (€/Wp) VAT 0%
OFF-GRID Up to 1 kW	Typically PV systems that are installed in boats, caravans, summer cottages and include lead-acid batteries.	5
OFF-GRID >1 kW	Typically PV systems for summer cottages with lead-acid batteries.	3.5
Grid-connected Rooftop up to 10 kW (residential)	Systems installed in grid-connected houses for self-consumption. These plants are typically roof-mounted.	1.3-2
Grid-connected Rooftop from 10 to 250 kW (commercial)	Systems installed to produce electricity for the self-consumption of commercial buildings, offices and public buildings.	1.05-1.35
Grid-connected Rooftop above 250kW (industrial)	Systems installed to produce electricity for self-consumption in industrial sites or large commercial buildings.	0.95-1.3
Grid-connected Ground-mounted above 1 MW	Utility-scale PV plants that generate electricity to be sold in electricity markets. No > 1 MW plants installed in Finland yet. The numbers represent the estimated price window.	1-1.2
Other category (hybrid diesel-PV, hybrid with battery…)	N/A	N/A

Table 8: National trends in system prices (current) for different applications – local currency.

Price €/Wp	1992					2014	2015	2016
Residential PV systems, P < 10 kW						1.5-1.8	1.45-1.75	1.3-2
Commercial and industrial						1.25-1.5	1.05-1.4	0.95-1.35
Ground-mounted						N/A	1.1-1.3	1-1.2

2.3 Cost breakdown of PV installations

The cost breakdown (VAT 0%) of a residential PV system in Table 9 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 20 €/h*1.5 = 30 €/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 indicated in the discussions with a PV system provider, but they include only the installation. In the literature[5], 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, there will always be working hours of installation staff that cannot be charged from customers, such as design work and 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 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 the installation work. It was assumed to also include customer acquisition and marketing costs. So far, there are no utility-scale installations (*P* > 1MW) in Finland. Thus, the cost breakdown is not given for a utility-scale PV plant in Table 10.

2.3.1 Residential PV System P < 10 kW

Table 9: Cost breakdown for a residential PV system – local currency.

Cost category	Average (€/W)	Low (€/W)	High (€/W)
Hardware			
Module	0.55	0.5	0.65
Inverter	0.2	0.18	0.2
Other (racking, wiring…)	0.19	0.13	0.27
Soft costs			

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

Installation	0.29	0.24	0.42
Customer Acquisition	0.1	0.1	0.1
Profit	0.1	0.1	0.1
Other (permitting, contracting, financing…)	0.04	0	0.07
Subtotal Hardware	1.23	1.07	1.39
Subtotal Soft costs	0.24	0.2	0.27
Total	1.47	1.27	1.66

2.3.2 Utility-scale PV systems > 5 MW

There are currently no PV plants with a capacity higher than 5 MW in Finland.

Table 10: Cost breakdown for an utility-scale PV system – local currency.

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

2.4 Financial Parameters and specific financing programs

The parameters for different financing schemes for PV in Finland are presented in Table 11. 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[6] 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 (estimate 10 %) than for house owners of municipalities.

Table 11: PV financing scheme

Average rate of loans – residential installations	0–2 % can be financed with home loans
Average rate of loans – commercial installations	10 % private companies, 1–2 % loans and leasing for municipalities

[6] Municipality Finance, available at: https://www.munifin.fi/ , accessed 26 June 2017.

Average cost of capital – industrial and ground-mounted installations	N/A

2.5 Specific investment programs

Despite the still small PV market size in Finland, there are several funding options for investments in PV plants or PV electricity (Table 12). 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 utility 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. Some utilities such as Mäntsälän Sähkö, Lappeenrannan Energia, Etelä-Savon Energia 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 12: Summary of solar PV funding options.

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

2.6 Additional Country information

The Statistics Finland was used as a source for the retail electricity prices[7]. 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 country information is presented in Table 13.

Table 13: Country information.

Retail Electricity Prices for an household (range)	11.7-18.55 €cent/kWh
Retail Electricity Prices for a commercial company (range)	8.4-11.2 €cent/kWh
Retail Electricity Prices for an industrial company (range)	6.1-8.4 €cent/kWh
Population at the end of 2015 (or latest known)	5 504 913
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

[7] Electricity prices, available at: http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ene__ehi/050_ehi_tau_105_fi.px/?rxid=7c5be7b5-61a6-48ba-bee3-b43c4b9ec588 , accessed 26 June 2017

Name and market share of major electric utilities.	The largest electricity distribution companies, proportion of customers (total 3.4 million)[8]: Caruna Oy, 19%, Elenia Oy, 12 %, Helen Sähköverkko Oy, 11%

[8] Energy Authority, Sähköverkko tekniset tunnusluvut 2015, available at: https://www.energiavirasto.fi//sahkoverkkotoiminnan-tunnusluvut-vuodelta-2015 , accessed 26 August 2017.

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 the PV development by incentivizing, simplifying or defining adequate policies. Indirect support policies affect 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 targets set for the solar PV capacity in Finland. An overview of active PV support measures is presented in Table 14.

3.1.1 New, existing or phased-out measures in 2016

3.1.1.1 Description of support measures excluding BIPV 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[9]. 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.

Agricultural sites

For the agricultural sector, an investment subsidy is also available for renewable energy production from the Agency for Rural Affairs[10]. The subsidy was 40 % of the total investment costs in 2016. The investment subsidy decisions are made based on applications. Only the proportion of the investment used in agricultural production is eligible for investment 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. 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 liberated from the payment of electricity tax. The tax liberation is also valid for larger plants (100 kVA–2 MVA), if the yearly

[9] Energy Support from the Ministry of Economic Affairs and Employment, available at http://tem.fi/en/energy-aid, accessed 28 August 2017

[10] The Agency for Rural Affairs, available: http://www.mavi.fi/en/Pages/default.aspx accessed 26 August 2017.

electricity generation is less than 800 MWh. Thus, PV plants with an installed capacity of less than 900 kW are practically liberated from the electricity tax.

Owning of a PV system is not regarded as a business activity (1535/1992, TVL)[11]. 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.

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 high-voltage grid owner and operator Fingrid. The system started on 1 January 2015. Guarantees of origins are granted as a blocks of MWhs. Hence, the system is not practical for micro-generation.

3.1.1.2 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.

3.1.1.3 Rural electrification measures

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

3.1.1.4 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.

Table 14: PV support measures (summary table).

	On-going measures residential	Measures that commenced during 2016 - residential	On-going measures Commercial + industrial	Measures that commenced during 2016 – commercial + industrial	On-going measures Ground-mounted	Measures that commenced during 2016 – 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

[11] Income tax law, available at: http://www.finlex.fi/fi/laki/ajantasa/1992/19921535, accessed 2 June 2016

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 buildign 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

PV self-consumption measures in Finland are presented in Table 15.

Table 15: PV self-consumption measures.

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

There were no governmental auctions or tender schemes arranged in Finland in 2016.

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 17 MW of new PV capacity installed in 2016, the cost of all PV support measures was approximately 6 M€.

3.6 Indirect policy issues

Currently, there are not many 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 HIGHLIGHTS OF R&D

4.1 Highlights of R&D

The Finnish R&D on solar PV is made at several universities. Academic applied research related to solar systems, grid integration, power electronics, and condition monitoring is conducted at Aalto University, Lappeenranta University of Technology, Tampere University of Technology and at Metropolia, Satakunta and Turku Universities of Applied Sciences.

In addition, there is also active research on silicon solar cells at Aalto University, on high-efficiency multi-junction solar cells based on III–V semiconductors at Tampere University of Technology and on roll-to-roll printing or coating processes for photovoltaics at VTT Technical Research Centre of Finland. There are also research groups working on dye-sensitized solar cells (DSSC), OPV and ALD-technologies at Helsinki, Aalto and Jyväskylä Universities.

The research work in universities is mainly funded by the National Agency of Technology and Innovations (Tekes) and the Academy of Finland. Tekes also funds company-driven development and demonstration projects. The largest R&D company in the field of solar PV is ABB. Other major players are for instance Valoe (PV manufacturing lines, back contacts), Luvata (solar wires), Salo Solar (PV manufacturing), Danfoss (inverters) and Beneq (ALD passivation).

4.2 Public budgets for market stimulation, demonstration / field test programmes and R&D

There are no specific budget lines, allocations or programs for solar energy R&D&I in Finland. PV is funded as part of the quite open energy programmes. In year 2016, the public R&D&I spending on PV was estimated to be around 7.5 M€ (Table 14). The Academy of Finland is funding basic research, with an estimated annual contribution of around 0.5 M€, and Tekes, the Finnish Funding Agency for Innovation is funding applied research, innovation and demonstrations with around 7 M€. Investment support for commercial installations is provided by the Ministry of Economic Affairs and Employment, the total amount being 5 M€ in 2016.

Table 14: Public budgets for R&D, demonstration/field test programmes and market incentives.

	R & D	Demo/Field test
National/federal	6.5	1
State/regional	N/A	N/A
Total	7.5 M€	

5 INDUSTRY

5.1 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 15).

Table 15: Production information for the year 2016 for silicon feedstock, ingot and wafer producers.

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

5.2 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 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[12] in Mikkeli and SaloSolar[13] in Salo. The modules produced by Valoe are of back contact type. Both companies produce mc-SI modules. The total production capacity in 2016 was estimated to be 20 MW and the produced capacity around 5 MW in 2016. The total PV cell and module manufacture together with the production capacity information is given in Table 16 below.

Table 16: Production and production capacity information for 2016.

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		10
2 Valoe Oy			1 (est.)		10
TOTALS			**5**		**20**

[12] Valoe Oy, available at: http://www.valoe.com/ , accessed 26 June 2017

[13] SaloSolar Oy, available at: http://www.arevasolar.fi/fi/salosolar , accessed 26 June 2017

5.3 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 2017.

ABB Oy

In Finland, ABB is one of the largest companies investing in R&D. For solar PV systems, ABB develops and 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 globally machines and services 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.

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

TheSwitch 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.

Vacon Oy

Vacon is located in Vaasa, and is a frequency converter manufacturer. The company was bought by Danfoss in 2014. Vacon develops and manufactures utility-scale PV grid converters.

Visedo Oy

Visedo is located in Lappeenranta. It manufactures power electronics mainly for electric transport purposes. However, they have a 50 kW power module that can be applied in integrated PV and battery 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.

6 PV IN THE ECONOMY

The R&D and manufacturing of utility-scale PV inverters are the main employers in the field of PV in Finland. The employment in solar PV installations is growing rapidly; however, the number of installations is still low.

6.1 Labour places

The estimated PV-related labour places in Finland in 2016 are presented in Table 18. There are no official figures available, and thus, the uncertainty in the estimates is high.

Table 18: Estimated PV-related workplaces in 2016.

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	100
Electricity utility businesses and government	50
Other	50
Total	500

6.2 Business value

The value of PV business in Finland in 2016 is estimated in Table 18. 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 18: Value of PV business.

Sub-market	**Capacity installed *in 2016* (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	17.1	1.3	22.2 M€	
Grid-connected centralized				
				23.7 M€
Export of PV products (estimate: utility-scale solar inverters, off-grid systems, switch gears, etc)				N/A
Change in stocks held				-
Import of PV products				17 M€
Value of PV business				**40.7 M€**

7 INTEREST FROM ELECTRICITY STAKEHOLDERS

7.1 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.[14]

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 4500 km of 400 kV lines, 2300 km of 220 kV lines, 7500 km of 110 kV lines and 113 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 the 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.[14]

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 grid company 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 electricity retailing market Nord Pool. Because of bottlenecks in power transmission capacities, there are several price areas. Hence, the area prices may differ from each other.

7.2 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[15] of the surplus electricity without VAT 24 %, which is roughly one-third of the retail electricity price.

[14] The power system in Finland, available at: http://www.fingrid.fi/en/powersystem/general%20description/Power%20System%20in%20Finland/Pages/default.aspx, accessed 26 August 2017.

[15] Nordpool spot prices, available at: http://www.nordpoolspot.com/Market-data1/#/nordic/table, accessed 26 August 2016

7.3 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 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, providing rooftop solar potential map services, and installing PV systems on the buildings owned by the municipality.

8 HIGHLIGHTS AND PROSPECTS

Some highlights of year 2016 in Finland related to Solar PV are listed below.

- The installation rate of PV systems increased approximately by 300 % from the year 2015. A strong growth is also expected to continue in year 2017.
- So far, the largest PV plant in Finland (P_n = 900 kWp) was invested by Ruokakesko Oy in Turku. It is located on the rooftop of a supermarket.
- A special investment subsidy (30 %) “kärkihanke” by the Ministry of Economic Affairs and Employment was granted to two utility-scale PV plants. The first one is Nurmon Aurinko Oy, which is going the build a 6 MW PV plant, and the second one was granted to Lempäälän Energia Oy for a project, which includes a 4 MW plant. Both the projects are the first ones above 1 MW. The projects will be probably implemented during the years 2017–2018.