IEA INTERNATIONAL ENERGY AGENCY

LUT Lappeenranta University of Technology

National Survey Report of PV Power Applications in FINLAND 2015

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

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PVPS

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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

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 2015. 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 2015 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2015, 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. 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 are built for the self-consumption of PV electricity.

1.2 Total photovoltaic power installed

There are no official data about the PV capacity for year 2015 available yet. Instead, the installation data of grid-connected systems were collected from several sources. The main information source was the FinnSolar research project[1] providing a survey of the PV capacity in Finland at the end of year 2015. According to the survey, there was about 10 MW of grid-connected PV capacity, and the addition in 2015 was 5 MW (Table 1). Practically all installations are BAPV (Building Attached Photovoltaics). With the estimated off-grid capacity of 10 MW, the estimate is 20 MW for the total PV capacity in Finland. 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 40 % of the capacity is residential, 30 % commercial and 30 % industrial installations. This is used as a basis of division 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 2015.

AC			**MW installed in 2015 (mandatory)**	**MW installed in 2015 (optional but HIGHLY NEEDED)**	**AC or DC**
Grid-connected	BAPV	Residential	5	2	DC
		Commercial		1.5	DC
		Industrial		1.5	DC
	BIPV (if a specific legislation exists)	Residential	0	0	DC
		Commercial		0	DC
		Industrial		0	DC

[1] FinSolar research project, available at: http://www.finsolar.net/ , accessed 10.5.2016

	Ground-mounted	cSi and TF	0	0	DC
		CPV		0	DC
Off-grid		Residential	N/A	N/A	
		Other	N/A	N/A	
		Hybrid systems		N/A	
		Total	**5**		

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 carried out by an official body or a private company/Association?	The data are collected from several sources, media, experts, system providers and grid companies
Link to official statistics (if this exists)	N/A
	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	2014 numbers
Total power generation capacities (all technologies, nominal capacity)	16.75 GW[3]	17.14 GW[3]
Total power generation capacities (renewables including hydropower)	N/A	Total: 5572 MW ; Hydro: 3008 GW; Biomass-CHP (industry + municipalities): 1598 MW + 196 MW; Wind: 630 MW; Waste: 140 MW[3]
Total electricity demand (= consumption)	82.5 TWh[2]	83.3 TWh[3]
New power generation capacities installed during the year (all technologies, mainly wind and waste)	N/A	N/A

[2] Statistics Finland, available at: http://tilastokeskus.fi/til/ehk/2015/04/ehk_2015_04_2016-03-23_tie_001_fi.html, accessed 3.5.2016.

[3] Statistics Finland, available at: http://pxweb2.stat.fi/sahkoiset_julkaisut/energia2015/html/suom0002.htm , accessed 3.5.2016.

New power generation capacities installed during the year (renewables including hydropower)	Wind power: 379 MW[4]	Wind power: 179 MW[4]
Total PV electricity production in GWh-TWh	15 GWh	12 GWh
Total PV electricity production as a % of total electricity consumption	0.02%	0.02%

Table 4: Other information.

	2015 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	**10**
Total capacity connected to the medium voltage distribution grid in MW	**0**
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	Stand-alone domestic	Stand-alone non-domestic	Grid-connected distributed	Grid-connected centralized
2014	*	N/A	5	0
2015	*	N/A	10	0
TOTAL (MW)	10*	N/A	10	0

[4] Tuulivoimayhdistys, available at: http://www.tuulivoimayhdistys.fi/tietoa-tuulivoimasta/tietoa-tuulivoimasta/tuulivoima-suomessa-ja-maailmalla/tuulivoima-suomessa, accessed 7.5.2016.

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 manufacuring 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
Standard module crystalline silicon price(s): Typical (€/Wp)	N/A	N/A	N/A	N/A	0.85	0.65
Lowest prices (€/Wp)	N/A	N/A	N/A	N/A	0.65	0.6
Highest prices (€/Wp)	N/A	N/A	N/A	N/A	N/A	0.7

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 2015. 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 – in €/Wp.**

Category/Size	Typical applications and brief details	Current prices per (€/Wp)
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.	1.45-1.75
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.	1.15-1.4
Grid-connected Rooftop above 250kW (industrial)	Systems installed to produce electricity for the self-consumption in industrial sites or large commercial buildings.	1.05-1.35
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.	1.1-1.3
Other category (hybrid diesel-PV, hybrid with battery…)	N/A	N/A

Table 8: National trends in system prices (current) for different applications – in €/Wp.

(€/Wp)	1992					2014	2015
Residential PV systems < 10 KW	N/A	N/A	N/A	N/A	N/A	1.5-1.8	1.45-1.75
Commercial and industrial	N/A	N/A	N/A	N/A	N/A	1.25-1.5	1.05-1.4
Ground-mounted	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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 kWp. 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 case (low, average and high). Even lower values, such as 1-2 h/module, were indicated in the discussions with an pv system provider. 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 be always working hours of installation staff that cannot be charged from customers.

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 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 < 10 kW

Table 9: Cost breakdown for a residential PV system – in €/Wp.

Cost category	Average (€/Wp)	Low (€/Wp)	High (€/Wp)
Hardware			
Module	0.65	0.6	0.7
Inverter	0.2	0.18	0.2
Other (racking, wiring, components for grid connection)	0.19	0.13	0.27
Soft costs			
Installation	0.29	0.24	0.42
Customer Acquisition	0	0	0
Profit	0.20	0.17	0.24
Other (permitting)	0.04	0	0.07

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

Subtotal Hardware	**1.04**	**0.91**	**1.17**
Subtotal Soft costs	**0.54**	**0.41**	**0.73**
Total	**1.57**	**1.32**	**1.89**

2.3.2 Utility-scale PV systems > 1 MW

There are no larger than 1 MW PV systems installed in Finland yet.

Table 10: Cost breakdown for an utility-scale PV system – in €/Wp.

Cost Category	Average (€/Wp)	Low (€/Wp)	High (€/Wp)
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			
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 the 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
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

[6] Minicipality Finance, available at: https://www.munifin.fi/ , accessed 25.5.2016.

contract may include the selling of electricity from a rooftop PV plant to local consumption with a fixed price and fixed time period (PPA). The panel renting is provided for instance by utility companies like Helen and KSS Energia. They offer customers the renting of a PV panel with 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 and Etelä-Savon Energia provide financing for a PV system investment. There are also two crowdfunding companies (Joukon voima, Solarvoima) that are funding also 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)	11.8-17.8 €cent/kWh
Retail Electricity Prices for a commercial company (range)	8.6-11 €cent/kWh
Retail Electricity Prices for an industrial company (range)	6.2-8.6 €cent/kWh
Population at the end of 2014 (or latest known)	5 471 753
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 distribution companies, proportion of customers (total 3.4 million)[8]: 1. Caruna Oy, 19% 2. Elenia Oy, 12 % 3. Helen Sähköverkko Oy, 11%

[7] http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ene__ehi/?tablelist=true

[8] Energy Authority, Sähköverkko tekniset tunnusluvut 2014, available at: https://www.energiavirasto.fi/tunnusluvut2014 , accessed 25.5.2016.

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 2015

3.1.1.1 Description of support measures excluding BIPV and rural electrification

Companies, communities and other organizations

The Ministry of Employment and the Economy grants investment support 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 30 % investment subsidy of the total costs of grid-connected PV projects. At the beginning of 2016, the subsidy level decreased to 25 %. The decision for the investment subsidy is made based on applications. 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 35 % of the total investment costs in 2015, and is increasing to 40 % 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 Employment and the Economy, available at https://www.tem.fi/en/energy/energy_support, accessed 10.5.2016

[10] The Agency for Rural Affairs, available: http://www.mavi.fi/en/Pages/default.aspx accessed 10.5.2016.

electricity generation is less than 800 MWh. Thus, PV plants with installed capacity 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 MWh:s. 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. The 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 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 Employment and the Economy can be applied also for energy storage projects.

Table 14: PV support measures (summary table).

	On-going measures residential	Measures that commenced during 2015 - residential	On-going measures Commercial + industrial	Measures that commenced during 2015 – commercial + industrial	On-going measures Ground-mounted	Measures that commenced during 2015 – 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 30%/35% applicable	Yes/ change of subsidy levels 25%/40%	Yes/ Investment subsidy 30%/35% applicable	Yes/ change of subsidy levels 25%/40%
Green certificates	No	No	No	No	No	No

[11] Income tax law, available at: http://www.finlex.fi/fi/laki/ajantasa/1992/19921535, accessed 2.6.2016

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	No	Yes/ MuniFin, green bond, starting 2016	No	Yes/ MuniFin Funding, green bond, starting 2016
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 Tenders, auctions & similar schemes

There were no governmental auctions or tender schemes arranged in Finland in 2015.

3.4 Direct Support measures

All support measures were already described in the previous sections.

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 Employment and the Economy 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 5 MW of new PV capacity installed in 2015, the estimated cost of PV support measures was around 1 M€.

3.6 Indirect policy issues

Currently, there are not many policy initiatives, which might rapidly influence the PV installation rates in Finland. For consumers, the potential implementation of hourly net-metering might have some effect.

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), Vacon (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 a part of the quite open energy programmes. In year 2015, the public R&D&I spending on PV was around 6.8 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 was funding applied research, innovation and demonstrations with around 5.8 M€.

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

	R & D	Demo/Field test
National/federal	5.8 M €	1 M€
State/regional	N/A	N/A
Total	6.8 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 16).

Table 16: Production information 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	None
None	sc-Si ingots.	tonnes	None	None
None	mc-Si ingots	tonnes	None	None
None	sc-Si wafers	MW	None	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 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 and the like. 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 2015 was estimated to be 15 MW and the produced capacity between 0.1 and 0.5 MW in 2015. The total PV cell and module manufacture together with the production capacity information is given in Table 17 below.

Table 17: Production and production capacity information for 2015.

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					
Salo Solar Oy	mc-Si	-	N/A	-	5
Valoe Oy	mc-Si	-	0.1 (est.)	-	10
TOTALS		**0**	**0.1–0.5**	**0**	**15**

[12] Valoe Oy, available at: http://www.valoe.com/ , accessed 11.5.2016

[13] SaloSolar Oy, available at: http://www.arevasolar.fi/fi/salosolar , accessed 11.5.2016

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. Plese contact the author of this report if something relevant in missing. The company listing will be updated for the report of year 2016.

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 chrystalline and thin film solar cells.

Endeas Oy

Edeas is located at 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, it delivers globally machines and services for the production off heat-treated glass for solar PV and CSP solutions

Luvata Oy

Luvata manufactures copper-based flat wire used to connect silicon cells electrically and to carry out 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 steel company SSAB. It provides façade 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+battery plants.

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 2015 are presented in Table 18. There are no official numbers available, and thus, the uncertainty in the estimates is high.

Table 18: Estimated PV-related workplaces in 2015.

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 2015 is estimated in Table 19. The main value comes from the manufacturing and global exports of utility-scale PV inverters by ABB. Compared with this, the business value of domestic PV system sales is much lower. The uncertainty of the estimate is at least ±20 %.

Table 19: Value of PV business.

Sub-market	**Capacity installed *in 2015* (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	5	1.4	7 M€	
Grid-connected centralized	0	-	0	
				8.5 M€
Export of PV products (estimate: utility-scale solar inverters, off-grid systems, switch gear, etc)				150 M€
Change in stocks held				-
Import of PV products				5 M€
Value of PV business				**163.5 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

Some utility companies such as Fortum, Etelä-Savon Energia, Helen , Mäntsälän Sähkö, Oulu Energy and Vattenfall 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.

Several utility companies have announced offers to buy surplus electricity from micro-PV plants. In July 2015, there were more than 10 utilities making offers to buy surplus electricity countrywide and several smaller utilities operating only locally. 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.

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[14] The power system in Finland, available at: http://www.fingrid.fi/en/powersystem/general%20description/Power%20System%20in%20Finland/Pages/default.aspx, accessed 28.7.2015.

[15] Nordpool spot prices, available at: http://www.nordpoolspot.com/#/nordic/table, accessed 27.7.2015

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, the promotion of PV installations in the area of municipality, the 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

The highlights of year 2015 in Finland related to Solar PV are listed below.

- The installation rate of PV systems increased by approximately 100% from the year 2014. An equivalent growth rate is also expected for the year 2016.
- So far, the largest PV plant in Finland (*P*n = 853 kWp) was invested by Helen Ltd. in Kivikko in Helsinki.
- A new efficiency record of black silicon cells (22.1%) was reported by a research group led by Prof. Hele Savin[16].
- A module production line was announced by SaloSolar in Salo aiming to assemble PV modules for the domestic use.

[16] H. Savin, et. Al., Black silicon solar cells with interdigitated back-contacts achieve 22.1% efficiency, Nature Nanotechnology, 10, 624–628, (2015), available at: http://www.nature.com/nnano/journal/v10/n7/full/nnano.2015.89.html

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