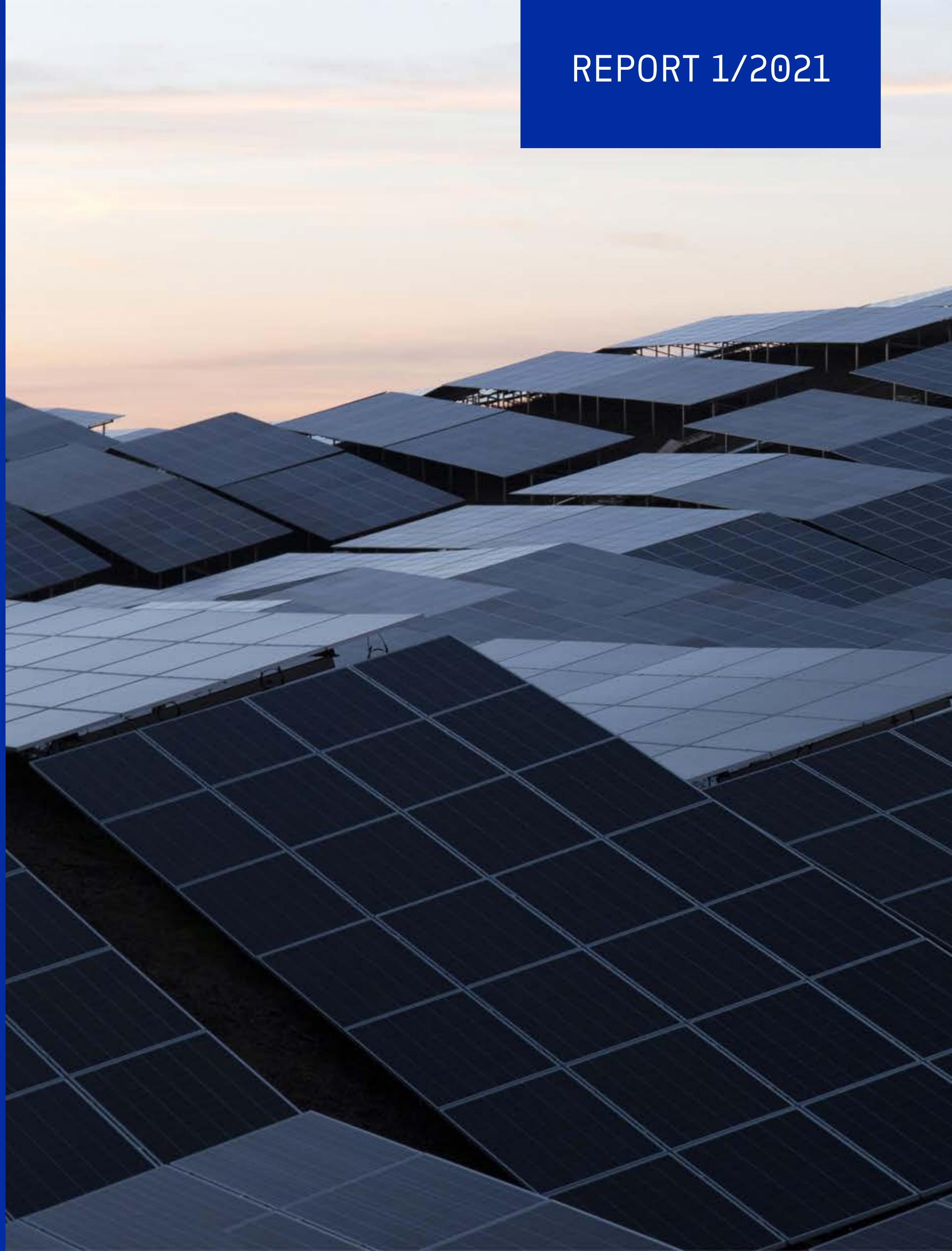
BUSINESS
FINLAND

REPORT 1/2021

SOLAR CLUSTER STUDY



Gaia Consulting Oy

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BUSINESS FINLAND

We believe in the power of ideas. That's why we fund and help Finnish companies grow quicker and develop their innovations to become global success stories.

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1 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

Solar energy is more and more becoming an integral part of the energy palette globally and in Finland – the solar market in Finland is growing and subsequently the business potential associated to it. At the same time Finland has technologies and capabilities that enable business in the European and global solar energy value networks. There is a need to look at the solar energy market and value network in Finland to determine its strengths and weaknesses. This enables to market the business and partnership opportunities in Finland for potential foreign companies and the Business Finland Smart Energy program to focus its activities.

The aim of the cluster study is to provide a clear mapping of the solar energy value network and to determine the potential of the various business and technology segments within the solar energy sector for acquiring inward foreign direct investments (FDI) in Finland (but also strengthen the Finnish market and our ecosystems and increase exports).

The focus of this study is mainly on solar electricity and solar thermal applications are only briefly considered. Also, it is important to consider in the study that solar technologies are part of wider domains such as smart energy systems and businesses as well as renewable energy production systems and businesses.

1.2 METHODOLOGY

Figure 1 presents solar energy as part of the wider renewable energy production context. As a methodology, this study considers solar energy business as part of smart energy systems/business as well as part of larger sustainable renewable energy production systems/business. In particular, the study considers solar energy/technologies/business as an entity in the context of the shown dimensions and at the same time covering the important interfaces, mainly that some of the system level components are integral to the solar/renewable energy applications, such as inverters. Thus, these will be considered as part of the main solar business. For other technologies and businesses that have important business specificities

Sustainable renewable energy production systems and business	• Change of modality from central to distributed energy production, e.g. local microgrids and energy communities • New players/companies reshaping the traditional energy production value networks • Role and dynamics of large companies vs. SMEs from the FDI point of view
Smart energy solutions and business	• Interface between solar technologies and smart energy solutions with different system components • Interface for example towards mobility, grid, storage, heating, demand response etc. solutions
Solar energy business	• Solar Photovoltaic technologies – electricity production • Solar Thermal technologies – heat production

Figure 1. Solar energy as part of the renewable energy production context. Source: Gaia Consulting

by themselves, such as batteries, no deep dive is done to avoid overlap with other Business Finland Smart Energy program work.

Gaia Consulting conducted this study for Business Finland in fall 2020. The results are based on a desktop study in which information was gathered from public sources complemented by ten interviews of Finnish solar energy experts. The experts were chosen to represent companies from various parts of the solar energy value chain. Also, expertise from the research and regulation environments was included. The main study questions were:

- The current status and operational environment and challenges of solar energy market in Finland.
- Future trends and developments in solar energy in Finland.
- Value network description with key companies.
- Conclusions on solar energy/power related business opportunities and related investments to Finland.
- Regulation is considered as part of the operational environment in Finland.

1.3 BRIEF OVERVIEW OF THE GLOBAL SOLAR ENERGY MARKET

The total installed solar capacity globally was in 2019 548 GW[1]. The development of global installed solar power capacity is presented in *Figure 2*. As exhibited in the figure, solar electricity installations have increased by an average yearly growth of 25 % between 2010 and 2019.

Most of the recent installations are taking place in Asia, especially in China. It should be noted that China is also the market leader in solar panel manufacturing, although there is movement in Europe towards mass production of European solar panels[2]. Also increasing amounts of solar panels have been installed in the recent years in Europe and North America. It is interesting that IEA has estimated that solar PV will overtake wind power this year 2020 in global electricity production capacity.

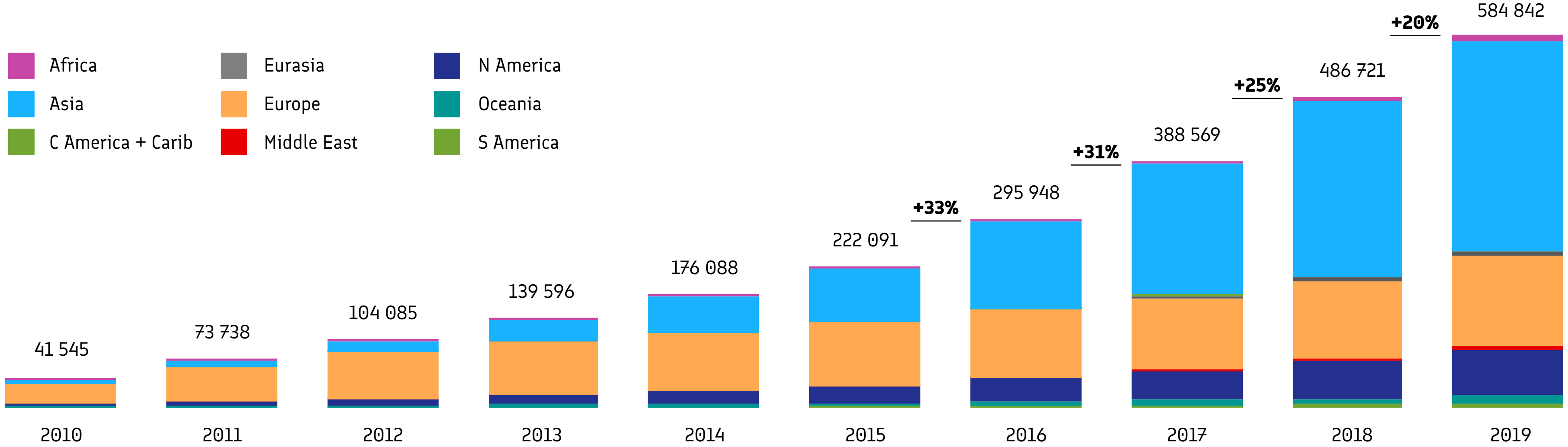

Figure 2. Solar power capacity development in 2010-2019 in different continents.

Solar PV is estimated to continue on its exponential growth path in the coming years. These IEA's estimations are presented in *Figure 3*.

The new installed capacity is distributed rather equally between installations made to individual housing, to industry and to commercial and retail buildings. From the point of view of power supply, solar power can mainly be regarded as distributed production that takes place nearby the point of consumption.[4]

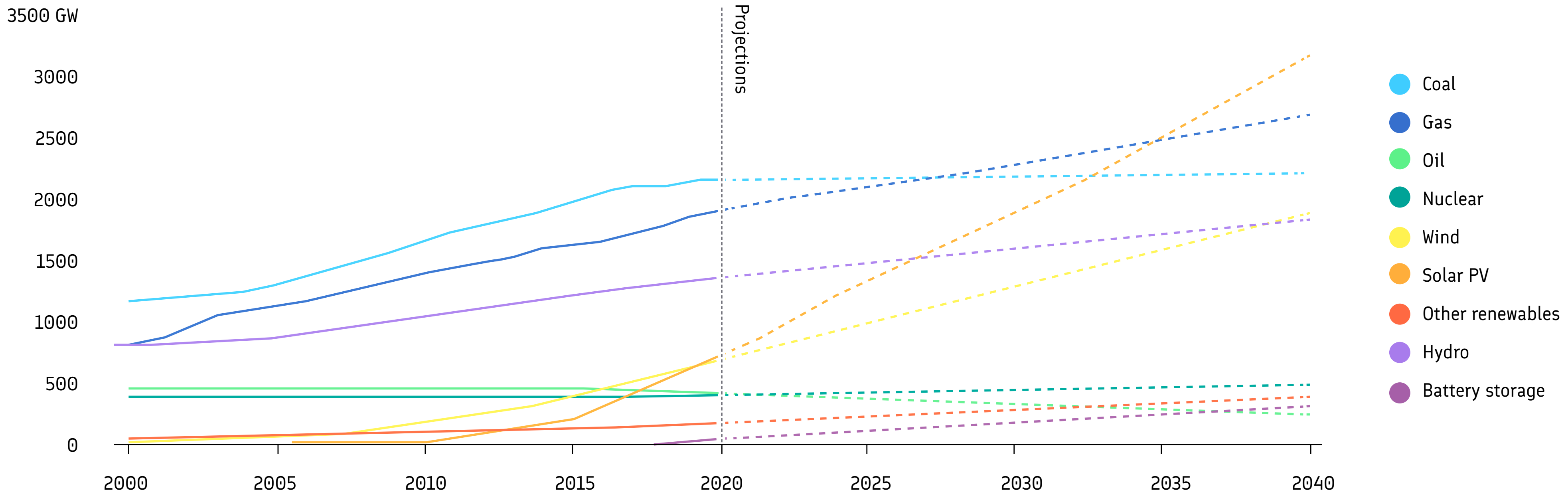

Figure 3. IEA stated policies scenario estimation of electricity capacities development.[3]

2 CURRENT STATUS OF SOLAR ENERGY IN FINLAND

2.1 OVERVIEW OF THE SOLAR ENERGY MARKET IN FINLAND

At the end of the year 2019 the installed solar power capacity connected to grid in Finland was 198 MW[5] which produced 178,1 GWh[6] of electricity (likely to grow towards 300 MW by the end of 2020[7]). In addition to this there is vast amount of smaller off-grid PV sites. The exact number of off-grid PV sites[8] is not known, but it is estimated that they may account for 90 % of all PV sites. 178 GWh equals the value of over 7,8 million euros for sold solar electricity, considering the average electricity spot price in Finland 2019 was 44,04 €/ MWh[9]. If solar electricity is utilized on-site, distribution costs and electricity taxes are avoided, which increases the benefits of PV consumption. Installed solar thermal capacity was 40 MW[10] at the end of year 2018. Altogether, solar technology industry is estimated to employ over 500 persons[5] in Finland in 2020. In 2019 share of solar electricity was 0,22 % of the total electricity produced in Finland. Shares of electricity produced in Finland 2019 is presented in figure below (*Figure 4*).

As is illustrated in *Figure 5*, Frost and Sullivan estimated in 2018 that annual installed solar energy production capacity in the whole Nordics would amount to some 400 MW in year 2019. As is referred above, the actual figures amount only for Finland approximately 200 MW, and it seems unlikely that Finland would account for about half of total Nordic solar production capacity. Hence, also in line with statistics from the Finnish Energy Authority, the Finnish solar market has grown more than expected[12].

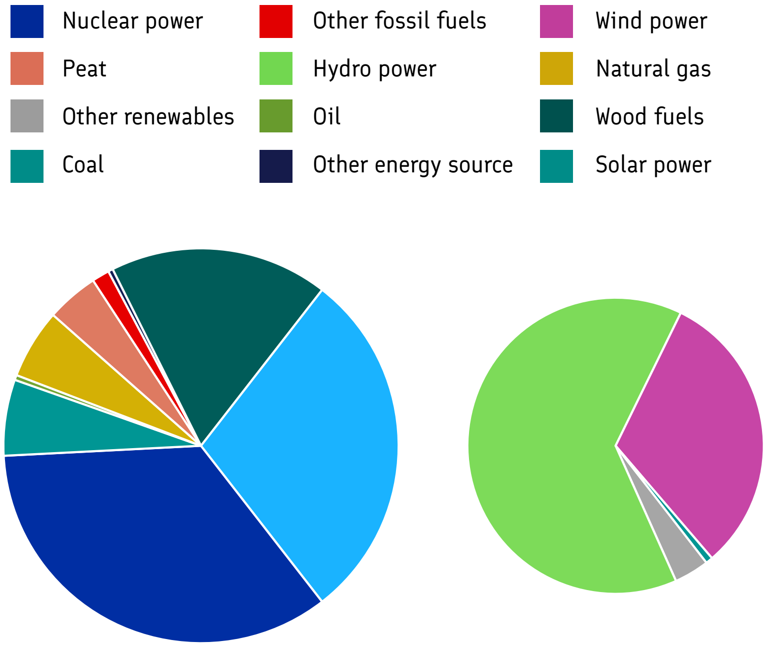

Figure 4. Produced electricity in Finland (GWh) in 2019. [11]

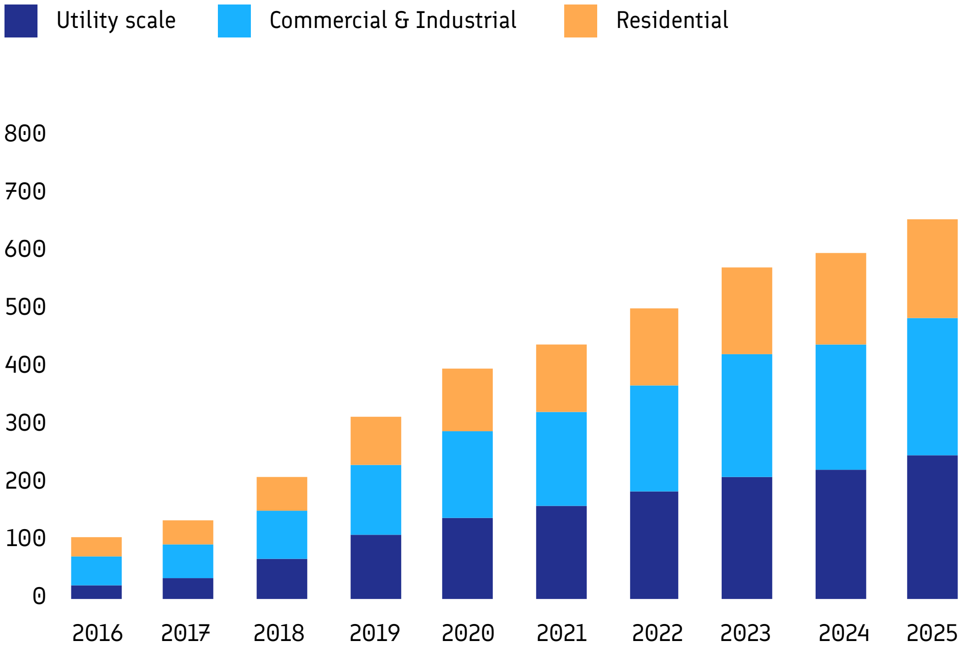

Figure 5. Annual Installed Capacity Forecast by Project Type, Nordic Countries 2016-2025. [13]

In *Figure 6* is presented the solar full load hours potential in Europe. Full load hours in Finland are similar to Northern Germany. Helsinki-Uusimaa Regional Council published a study[14] in 2017 about the prerequisites for large scale solar PV production in the Uusimaa region. In it was concluded that even if the solar radiation levels in Finland are far less compared to Southern Europe levels when measured on horizontal plane, the tilt of the modules when installed decreases this difference. In general, the profitability of a solar power plant depends on several factors, one being the solar irradiation level. Other factors are efficiency of the panel and system or how well the incoming irradiation is being utilized to its full extent, price of the electricity and investment costs. In the past years, decreasing solar panel and subsequent investment costs have had a positive affect on the profitability of solar power systems in Finland whereas decreasing electricity price has had negative effect on profitability.

The Finnish solar energy market consists of two main customer segments: industry and consumers. For the industries, the trend has been to install large solar power plants at own premises to produce sustainable energy for own use. For example, some food industry, retail and manufacturing industry companies have installed solar panels with total capacities of 3 - 80 MW. Energy-as-a-service -solutions are growing as a common product solution in the solar industry. Companies take care of the installation and investment costs and customer will utitize the solar energy produced.

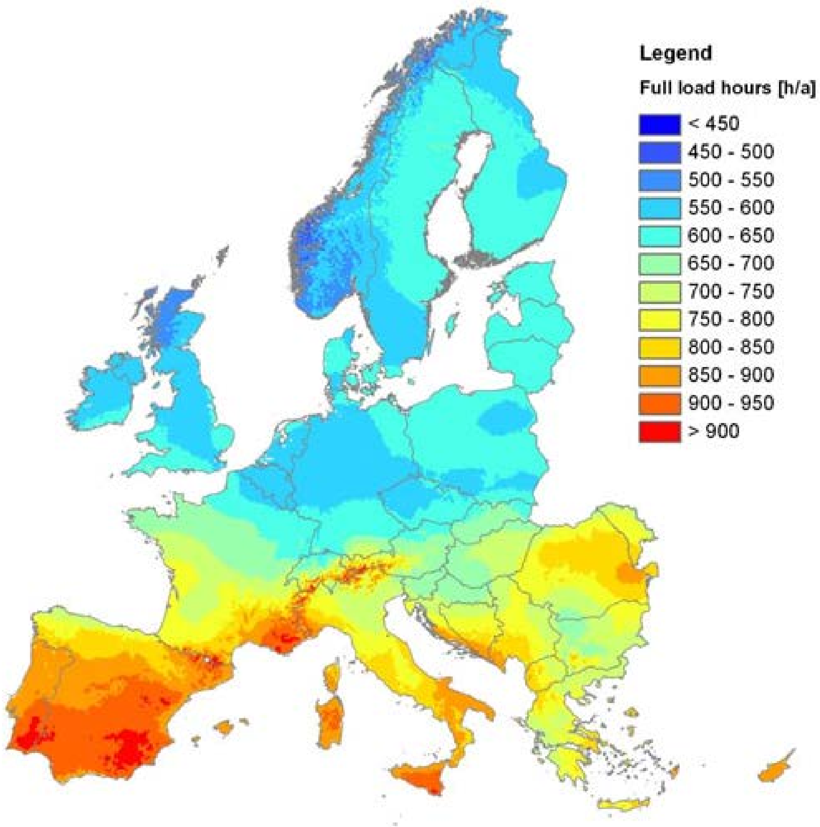

Figure 6. Solar power full load hours in Europe. [15]

In the consumer segment, several energy companies install solar panels and systems as a service to households. Some energy companies also provide as product the possibility to buy solar production from installed capacity elsewhere with i.e. PPA agreements.

There are four trends that have been visible already for a couple of years on the solar market, both in Finlandas well as globally. These are: [16]

1. The size of average solar power stations is growing

In Finland already several MW size solar power plants have been installed in the recent years compared to much smaller entities before. Globally, for example in China, the plants have grown already to GW scale. In Finland, the driver for the growing size of the installations has been the cooling needs in commercial, office and industry buildings for which a solar PV power plant on the roof of a building brings a well-suited solution. In particular, for such public buildings, the consumption of electricity go well hand in hand with the solar power generation curve - consumption occurs at the same time with the expected generation peaks.

2. The business models are developing, and there is increasing demand for maintenance services.

The business models develop from simple sales of systems that an end customer owns and maintains to a more complex set of business opportunities where the investment is done by a company that provides the end customer with the electricity that the system produces and is in charge of the maintenance of the system. IoT and smart monitoring systems become part of the maintenance process.

3. Energy storage solutions enable production to be shifted from quiet hours to peak hours.

The solar system gradually evolves towards a smart and in some cases microgrid based system entity that provides also new market opportunities in developing countries and coarsely populated areas.

4. Software becomes an integral part of the solar system.

The solar power sector provides new business opportunities for the software sector that is at high-level in Finland. When the electricity systems become smart, information needs to be smoothly exchanged between various system components and devices. Software solutions along with hardware become an integral part of the end product.

2.2 SOLAR ENERGY VALUE NETWORK

A simple description of solar electricity value network is in *Figure 7* below. The main value network is composed of six different parts: 1) raw materials, 2) manufacturing of solar panel components, 3) manufacturing of solar panels, 4) balancing system technology and 5) reuse and recycling. In addition to main value networks, complementary value networks reinforce the main value network. Complementary value networks include component wise for example such product and service areas as mounting systems, wiring, switches, inverters, storage systems, energy management, home automation, metering and communication, and waste management. Implementation wise complementary value networks consist of such services as site & system design, development, installation, project management, inspections, finance and insurance. In this study, the main focus is on the "balance of system technology" and complementary value networks of the network even if also other parts of the network are looked at. "Balance of system technology" contains such products and services as inverters, switches and other system balancing services. These parts of the value network were chosen as the focus of this study on the basis that a lot of companies and knowledge exist within these areas in Finland as well as that substantial development is being seen in such areas as smart grid and thus these areas hold significant business potential also relevant from the solar energy perspective.

Main value networks

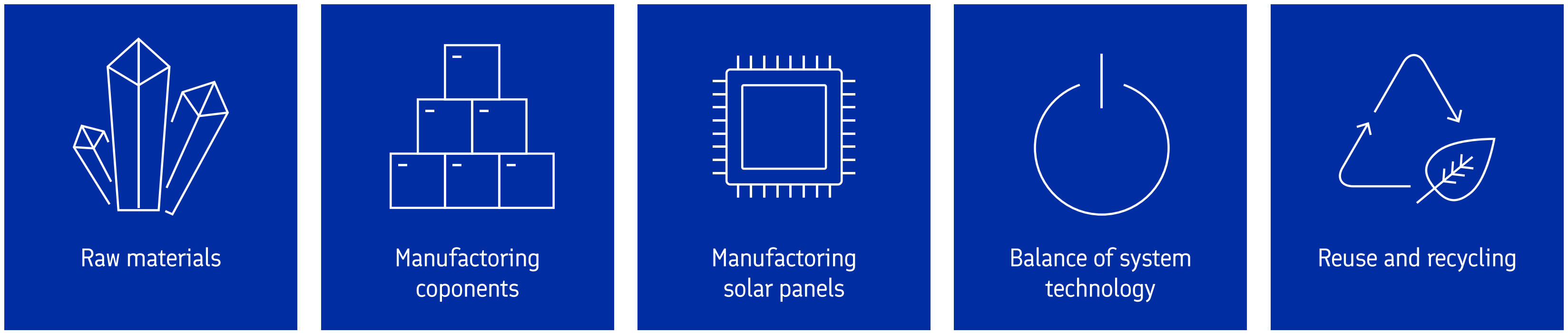

Figure 7. Solar power value network

Solar power has an important role and subsequently many interconnections to the value network presenting the so called new energy system which reflects the electrification of the society. The most important sector couplings of solar power sector to other sectors in that value network are presented in *Figure 8*. Solar power can be in a significant role for example in connection to the emerging energy communities and smart grids. Solar electricity is one of the main potential renewable energy production alternatives when producing energy to such energy carriers or energy vectors as hydrogen as part of the new so called Power-to-X energy systems in global scale. Power-to-X ecosystem is covered in more detail in another study commissioned by Business Finland.[17] The wide area of energy storage and batteries is another important sector having significant interface to the solar electricity production. Batteries were covered in detail in a previous study for Business Finland.[18] Thus these mentioned wider value network areas were left out from this study as such but the interface and connections of solar energy to them are considered.

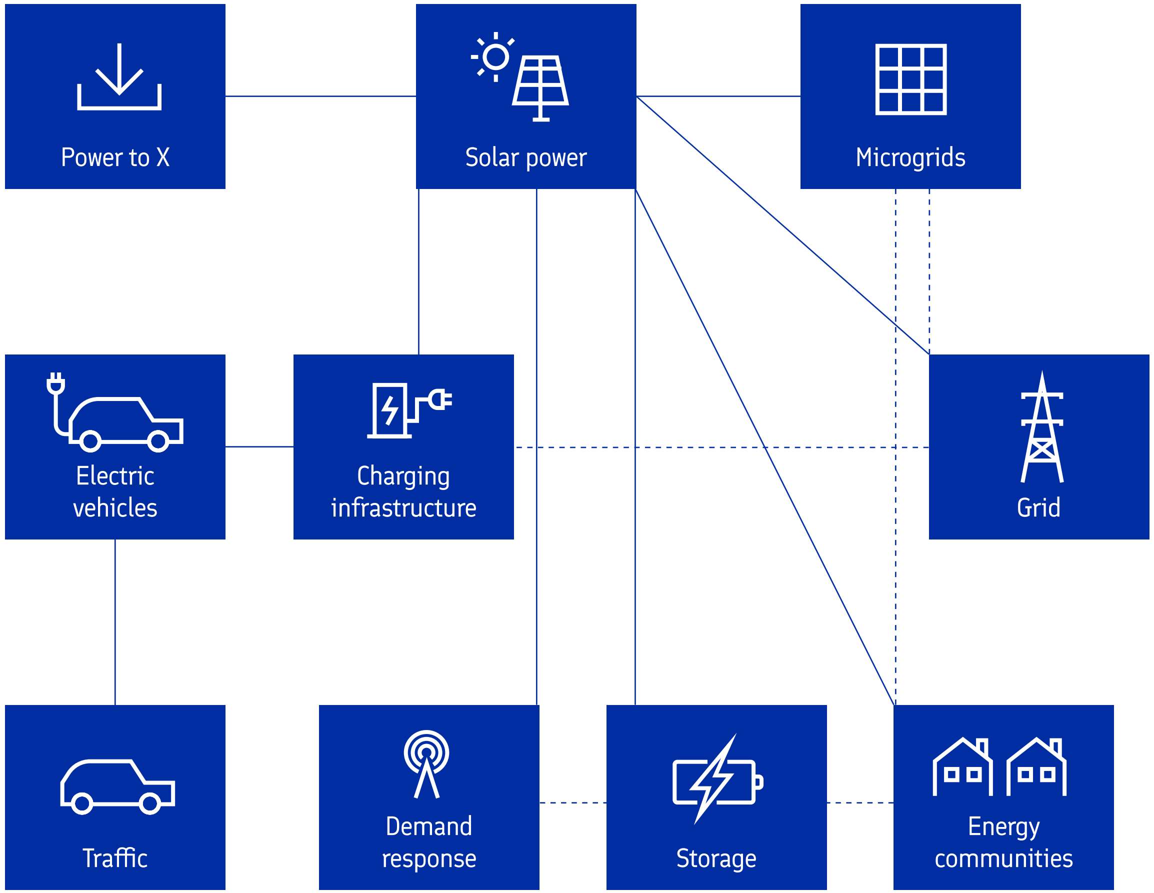

Figure 8. Solar power sector coupling. Direct connections to solar power marked with consistent line and other connections with dashed line.

One example of significant connections between these different sectors and in particular between solar energy and the smart energy systems is presented in *Figure 9*. As can be seen in the figure, there are already a large quantity of solar PV system retailers in Finland as well as smart energy service providers in general. Notable from the figure is that the variety of these smart energy service providers is large and that there are also a large number of such retailers that are not yet interconnected to solar energy. This group obviously presents a potential from the solar energy market point of view.

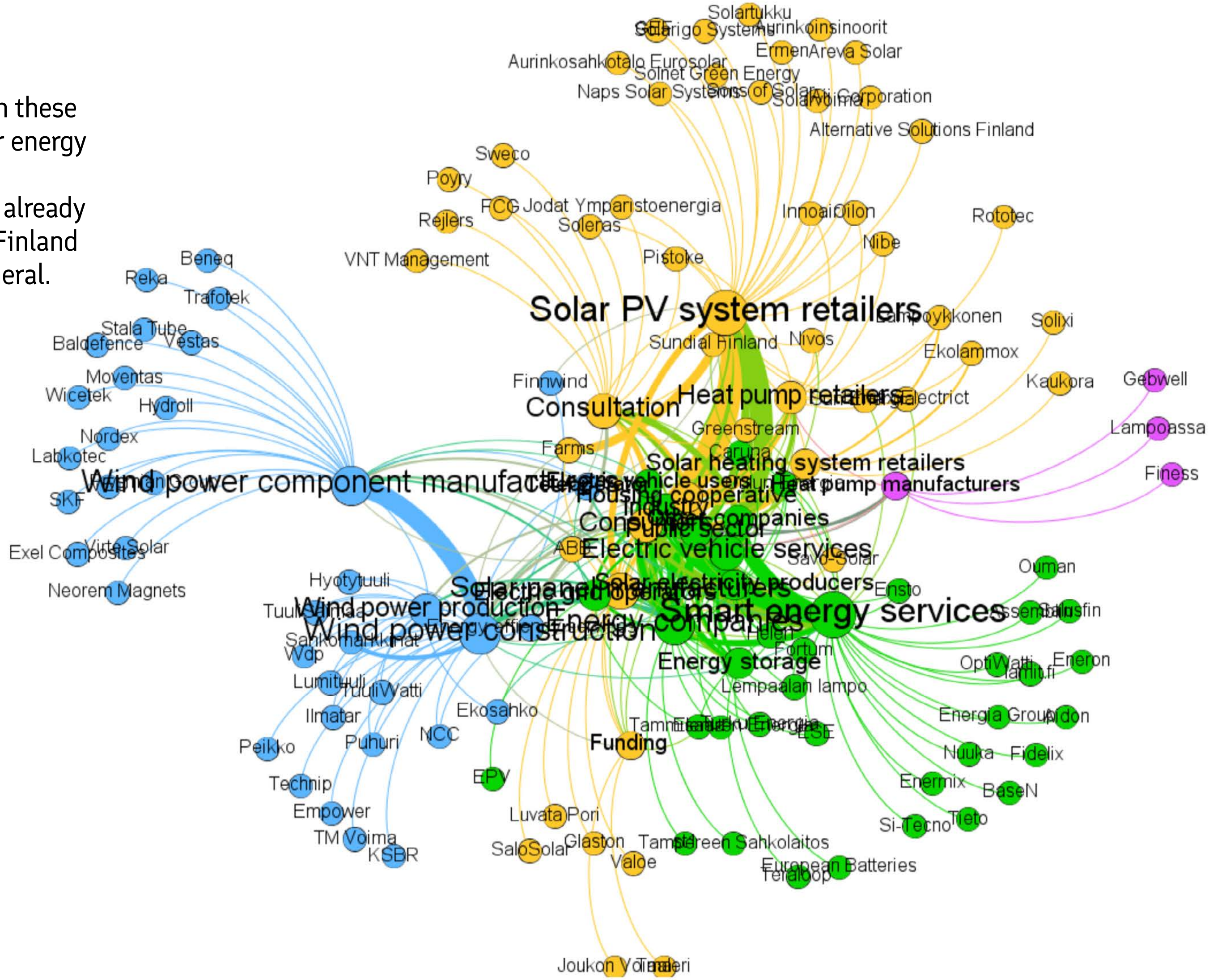

Figure 9. New energy system actors in Finland.[19]

During this study a total of 55 companies in Finland were recognized as being part of the solar energy value network. These companies are presented in *Figure 10* below. These numbers and the list are not exhaustive.

Finland has a 150-200 year long engineering tradition[20], and the technology industry is the most important export industry in Finland. Technology companies make up over 50% of all

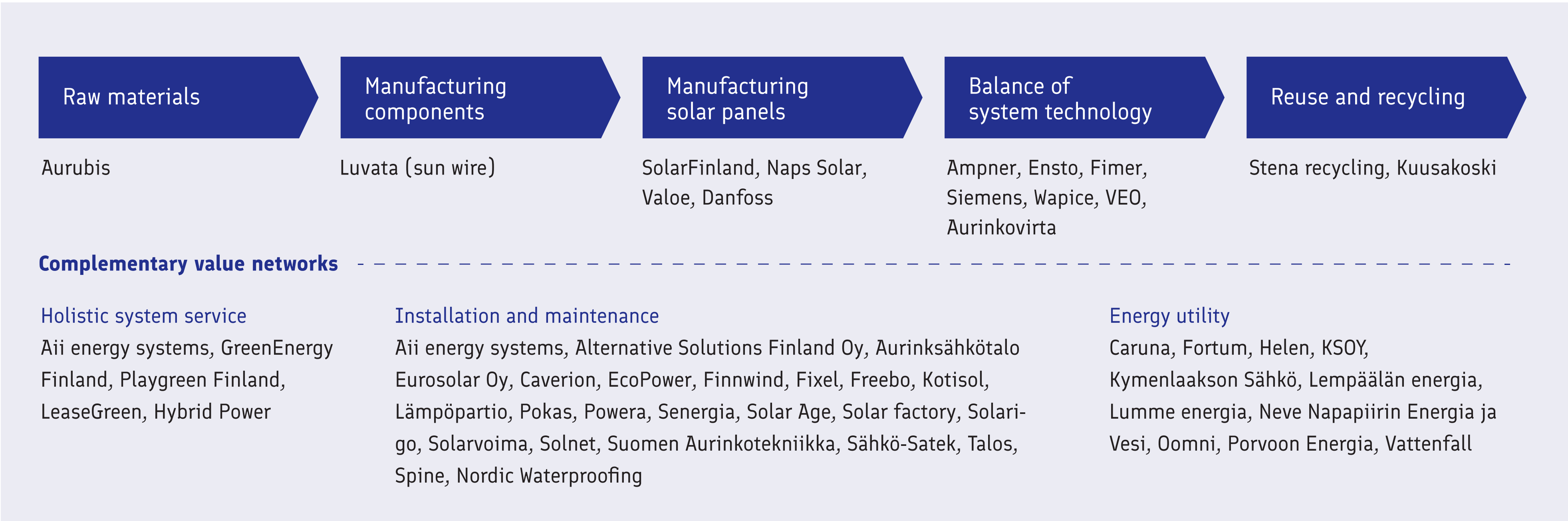

Figure 10. Solar value network companies in Finland.

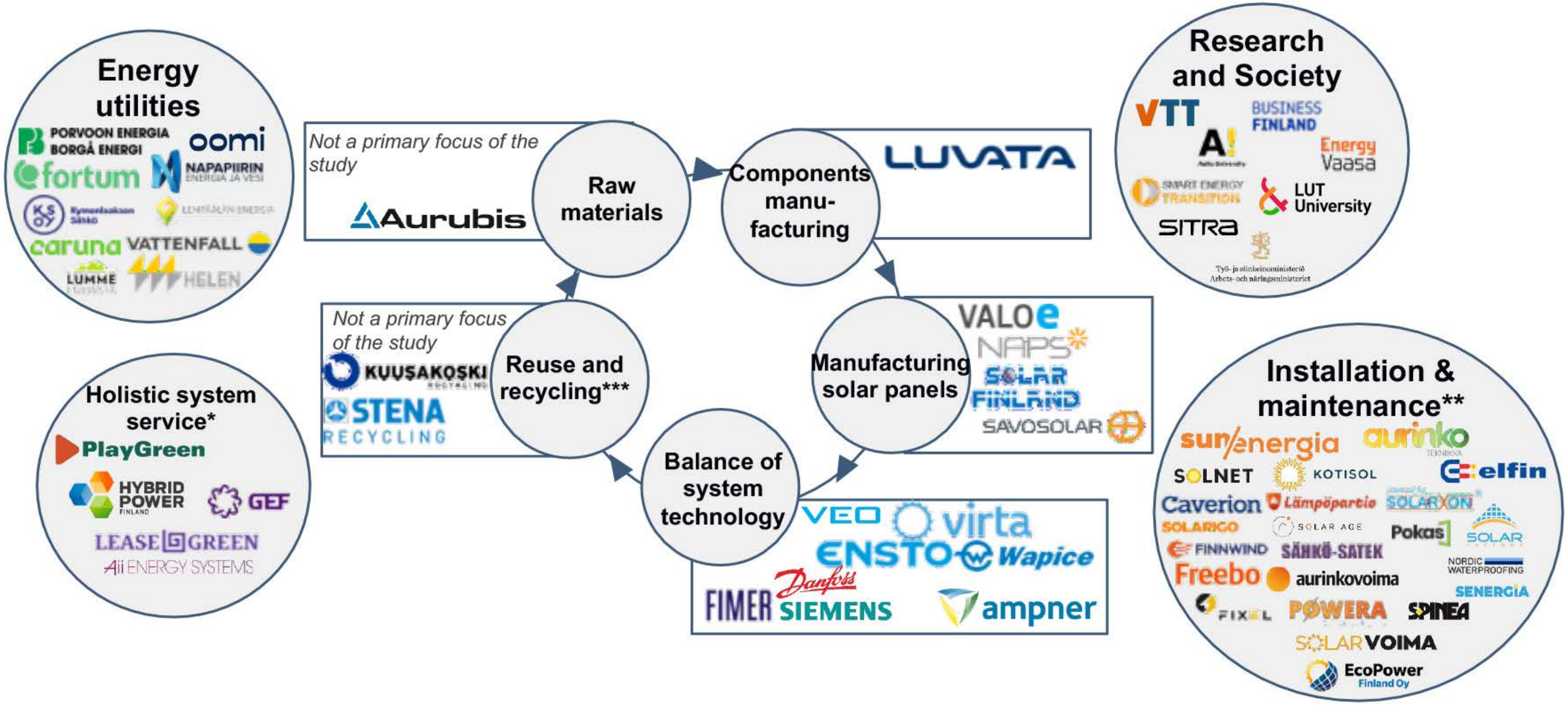

Figure 11. Solar technology value network in Finland. *These companies provide system design, installation and maintenance considering the energy system for the customer. Customer is typically a housing cooperation, industrial building etc. **These companies provide design service, installation and maintenance for PV systems.

Finnish exports, and more than 300,000 persons work in technology companies, while a total of around 700,000 people work in the technology sector either directly or indirectly[21].

Of the companies active within the PV energy system in Finland, the largest number are active within installation and maintenance as is presented in *Figure 11*. This distribution largely reflects Finland's engineering tradition, as well as recent decades global position as a country strong and on the forefront of digital and smart solutions and services. The market actors consist of a handful of larger companies and a long list of smaller ones. There are only a few companies that could be considered medium sized e.g. Danfoss, Wapice, Ensto.

With the trend of increase of solar PV across the world it is no surprise that the development is also mirrored in the Finnish market landscape, and a number of companies are providing solar energy either as a stand-alone service or bundled with other energy related services. *Figure 12* and *Figure 13* compares the financial performance of a selected number of companies.

The market exhibits a presence of both large established companies as well as newer smaller enterprises, and in particular the latter group has during the past years experienced a significant increase in growth. However, despite the growth of these small enterprises, the operating profits are not as healthy as with more established actors, and some small companies are currently operating at a deficit. Larger companies might experience not as large percentage increase in turnover but in turn deliver more stable financial operating returns. Selected KPI's of mid-sized and small companies are presented in *Figure 13*.

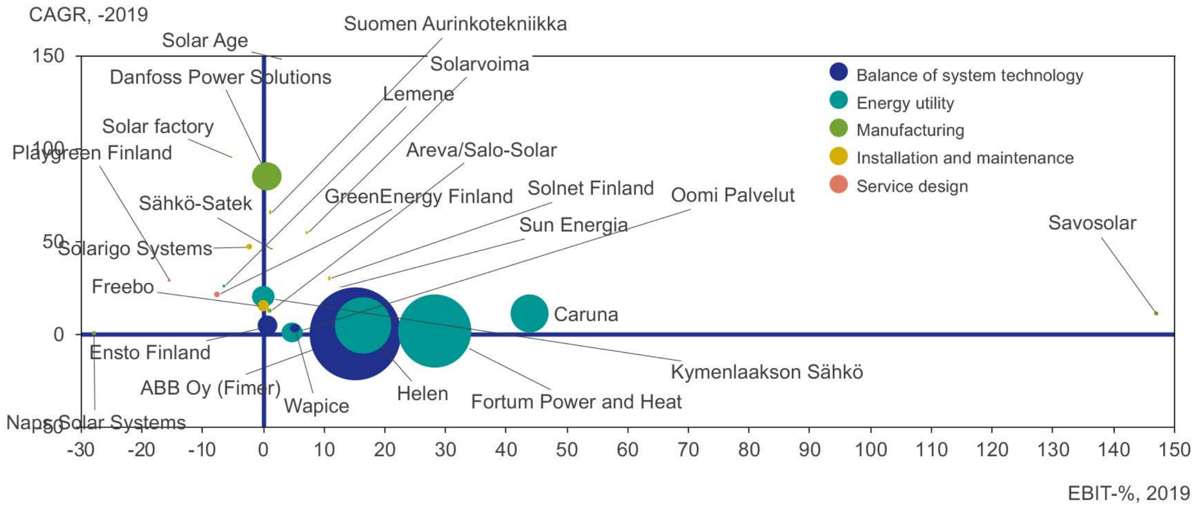

Figure 12. Financial performance of selected companies in the solar technology value chain in Finland (CAGR 2015-2019 vs. EBIT-% 2019; company size is indicated by the size of the sphere)

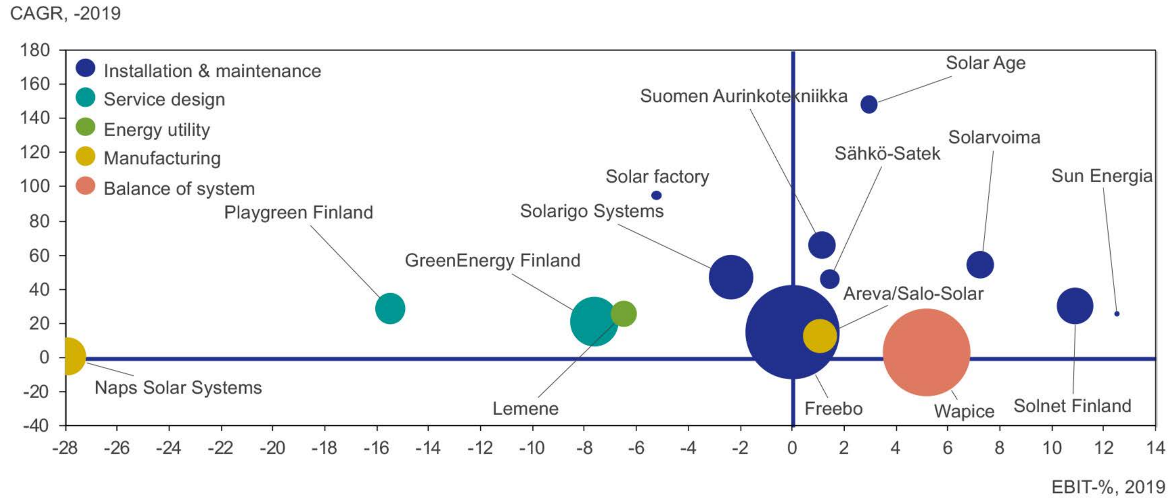

Figure 13. Financial performance of selected companies in the solar technology value chain in Finland, larger actors and outliers excluded (CAGR 2015-2019 vs. EBIT-% 2019; company size is indicated by the size of the sphere)

2.3 COMPANIES AND OTHER ACTORS WITHIN THE SOLAR ENERGY VALUE NETWORK IN FINLAND

In the following a short description of selected solar power value network actors in Finland are provided. Actors are grouped into balance of system technology, energy utilities, system service providers, installation and maintenance. System service providers offer energy system design for example industrial buildings or for housing cooperative. Their offer may include other than solar technology as well. Installation and maintenance main focus is designing, installing and maintaining solar systems.

BALANCE OF SYSTEM TECHNOLOGY

Fimer (former ABB)[22] is a leading global manufacturer of inverters for utility scale solar systems. The main product consists of, besides the hardware, most importantly of the control system including simulation models, testing and verification and service contract. In 2020, ABB completed its divestment of its solar inverter business to the Italian company FIMER SpA[23]. Significant part of this former ABB and now Fimer solar PV inverter business is based in Finland, mainly the global utility scale product management and business development. In particular, Fimer now owns and runs in Finland the R&D, testing and certification laboratories for which significant investments were made in 2016[24].

Danfoss Power Solutions[25] is a world-class provider of mobile hydraulic and electrification products and solutions. Danfoss is actively developing datadriven digital services for drives using information collected from the drives. This improves energy efficiency of the applications, decreases emissions and reduces maintenance needs. It also provides new possibilities to monitor the process and application at the level of each actuator[26]. Danfoss Finland is also part of the "The Intelligent Industry Ecosystem" of top Finnish companies pursues growth through better utilization of data and AI, leading to tens of thousands of new jobs, saving energy and combatting climate change.

Ensto Finland provides smart electrical solutions for electricity distribution networks, buildings, marine and electric traffic. Ensto is currently building its own solar power plant to its headquarters in Porvoo, Finland, which will cover part of its factory's electricity production and serve as a test field for Ensto's product development, with an estimated annual output of approximately 130,000 kWh (152,000 Wp). Ensto sees that smart solutions are needed to balance electricity production and consumption. Together with the solar panels, a battery energy storage system with inverter units will be installed, which will enable smart energy management of the building in the near future. In addition to electricity generation, the solar power plant will act as a test environment for Ensto's own product development[27].

Wapice is a Finnish full-service software company whose solutions are used by domain leading industrial companies around the world. The company offers close technology partnership and digital services, and seeks to make the best use of digitalization opportunities. We enhance our customer's business and bring them to the forefront of digitalization.

MANUFACTURING SOLAR PANELS

Naps Solar Systems supplies high-quality photovoltaic systems for home, leisure, business use and demanding conditions with four decades and over 250.000 installations experience[28]. Naps use chain-specific optimization or module-specific optimization. Naps sees that module specific optimization in Finnish conditions is seldom economically viable in the long run, because in module-specific optimization, the number of separate electricaldevices required for the system increases and thus increases the need for maintenance[29].

SaloSolar is a manufacturer of solar photovoltaic panels in the ASTRUM-center, Salo, Finland. The factory was established in 2015 and it manufactures solar photovoltaic panels in the size of 1,6 m2 and 2 m2; 270 / 330 W. Each of our solar panels is tested electronically, allowing us to guarantee top quality and efficient solar panel performance. The export objective of SaloSolar is to sell PV panels and PV panel lines and panel factories, as our factory line has attracted a lot of interest in the international market.

Savosolar is a Finnish company that manufactures internationally award-winning solar thermal collectors with the highest energy efficiency and energy density in the market. Savosolar seeks to provide the world's most efficient energy supply at the lowest energy cost. The company focuses on solar thermal collectors for large scale systems, invented by a group of Finnish entrepreneurs and engineers who wanted to use their coating expertise to make a difference by offering the world better and cleaner energy solutions. Savosolar also has representation in Germany, Denmark and France, and is a listed company.

Valoe is a Finnish company that manufactures IBC solar cells, solar panels and Odd Form-solar panels. Valoe providers installations services with traditional solar panels or integrated solar panels. Valoe has strong R&D effort and is involved in Horizon 2020 HighLite development program of which purpose is to produce environmental friendly European solar panels with high quality. Valoe is a listed company.

ENERGY UTILITIES

Caruna distributes electricity and maintains, repairs and builds a weatherproof electricity network for its approximately 700,000 customers in South, Southwest and West Finland, as well as in the city of Joensuu, the sub-region of Koillismaa and Satakunta.

Fortum Power and Heat operates as an energy company. The Company manages power plants which generates and sells electricity and heat. Fortum Power and Heat serves customers in Finland[30]. Fortum offers solar solutions to private and business customers, including offer turnkey deliveries, where the company delivers and installs solar panels onsite[31].

Helen offers its customers electricity, district heating and district cooling, along with a wide range of services for small-scale energy production and the customers' own energy use and improving its efficiency. Helen produces energy at its power plants and heating plants located in Helsinki, as well as through its power assets. Helen Ltd is owned by the City of Helsinki, and aims to achieve 100% carbon neutrality in its energy production. The company has over 450,000 customers throughout Finland. Helen provides solar solutions for both households and companies.

Kymenlaakson Sähkö (KSOY) is an energy group owned by 10 towns and municipalities in Eastern Finland. The company's distribution area has some 150,000 residents, and sells electricity to more than 100,000 customers. KSOY has productified its solar energy offering into a service called "Oma solar" a complete package of solar panels aimed towards households, businesses and farms. The photovoltaic system includes software that allows users to monitor the output of the system.

Lemene. Energy Self-Sufficient Lempäälä is a project of Lempäälän Energia Ltd. It has been chosen as one of eleven key projects concerning renewable energy and new technology in 2017. As a key project, Energy Self-Sufficient Lempäälä has been granted an investment aid from The Ministry of Economic Affairs and Employment (MEAE). The key projects focus on future energy solutions so that Finland can achieve its national targets and those laid down at EU level for 2030. The project objective is to create an energy self-sufficient business district in the Marjamäki industry area in the municipality of Lempäälä.

The energy is going to be produced using renewable energy sources, such as solar power and biogas. There will be a 4 MW solar power plant (2 MW + 2 MW), gas engine capacity of 8,1 MW, and fuel cell solutions providing a total of 130 kW.

Oomi Energia is one of Finland's largest electricity sales companies, and is owned by: Vantaan Energia, Lahti Energia, Pori Energia, Oulun Seudun Sähkö and Oulun Sähkönmyynti Oy and its shareholders: Oulun Energia, Tornion Energia, Haukiputa Sähköosuuskunta, Raahen Energia, Rantakairan Sähkö and Tenergia. Oomi has more than 400,000 customers and employs about 40 people, and offers installation and operation of PV solutions.

INSTALLATION & MAINTENANCE

Freebo is a Finnish solar power company that supplies high-quality solar power plants for detached houses and small properties in Finland and Sweden. The company helps people save the environment with sustainable and easily available solar energy solutions.

Solar factory sells and delivers both grid-connected on-grid and independent off-grid solar panel systems installed and ready for use. The company serves both private consumers and industry, agriculture and business premises. Solar factory delivers the systems installed, manage local licensing issues, handles communicate with the network company, guides the operation, and monitors the electricity production. The company seeks to be a pioneer in new technology and microgeneration trends.

Solarigo Systems is a Finnish energy company offering renewable solar power. The company offers locally produced solar energy for its customers with full-service package. The company built more than 40 solar power plants built in 2019, totaling 27 MW.

Solarvoima is a Finnish expert company specializing in solar panel systems. The company focuses on solar panel deliveries of detached houses and commercial properties on a turnkey basis.

Solnet Group is a leading Smart Solar Solutions provider offering IoT enabled solar utilities and systems integrations for B2B customers easily, conveniently and cost efficiently as a managed service and turn-key solutions. Solnet Group offers Turn-Key solutions for sustain able and reliable energy production and Solar PPA's below grid parity throughout Europe. From financing to hardware procurement, installations to repairs, we take responsibility for everything based on our customers needs.

Sun Energia is a Finnish clean-tech start-up founded in June 2014. The company seeks to generate unbiased information about solar power and speed up the growth of the solar power market. Sun Eneriga provides property owners with high-quality, reliable information about the solar radiation their roof receives and the true solar production and savings potential of each building. The company aims to be Europe's largest producer of location-based renewable energy data.

Suomen Aurinkotekniikka is a growth company operating in the field of renewable energy, and deliver systems using renewable energy sources as a turnkey service. This means that the company designs the system, installs it ready for use, and takes care of all required permits[32].

Sähkö-Satek is a company specializing in electrical renovations, electrical installations and photovoltaic systems for detached houses. From the very beginning, the basic idea has been to improve the electrical safety and energy efficiency of detached houses.

SYSTEM SERVICE PROVIDERS

GreenEnergy Finland[33] (GEF) plans and delivers solar power solutions to private houses and big megawatt-class solar power plants. The GEF Vision service is an example of the company's unique product development. The service allows customers to minimise the share of electricity they sell back to the grid to get the most out of their solar power plant.

Playgreen Finland provides experienced and expert know-how for the procurement of photovoltaic systems, charging points and energy storage. The company offers tailor-made packages to a wide range of user groups e.g. private businesses, farms, individuals and housing companies[34].

3 COMPETENCES, TECHNOLOGIES, R&D AND PILOTS IN SOLAR ENERGY IN FINLAND

3.1 PILOTS AND DEMONSTRATIONS CARRIED OUT IN FINLAND

There are a few pilot projects that have been carried out in Finland during the past years, some of which are described below. Overall, several installations[35] have been implemented by different parties, the following present some examples of those.

In the LEMENE -project an isolated energy community was piloted. An energy community with a distributed energy system consisting of solar power, gas motors and hydrogen fuel cells as energy production methods was implemented.[36] The project finished in year 2019. A particular aim of this study was to pilot energy communities that produce electricity with solar and balance the system with batteries and gas network. In the occasion of transmission power outage, this energy community is able to operate as an isolated island with self-sufficient energy.

A project for developing demand response for solar thermal was conducted 2013-2017 by a number of companies including Oulun Energia and Savosolar and funded by Business Finland[37]. The findings from this project are now being utilized in a new, still on-going project in which Oulun Energia and Savosolar are developing demand response services. Focus on this new project is to demonstrate the benefits of solar thermal integrated with demand response.

The Finsolar research project carried out several solar energy pilots during 2010-2019 and involved about 50 partners. For example, a model for sharing solar power within a housing cooperation was implemented.[38] The aim for the pilot was to create a nationally scalable, replicable and economically viable model for the production of solar electricity by the residents of housing associations.

The Smart Otaniemi project[39] funded by Business Finland pilots for example integration of prosumers and hybrid energy systems and also aggregator business models. The project gathers a multitude of companies, research organizations, and building and infrastructure owners to conduct various pilots to find smart solutions for future technologies.

An interesting idea is to utilize the vast land area around large wind parks for solar power installation. One such pilot that has been inaugurated in August 2016 is the Mäkelänkangas solar power park in the Hamina region in Eastern Finland which is built in the area of the existing Mäkelänkangas wind park. The park is commissioned by Suomen Voima Oy which is a company owned by several small regional energy companies. The park hosts 2784 solar PV panels with the nominal power production capacity of 0,725 MW and annual production of 650 MWh.[40]

Another installation project that is under construction combining wind and solar power production, is the Kalajoki Läntinen Renewable Energy Park in Western Finland due to be finished maybe 2021.[41] The aim with the solar power is to reach 11 MWp nominal power production capacity with 40 000 installed solar panels. The park is being built by Hybrid-Power Finland.[42] Another interesting feature in this park is that it also aims to combine Controlled Growth Platform technology/modules for agricultural food production patented by the company Hybrid-Power Finland. The modules are to be installed between the solar panel lines and will utilize the produced solar power to for example optimize light conditions with IoT technology.

A concept that is currently being planned for is to utilize closing peatlands in Finland for solar power production. One such project that is in planning is the Heinineva peatland in Lapua in Western Finland.[43] The industrial size power plant is being planned by EPV Energia Oy. The plan is to cover the 170-ha peatland with 300 000-400 000 solar panels to produce 80-100 MW of power, corresponding to power production of 20 windmills. The company has received permission to continue planning of the solar power plant and next step will be to draft the construction plan. The power production is aimed to start by the end of the decade 2020. The company expects that with the current prerequisites, reaching profitability for such large-scale solar power plant in Finland is a challenge. However, with the constantly improving efficiencies in new panel technologies the situation is changing developing towards favoring also solar power production in as far north as Finland.

3.2 TECHNOLOGIES AND R&D

The Finnish tradition of being an engineering nation is also visible in the context of strengths at technology level. Concerning cells and modules, bulk of the small production quantities in Finland or by Finnish companies is based on state-of-the-art technologies. An exception to this is for example the company Valoe, which is investing in technology development for application areas in the niche markets. They are developing so called odd form cells and modules with qualities that endure the requirements of the Vehicle Integrated PV market or VIPV[44]. This development they are doing for example together with a Munich (Germany) - based startup car manufacturer Sono Motors that aims at starting the production of its solar EV car Sion at the former SAAB factory of Trolhättan, Sweden in 2022 [45,46 47,48].

Valoe is developing its cell and module technologies partly also in the context of the EU project HighLite[49]. The project aims to substantially improve the competitiveness of the EU PV manufacturing industry by developing knowledge-based manufacturing solutions for high-performance low-cost modules with excellent environmental profiles. The project will focus on bringing two competing technologies to high technology readiness levels (TRL 6-7). Valoe focuses in the project on improvement of its production tool of IBC Module assembly for standard and custom applications (such as BIPV & VIPV). Further, Valoe will develop a new assembly concept, based on far smaller cells (16th of a cell, or similar) based on experience in automation in electronics industry. Valoe will work on solutions to minimize cut edge losses and will contribute to indoor characterization, outdoor demonstration, and cost and life cycle analyses[50] and thus has a significant technology development, implementation and commercialization role in the project.

The few major R&D projects in Finland are conducted mostly by Aalto University and Lappeenranta University of Technology (LUT) and VTT. At Aalto University, research is done on different materials for solar PV cells and modules to utilize new printing technology to manufacture transparent solar panels to be installed in windows[51].

At LUT research is conducted on new energy systems and sector coupling. For example, in the Soletair project, a system producing carbohydrates from renewable energy such as solar power was developed by LUT and VTT together.[52] A spinoff utilizing this developed technology, Soletair Power[53], was created in 2019 gaining significant seed funding from Wärtsilä[54].

Fimer (former ABB) develops inverters for solar power technology and they have constant R&D development on-going.[55]

The expectation is that the growing market of solar power installations will in the coming years also spur new research and development in the solar sector. The vast number of currently rather small installation and service companies will gradually seek growth which for example innovations in related to the system integration and installation of the systems might bring to them.

4 KEY POLICY, LEGISLATIVE AND REGULATORY FRAMEWORK **FOR SOLAR ENERGY AND FUTURE LEGISLATIONS**

4.1 WINTER PACKAGE EU

Europe is a continent set to be climate-neutral by 2050[56] . The current legal frameworks for energy markets in all Nordic countries are designed to fulfil the requirements of the regulations of EU's Third Energy Package[57] described in the EU directive 72[58] published in 2009.

The directive states that the EU internal energy market is built on well-established principles, such as the right of access for third parties to electricity grids, free choice of suppliers for consumers, robust unbundling rules, the removal of barriers to cross-border trade, market supervision by independent energy regulators, and the EU-wide cooperation of regulators and grid operators.

The EU Commission has in 2016 issued new proposals for amendments to facilitate the transition to a clean energy economy. The package called "The Clean Energy for All Europeans"[59], also called "The Winter Package", aims to reform the design and operation of the European Union's electricity market. The amendments are scheduled to come into force starting from 2020.

The Winter package aims to transition the Europe to a low carbon economy by 2050. EU citizens as well as industrial users should over time switch to electricity not only as a source of light, heating and cooling but also transportation. Electricity should in turn stem from low carbon sources, including non-fossil fuels such as hydro, solar and wind energy but also biobased sources (e.g. biofuels, biomass and biogases)[60]. The Winter Package could be divided into three main categories[61]:

1. Proposals amending existing energy market legislation

    a. Measures aiming to bring about a new market design–also known as the market design initiative (MDI) and amending and repealing regulation on the internal electricity market and electricity market liberalization measures

2. Proposals amending existing climate change legislation

    a. Measures aiming to better align and integrate climate change goals into the EU's new market design; includes a revised renewables directive and revised energy efficiency directive

3. Proposals for new measures

    a. New regulation on risk-preparedness in the lectricity sector and proposed regulation on governance of the Energy Union.

In its assessment of The EU Winter Package CEER (Council of European Energy Regulators) highlights e.g. the following issues to consider in relation to the market overall:

- Solar generated energy[62]:
    - o An obligation for EU Member States to always provide visibility on support mechanisms for at least three years ahead mandatory one-stop shops for permit granting, with a time limit.
    - o New buildings and buildings undergoing major renovation must incorporate minimum shares of renewables (RES; renewable energy source).
    - o There is an obligation to deploy RES volumes after 2020, and there is a binding renewable apacity target of least 27% renewables by 2030[63] (increased to 32% in RED II). Solar PV is one of the leading renewable technologies, and this is likely to thrust solar power into a prefer red option 2020-2030. In 2030 almost half all electricity consumed in the EU will have to come from solar, wind or other renewable electricity technologies.
- Smart home technologies and Internet of Things: EU Member States could consider whether there is a need for additional regulation on smart meters (in cases where private solutions for meters are installed);
- Self-generation of electricity: For the self-generator to be able to feed excess electricity into the grid and be financially compensated for it, they must sign a contract with a supplier that also sells electricity to the self-generator;
- Electrical energy storage: Customers' improved access to affordable energy storage may raise legislative issues regarding redistributive economic effects. Similar to electricity generated from on-site production, there is a matter of transparency

as consumers may experience difficulties with understanding the costs, risks benefits of energy storage;

- Charging stations and electric vehicles: A key question is if the general consumer and competition legislation is sufficient or is there a need for energy-specific rules in order to ensure an appropriate level of competition; and,
- Blockchain application in the energy market: The emergence of blockchain to manage transactions, together with the development of decentralized initiatives in the energy sector may challenge regulators' traditional approach to data exchange, centralized at DSO and market operator levels. It also raises the question of whether it is possible to regulate this market, considering its decentralized nature and possible lack of transparency resulting from peer-to-peer transactions.

4.2 RENEWABLE ENERGY IN FINLAND

In Finland, electricity from renewable sources is promoted through a technology neutral tender based premium scheme for electricity from wind, solar, biogas, biomass wood fuels and wave power and through a premium tariff for electricity from wind, biomass and biogas.

In Finland, the use of the grids for the transmission of electricity from renewable sources is regulated by the general legislation on energy[64]. There are no special provisions for electricity from renewable sources. Legislation change to distribute solar power production in housing cooperatives is implemented in the beginning of the year 2021. This enables feasible solar power production also in housing cooperatives/housing companies as well as installing larger solar panel systems for these[65].

4.2.1 FINNISH GOVERNMENT'S NATIONAL ENERGY AND CLIMATE STRATEGY FOR 2030

The Finnish Government published the National Energy and Climate Strategy for 2030[66]. New National Energy and Climate Strategy is being prepared by the Government, and it will be published in fall 2021.[67] Current strategy outlines actions that will enable Finland to attain the targets specified in the Government Program and adopted in the EU for 2030, and to systematically set the course for achieving an 80–95% reduction in greenhouse gas emissions by 2050:

- The strategy outlines that with minor exceptions, Finland will phase out the use of coal for energy by 2030;
- The minimum aim is to have 250,000 electric and 50,000 gas-powered vehicles on the roads (According to the new baseline forecast[68] of greenhouse gas emissions in transport, there would already be about 350,000 electric cars in Finland in 2030, and the majority of these (approximately 290,000) would be chargeable hybrids. The report further comments that the target for electric cars

needs could be significantly tightened, and a new target for electric cars in Finland by 2030 could be to set to 600,000-700,000 electric cars; with the majority of these being fully electric cars);

- The electricity market will be developed at the regional and the European level;
- The flexibility of electricity demand and supply and, in general, system-level energy efficiency will be improved;
- Technology neutral tendering processes will be organized in 2018–2020, on the basis of which aid will be granted to cost-effective new electricity production from renewable energy; and,
- The share of renewable energy in the end consumption will increase to approx. 50 per cent and the self-sufficiency in energy to 55%.

4.2.2 COMMENT ON FINLAND AS ASSESSED BY THE CONSORTIUM SMART ENERGY TRANSITION[69]

Transitioning to a low carbon economy face numerous challenges in most of the countries, even including those with more favorable policies like Germany and Denmark, and there are clear cultural barriers observed on the eastern side of the Baltic Sea. Recommendations include:

- Creating a stable policy framework for renewable energy investments. Given that many energy projects valuate their viability over a long timeframe, e.g. electricity feed-in tariffs must be reliable and stable, and not subject to change at the time of investment decision;
- Eliminating regulatory barriers. Today, self-consumption of solar electricity in apartment buildings is only limited to the electricity needed to power the common parts of building; however, excluding dwellings. This regulatory regime is not encouraging adoption PV solar. Also, building permitting and grid connections must be swift and agile;
- Promoting training and access to information. Those seeking to engage with RES must have access to current and accurate information; this is also crucial for those wanting to establish energy communities;
- Providing early stage funding. Dedicated finance support schemes for energy communities are needed both from national and regional bodies, e.g. to complete feasibility studies and expert consultancy;
- Providing long-term and low-interest investment funding schemes. For example, community energy projects need dedicated financing instruments e.g. low-interest state guaranteed loans and/or low-cost capital for community energy groups;
- Promoting cultural change. A cultural change is required in the mindset of policymakers, especially regarding policy makers in the Eastern Baltic. Community energy is an expression of a different set of values and needs, and policymakers must realize that without citizens' participation in the energy transition, ambitious climate goals may not be achieved due to local resistance to renewable energy projects.

4.3 EU TAXONOMY

The EU Taxonomy[70] is one of the key defining factors of sustainable finance in the coming years, and is a tool to help investors, companies, issuers and project promoters navigate the transition to a low-carbon, resilient and resource-efficient economy.
The Taxonomy sets performance thresholds (referred to as 'technical screening criteria') for economic activities which:

- Make a substantive contribution to one of six environmental objectives

    1. Climate change mitigation;
    2. Climate change adaptation;
    3. Sustainable and protection of water and marine resource;
    4. Transition to a circular economy;
    5. Pollution prevention and control; and,
    6. Protection and restoration of biodiversity and ecosystems.

- Do no significant harm (DNSH) to the other five, where relevant;
- Meet minimum safeguards (e.g., OECD Guidelines on Multinational Enterprises and the UN Guiding Principles on Business and Human Rights).

The performance thresholds will help companies, project promoters and issuers access green financing to improve their environmental performance, as well as helping to identify which activities are already environmentally friendly. In doing so, it will help to grow low-carbon sectors and decarbonise high-carbon ones.

For electricity and heat generation activities, an ISO 14067 or a GHG Protocol Product Lifecycle Standard compliant Product Carbon Footprint (PCF) assessment including measurement of fugitive emissions is required. There is an overarching technology-agnostic emissions intensity threshold of 100g CO2e/kWh, including for electricity production. This threshold will be reduced every five years in line with political targets set out to achieve net-zero emissions by 2050[71]. PV solar is currently allowed to derogate in terms of performing PCF:s, but this could be subject to review when the thresholds are lowered.

The taxonomy basically outlines what is meant by sustainable finance, and includes environmental, social and governance (ESG) topics as integral part of business and investment strategies. What is considered sustainable or green in the finance industry, however, is defined by multiple international reporting and governance frameworks.

- Promoting cultural change. A cultural change is required in the mindset of policymakers, especially regarding policy makers in the Eastern Baltic. Community energy is an expression of a different set of values and needs, and policymakers must realize that without citizens’ participation in the energy transition, ambitious climate goals may not be achieved due to local resistance to renewable energy projects.

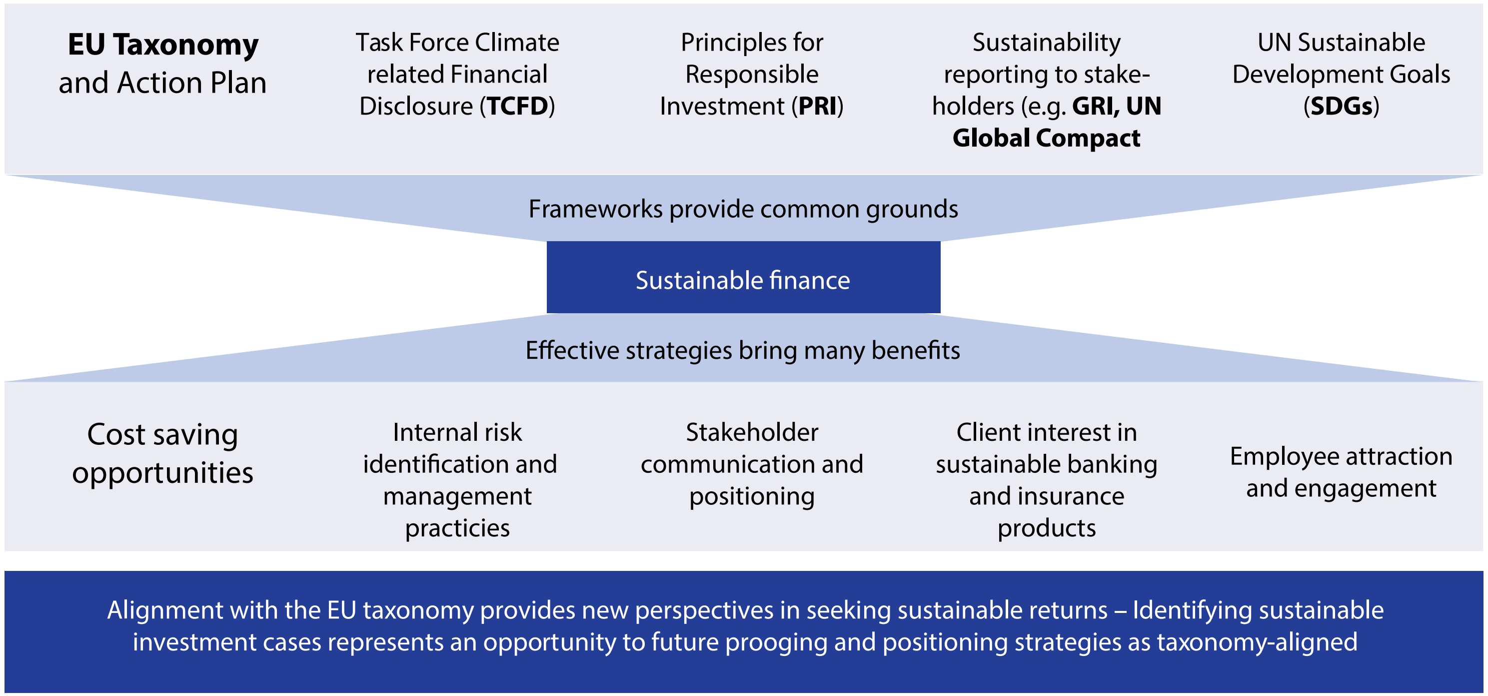

Figure 14. Sustainable finance framework, of which the EU Taxonomy is part

4.3.1 PRODUCTION OF ELECTRICITY FROM SOLAR PV

Note that production of electricity from solar PV is unlikely to be performed in a way that substantially undermines climate change mitigation objectives (one of six environmental objectives listed above), as the life-cycle emissions will likely always fall well below the substantial contribution thresholds recommended by the TEG[72]. The TEG therefore has not felt it necessary to define a DNSH (Do no significant harm) threshold for this activity.Do no significant harm assessment

The main potential significant harm to other environmental objectives from the installation and operation of photovoltaic (PV) panels relate to:

- The PV installation siting: impacts on ecosystems and biodiversity if built in a designated conservation area or other areas with important ecosystem and biodiversity value.
- The impacts from the production and end-of-life management of the PV systems and its component/ materials: potentially significant environmental impacts are associated with the sourcing/production of materials and components of PV systems (see 'Manufacture of Low Carbon Technologies' for DNSH criteria)

4.3.2 PRODUCTION OF ELECTRICITY FROM CONCENTRATED SOLAR POWER

Any electricity generation technology can be included in the taxonomy if it can be demonstrated, using an ISO 14067 or a GHG Protocol Product Lifecycle Standard-compliant Product Carbon Footprint (PCF) assessment, that the life cycle impacts for producing 1 kWh of electricity are below the declining threshold.
Do no significant harm assessment. The main potential significant harm to other environmental objectives from CSP is associated with:

- The construction of the installation and the substantial land-take associated with the installation
- Impacts to birdlife from the high temperatures generated by the plant
- Impacts of the cooling system on water resources

4.4 REUSE AND RECYCLING

WEE directive requires solar panel manufacturers to take care of recycling solar panels. Solar panels can be recycled as electrical appliances.[73] In general the decommissioned solar panels are being globally considered as a ticking bomb and various ideas for recycling options start to incur.[74]

5 CONCLUSIONS

5.1 SUMMARY OF THE EXISTING AND FORESEEABLE FUTURE BUSINESS AND INNOVATION ENVIRONMENT OF SOLAR ENERGY IN FINLAND

In general, on the solar energy market, competing with Asian producer on bulk products is not opening significant business opportunities for the Finnish solar energy companies. On technology level, especially in the beginning of the value chain in cells and modules, niche application areas requiring specific qualities and custom made solutions, even if in the end applied in mass manufacturing applications, is a growing market which Finnish actors are capable of catering with their solutions. Finnish strengths in automation technologies further strengthens competitiveness building in such customized niche markets.

Such emerging market is for example the vehicle integrated PV or VIPV market. Another interesting growing niche market with very specific and tough PV cell and module requirements is the space equipment and device market such as satellites and satellite swarms. Even if the market for one particular application area might not be extremely big, if the Finnish companies are able to find business and commercialization models not only from the point of view of end products but also in terms of custom development and manufacturing process optimization and automation, the different niche areas together can constitute significant market opportunities.

Another competitive edge for the Finnish solar energy solutions is taking environmental considerations as an integral part of the product concept. For example, considering harmful materials such as lead potentially present in cheap alternatives and making CO2 footprint calculations obligatory for the modules, would differentiate positively the Finnish module technologies and products on the market. Also, posing recycling tax to used modules and requiring certificates for recyclability would bring diverse decision-making indicators to the solar energy investments compared to that currently price is the main aspect used in decision making.

Further along the value chain, business opportunities for Finnish companies exist in the micro- and minigrid solutions development as well as on the system management level. Finland could constitute a lucrative pilot environment for micro- and minigrid solutions and systems development which then could find significant market potential for example in the developing markets such as Africa or India.

In the bigger picture, although focus is more and more placed on renewable energy and climate change and its mitigation and adaptation, Finland is still reliable on nuclear energy. Also, the current energy mix in Finland is very price competitive, which means that renewable energy alternatives, including solar PV, must be and remain price competitive in order to have a chance of success (provided that feed-in tariffs are not employed).

In order to gain the most out of the growing solar energy market, attention should be paid in Finland to strengthen the horizontal competencies such as business development and integration of expertise between different market segments, e.g. electricity markets, property automation development and energy storage solutions, and competence to communicate and disseminate about the solar power to various stakeholders such as politicians and the general public.

In general, the regulative environment is not viewed as posing significant challenges to the market actors for the implementation of solar power. However, incentives to support small-scale production would boost the market further. This could be done for example by regulation. In addition, harmonization is called for to the cross-cutting authorities' operations. Solar capacity increase is calling for increased building integration or BIPV implementation. To ensure the increase of BIPV solar capacity, there is a need to integrate solar panel installations to the building planning and construction process. Also, hybrid solutions, such as aggregation of storage solutions with BIPV and energy automation with building automation create new technology opportunities in the solar sector. Sector coupling is also needed in agriculture sector, for example when utilizing agricultural land and buildings jointly for livestock and solar power production. Combining solar heating and cooling to new storage alternatives posed by Power2X can create new business opportunities. However, to leverage these cross-sectoral opportunities to their full potential, also regulative aspects need to be paid attention to.

5.2 POSITIONING OF SOLAR INDUSTRY IN FINLAND AS PART OF THE EU DEVELOPMENTS

In general, Finland and the Finnish solar energy actors should be more active in the EU networks and participating in the EU projects. If for example a Finnish SME is commercializing specific solar energy technologies, participation in EU project and networks brings opportunities to, on one hand, finance the development investments to be made, and on the other hand, build networks to future customers and partners. Active participation in the EU clusters could be seen as staying informed and also being able to influence future market opportunities, enabling to build awareness and brand on one's offering and capabilities in front of potential future customers and partners. Market actors perceived that at the moment Finland is fast adapter to the solar trends and directives coming from EU but not a contributor leading the solar market development in EU.

Another important issue is the participation of Finnish companies and other relevant entities in the standardization work related to solar power but also to the entire system and its control including storage and microgrids etc. For example, Fimer is actively participating in such work. This work can be correlated to former work done by Nokia in contributing to the creation of telecom standards. Contributing actively to the standardization work will ensure that the Finnish companies develop their technologies to such direction that will maintain and increase their competitive edge in the vast emerging markets of renewables utilization and Power2X development. Participation in standardization work is also a window of opportunity for the Finnish companies to network with possible partners and customers on European and even global level. Participation of research actors will give the possibility to showcase the strong knowledge basis of the Finnish actors. Altogether, such visibility of Finnish actors can also positively strengthen the image of Finland in general as viable alternative for FDI activities.

5.3 STRENGTHS AND WEAKNESSES OF THE FINNISH SOLAR ENERGY VALUE NETWORK

Perceived strengths and weaknesses of the Finnish solar energy value network are presented in *Table 1* below. The perception on the strengths and weaknesses vary according to the organisation and its position in the value network, however, in the table a general view is taken.

As a summary, strengths are seen especially in technological readiness and competencies also beyond immediate solar energy focus, and in research and project management capabilities. Main weaknesses are seen regarding geographical location, political support and the small size of the market.

STRENGTHS	WEAKNESSES
• Stable electricity markets and strong overall connectivity • Readiness to apply balance management and demand response on the electricity market • Excellent capabilities, know-how and technologies for system level design • Excellent technical know-how regarding smart digital solutions and their development • Long traditions on R&D of solar energy systems and components • Well-established engineering and project management know-how • Market growth potential • With the development of solar technologies and with rising costs for fossil-based energy solar energy is increasing gaining economic viability as an alternative in Finland	• Finland's geographical location, and winter conditions for producing solar energy • Lacking economy of scale in developing solar due to small market size, dispersed knowledge and mostly small-scale industry operations in the context of the solar sector • Solar energy not regarded as a viable alter-native and thus not given due attention on political and societal level, e.g. in regulative work • Proper industry participation in the stand-ardization work related to solar power and its utilization as part of the changing energy system, and subsequent potential compati-bility issues for Finnish products on the market; also missing potential opportunity to take a leading role on electricity system level development

Table 1. Strengths and weaknesses in Finnish market

5.4 BUSINESS, COLLABORATION AND JOINT-VENTURE OPPORTUNITIES IN SOLAR ENERGY IN FINLAND

The niche technology know-how as a strength for the Finnish solar energy sector entails new kind of business model possibilities with European and even global companies. For example, application area specific companies in new technology areas, such as storage solutions or VIPV technologies, tend to still be startups or small ventures along the side of major bulk conventional business areas. In these business settings the technology and business risks are such high that, in order to enter to the market, risk sharing is required. Risk sharing can be accomplished for example by jointly forming a joint venture company for the commercialization of the product, instead of the conventional format of selling technology or final products to the end customer. Another business format can be that when selling the technology or product, part of the revenue is based on royalties of the use of technology and thus the income will increase if the end product, such as a car, sells well on the market. These new business formats require very close business and innovation development partnerships between the technology providers and end users.

Finland could act as a pilot test bed for hydrogen economy solutions as well as micro- and minigrid solutions. Finland has all the prerequisites to effectuate such pilots and as such give a marketing lookout for the Finnish technologies and knowhow as well as provide a kind of soft landing opportunity for non-Finnish technologies and companies to test and build partnerships with the Finnish companies and other actors.

The solar projects are growing in size also in Finland which means new business models and ownership of the project and investments compared to small e.g. residential projects. Such projects in some sense and extent start to resemble wind project developments even if the scale is smaller in general. There is good know-how and proficiency in Finland to conduct large scale projects and their project management. Such large, more than 100 MW solar power plants are calling for national grid connection and for example Nordic collaboration to enable selling the electricity produced to the NordPool power market to gain economic feasibility. Also new kind of financing solutions will be needed including engaging investors to drive such project development. Such large-scale projects could also be coupled under the Power2X project umbrella for pilot project development, prerequisites to develop such projects exist in Finland. For example, combination of existing infrastructure for gas network and solar technologies could be utilized as a platform for such projects, however, project executors and technology providers are needed.

Solar heat is not as prevalent in Finland as solar electricity and its application. Finnish district heating know-how is utilized to develop export markets for solar heating in the context of district heating elsewhere, for example in Denmark and France, but such markets have not yet emerged in Finland. To create such markets also in Finland, pilots would be needed in which combination of solar heat technology and storage solutions would be implemented.

In general, there is a need for such ecosystems in Finland that would bring together small-scale and large-scale actors to develop commercial and scalable solutions for solar energy pilots including both solar technologies as well as knowledge on balance of systems perspective. Such business ecosystems would form a proper platform for possible joint-ventures and FDI activity as well as exports.

5.5 KEY RATIONALE FOR FDI

Key rational for FDI activities is created through widening the viewpoint in Finland from immediate solar energy, electricity and technology field to the perspective of utilizing solar technologies in different applications. Future potential is presented in for example such application areas as solar technology integrated into buildings and cars and other vehicles. Also, integration of solar technologies to some specific energy consuming operations within various industries creates potential, such as usage of drones in logistics or production of cold in the food and retail industry. Finland has good prerequisites from its long traditions in engineering and electric engineering industries to enter these fields. Connecting these fields through for example in facilitating ecosystem creation could spur such technology platforms that might be attractive and visible also to foreign investors. Such ecosystems might also spur startup culture to the solar energy field which is currently lacking such culture and undergrowth of new business activities: startups are a good vehicle to showcase the Finnish know-how and innovations and as such getting attention of potential foreign investors. Startup culture and new undergrowth is also needed since the global markets for basic applications of solar power and solar heat technologies are already rather saturated and thus the focus should be put on new applications and new technologies to be interesting for foreign investments.

In *Figure 15* such short-term and long-term developments in solar technology in Finland are indicated that give rational for foreign direct investments. The developments are not presented in chronological order but rather scaled more coarsely to something that will happen sooner and later.

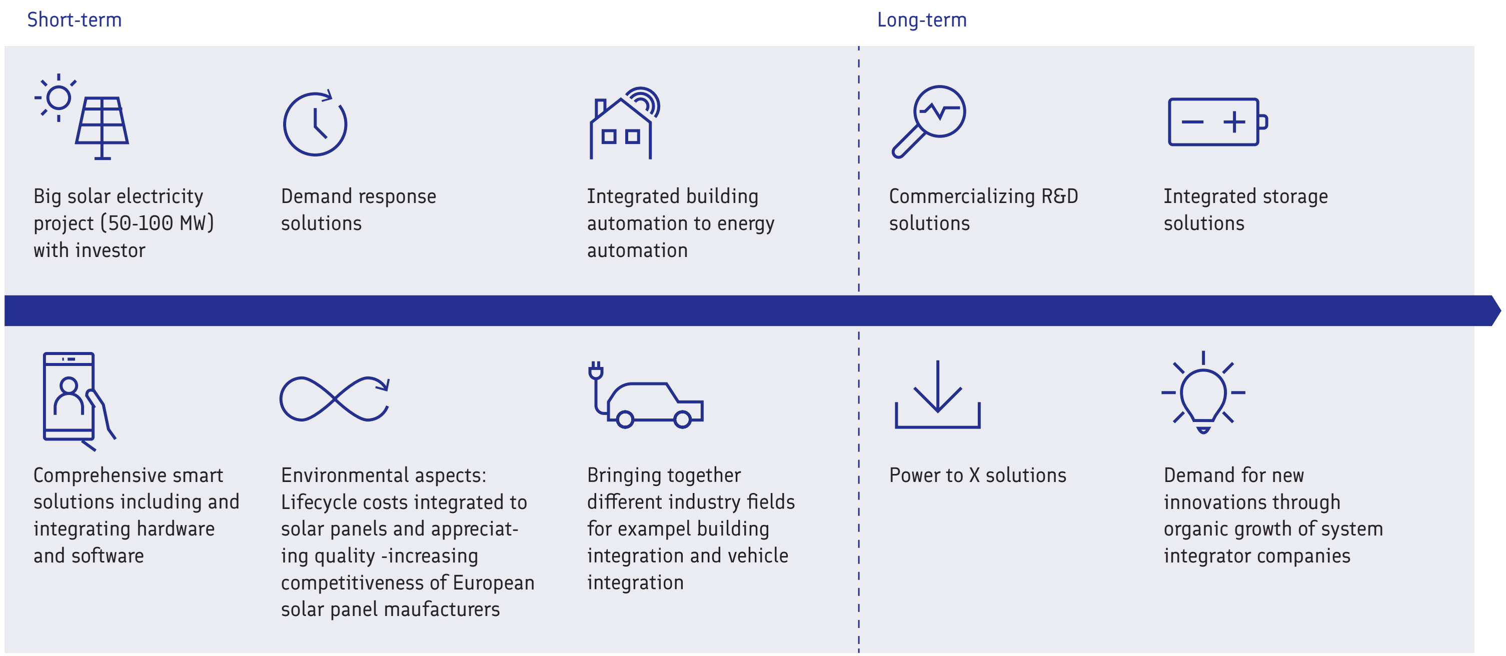

Figure 15. Short-term and long-term trends in solar technology.

5.6 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

The largest provider of solar panels globally and also from a national standpoint is China, although there is solar panel manufacturing in Finland, as well as in other European countries, such as Germany. New European solar panel development and manufacturing initiatives focus on non-silicon-based technologies, e.g. making use of perovskite[75], but these are still to be commercialized on a larger scale. Aalto University is also engaged in perovskite development, and there are plans to scale up carbon based printed perovskite solar cell technology[76].

Companies as well as academic institutions in the value network's thematic sections balance of system technology and the complementary system service, installation and maintenance parts all report a turnover coming from solar PV in the range of 1-5%. Although these percentages differ by a magnitude of about 10 compared with installed capacity in 2018 (Figure 4), the conclusion still points to the same direction: solar PV has not yet taken off ground in a big fashion in Finland, although there are number of pilots and installations across Finland.

Many companies irrespective of activity in the value network offer services related to installations in some way. The numerous service and installation companies most likely will have an appetite to grow at some point in the future. Such growth thinking most probably spurs new innovation activity to support the growth, especially if there is at the same time clear indications that market opportunities continue to grow related to solar energy and renewables in general.

Many pilots and initiatives focus on electricity generation, also e.g. the creation of energy communities. However, the use of solar PV together with other sources of energy e.g. geothermal heat and/or other thermal related applications (e.g. pumps) are still in testing phases. Also, the use of solar PV for heating water (for example for household use of indoor heating) does not seem to be very prevalent yet.

The number of solar PV installation in both commercial uses and for household applications have increased, but there is a clear call for larger scale either pilots and/or solar farms. More large-scale solar plants would not only bring an increased volume of renewable energy to meet an increased demand, but would also allow for testing, development and implementation of commercial solutions related to smart solutions and efficient energy community models. From a consumer point of view solar PV might not yet bring particular economic benefit, but many still favour renewable solutions as part of an overall solution – connected to this is also the notion that a solar PV installation might actually also contribute to the increased value of property and/or asset.Renewable, including solar energy technologies are continuously advancing, and even though predicting the future has its challenges, some clear indications that give sight to the future are visible for the next 5-10 years perspective. Some of these are as follows:

- Solar panels are becoming more and more of a bulk good, a standard hardware part of the system entity, especially when considering large solar installations. At the same time however, profitable solar power plant might need optimization of the technology utilized according to available solar intensities. On the niche side there is increasing room for customary application related solutions.
- Assuming that PV solar markets are growing also in Finland, the focus will be towards building larger entities as well as integration of energy storage solutions into the system.
- Project operation becomes even more professional and industry becomes more standardized. Regulative and quality insurance processes become more standardized.
- New renewable energy related technologies are making inroads to the energy system, such as hydrogen.
- It is expected that during this decade large scale solar farms will make their entry also to Finland, e.g. in the range of 30-40 MW or up to 100 MW, even if gaining profitability for such farms is more challenging in Finland and in some more solar intensive geographical locations.
- A change will be needed towards customer-oriented solution development: offerings must be better than currently tailored to mirror the way consumers (not experts) reason. For example, the notation of “kWh” might clear to an expert, but an average consumer might not fully understand its meaning. Such customer-oriented perception can also contribute in gaining needed political support for solar energy utilization in Finland.
- There are clear opportunities for the Finnish solar energy related industry when focus is placed on the entire system (e.g. balance of system technologies, batteries, smart digital means and software) and its optimization and control.

Overall, the main actors in the solar power field seem rather dispersed in Finland especially when considering the smart energy solutions and business as well as sustainable renewable energy production systems and business levels as indicated in *Figure 1* in the methodology-section of this report. The Business Finland Smart Energy program is funding projects and ecosystems creation that also consider solar energy as part of the possible energy palette. However, in these activities, solar energy is a side issue and does not seem to be gaining such a role that the activities would strengthen the solar energy cluster as such in Finland. Some kind of ecosystem creation around the solar cluster in Finland, building it especially from the solar point of view and business oriented in nature, for example as test beds for developments that cater global emerging and growing renewable energy markets or some growing niche areas that utilize solar power, could strengthen the visibility of all relevant Finnish actors in European and global markets beyond solar including system control and storage technologies. This could result in both increased export opportunities as well as positive attention towards possible FDI activities.

6 APPENDIX

6.1 APPENDIX 1: LIST OF INTERVIEWEES

1. Fimer
2. Caruna
3. Fortum
4. Valoe
5. Naps Solar
6. Lappeenranta University of Technology LUT
7. Lemene/Lempäälän Energia
8. YIT
9. Wapice
10. Savosolar

7 SOURCE REFERENCES

1. www.irena.org/publications/2020/Mar/Renewable-Capacity-Statistics-2020
2. Mass-produced European solar panels on the horizon
3. www.iea.org/data-and-statistics/charts/installed-power-generation-capacity-by-source-in-the-stated-policies-scenario-2000-2040
4. www.abb-conversations.com/fi/2016/02/100-miljardin-markkina-odottaa-ottajaansa/
5. www.lahienergia.org/lahienergia/aurinkoenergia/
6. Finnish statistics, Sähkön hankinta energialähteittäin, available at: https://pxhopea2.stat.fi/sahkoiset_julkaisut/energia2019/html/suom0002.htm
7. Project interview
8. julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161978/VNTEAS_2019_73.pdf?sequence=1&isAllowed=y
9. Nordpool, historical market data, Elspot prices 2019 hourly, available at: www.nordpoolgroup.com/historical-market-data/, transmission and taxes are not included.
10. IEA Solar heat worldwide 2020, available at: www.iea-shc.org/Data/Sites/1/publications/Solar-Heat-Worldwide-2020.pdf
11. Tilastokeskus, Sähkön tuotannon energialähteet 2019 Lähde: http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ene__salatuo/statfin_salatuo_pxt_12b4.px/
12. Aurinkosähkön tuotantokapasiteetti lisääntyi 82 % vuodessa
13. Frost & Sullivan, 2018, European Power Market, Forecast to 2025
14 https://www.uudenmaanliitto.fi/files/21285/Uudenmaan_aurinkoenergiaselvitys_%28E193-2017%29.pdf
15. https://green-x.at/RS-potdb/potdb-long_term_potentials.php
16. https://www.abb-conversations.com/fi/2018/06/aurinkosahkon-nelja-trendia/
17. https://www.businessfinland.fi/ajankohtaista/uutiset/2020/power-to-x-ekosysteemi-tarttuu-tulevaisuuden-haasteisiin-energian-varastointiratkaisuissa/
18. https://www.businessfinland.fi/49cbd0/globalassets/finnish-customers/02-build-your-network/bioeconomy--cleantech/batteries-from-finland/batteries-from-finland-report_final_62019.pdf
19. http://smartenergytransition.fi/wp-content/uploads/2019/05/emerging-business-ecosystems-behind-the-new-energy-services-in-finland-1.pdf
20. The Birth of Engineer Education in Finland, European Journal of Engineering Education, 2007
21. Technology industries
22. https://global.abb/group/en/about
23. https://new.abb.com/news/detail/57766/abb-completes-divestment-of-solar-inverter-business-to-fimer-spa
24. https://www.tekniikkatalous.fi/uutiset/abb-laajentaa-aurinkovoimalaboratoriota-helsingissa-lupaa-markkinoille-uutta-aurinkotekniikkaa-energiavarastoineen-jo-tana-kesana/6fe0e5b3-f669-395a-a924-ca183961a295
25. https://www.danfoss.com/en/about-danfoss/our-businesses/power-solutions/
26. https://www.danfoss.com/en/about-danfoss/news/dds/danfoss-is-among-finlands-top-industry-striving-to-be-global-leader-in-utilizing-data/
27. https://www.ensto.com/company/newsroom/company-news/solar-power-plant-for-ensto-in-porvoo/

28. https://napssolar.com/en
29. https://napssolar.com/en/what-photovoltaic-energy
31. https://www.fortum.com/products-and-services/smart-energy-solutions/solar-solutions/solarplus
32. https://www.aurinkotekniikka.fi/
33. https://www.gef.fi/
34. https://www.playgreen.fi/
35. https://fi.wikipedia.org/wiki/Luettelo_Suomen_suurimmista_aurinkovoimaloista
36. http://www.lempaalanenergia.fi/content/fi/1/20126/LEMENE.html
37. https://www.businessfinland.fi/ajankohtaista/uutiset/uutiset-2017/fiksu-kaupunki--tutkimushanke-alya-energiankulutukseen-optimoinnilla-ja-automaatiolla/
38. https://finsolar.net/
39. https://smartotaniemi.fi/
40. http://www.reimari.fi/2016/08/23/makelankankaan-aurinkovoimala-vihittiin-kayttoon/
41. https://yle.fi/uutiset/3-10453579
42. https://www.hybrid-power.fi/hankkeet/
43. https://www.maaseuduntulevaisuus.fi/talous/artikkeli-1.1227581
44. http://www.pes.eu.com/solar/new-opportunities-for-integrated-solar-electricity/
45. https://www.pv-magazine.com/2020/03/12/finnish-solar-manufacturer-touts-self-charging-car-deal-as-e3-5m-fundraising-ticks-down/
46. https://www.pv-magazine.com/2020/05/07/finnish-solar-manufacturer-gets-lithuanian-factory-purchase-over-the-line/
47. https://www.pv-magazine.com/press-releases/sono-motors-launches-a-unique-investment-campaign/
48. https://sonomotors.com/en/about-us/
49. https://www.highlite-h2020.eu/
50. https://www.highlite-h2020.eu/partner/
51. https://www.uusiteknologia.fi/2020/01/13/aurinkokenno-voidaan-tulostaa-suoraan-ikkunaan/
52. https://soletair.fi/
53. https://yle.fi/uutiset/osasto/news/fuel_from_solar_energy_and_air_-_finnish_startup_gets_funding/10740884
54. https://www.soletairpower.fi/
55. https://www.uusiteknologia.fi/2018/06/15/abb-laajentaa-aurinkovoimalaboratoriotaan/
56. Eurostat Renewable energy statistics
57. European Commission Market legislation,
58. EUR-Lex: Directive 2009/72/EC
59. Clean energy for all Europeans,
60. The EU Winter Package Briefing Paper, Prof. L. Hancher and Mr. B.M. Winters, February 2017
61. The EU Winter Package, Briefing Paper, 2017

62. The Winter Package: what does it mean for solar?, Solar Power Europe
63. In RED II, the overall EU target for Renewable Energy Sources consumption by 2030 has been raised to 32%. The Commission's original proposal did not include a transport sub-target, which has been introduced by co-legislators in the final agreement: Member States must require fuel suppliers to supply a minimum of 14% of the energy consumed in road and rail transport by 2030 as renewable energy (https://ec.europa.eu/jrc/en/jec/renewable-energy-recast-2030-red-ii). RED II also makes way for the estab-lishment of decentralized energy systems and energy communities, meaning that EU citizens become prosumers with the possibility to also become active parties in the overall EU energy transition.
64. Electricity Market Act - Sähkömarkkinalaki - 588/2013
65. YLE article, "More attractive solar energy", October 2020
66. Ministry of Economic Affairs and Employment of Finland, Energy and climate strategy
67. The Ministry of Economic Affairs and Employment's climate and energy strategy (in Finnish)
68. Road map for fossil-free transport – Working group final report, October 2020
69. Smart Energy Transition
70. Taxonomy: Final report of the Technical Expert Group on Sustainable Finance, March 2020
71. EU Taxonomy, Technical Annex, Updated methodology & Updated Technical Screening Criteria, March 2020
72. EU Taxonomy Technical expert group
73. https://kiertokaari.fi/jatehaku/aurinkopaneeli/
74. https://www.pv-magazine.com/2020/05/27/solar-panel-recycling-turning-ticking-time-bombs-into-opportunities/
75. Forget silicon. This material could be a game-changer for solar power, Oct 14, 2020 (accessed Oct 27, 2020)
76. Scaling up carbon based printed perovskite solar cell technology at Aalto University

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