

**UNIVERSITY OF VAASA
SCHOOL OF MANAGEMENT**

Timo Hämeen-Anttila

**BUSINESS CONCEPTS OF SOLAR PHOTOVOLTAIC ELECTRICITY
GENERATION FOR SYSTEMS INTEGRATORS**

Master's thesis in
Strategic Business Development

Master's programme in
Strategic Business Development

VAASA 2018

TABLE OF CONTENTS	Page
LIST OF FIGURES	5
LIST OF TABLES	7
ABSTRACT	9
1. INTRODUCTION	11
1.1. Background of the study	11
1.2. Research gap	15
1.3. Objectives and limitations of the study.....	15
2. THEORETICAL BACKGROUND	18
2.1. Definitions	18
2.2. History of photovoltaic and techno-economic overview	22
2.3. Business models, theories and concepts for Systems Integrator	26
3. RESEARCH METHODOLOGY	32
3.1. Methodological choices and arguments.....	32
3.2. Research process.....	33
3.3. Data collection	33
3.4. Evaluation of reliability and validity	34
4. EMPIRICAL RESEARCH AND RESULTS	37
4.1. Results analysed and presented.....	37
4.2. Key findings and conducted models.....	47
5. SUMMARY AND CONCLUSIONS	55
5.1. Summary and key findings	55
5.2. Theoretical contributions	60

5.3. Managerial implications	61
5.4. Suggestions for further research	63
REFERENCES	64

LIST OF FIGURES

- Picture 1. Global new investments in renewable power and fuels (NREL 2018).
- Picture 2. Global investment in new power capacity (NREL 2018).
- Picture 3. Solar PV module prices 2010 to 2015 by technology (IRENA 2018 i).
- Picture 4. Global solar insolation map (2017 The World Bank, Solar resource data: SolarGIS).
- Picture 5. Solar irradiation in Finland (PVGIS 2018).
- Picture 6. Photovoltaic systems categorization (DGS 2013).
- Picture 7. Hybrid solar PV-plant topology.
- Picture 8. Finland: RES electricity development in National Plan (Cross et al. 2015: 1772).
- Picture 9. Californian “Duck Curve” (NREL 2015).
- Picture 10. Hypothetical electricity market dispatch curve (Matek & & Gawell 2015).
- Picture 11. Basic Systems Integrator business model.
- Picture 12. Organisational structure of integrated solution (Davies et al. 2006).
- Picture 13. Business concept framework (Bocken & Short 2016).
- Picture 14. Monthly values of global radiation in Helsinki and Rostock (Finnish Meteorological Institute 2014:5)
- Picture 15. Population served by off-grid renewable energy solutions globally (IRENA 2018 ii).
- Picture 16. Annual diesel genset installation capacity by region, world markets: 2013-2018 (Navigant Research).
- Picture 17. Segmentation of Solar photovoltaic systems by power range.
- Picture 18. Electricity transfer price development in Finland. Ref. small house 5 000 kWh / year, the average price for the whole country from 01.01.2000 to 09.08.2018 (Energy agency 2018).

LIST OF TABLES

Table 1. Explanations of the abbreviations.

Table 2. Systems Integrators value creation.

Table 3. Interview frame and questions.

Table 4. Introduction of the selected companies.

Table 5. Company A value proposition.

Table 6. Company A value creation.

Table 7. Company A value capture.

Table 8. Company B value proposition.

Table 9. Company B value creation.

Table 10. Company B value capture.

Table 11. Small-scale (< 1MW) electricity generation in Finland (Energy Authority 2018).

UNIVERSITY OF VAASA**School of Management****Author:**

Timo Hämeen-Anttila

Topic of the Thesis:

Business concepts of solar photovoltaic electricity generation for systems integrators

Name of the Supervisor:

Iivari Kunttu

Degree:

Jukka Vesalainen

Master of Science in Economics and Business Administration

Master's Programme:

Master's Programme in Strategic Business Development

Year of Entering the University:

2011

Year of Completing the Thesis:

2018

Pages: 72

ABSTRACT

The world's energy systems are changing at an accelerating pace. The drivers for the development are constantly increasing the demand for energy, the growing population and the economic output. Whereas, the global challenges of the energy sector have enabled the development of new technologies for energy production in accordance with the principles of sustainable development. Electricity production is emerging as the most popular form of renewable energy.

In this thesis, the business concepts of solar photovoltaic electricity generation for systems integrators are discussed. The theoretical framework referred to in this paper is servitization. The study has examined the theory and assessed what kind of business concepts and value creation models exists in scientific literature in service context currently. The practical part of the study was conducted as a case study. Two well-known Finnish energy companies have been selected for this research, which have recently moved to commercialization of solar energy systems as part of their current business.

The study suggests that solar photovoltaic is no longer an actual “green statement” but has become an economically fully competitive energy solution with traditional power generation solutions. According to the study, the broad market penetration of photovoltaics among other renewables, has significantly changed the dynamics of the electricity market. Renewable energy systems replace basic power generation solutions and the need for so-called “reserve power” increases. The reserve power must respond very quickly to the fluctuations in production and the consumption of energy. It must be flexible and reactive. In the North and South of the globe, photovoltaic power cannot replace the current base power solution, but it will be installed to increase energy self- sufficiency.

KEYWORDS: Systems integrator, solar photovoltaic.

1. INTRODUCTION

1.1. Background of the study

An intense discussion of sustainable energy solutions has been emerging over the past few decades about globalization and climate change. It has been argued about how much of the global warming is indigenous from human influence, but the earth's surface temperature in 2016 were the warmest since modern recordkeeping began in 1880. It was 0.99 degrees Celsius warmer than mid-20th century mean (National Aeronautics and Space Administration 2017). Regardless of whether this period of time is too short to make conclusions about global warming, it is widely accepted that climate change is an adverse global phenomenon and climate change mitigation and reducing greenhouse gas emissions are for the good of the public (IPCC 2014). Indeed, climate change has been interpreted so harmful that international treaties have been made to prevent it, take *Kyoto Protocol 2005* or the *Paris Agreement 2016* for example (UNFCCC 2017 i; UNFCCC 2017 ii). This is still valid despite US withdrawing from the Paris Agreement which is considered as a setback for climate change mitigation according to the press around the world. The European Union, on the other hand, has not only committed to these international efforts, but has also set preventing actions towards climate change as a key priority. According to the European Commission (2017) the EU key targets for 2030 are:

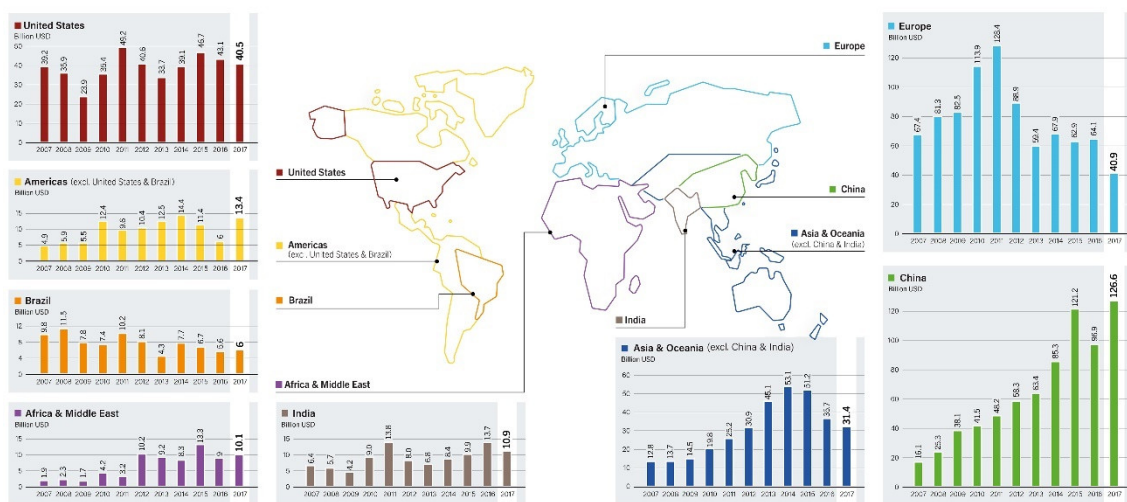
- at least 40 % cut in greenhouse gas emissions compared with 1990
- at least 27 % of total energy consumption from renewable energy
- at least 27 % energy efficiency

The energy sector is the largest source of greenhouse gas emissions on a global scale. It has been predicted by several authors, that the global energy sector is facing relatively rapid changes over the forthcoming years and decades. This trend has already begun with an increasing pace. The key drivers regarding energy production are *simultaneous growth of energy demand, population and economic output*. The main challenges, on the other

hand are to secure energy production, so that production should meet the demand at all times, and a reduced impact on climate change without interfering human wellbeing (Larjava et al. 2009).

Every challenge provides an opportunity. Renewable energy sources are competing with traditional energy sources and especially with fossil fuels. They are considered to be a sustainable way of providing energy but also, they are becoming more cost efficient as the technology is developing (e.g. SBH Resources 2017). These provide an increasing amount of investments and new opportunities to companies within the energy sector. Global new investments in renewable energy power and fuels are presented in Picture 1. The global trend, excluding Europe, is ascendant.

Global New Investment in Renewable Power and Fuels, by Country or Region, 2007-2017



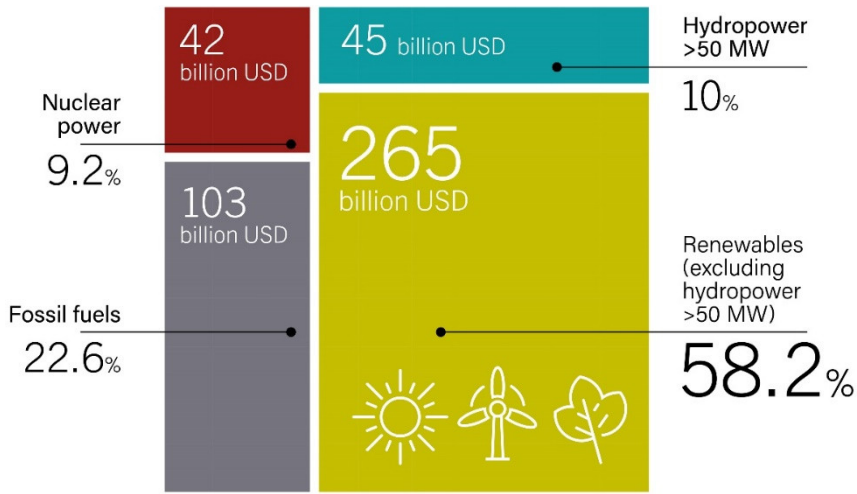
Source: BNEF



Picture 1. Global new investments in renewable power and fuels (NREL 2018).

According to the EIA (2017), renewable energy sources are the fastest growing energy source and electricity is the world’s fastest growing form of end-use consumption. When compared to other renewable energy sources, solar photovoltaic (PV) has gained dominating position due to development of technology and a substantial decrease in price.

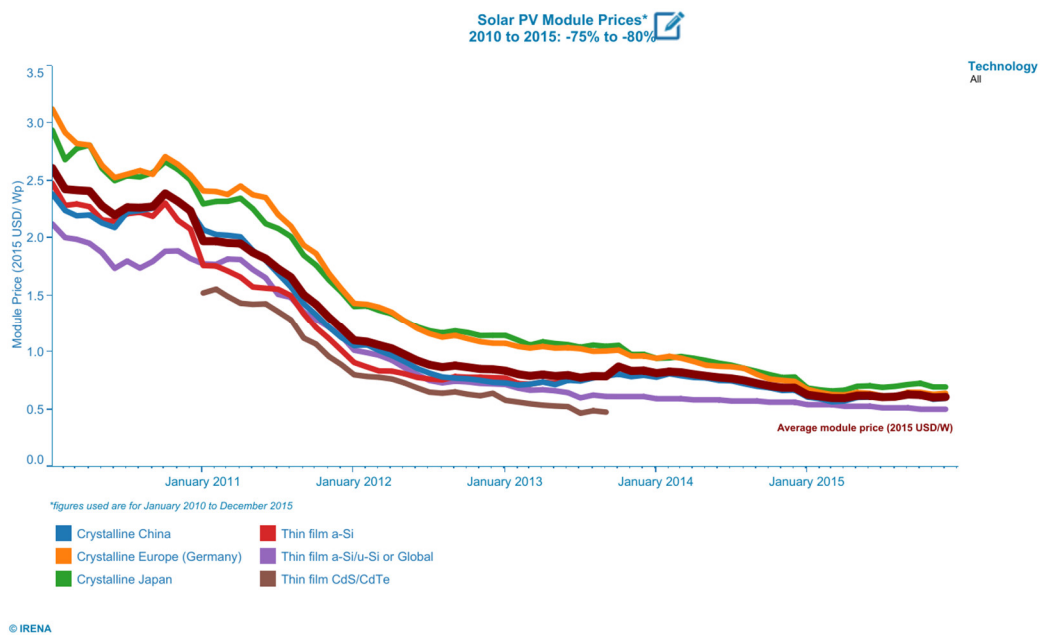
Global Investment in New Power Capacity, by Type (Renewables, Fossil Fuels and Nuclear Power), 2017



Source: BNEF

REN21 RENEWABLES 2018 GLOBAL STATUS REPORT

Picture 2. Global investment in new power capacity (NREL 2018).



Picture 3. Solar PV module prices 2010 to 2015 by technology (IRENA 2018 i).

In Germany, for example, the price level for grid-connected photovoltaic systems have decreased by 80 % within the past 23 years and at the same time, the efficiency of commercial solar panels made of monocrystalline or polycrystalline are reaching 20

percent. Since the turn of the millennium, Germany has become a major market for solar photovoltaic systems (Seel et al. 2014, DGS 2013: 5).

The development of energy markets and the utilization of renewable energy sources has given rise to new opportunities for contributors within the energy sector. In solar PV, the competition within solar panel markets came close to a trade war between EU, the largest market for solar panels, and China, the largest solar panel manufacturer in the world. Since the EU claimed against China for unfair competition and manipulating markets by dumping solar panels heavily underpriced to manufacturing costs (EIAS 2017).

Competition between panel manufacturers is extremely fierce. We have already seen that large German-based solar panel manufacturer SolarWorld have gone bankrupt again, less than one year after getting a second chance. According to press report, this second insolvency filing has been due to price dump in China and 30 % import tariffs in the United States. Although the industry is growing tremendously, corporate operating profit has not risen to the same extent as net sales (Solar power world 2018).

From the solar PV system integrator point of view, the high price competition has contributed to favourable development at the expense of others traditional and renewable energy sources. The markets in this field are growing and technology is developing fast. Here in Finland, there are valuable engineering and manufacturing knowledge, providing attractive business opportunities for systems integrators both internationally and domestically. Also, as far as the writer is aware of, this topic is not explored in this context before.

In this research, solar photovoltaic business opportunities are studied from a Finnish Systems Integrators point of view. It is intended to be rather pragmatic, providing insights for the branch itself and business opportunities within the renewable energy sector.

1.2. Research gap

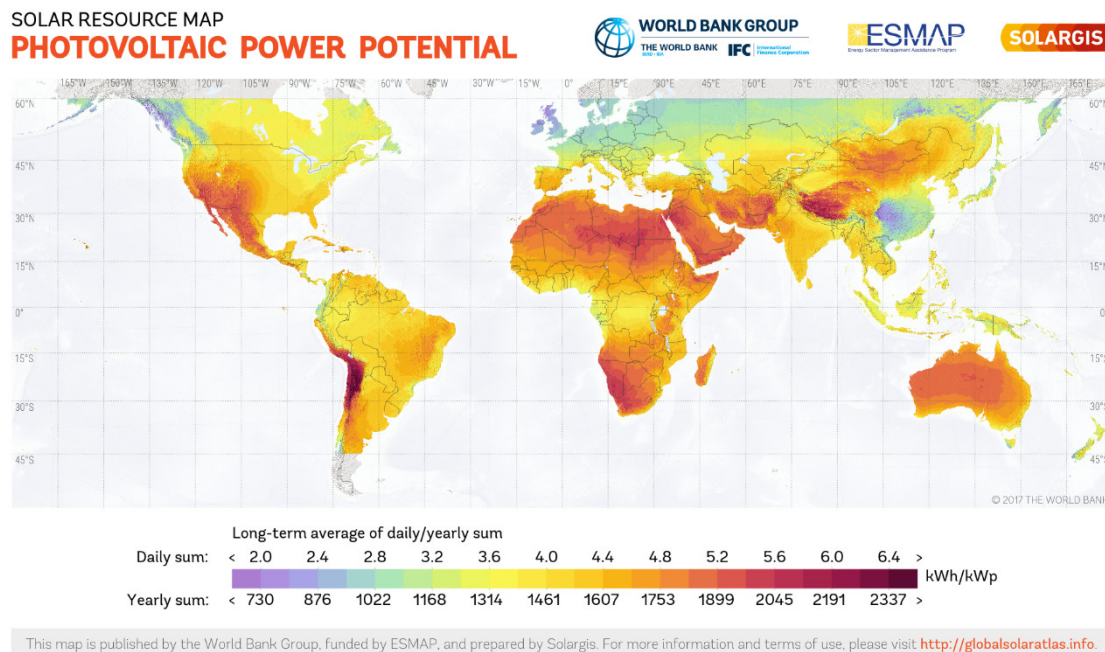
A lot of renewable energy sources have been studied in scientific literature. Often studies have explored how economical or profitable these energy sources are in relation to traditional energy sources. Traditional sources of energy, in particular coal-based energy have been the subject of criticism since they have been found to be poorly suited to environmentally friendly energy production. On the other hand, while new technologies are developing in this area, new kinds of intelligent energy solutions and multi-format intelligent control solutions are also emerging. The key issue is also the advantages and disadvantages of centralizing versus diversifying energy production.

From the Systems Integrators point of view, the service business has been examined in various forms and these issues are discussed in more detail in the theoretical part of this study. After the literature review, it is noted that apparently no similar research has not been done in the past. Thus, it can be argued that it has been justified to conduct this research and but also to increase the overall knowledge of the business regarding photovoltaic systems.

1.3. Objectives and limitations of the study

The aim of this study is to expand the understanding of the solar PV business by exploring *what kind of business opportunities photovoltaic systems may provide for Systems Integrators*. Experts in this area have been interviewed and interviews have been interpreted. These interpretations illustrate also this time, and it is good to keep in mind that the whole industry is undergoing a major change and the future may look very different. Another thing to note is that the industry is large and the local conditions differ considerably. This thesis is, in principle, intended to cover the business opportunities in general and not so much about focusing on the local conditions here in Finland. One of the two companies surveyed is operating only in Finland, consequently the local

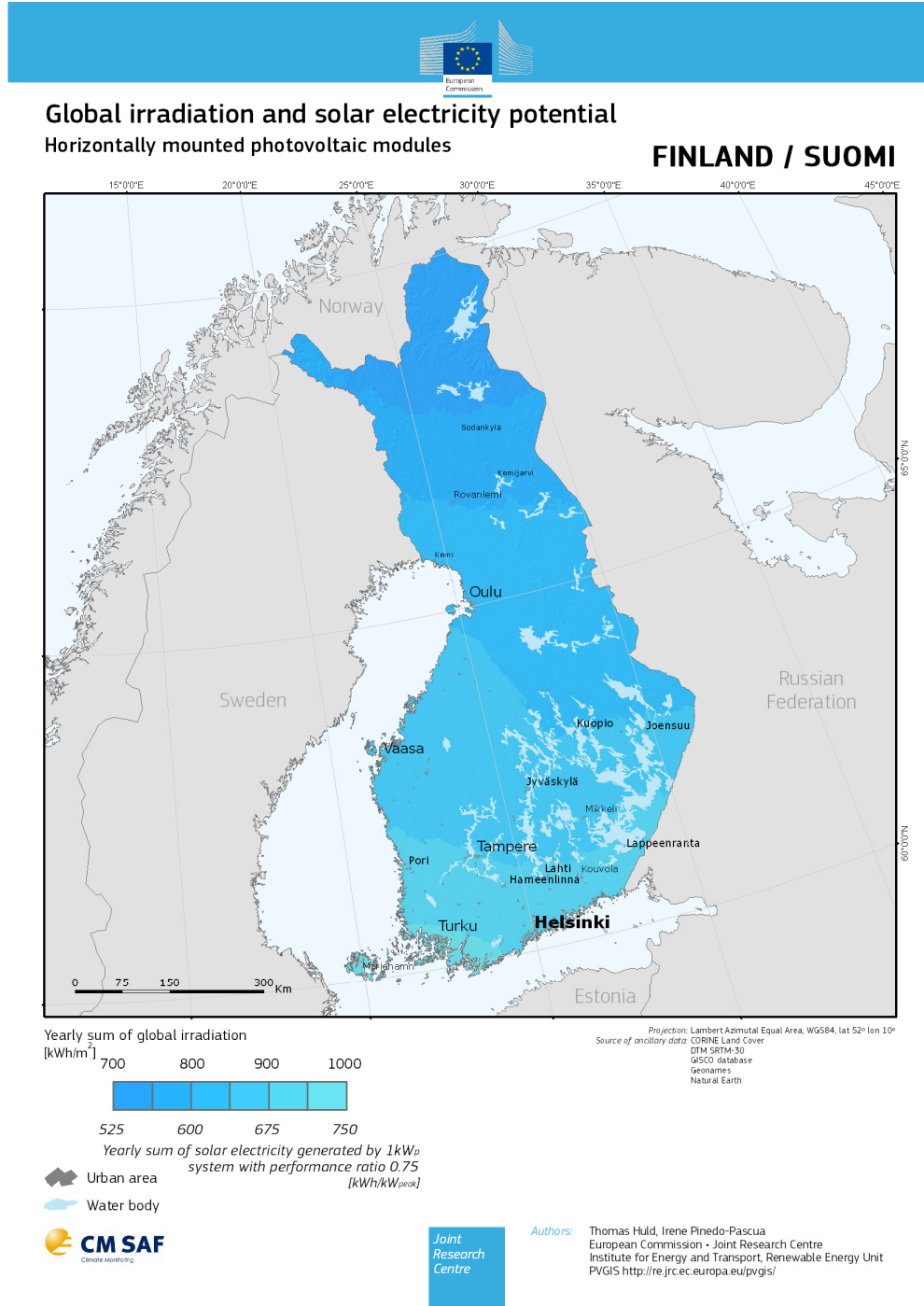
perspective is represented in this thesis also. As research has proceeded, it has become clear that the energy market is very different; only in Finland there may be about ten different types of markets. There are certainly hundreds of them globally. In addition, the price of electricity globally varies considerably, as does the intensity of solar radiation, and the potential for producing solar electricity at the Earth's north and south is naturally lower than in the central regions.



Picture 4. Global solar insolation map (2017 The World Bank, Solar resource data: SolarGIS).

Solar energy potential can be better harvested in central areas of globe where solar irradiation intensity is prominent. In southern Finland, the intensity of solar radiation corresponds to the conditions in northern Germany. However, the amount of solar radiation varies significantly between southern and northern part of Finland. The arctic circle passes through the country near the city of Rovaniemi. The angular distance of the polar circle and the north pole is the same as the Earth's rotational axis inclination compared to the level of the Earth's track plane. As a result, in the summer, there is about two months period when the sun does not set and, in the winter, there is a long dark period in which the sun does not rise above the horizon.

Given these changing circumstances, it is challenging to describe the whole industry within the context of this research, but due to this, some generalizations have been made.



Picture 5. Solar irradiation in Finland (PVGIS 2018).

2. THEORETICAL BACKGROUND

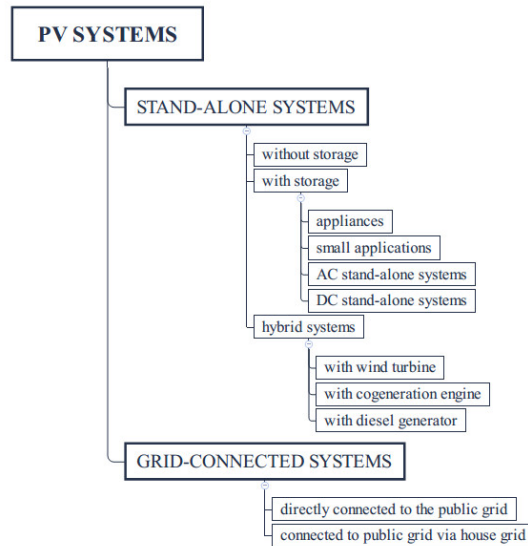
The theoretical part of this thesis is two-fold. When discussing the change in the energy sector, efforts have been made to refer only to recent studies. Over the past five years old articles have generally been considered obsolete as the sector is constantly developing tremendously fast. Instead, studies related to history and theoretical business models have been considered relevant, even if they have been published earlier than five years ago.

2.1. Definitions

Systems Integrator is a party which provides a desired output by combining sub-systems together and ensuring that these sub-systems function properly. In this study, the Systems Integrator provides a solar photovoltaic system (PV-system), which generates electricity from sunlight. The Systems Integrator (SI) concept is inherited from the IT technology sector and is derived therefrom. The most frequently used form of this kind of operator in energy technology is Project Developer (PD) or EPC (Engineering, Procurement & Construction). However, it should be noted that the concept of EPC is widely used, for example, the building of the power plant to be set up. The EPC agreement is the most common model for the PV power plant when talking about large, utility-scale/ megawatt-class systems. Within the framework of the agreement, the EPC operator is responsible for planning the power plant, the necessary purchases and the construction of the plant. At the same time, the EPC instructor undertakes the supply of the power plant at the agreed price and time. Furthermore, the power plant's performance corresponds to the terms of the agreement (EPC Contracts 2015: 103). Although the terms SI, PD and EPC are different or are only partly overlapping concepts, the EPC is included in the SI concept in this study.

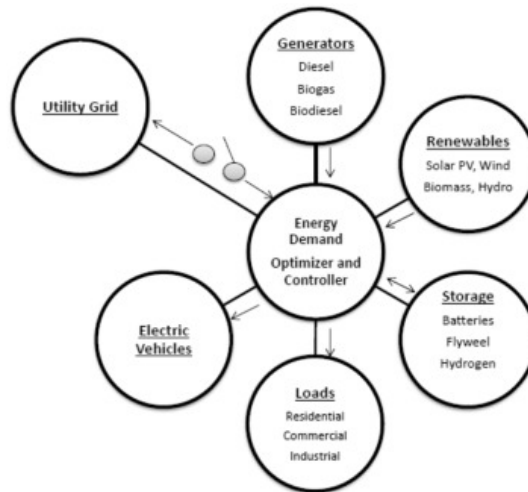
PV-systems can be divided into two groups depending whether they are connected to public grid or not. There are local regulations concerning the grid-connected systems,

which are controlled by local authors and referred as “grid codes”. Where these grid-connected PV-systems are they must comply. Stand-alone systems are connected to grid which are isolated from public grid. These isolated grids are also called as micro-grids or island grids. They are common in places that are not sensible to build a public network such as distant villages or mines.



Picture 6. Photovoltaic systems categorization (DGS 2013: 9).

One common feature of power systems, regardless of the source(s) of energy, is that energy production must exceed energy demand at all times. It is possible to connect other power generators in parallel with solar generator and vice versa. Wind and diesel generators are commonly used in these hybrid systems. Also, an energy storage is possible to connect with PV-systems to cover fluctuations in energy demand and to provide energy during night time when sun is not shining (e.g. Rehman et al. 2012, Ghenai et al. 2018).



Picture 7. Schematic of a hybrid power system (Ghenai et al. 2018:173).

Picture 7 shows a simplified model of hybrid power system. In this, the energy produced by the sun is direct current (DC) which is transformed into alternating current (AC) by a solar inverter and this alternating current is directed to the low voltage network. Surplus electricity from the photovoltaic plant can also be diverted to an energy storage system (ESS) to equalize the load consumption peaks. In addition, a wind or diesel generator can be connected in parallel to the system, and these systems together supply local load. If the system is connected to a public network, as in this figure, the low voltage can be raised to a medium voltage by a LV/MV -transformer (Ghenai et al. 2018).

Table 1. Explanations of abbreviations.

Term/ Abbreviation	Definition
AC	Alternating current
DC	Direct current
EPC	Engineering, Procurement and Construction
ESS	Energy Storage system
Genset	A diesel engine with an electric generator to generate electrical energy.
Grid operator	The Grid operator owns and maintains the electrical network in its area.
IPP	Independent Power Provider: owns facilities to generate electricity for sale to utilities and end users
kVA	Power unit, indicates the active power
kW	Power unit, indicates the apparent power
kWh	Energy unit, corresponds with one hour of 1 kW of power
kWp	Power unit, peak power
LCOE	Levelized cost of electricity. (<i>Assumptions: 25-year life span, nominal discount rate of 4.5 %, O&M \$100/year, one inverter replacement over the system lifetime for 1200 \$, derate factor of 0.77, degradation rates of 0.5%/year</i>)
Micro grid	<i>A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode (Federal US Department of Energy, DOE).</i>
Mini grid	<i>Isolated, small-scale distribution networks typically operating below 11 kilovolts (kV) that provide power to a localized group of customers and produce electricity from small generators, potentially coupled with energy storage system (The World Bank).</i>
O&M	Operations and maintenance
PD	Project Developer
PPA	Power Purchase Agreement: a contract between two parties, electricity provider (seller) and electricity consumer (buyer).
PV	Photovoltaic, a conversation of light into electricity
RE	Renewable energy. Sources: <ul style="list-style-type: none"> • Biomass • Hydropower • Geothermal • Wind • Solar <p>Some of the renewable energy sources are characterized by their intermittency. However, not all RE sources are dependent on the environmental conditions such as biomass or biogas. In this thesis, when referred to unpredictable behaviour of the RE sources, it is referred especially to solar, wind and to some extent hydro power.</p>
SI	Systems Integrator

2.2. History of photovoltaic and techno-economic overview

The photovoltaic phenomenon was first discovered by a young French scientist, Edmond Becquerel in 1839. He observed that if two metal electrodes are placed in solution and exposed to sun light, electric current began to flow. Smith and Adams reported photoconductivity in 1873 and 1876 respectively (Spanggaard & Krebs 2004: 126). At that time and long after, the effect was very small and insignificant, rather a curious physical effect without any practical value. But this discovery remained unforgotten (Goetzberger et al. 2003: 2, Spanggaard et al. 2004: 126, DGS 2013: 1-3).

The first silicon solar cells were developed in 1954 at Bell Laboratories and for outdoor use, year after that in 1955 with an efficiency of only 6 percent. The first silicon solar cells were developed for investigation of technology potential for powering telecommunications systems but soon after the development of space technology boosted also the development of solar cell technology as they were used as power generators in satellites. It turned out that solar cells exceeded all expectations in terms of their life span and usability. Therefore, rather small but high-end markets for solar photovoltaic were born (Green 2005: 447-448, Goetzberger et al. 2003: 2-6, Spanggaard & Krebs 2004, DGS 2013: 1-3).

After the oil crisis in 1973, solar energy developed significantly, and the first real commercial solar systems started to develop. As demand and technology evolved, the price level of panels began to challenge traditional energy sources, and today the price of solar energy is completely competitive with traditional energy sources (Green 2005: 447-448, DGS 2013: 5-6). For example, in Netherlands, the grid parity conditions were apparent already in 2012 for 2.5 kWp PV system, that is, a LCOE were 0.194 €/kWh compared to electricity retail price of around 0.23 €/kWh (van Sark et al. 2014). In Germany and in US, the average installed PV system price (<10 kVA) have decreased about 75 % in Germany to \$2.26 /W and about 50 % in US to \$4.92 /W between the time period of 2001-2012 (Seel et al. 2014:218-219).

Solar PV sector has developed through different phases. Three distinct phases have been identified. In the first phase (*fluid phase*), between 1965 and 1990, solar energy has been the subject of research and no actual market has yet emerged. However, there are numerous small businesses in the industry. In the second phase of the development (*transitional phase*), the first mass market emerged between 1990 and 2005, technology developed tremendously and new or emerging enterprises all over the world moved to the industry. After 2005 (*standardized phase*), PV modules and their markets were consolidated and standardized into one global commodity mass market (Binz et al. 2017: 389).

The European Union has set itself the objective of being the world's forerunner in energy and climate policy by providing a mandatory renewable energy directive for its member states in 2009. The directive sets member specific targets by 2020, namely the directive has obliged member states to set "*National Renewable Energy Action Plans*" in which is detailed descriptions how the targets can be attained. (Cross et al. 2015: 1768)

Generation type	2005	2010	2011	2012	2015	2020
Hydro	13,910	14,220	14,220	14,220	14,220	14,420
Solar PV	0	0	0	0	0	0
Wind	150	360	590	820	1520	6000
Solid biomass	9640	3930	4520	4760	5300	7860
Biogas	20	40	40	40	50	270
Bioliquids	0	4120	4350	4390	4530	4780
Total	23,720	22,670	23,720	24,230	25,620	33,330

Picture 8. Finland: RES electricity development in National Plan (GWh) (Cross et al. 2015: 1772).

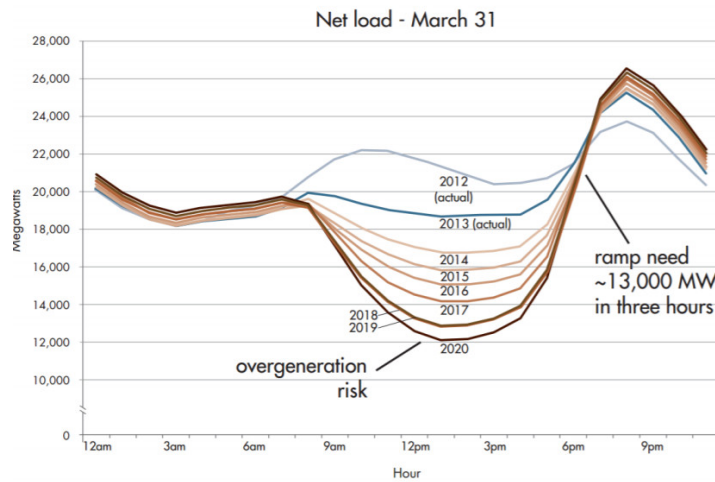
The achievement of the goals has been monitored and it has been found that the goals are being reached, but there have been some concerning observations. Some countries, including Finland, underperform with some types of RES and over-performs with another. According to the Cross et al. (2015: 1774), Finland produces too much energy with biomass, which can be attributed to the long traditions and previous experience from it. This proportion is off from other renewable energy sources (Cross et al. 2015).

On the other hand, after the Fukushima nuclear accident in 2011, many European states have changed their energy policies by deciding to renounce nuclear power. Nuclear power is a traditional and reliable way of generating energy and does not produce CO₂ emissions. As a result of policy change, many European countries are producing more CO₂ emissions than they have been aiming for. However, in Finland nuclear power is generally accepted as it is considered to be a reliable and cost-effective way of generating stable baseload energy (Syri et al. 2013).

It is also appropriate to discuss the phenomena associated with renewable energy sources. Widespread penetration of renewable energy sources has changed and will continue to change the energy system. Annual environmental conditions, however, vary a lot and this increases the volatility of power generation and hence the electricity price and the amount of CO₂ emissions. The effect of solar PV energy on electricity price is higher than wind energy. It is also estimated that, by 2030, the CO₂ emission and cost variability will be fivefold compared to the level of 2015 and at times renewable energy sources will have to be curtailed (Collins et al. 2018, Goop et al. 2017: 1128).

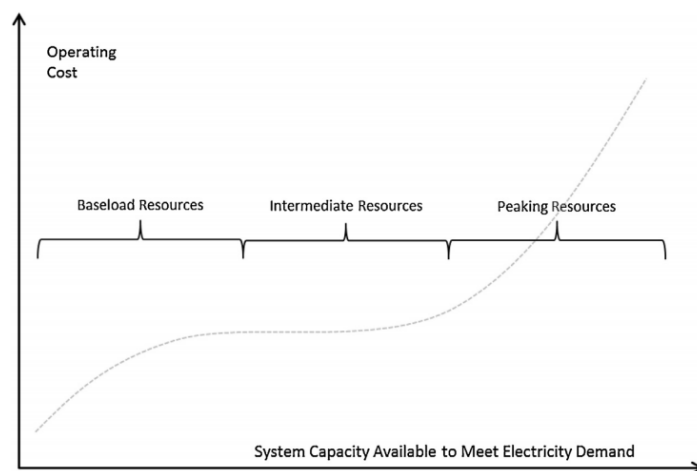
The low-price level has made solar energy a major source of energy in some parts of globe, and this has even led to overproduction of energy and the resulting another special phenomenon. For example, California has enormously installed solar energy, and this has led to an interesting situation which is presented in Picture 9.

California has invested heavily in solar power in the public network. As a result, at the brightest time of day, solar energy is available above the supply and demand level and it has had to be dumped on the market even at a negative price or the renewables had to be curtailed from the power supply system. Another problem comes when the sun is setting, meaning that it can be concluded from the figure that energy production must be able to react to a very fast-growing energy demand. That is, while the sun is no longer producing energy, the consumption is growing, and this is a very challenging place for traditional power plants (NREL 2015, Radermacher 2017, Sioshansi 2016). Conventional power plants, such as nuclear power or coal, are challenged to respond to the rapidly changing energy needs.



Picture 9. Californian “Duck Curve” (NREL 2015).

The California example is instructive in many ways. Firstly, it is an example of how the electricity grid behaves when a lot of solar PV energy is connected in a short period of time. Secondly, connecting solar photovoltaic on this scale will change the role of traditional power plants. They replace (to a certain extent) the baseload generation system and increase the need for flexible backup power plants. Flexible means fast ramp-up and -down time as economically as possible. As the baseload system changes, the costs of peaking resources increase and thus limit the usable RE integration (Matek & Gawell 2015).



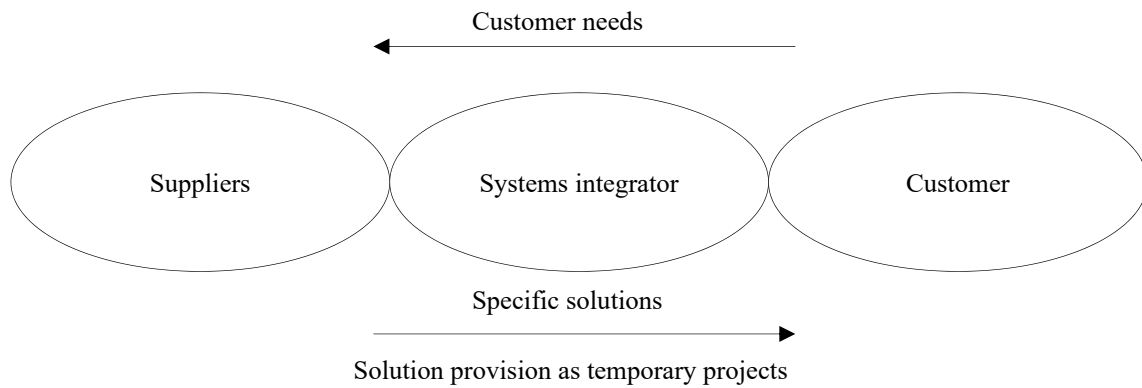
Picture 10. Hypothetical electricity market dispatch curve (Matek & & Gawell 2015).

Thirdly, similar behaviours in the power grid have also been observed elsewhere, at least in Europe and Australia (e.g. Energy Matters: Andrews 2017). It is obvious that intermittent energy systems cannot entirely create cost-effective baseload resources for balanced grid. In fact, renewable energy systems are both a challenge and an opportunity. Especially the wind and the sun will increase the volatility of energy prices and the manageability of production. (Matek & Gawell 2015, Zakeri & Syri 2015).

System Integrators should understand and make use of this development in the energy sector. In the future, there will be a growing demand for flexible energy solutions and energy storages. It is estimated that solar PV penetration level above 20%, it will become economically viable (Goop et al. 2017).

2.3. Business models, theories and concepts for Systems Integrator

Systems Integration as a business can be reasonable included in the theoretical framework of customer-centric servitization. The basic business model for a Systems Integrator in this context contains provision of services and solutions that are valuable for customers by combining components and sub-systems from variety of suppliers and ensuring proper operation of the integrated solution. Instead of single transaction, the idea behind servitization is to provide solutions according to customers' needs during the entire product life cycle (Davies et al. 2007, Almendinger & Lombreglia 2005, Wise & Baumgartner 1999, Davies et al. 2006).



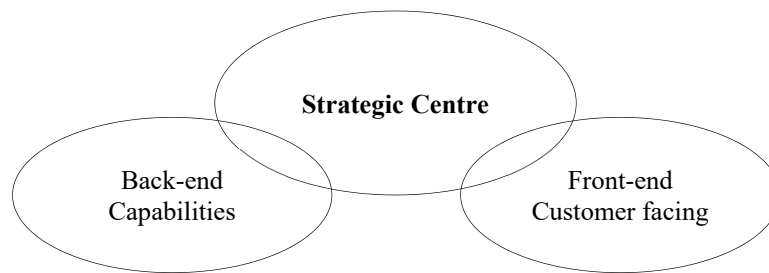
Picture 11. Basic Systems integrator business model (adapted from Davis et al. 2007.)

When discussing how systems integrators are organized to produce different types of products and service packages, decisions can be compared to a make/buy analysis. Davies et al. (2007) had identified two contrasting types of organizational structures amongst integrated solutions providers. The traditional form is called “Systems Seller” and it refers to a vertically integrated type of organization which produces all or most of the required components by itself. Systems Sellers may take advantage of in-depth product expertise, reduced purchase costs and better control of the value chain. On the other hand, some issues regarding the agility of such an organization may arise as well as the fact how in-house manufacturing ties assets (Davies et al. 2007).

The second type of organization is called “Systems Integrator or Solution Seller” and it refers to a Solution Seller which acts as a prime contractor for the customer and is responsible for the overall design of the functional system. The Systems Integrator may have some advantages over the Systems Seller. It may take advantage of specialization and expertise available on the markets and focus on providing standardized, modular solutions for the customers. Key knowledge for Systems Integrator is about how different sub-systems interact with one another (Davies et al. 2007).

It is estimated that the advantages of a pure systems seller are becoming less attractive as the complexity of the solutions are increasing and therefore increasing number of

operators have shifting their operations from being vertically Integrated Systems Seller towards being an integrated part for their customer's needs and a more complex pattern of organizational structure is needed (Davies et al. 2007). This may require specific capabilities. The first capability is Systems Integration, that is, the knowledge of how to specify, design and integrate the components into a working solution including hardware and software expertise. Secondly, the ability to offer operational services to maintain such a solution. Also, a business consultancy and financial services may be required for successful business implementation. Davies et al. (2006) suggests a three-tier organisational structure as presented in picture 6 including a customer facing part, built with back-end capabilities and strategic coordination between these two ends (Davies et al. 2006).



Picture 12. Structure of integrated solution (Davies et al. 2006).

Almendinger & Lombreglia (2005), emphasize the business opportunities of services instead of products for the Systems Integrators. Their idea is to provide “smart services” along the entire life cycle of the product rather than single transaction enabling: The advantage is continuous cash flows and predictability for their business. Wise & Baumgartner’s (1999) article provides support for the previous one. According to them manufacturers are creating new business models which are capturing profits at the customer’s end of the value chain for a simple reason: downstream markets usually have higher margins but also require fewer assets than product manufacturing. The goal is not to gain largest share of customers but to create strongest relationships with the most profitable ones (Wise & Baumgartner 1999).

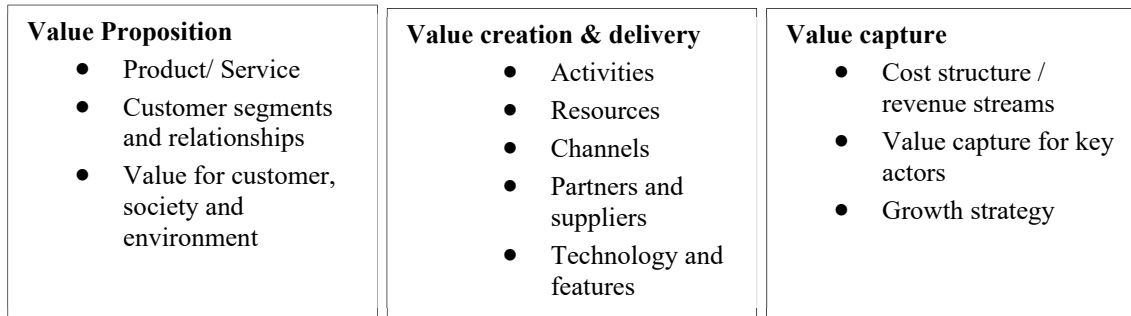
The customers on the other hand, may benefit from the services provided by the Systems Integrators in several ways. Identifying these business opportunities and value adding activities is best achieved by identifying, exploring and analysing the customer activities and needs widely with respect to the whole product lifecycle (Almendinger & Lombreglia 1999, Davies et al. 2007). Obviously, life cycle- value adding activities are related to financing, engineering and consulting. The literature review reveals in more detail, how a Systems Integrator may add value to their customers. These activities are listed on the Table 2.

Value creation activities can also be bundled into different categories depending on the viewpoint. According to Davies et al. (2006) Systems Integrators may create value by leading complex projects and manage large networks of suppliers. Systems Integrators may also provide operational services such as maintaining and upgrading a system during its lifecycle. In addition, they may provide business consultancy and solve operational and/or strategic problems for their customers. Some Systems Integrators may also provide financial services such as some form of value-sharing contracts of the operational system, (Davies et al. 2006). This is particularly interesting from the solar photovoltaic point of view, since PPA-contracts (Power purchase agreement) can be strongly related in value-sharing business model.

Table 2. Systems integrators value creation.

Value creation	Author(s)	Resource
Reducing purchasing costs	Davies et al. 2007	Systems seller vs. Systems Integrator
Improving system operational performance		
Facilitating system growth		
Solving operational problems		
Real-time system diagnoses	Almendinger & Lombreglia 1999	Four Strategies for the Age of Smart Services
Delivering spare parts	Wise & Baumgartner 1999	Go Downstream: The New Profit Imperative in Manufacturing
Leasing		
Time schedules and capacity planning		
Storage services, supplement parts		
Logistical services		
Customer trainings		
System maintenance services		
Installed base upgrades	Davies et al. 2006	Charting a Path Toward Integrated Solutions
Leading complex projects		
Manage large networks of suppliers		
Incorporate new technologies		
Develop business plans		
Improve customers business processes		
Help customers transform traditional business models		

On the other hand, according to sustainable development, new business models are developed according to the corresponding principles. It is appropriate to exploit natural resources responsibly and without jeopardizing the future. Business concepts can be understood in different perspectives. In this study, the business concepts include the above-identified value-creation models and, on the other hand, Bocken & Short (2016) - model of business concept for the sustainable business model. The Business Concept is based on three elements, which are shown in Figure 13.



Picture 13. Business concept framework (Bocken & Short 2016).

Value proposition strives to answer the question of what value can be produced and where. The second part includes value creation & delivery, i.e. how the value is delivered, and the third part looks at how an enterprise can generate revenue and capture other forms of value (Bocken et al. 2014: 43, Bocken & Short 2016).

The above models relate to this research and form a theoretical framework for the research part of the study. The model of the study is presented in more detail in the next section, but especially in the theoretical framework, business concepts and value creation have been an important part of the research.

3. RESEARCH METHODOLOGY

3.1. Methodological choices and arguments

This research has been conducted by using a qualitative research method which is commonly used in business research. However, it has been criticized, for example, that quantitative research may exclude many aspects that play a central role in understanding complex phenomena and functions (Koskinen et al. 2005: 14; Eriksson & Kovalainen 2016; 4-5). Generally speaking qualitative research gives a richer and more holistic understanding of the subject (Eriksson & Kovalainen 2016), but sometimes there is not quantitative data even available in the subject which is being studied.

When discussing appropriate or most suitable methods and approaches to conduct qualitative research, it is important to understand the major advantages and limitations of different methods (Eriksson & Kovalainen 2016). A case-study has been selected as an approach for this research and series of interviews has been conducted by selecting appropriate companies for these interviews. These companies represent solar PV-branch in Finland.

On the other hand, the theoretical background is inferior to that of other qualitative research approaches (Eriksson & Kovalainen 2016), but in case of this study, a case-study is considered to be an appropriate method related to the topic and the aims of this research. The aim of this study is to provide insight about business opportunities within this fast growing and interesting branch. Another goal is to provide content for the reader which may enable a new way of thinking. The issue itself is aimed to be described rather deeply than widely. However, it should be noted that the business opportunities are time-dependent but also enlightened interpretations of different people, albeit prestigious professionals, and the issues presented here best reflects this time as well. Another point to note is that, in principle, the purpose of this study is not scientific but it is intended to represent scientific realism, that is, interested in facts.

3.2. Research process

The research process starts with the research plan even if the plan is not strictly followed. The elements of the research process follow the framework of Eriksson & Kovalainen (2016) and Koskinen et al. (2005) about qualitative methods in business research. During the design phase, the research area and the purpose to be studied has been selected. The topic has been identified and research question(s) have been formulated. After that, the appropriate research methodologies have been selected. In addition, the scientific background of the research is defined, which in this study is servitization including data collection has been designed.

In defining the requirements of the research, it has been taken into account that the findings are reproducible, and the results are justified. Also, the purpose is to minimize the impact of the researcher to the substance. The subject to be studied is from the perspective of the people involved in the research or through meanings created by them (Koskinen et al. 2005: 31). After the interviews, research proceeds through data analysis, interpretation and argumentation (Koskinen et al. 2016). Data analysis is a research phase that has created a structure for the material. The purpose of the interviews and analysis is that research leads to a clear interpretation, which is presented at the end of the study.

3.3. Data collection

Two companies have been selected to cover the research area. Both companies have also several business areas other than photovoltaic systems. The first company (Company 1) is large, operates globally and supplies entire power plants. These power plants can be diesel or biogas plants, for example. Hybrid power plants are also part of the company's deliveries. Another company (Company 2) is a medium-sized energy company and it

operates only in Finland. The company's products and services include electricity, power grids, i.e. electricity transmission and district heating in addition to solar energy.

The study data was collected in such a way that was firstly agreed in the interview. For the interview, a semi-structured interview frame has been drawn up on the basis of the theoretical framework and these issues have been discussed. The interviews, each about 1.5 hours, are recorded, transcribed and coded. After coding, general interpretations and models of interviews have been derived and these are presented to the interviewees. That is, the interpretations have been circulated and this has been ensured that the interpretations are in line with the views of the interviewees. Finally, the results are presented at the end of this study.

Table 3. Interview frame and questions.

Grounding	Specifying topics/ prompt questions
Describe shortly the history of your company?	
Key indicators	Financial metrics, customer metrics, business processes
Business environment	Backgrounds and drivers for solar energy
	What value is proposed and to whom?
	Segmentation
	How is value provided?
Markets and business attractiveness	Channels, suppliers' technologies etc.
	Clientele attitudes and behavior
	Own services and products (more detailed)
	Customer side
Future outlook	Supplier side & technology
	Visions of the future and the development

3.4. Evaluation of reliability and validity

The basic assumption of good research is reliability and validity, but also the followability of deduction of the research by an external observer, which also increases the reliability of the study (Koskinen et al. 2005; Eriksson & Kovalainen 2016). In this section these issues are discussed more detailed.

Validity refers to the extent to which a particular claim, interpretation or result indicates the subject to which it refers (Koskinen et al. 2005: 254; Eriksson & Kovalainen 2016: 305; Grönfors 1982: 173-179). The validity is divided into two sub-categories which are internal and external validity. Internal validity refers to the internal logic and contradiction of interpretation. External validity, in turn, means how well the interpretation can be generalized in non-investigated cases (Koskinen et al. 2005: 254). Generally, building validity is based on analytical induction, triangulation and member check (Eriksson & Kovalainen 2016: 305). According to Glaser and Strauss (1967: 102) *analytic induction should combine the analysis of the data after the coding process with the process when the data are integrated with theory*. Triangulation refers to the process of using multiple perspectives to clarify the findings of the research. Member check refers to the procedure which interpretation of the study are recycled to the participants to check their validity (Eriksson & Kovalainen 2016:306-307).

Reliability refers to the consistency of the research, in other words, how accurate are the results with each other or yield same results if the test is repeated (Eriksson & Kovalainen 2016: 305). This means the degree of consistency whereby cases are placed in the same class by different observers at different times (Koskinen et al. 2005: 255). Reliability can be accurately understood consisting of four sections. Congruence means coherence, i.e. how different indicators measure the same thing. Instrument accuracy is measured as the observation accuracy of a recurrent phenomenon and can be improved, for example, by asking the same question in a different format several times. The objectivity of an instrument refers how accurate the other person understands the purpose of the observer. Objectivity can be improved, for example, by using more observers to explore the same subject. The continuity of the phenomenon indicates the continuing similarity of the observation. This can be ensured by making observations at different times (Koskinen et al. 2005: 255).

The concepts of reliability and validity apply poorly to qualitative research. Validity has a clear significance only in an experimental study that seeks to prevent certain errors in advance by appropriate research-design. Often, interviews with internal validity remain

largely theoretical framework, and more important is the internal logic of the research. (Koskinen et al. 2005: 256). In qualitative research, understanding the context is a more important research criterion (Eriksson & Kovalainen 2015: 308).

4. EMPIRICAL RESEARCH AND RESULTS

4.1. Results analysed and presented

Two companies were selected for the study area. Even if more companies could be included in the research, these two already have a very comprehensive overview of the current solar PV business situation. The selection criteria were that companies have been in business for over 35 years and have recently decided to expand their business to solar PV. It is assumed, in principle, that in expanding their business, these companies are thoroughly acquainted with the business area and have developed their own strategies on this basis.

Secondly, one of the companies surveyed operates globally and represents the global perspective of research. The global perspective, on the other hand, is somewhat different from the local one, as the research progressed. The domestic perspective is somehow similar to a business concepts that we have already seen, for example, in Germany a few years ago.

Above all, these companies are credible and the views they represent are exceptionally valuable. It should be noted that solar PV business is expanding explosively in most parts of the world and inevitably this branch has a huge number of different players. For this reason, this research was specifically aimed to include credible companies. Finally, it can be said that attempts were made to get one more company involved, but unfortunately, due to scheduling problems, this did not succeed.

The companies involved in the study are shortly presented in Table 4. The companies were interviewed and the interviews were recorded. These recordings were copied and encoded. Finally, the encodings formed a researcher's own interpretation that was sent to the interviewees for comment. This has been done to increase the reliability of the research, especially with regards to interpretations. Since there are only two companies

studied, they have been decided to be anonymous. Next, the companies participating in the study will be presented in more detail.

Table 4. Introduction of selected companies.

	<i>Company A</i>	<i>Company B</i>
Revenue (2016)	4801 M€	51.3 M€
Personnel	18000	108
Areal scope of operations	Global	Domestic (Finland)
Corporate business areas	Energy solutions, Marine solutions, Services	Energy, Power
Solar PV business started	2016	2015
PV Power range	Utility size (10-1000 MW) (<i>Sweet spot 200-300 MW</i>)	Utility size (700 kW-10 MW) Industrial size (100-700 kW) Agricultural, small industrial (15-100 kW) Households (500 W- 15 kW)

Company A

Company A has been established nearly two hundred years ago. Today, its main business areas are Marine Engines and Power Plants. The brand is well known, and the company is listed on the public stock exchange. The net sales are globally distributed evenly as well as the company's net sales by its business areas. The company is committed to its strategy to operate in accordance with the principles of sustainable development and can provide technically advanced solutions to its customers. The company's energy business covers, for example, flexible fuel power plants, LNG-solutions and currently also solar power plants. Solar power plants and hybrid plants are well suited to the company's offerings and are rather supporting other business lines and operations.

For the target company, sustainability principles mean profitable business, environmentally friendly products and social responsibility. In line with its strategy, the company delivers solutions that are high in efficiency and low in environmental burden. Products and services are designed based on their lifecycle thinking and company is investing heavily in research and product development.

In 2016, the target company started solar PV business to support its other business lines. The power range is a relatively tightly defined to utility scale, i.e. the company supplies large plants and hybrid power plants to its customers. Power plants are built into a modular base and can be tailored also later. According to the company's own words, “each power plant is tailor-made”. This means that the company does not seek to compete with so-called off-the-shelf markets, but each power plant is treated as a special order and technically the best power plant is planned for it. Of course, everything is not planned from the scratch, but some technical solutions are being utilized when designing a new power plant.

The company's solar power solutions are offered as total solution deliveries, including project management, civil engineering, site management and control, design, materials and equipment, and comprehensive system integration. The delivery includes a dedicated service network to ensure that the power plant operates smoothly throughout its lifecycle. The company sees it as a significant added value that it takes care of all the needs of the customer whenever it is needed. The company's thermal power plants have such a competitive advantage over other power plants that they can be started up and shut down very quickly, that is, they are flexible. Hence, the company's power plants can be sold to destinations where the load swings are large and fast. For example, the company views the development of California as a particularly good news for itself. The target company manufactures power plants that are faster to ramp-up and -down than their competitors. Thus, solar power has in fact created a competitive advantage that its competitors do not have. It is the core business of a company, that is, thermal power plants, to start up quickly and economically.

In many respects, the Duck Curve explains why, for example, coal power plants are ultimately eliminated from power plants. They are no longer flexible enough to cope with rapid changes in electricity consumption and, on the other hand, are not economically viable to keep up to date. Ironically, it can be thought that coal power plants could be being decommissioned because they are no longer economically viable.

Table 5. Company A value proposition.

What value is proposed and to whom?	Company A
Value proposition	Complete turn-key PV-plant solutions Hybrid plants Tailoring Demanding targets and managing demanding projects Plant modifiability Life cycle services
Segmentation	Utilities IPP's Large industrial power consumers

Table 5, shows the company's summarized value proposition. As the company is well-known, it may also be considered that the company's brand is part of the company's value proposition. The customer group is limited because the size of the company's power plants is so large that the customer base is relatively small. In addition, the necessary investments in such large power plants are so massive that to succeed in this segment is the credibility of the company and the resources must be on a high level as well.

The company specializes in managing demanding projects and over the years has gained a good reputation in managing these particularly challenging projects. Basically, the company is a technologically oriented, and different systems integration fits well into the corporate image. In accordance with the construction of hybrid power plants, the EPC business is also part of the company's offering. After the construction of the power plants, the business remains in O&M operations. In addition, the company has a financial service, but according to the company's own words it has a somewhat smaller role where customers are not particularly interested in funding but often have the necessary capital already. On the other hand, the target company may in some cases become a part-owner of the power plant, but these cases are exceptions.

As the company has a long history of deliveries of thermal power plants, they also have well-functioning channels for both customers and technology suppliers. These channels generate synergies that the company can take advantage of in connection with new projects. The technology used must be reliable and tested in practice. There are lots of suppliers and high competition rates among these technology suppliers as well. Markets

in the supplier's side operate based on competitive tendering and, after certain quality standards, they resemble the commodity markets. Table 6, summarizes the company's value creation & delivery functions.

Table 6. Company A value creation.

Value creation & delivery	Company A
How is value provided?	<ul style="list-style-type: none"> Project management Systems integration EPC O&M Financial services
Channels, suppliers, technologies	<ul style="list-style-type: none"> Already existing customer relationships and channels. Synergies involved. Suppliers and procurement processes are highly competitive and suppliers can be exchanged according to their tenders The technology used must be reliable and well-established

Large power plant projects do not come as a surprise to our target company. They have already been known before the power companies issue bidding inquiries. They have been prepared well in advance and tenders can be provided quite quickly. In many cases, tender inquiries include such studies that will eliminate many operators (SI's) from bidding. On the other hand, it is noticeable that solar PV components are falling in the price level and this has been continued a long time. Customers assume that if the price level is today this, then it automatically will be so many percent lower for the next year. They consider the timing they will issue bidding requests and conclude the approved price level in advance. This is, on the one hand, challenging because the price level cannot be decrease indefinitely, but will settle to a certain level sooner or later.

Current developments in the energy sector have led to a situation where renewable energies have become part of a modern power generation system on a broad scale. Generating solar energy is marginally free and it should be produced when it is available. This has contributed to the fact that the entire energy market system has changed. Today, solar energy replaces traditional baseload power, but behaves like renewable energies usually does, unpredictably. This has caused the network management to be considerably more challenging than before. Secondly, the adjustment power (load following power, peaking power reserve) is also needed much more than before and this must be ramped

up very quickly. The load peaks vary as well as the amount of solar energy (wind has the same issue) and their interaction causes new demands on the control power plants. They must be able to respond to fluctuations in loads in minutes and must be economically viable.

Table 7. Company A value capture.

Value capture	Company A
Background and drivers for solar energy	<p>Renewable energy sources have become part of modern power generation systems on a large scale.</p> <p>These energy sources are completely economically competitive way of generating energy in the free markets.</p> <p>Solar power has been installed significantly in recent years and this development will continue in the future. Growth will be in fact exponential over the next twenty years.</p>
Visions of the future	<p>Generally, the <i>cost of production</i> of renewable energy is marginally non-existent, so when it is available, it will be fed into the grid.</p> <p>RE are characterized by their sensitivity to weather changes and intermittent fluctuations of power supply. As a result, the management of electricity grids in the future will be fairly demanding.</p> <p>Consequently, renewable energy has already transformed traditional power generation. That is, RE energy has replaced the traditional base power systems and the need for adjusting (peaking) power will increase.</p> <p>A very good example of this is known as “the California Duck Curve”. California has a lot of solar energy installed and this has affected the load profile in such a way that, with the highest time of consumption, the rise gradient of power demand has increased considerably. This is an excellent example of how the electricity market behaves when it has a lot of RE energy installed.</p> <p>On the other hand, this change drives for example the coal-based power plants to finally retire. Not only because they are polluting, but <i>because</i> they are no longer competitive and flexible enough in the current market.</p> <p>In many large markets such as in India, China or Germany, construction of new solar power and power generation are economically profitable than using coal-based power plants.</p> <p>One point of note in the future may be the availability of land. They may not be available as they are today. It should be noted that large Utility-scale power plants are being built near transmission lines. In addition, they require a fairly large amount of land area and there may be a shortage of these areas in future.</p>
The market	<p><i>Customer side</i></p> <p>This is a highly competitive market and prices continue to decline. Customers also extrapolate prices and expect the same development to continue in the future. In reality, the market will not endure the current price pressure indefinitely and a number of players in this area will fall, this has already happened.</p> <p>Since solar and wind power has been widely entered to electricity market, it has caused a high degree of variation in the market volatility.</p>

	As the electricity market has often evolved in the sense that the role of fast reaction on fluctuations of power consumption and generation is significantly increased, one could say we are competing in the flexibility game.
	Plant design is driven by a structure of PPA contract, usually concluded for about twenty years. Of course, the large power plants are to avoid stranded assets since the total investment may rise to several hundreds of millions of dollars at these sites. Naturally, banking institutions require huge amounts of due diligence at these sites.
	<i>Supplier side & technology</i>
	The supplier side has the same competitive situation. In such a market, one cannot commit too much to one or even two suppliers, but the market resembles commodity markets where the most credible bid wins. Technology of course must be reliable.
	In the future, new battery technologies can provide ultra-fast response capability, but so far battery technologies are often too expensive for large-scale energy storage.
	In certain situations, current battery technologies are an economically justified option, but it depends very much on where that electricity market is located, for example, what is the primary energy price at that site
	String inverters will be used because their maintenance does not cause interruptions to the power plant itself
	Trackers are designed simple and as maintenance free as possible

	The power plant is a long-term investment, although the lifecycle for new power plants is far shorter than in conventional ones. Typically, the life cycle of the solar power plant is about 20 years and, as technology evolves, power plants will change over their lifecycle. As a result, hybridization of power plants is a clear added value that we can provide and this has also enabled us new business opportunities
Own services and products	Our competition is in the flexibility market, that is, our products have built-in flexibility as a feature. We can very quickly and advantageously produce adjusting/ peaking power when needed
	Our products are tailor-made, so we do not offer the customer off the shelf solutions. We are profiled to manage challenging projects and we are very good at it.
	Our offering may also include funding, but in our case, funding is rather Enabler-type of operation.

Company B

Our second target company is also old, it has over one hundred years of history. The company has begun its operations in the early 20th century and has provided, for example, one of the first electronic lighting solutions in Finland. The company has been supplying electricity for 117 years.

Today, the company's business includes district heating, network business, biogas and various power plants. The company defines itself as an energy company with a turnover of over € 50 million and its staff has just over 100 employees. The company operates in Finland.

The company carries its responsibility for environmental issues by delivering nearly 100% of environmentally friendly and renewable energy. As sources of energy, the company uses wood, water, biogas and solar energy. In addition, the company also assists its customers to save energy. In the solar energy business, the company started in 2015 and supplies a wide range of solar power plants of different sizes to different customer segments. These deliveries are located in Finland.

Table 8. Company B value proposition.

What value is proposed and to whom?	Company B
Value proposition	Environmentally friendly electricity by photovoltaic systems Surveillance systems Consultant services Turn-key solutions Demanding projects
Segmentation	Households Industrial customers Farms Utilities

The company has developed its own technologies for solar technology, such as systems monitoring service. This monitoring system provide real-time information about the state of the solar system. It monitors the energy produced by the system and compares it to how much the system should produce. The deviation is reported to the owner of the system. The monitoring system is intelligent because the comparison of the energy generated and expected by the solar energy is relatively difficult for the system owners, especially for small-scale power plants in households. In addition, the system can predict future production based on the weather forecasts.

The challenge for the sale of the monitoring system is the customers' assumption that it should, in their opinion, be included in the solar power package without incurring any additional costs. Customers are usually not willing to pay an additional price for that service, even though it has been shown to be a reasonable additional investment.

Table 9. Company B value creation.

Value creation & delivery	Company B
How is value provided?	Project management
	Systems integration
	Installations
	Financial services
	Value added services

Today, however, the interest of solar power is very strong in Finland and customers are enthusiastic about investing in solar energy. Interest has been boosted by potential savings and examples by others. On the other hand, the electricity transmission pricing has risen significantly in recent years and people are tired of paying more than ten percent of the annual growth rate of the transfer price. Already, the electricity transmission price will start to be higher than the price of electricity and people will be happy to invest in solar electricity as a protest for continuous price increases in transfer prices.

Table 10. Company B value capture.

Value capture	Company B
Background and drivers for solar energy	The company started in 1901. Today, the company defines itself as energy company.
	Other corporate business operations include grid administration, district heating, biogas and power plant business.
	2016 delivered first large scale solar farm which is upgraded in 2018 for hybrid park
	Driving forces for solar PV in Finland are the general curiosity in photovoltaic electricity, the price level is reasonable and the EU's provisions come from, for example, energy efficiency and energy self-sufficiency in housing.

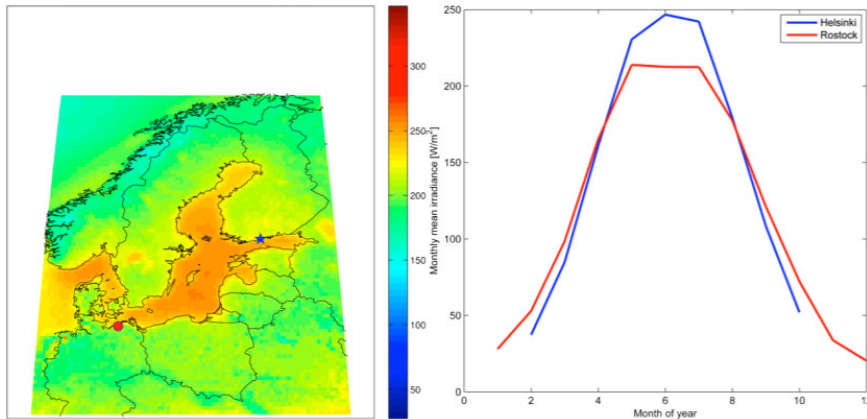
Visions of the future	The prize level of PV panels and inverters will stabilize.
	Some panel manufacturers will fall. If we look at how the panel manufacturing capacity has grown in recent years and compared to it with their turnover, it can be stated that these have not grown in same proportion.
	In particular, the competition among the so-called bulk panels is very fierce.
	This will distribute the production of volume products then specialty products for panels.
	The same can be seen on the inverter side. Manufacturers are looking for cost-effectiveness and some kind of harmonization between products.
	The future for batteries (energy storage) will surely be the same as in the panels has been, i.e. when enough mass is produced, the production costs will get decrease sufficiently and this will inevitably increase the number of batteries in energy

	<p>solutions. Probably the combination solutions will be seen, for example solar + battery and related management system.</p> <p>According to the estimation, in the time window of 2030-2040 wind power can be seen as a 30-40% reduction in investment costs. The same figure for solar energy may be up to 50%, but the biggest reduction in battery technology is about 70%.</p> <p>It can be concluded that learning curve is applicable for renewable energy technology.</p> <p>Photovoltaic energy as a source of energy is coming alongside with traditional power generation systems in Finland, but they will not replace them in the future.</p> <p>In addition, off-grid solutions will become more common, at least in remote and challenging locations.</p>
--	---

The market	<p>The grid connected solar electricity capacity in Finland in 2016 was about 27 MW and 50 MW at the end of 2017. The growth in solar energy accelerates rapidly in Finland.</p> <p>Many players have come to the field and it is difficult to compete for price alone, specialization is needed for profitable business.</p> <p>On the other hand, technology has developed a lot and the price level is now attractive. Return on investments in solar PV systems is in attractive level as well.</p> <p>There is also a successor phenomenon on the market, many of the sceptical customers have gone to invest in solar after the "pioneers".</p> <p>People are also driven by simple curiosity.</p> <p>The challenge for value-added services is that competition in PV systems is hard and the customer usually chooses the cheapest solution. They are often not willing to pay for value added services, even if they are well-founded.</p>
------------	---

Own services and products	<p>Energy supply</p> <p>Control systems + maintenance</p> <p>Project management</p> <p>Customer specific tailoring</p> <p>EPC, System integration</p> <p>Hybrid power plants</p> <p>Financial services, for example, with a monthly charge.</p>
---------------------------	---

So far, customers have not been interested in additional financial services. People who are investing in solar energy often finance their investment by themselves. In Finnish conditions, solar energy systems are productive during the summer. Solar energy can be produced even at night because the nights are bright during the summer and to produce solar power, the system does not necessarily need direct sunlight. The darkest periods of the winter are, however, are poor in terms of electricity generation. The variation of the sun's radiation is considerable between the southern and northern part of the country. The circumstances of southern Finland correspond to the conditions of northern Germany (Finnish Meteorological Institute 2014:5).



Picture 14. Monthly values of global radiation in Helsinki and Rostock (Finnish Meteorological Institute 2014:5).

4.2. Key findings and conducted models

The interviewees shared the same views on many issues and phenomena related to solar energy, but some differences have also been observed. These differences were mostly related to the regional scope of operations. Here are discussed some of views that were aligned.

Both companies have expanded their business to solar PV to strengthen and support their existing business. The change has been natural for both companies and their brand in the energy business has been familiar with customers already.

Solar PV energy continues to grow strongly, and growth is expected to continue long into the future. Currently, it is a cost-effective alternative and fully competitive with conventional power generation solutions. As a renewable energy including photovoltaic becomes more common, it will change the whole energy system and the market. The intensity of the changes depends mainly on the location and policy of the region. Both centralized and de-centralized PV systems are becoming more common solutions

depending on the purpose of the energy system. Naturally, solar energy production is more productive in the middle of the globe than in the northern and southern parts and most of the installations are addressed to the most productive areas as well.

Price competition among technology vendors is fierce and it is expected that at some point it will level out. So far, the downward prices have shaped customers' purchasing behaviour in the direction that future price levels are already indicated in current bidding. It has also been found that, for example, many panel manufacturers are struggling with business profitability.

The value creation models in Table 2 are part of normal business for both companies. However, these weights were dependent on the company's own practice to do business. Both companies favour components and technology vendors whose quality is known to be at a high level. That is, virtually neither of the companies wanted to compete at a cheap price level but opted a high level of quality for the specialization factor. However, in the case of components, tenders are similar to commodity markets where price competition is very strong. On the other hand, this is possible because the components and technologies are broadly compatible with each other and are not manufacturer-dependent.

The delivery of a solar PV system project includes definitions and designs of the system, purchase of the components and installation. In large projects, the project involves more activities, such as authorizations and construction. Both target companies stated that they are interested in challenging projects, for projects that require more in-depth expertise and tailoring. The level of challenge depends largely on what is the power class of the plant being delivered. In small, household systems, the challenge is usually associated with the quality of the transmission grid or the installation itself. For example, it is demanding to implement a very sloping roof installation. Many of the demanding installations have also poor access. There are other challenges in large power plant projects, particularly the adequate economic scale and the credibility of the Systems Integrator. These are a prerequisite for the supply of large power plants. In addition, large power plants are technically considerably more challenging than small and require different control and backup systems as well as the integration of different technologies.

As a result, in large power plant projects, the content of the deliveries includes a lot of engineering work, even if power plants to be designed do not need to start from scratch.

The companies also had some different views on the solar energy business. It is obvious that companies operate in very different markets and the differences are largely due to the geographical locations of the companies themselves.

Next, the differences in views are discussed. The first target company operates in the global market and has extensive experience of them for a very long time. In this global viewpoint it has been suggested that renewable energy sources will replace traditional power generation solutions on a large scale in the future. This means that solar and wind power will become part of the baseload power generation solutions and this has already been seen. For example, in California, which has already been referred in this thesis. This and similar European examples, however, are very useful from a business point of view as they clearly reflect how the electrical system behaves in a large scale when it has a lot of renewable energy sources included. The production of renewable energy sources changes are partly unpredictably according to the environmental factors. Available production is conducted to the grid and consumption but sometimes there may be overproduction, which sometimes must be sold even at a negative price. At the same time, when looking at a typical load curve, there are some regularities in timing of the load peaks. In the evening, when people come home from work and take care of housework, for example, preparing food, washing laundry and watching TV, increasing electricity consumption to its daily peak. At the same time, the sun is setting, and the productivity of solar power plants decreases, a strong need arises to produce reserve peaking power.

Currently, new requirements are being imposed on the peaking power plants because they must be available in minutes, in the future perhaps in a fraction of a second. Traditional thermal power plants operate at the best efficiency when driven at full power. It is not economically viable to keep these power plants at full power or to ramp up and down every day. In the future, ultrafast peaking power will be available for example from electrical energy storages but so far, their penetration in the markets broadly is slowed by their relatively high price. However, the price level will fall in the future, just like

happened with solar panels, and there will be tremendous demand for these energy storages. There are already many locations where energy storages are a viable investment, but in the future, demand will be considerably higher.

According to the interview of company B in this study, the situation in Finland seems somewhat different. In Finland, solar energy will not replace traditional power generation solutions. A simple explanation is the northern location of Finland and the resulting low light in winter times. Instead, solar energy solutions come alongside traditional power solutions and thus into the entire national energy system. The peaks of the load are aligned with the energy production resources so that in practice there will not be such a situation consumption will increase to greater than production.

Table 11. Small-scale (< 1MW) electricity generation in Finland (Energy Authority 2018).

Small-scale production		
Source	Installed power 2017 [MW]	Installed power 2016 [MW]
Solar	66.2	27.2
Wind	17.5	15.5
Bio	16.3	15.3
Hydro	36.2	34.2
Diesel	38.2	37.4
Others	3.3	2.8
	177.7	132.4

At present, the demand for solar energy is growing rapidly in Finland (Table 11). It is evident that many individuals are enthusiastic about investing in solar energy and energy-saving solutions in general. It is not really a green statement, but the price level of the systems is relatively inexpensive and the possible cost savings may also be considerable. The number of decentralized energy solutions will increase in Finland over the next few years, both for grid connected systems and for off-grid systems. In many locations the off-grid solution is also economically the only possible energy solution. For example, there is a lot of archipelago in Finland and the installations of electric cables in the archipelago is not possible at all places.

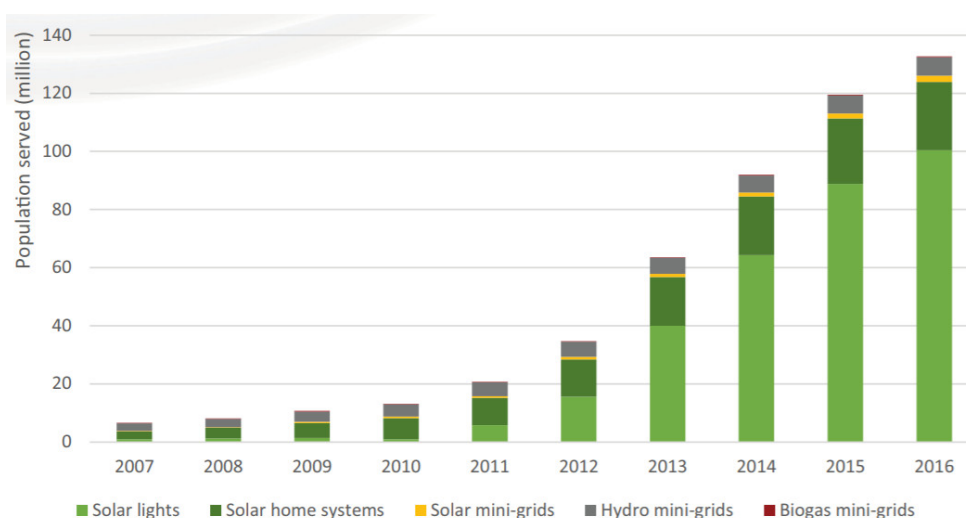
It has been interesting to see that some people have been interested in solar electricity due to constantly rising electricity pricing. A rebellion has been noticeable since electricity transmission companies have raised transmission fees each year, even though electricity itself is inexpensive in Finland. Customers interested in photovoltaic electricity seem to be tired of transfer prices and seek to increase their self-sufficiency.

Systems Integrators supplying solar energy solutions can specialize in many ways. When discussing small scale solar energy systems for households, one can see the basic SI's who compete mainly at cheap prices. This class of SI's does not require any special engineering or design and solutions are off-the-shelf solutions. The components are cheap, and the installation sites are chosen as easy as possible. Specialization can be provided, for example, with higher quality parts and system monitoring. Additionally, installing PV systems in challenging location can be a specialization factor.

System Integrators closely monitor the development of technology and can provide solutions that others cannot. The expected lifecycle of the solar PV power plant can be around 25 years, but alongside traditional power plants it is relatively short time. With the development of technology, however, 25 years is a very long time and many things are changing in that time. Upgrading solar PV power plants to newer technology can also provide systems integrators with opportunities for business. It is expected that in the future, different hybrid power plants will become more common. Naturally, these involve different types of energy solutions, but also the control and coordination of these different systems will be technically challenging. In addition, maintenance and the repair of power plants enable new business operations for System Integrators.

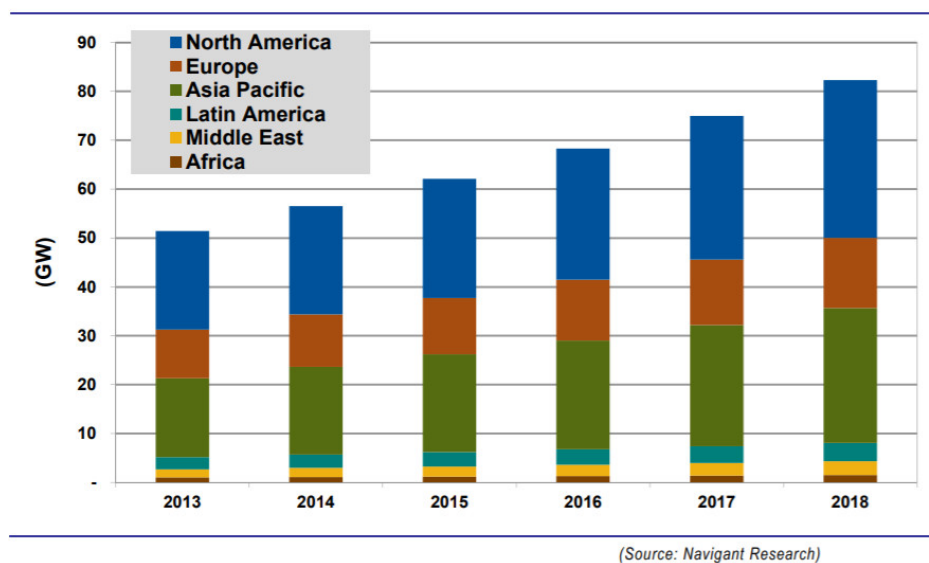
Target company A states that its power plant solutions will be readily compliant with future needs. On the other hand, target company B has developed its own technological value-added services, such as system tracking equipment and panel mounting brackets suitable for Finnish or Nordic conditions. With added value services, the company also strives for international markets. Both companies estimate that some specialization factors are vital even for system integrators in the case of solar PV energy systems.

Off-grid and Mini-grid solutions should be discussed separately. They are not connected to the national grid and they form an island network with its own electrical characteristics. It is estimated that world-wide there are approximately 1.6 billion people living without the national electricity grid. Most of these are in distant areas, in rural areas and in emerging economies. It has not been economically feasible to construct an electricity transmission network for these destinations, and electricity has been produced in some other way. Solar energy is also installed in these locations, but often the systems are made with low-quality components and they are under-sized (DGS 2013: 292-293).



Picture 15. Population served by off-grid renewable energy solutions globally (IRENA 2018 ii).

According to International Renewable Energy Agency, only 140 million people were served by off-grid renewable energy solutions, most of which are related to lighting and household electrification. However, it can be noticed that the number of installed systems will increase as the general trend in solar energy is. There is still a lot of growth potential in these markets and business opportunities for system integrators. However, the small size of the systems is challenging, as profitable business may require considerable volumes.



Picture 16. Annual diesel genset installation capacity by region, world markets: 2013-2018 (Navigant Research).

On a larger scale, electric power is generally generated by diesel generators in remote locations. They are a reliable way to generate electricity and operate regardless of the environmental circumstances. Electrification is relatively simple and spare parts are available on the market for their service. According to market trends, demand for diesel generators will continue to grow but they also have their own challenges. Diesel generators are not particularly environmentally friendly and cost-effective. Oil is a costly way to generate electricity and oil prices fluctuate constantly. In addition, the logistical costs for remote destinations are high and, consequently, diesel generated electricity is expensive. Different solar photovoltaic-diesel Genset hybrids can be the most rational way to generate electricity in distant locations.

It is discussed about the core business models of Systems Integrators in the field of photovoltaics. Systems Integrators may also boost their business operations by creating enabling businesses. As previously discussed, the target companies enable their business by providing financial services, if necessary. In this enabling category one could also include new business models such as Electricity as a Service or Plants as a Service. In the EaaS/ PaaS -business models the ownership of the assets remains as a property of Systems Integrator or the entity set up by SI. Only electrical energy produced by the plant is sold to the customer. Also, leasing business is possible with solar energy. Customers lease a solar panel for a certain price and receive the electricity produced by the panel in exchange for it. These business models are not really system integration business, but on the other hand, they enable the actual business to occur.

5. SUMMARY AND CONCLUSIONS

5.1. Summary and key findings

Renewable energy sources have come to energy markets on a large scale, and especially electricity from renewable sources, which continue to grow significantly. There are many reasons for this, such as renewable energy sources which have been perceived to be an environmentally friendly way of generating energy. However, in this study, interviewed experts stated that only after the renewable energy costs had come down sufficiently, their widespread entry into the market had become possible.

In this paper, it has been studied what kinds of business opportunities and concepts solar photovoltaic electricity generation may provide for System Integrators. Business opportunities and concepts can be understood in many ways. This study used the previously proposed model of Bocken & Short (2015) and Short et al. (2014) as a model of business concept. In the model, the business concept is understood to consist of three elements related to the company's value creation logic.

The first element contains the proposition, i.e. what value the company is proposing and to whom it is addressed. This includes the company's most important functions, based on the operations of the entire company. In the context of this research, focus was on the solar photovoltaics.

The study also discusses how System Integrators create and deliver value. Since value creation is perhaps the most important business element of a company, more material has been sought from the scientific literature in this regard. In particular, Davies et al. (2006 & 2007) have previously explored the value creation models used in the service business. These and other value creation models are summarized in Table 2. The study shows that System Integrators are actually technology and project companies and implementing demanding engineering operations and managing challenging projects is their specialty.

This includes all procurement, engineering and installation (EPC). Also, operations and maintenance of the power plant at a later stage of the project. Financial services are also included in this element, but according to the study, funding in this context is an enabling operation rather than actual business model. Value-added services are also part of the overall supply of System Integrators. The companies in this study have developed their own technical solutions that provide added value to the customer. Value-added services can also be counted as a specialisation factor for companies.

The third element contains the company's value capture. In the original business concept model of Bocken et al. 2014 and Bocken & Short 2016, value capture explains what kind the cost structure of the company is and where its revenue is generated and what its growth strategy is. In this study the model differs substantially from the original. The value capture element incorporates experts' views on how they see solar photovoltaics now and in the future. How they describe the market from suppliers and customers side and how their own products and services are placed in this context. This is because it is not appropriate to inquire about the cost structures or cash flows of the companies that are interviewed because they are not compared to other similar companies, it is not the point of this study. Instead, more important is to understand how the market behaves in solar photovoltaic now and what kind of business opportunities experts see in this business.

Indeed, the study was carried out as a qualitative study, in which experts from the field were interviewed. The interviews were prepared by studying the scientific literature in the field and by defining a theoretical framework for the interview. The interview was arranged as a semi-structured model, where the conversation itself in the interview does not follow strictly the interview frames. Interviewees explained quite freely their own views on issues and the field in general. The results of the interviews were mainly aligned with each other with the examined theoretical framework.

Two Finnish companies were selected for the interview, who have decided to start the solar energy business in the recent past. Solar power systems supplied by these companies cover all areas of power except for the largest, more than 1,000 MW installations in the utility scale segment. The research process proceeded as in qualitative studies in general.

The interviews were recorded and the recordings were converted into written form. Written form was encoded and interpretations were generated from coding. Interpretations were sent to the interviewed persons for comment to ensure the correctness of the interpretations.

There are many business opportunities in the solar energy sector for Systems Integrators. System Integrators specializing in small systems can offer their products for small consumption for households and personal customers. In this class, system design does not require very specific engineering, but in principle, the solution once designed is often suitable for many different sites as well. The location of sites, the quality of the electricity network and the requirements of installation may make these sites more demanding but at the same time they enable specialization. Both interviewed companies consider specialization as important. This is partly due to the fact that each site is different and according to good design principles it requires a unique system solution even if customization is only a bit.

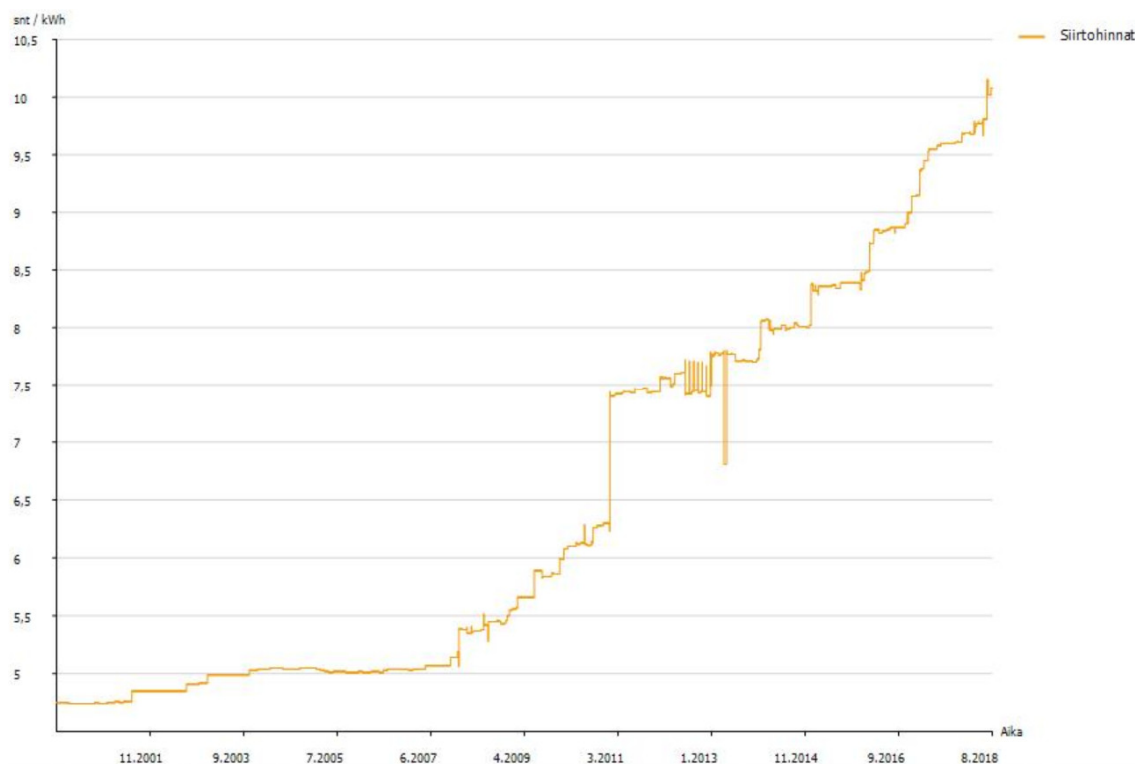
Segmentation	Power range
Utility	> 1000 MW
	10 – 1000 MW
	0.7 – 10 MW
Industrial	100 – 700 kW
Small industrial	15 – 100 kW
House holds	1 – 15 kW

Picture 17. Segmentation of Solar photovoltaic systems by power range.

Photovoltaic systems and power plants that are higher than 10 kW, have increasing technical demands. Network companies are interested in small power plants that are connected to their power grid. They set certain requirements for solar photovoltaic systems that are network-connected. For example, if a nationwide network goes down for some reason, a power plant connected to the network must be able to independently loose

the network. This operation is commonly referred to as anti-islanding and ensures the safety of the network maintenance functions.

On the other hand, this segment has plenty of potential for System Integrators. The customer base is large, and a wide range of solutions are needed. The segment can include private customers, small businesses and farms as well as bigger companies. Many of this segment's customers expect cost savings when investing in solar photovoltaic electricity. In Finland, customers are also tired of continuously rising electricity transmission prices and seek to increase their energy self-sufficiency (Picture 13). The same applies to enterprise customers, but some companies have also taken advantage of the value of photovoltaic electricity as taking responsibility of the environment in their marketing.



Picture 18. Electricity transfer price development in Finland. Ref. small house 5 000 kWh / year, the average price for the whole country from 01.01.2000 to 09.08.2018 (Energy Author 2018).

There is also a growing demand for off-grid, mini-grid and micro-grid solutions as well. There are many places where it is not economically viable or even possible to build an

electricity transmission network and often these sites generate the electricity they need with diesel generators. These sites can be remote villages, mines and islands around the globe. At these sites, however, the price of electricity can be disproportionately high, as the price of oil is high, and the logistics costs are high. Thus, these sites have a tremendous potential for System Integrators, i.e. the possibility to replace diesel generators or to build a solar photovoltaic power plant alongside an existing system.

Large, utility scale photovoltaic power plants were discussed also in this study. The need for large power plants will continue to grow in the future, and System Integrators of this size range will generally implement different hybrid power solutions. Variable renewable energy sources are characterized by the fact that the amount of electricity produced by them is influenced by environmental. For hydroelectric power plants, it means the amount of water in the ponds, for wind power the amount of wind and for solar photovoltaic the amount of solar radiation. However, these conditions vary unpredictably. On the other hand, the price of electricity produced by renewable energy sources is marginally non-existent, so electricity produced should be directed to the grid. This can sometimes lead to an absurd situation when there is excess supply of electricity and must be sold theoretically at a negative price.

The unpredictable behaviour of some sources of renewable electricity increases the challenge of network management substantially. There is a need to prepare for strong fluctuations in production and consumption. As renewable energy sources have become part of a modern power generation solution, part of the traditional power plant solutions will become obsolete. They are no longer economical enough to produce reserve power and they are not able to respond to changes in consumption sufficiently quickly. Thus, System Integrators develop such technology solutions that meet this and future challenges. It should be noted that renewable energy systems are not sufficiently reliable, but other power plant solutions will be needed to cover the entire energy system. One kind of renewable energy source alone cannot produce a balanced network energy, but a mix of different power plant types is needed to secure future energy needs and this solution should also be cost-efficient.

It is also possible to apply for subsidies for solar power investments. In Finland, this support is granted by Business Finland and certain conditions must be valid. The purpose of the subsidy is to promote new technology and its commercial exploitation as well as new energy-efficient solutions that change the energy system to low carbon. The amount of funding for applicable photovoltaic projects in Finland is 25 % (Business Finland 2018). Similar subsidies are possible in other countries as well.

Subsidies increases the profitability and the volume of investments. As a result, System Integrators can increase their own services and volume. On the other hand, subsidies may involve a political risk. Policies may change after the end of the reign period; thus, it is important to evaluate the risks of subsidies over a long period of time (Forbes 2018). Political risks may even lead to reluctance to make investments. In addition, subsidies distort the free market and may make unfavourable technical solutions affordable at the expense of others.

5.2. Theoretical contributions

The exploitation of renewable energy sources has been studied from a wide range of perspectives. The starting point for the research has often been the technical aspect. Commercial studies have also been carried out on this subject, but there has been little attention to mapping business concepts for SI's within the solar PV's. The aim of this thesis is to evaluate business concepts and opportunities for System Integrators supplying solar photovoltaic energy systems.

This research has in principle been rather practical view of the solar photovoltaic business opportunities for Systems Integrators. The referred theoretical framework has been the adopted from scientific literature on services, as system integration in business can be well incorporated into servitization.

However, theoretical literature is often a generalization of the phenomenon being investigated. It is usually not enough to describe certain phenomena with the precision that one could understand certain industry more in-depth. In this study, it is referred to that the scientific literature is well suited to the research, i.e. it describes essentially those phenomena that are also identifiable in the photovoltaic business. However, the aim of this study is to understand the photovoltaic business for System Integrators by interviewing experts in the field and by making interpretations that are valid for the industry as a whole.

The theoretical framework creates a good starting point for understanding phenomena and issues that can be identified in practical examples such as exploring business within photovoltaic power generation. The greatest theoretical contribution of this thesis is that it is not known that similar research was previously done focusing on System Integrators in the photovoltaic industry. The term System Integrator is, however, not a well-established term. Other terms used in the industry are Project Developers and EPCs. However, the SI, it is emphasized its technological dimension. Likewise, it can be assumed that the EPC would be more oriented towards civil engineering and the Project Developer is a company focusing on social relationships with different stakeholders.

5.3. Managerial implications

Solar photovoltaic is part of a modern power generation solution. The price level of systems has declined for years and are now fully competitive with other energy solutions. Investment in photovoltaics is no longer a green statement, but rather a cost-effective way to generate electricity. In some places, even the only possible way to generate electricity.

According to a number of market studies (e.g. Gerlach et al. 2015, Goop et al. 2017, Energy Transition Outlook 2017, Annual Energy Outlook 2017) the amount of photovoltaic electricity will continue to grow far into the future. At the same time, photovoltaic system prices have been falling for years, as the number installed PV

capacity has increased (van Sark et al. 2014, Seel et al. 2014). The increasing demand for photovoltaic has allowed new business opportunities for Systems Integrators. Germany and other central European countries appear to move at the front of this development, but the same development is expected to north within few years. For example, in Finland, the Energy Authority has reported a large increase in network-connected solar electricity systems last year (Energy Authority 2017). Of course, environmental conditions and the intensity of solar radiation in Finland are different from those in Central Europe, but for example, the amount of solar radiation in southern Finland is roughly the same as in northern Germany (Goop et al. 2017).

This study also discusses why customers are purchasing solar electricity systems. Photovoltaic power has been felt to be an environmentally friendly and responsible way of generating electricity, but today it is also a cost-effective alternative. Households seek to increase their energy self-sufficiency by building energy-efficient homes and adding small solar power plants mainly for self-consumption. There is a general interest in the subject and after one household invests in photovoltaic electricity many others will follow.

The same development has taken place regardless of the size of the photovoltaic power system. System Integrators can specialize in many different customer segments, and there are plenty of available markets globally. In the category of small to medium size photovoltaic power plants, it has been predicted that various off-grid and mini-grid solutions will become more common. Decentralized photovoltaic systems will be installed alongside or they even replace existing energy systems in these distant locations, especially diesel generators.

Photovoltaics are also increasingly being produced at utility scale power plants. In this segment, solar power replaces traditional power generation solutions, that is, solar power has become part of the base power generation solution. This will change the entire electricity market in time. Firstly, many conventional power plant solutions are no longer economically competitive with new solar (hybrid) power plants. In particular, according to interview experts in this thesis, coal is believed to be eliminated as it is no longer

economically viable. Nor is it an eco-friendly way of generating energy, but in the end, the cost-inefficiency will eventually drive it to retirement. Secondly, many thermal power plants are not fast enough to react to rapid load fluctuations. Solar power, such as renewable energy sources in general, depends on the environmental conditions and is difficult to forecast. In any case, renewable sources of energy require additional adjustable reserve power, and it is predictable that reserve power and utility scale energy storages will become significantly more common. At present, their entry is only slowed down by their relatively high price level.

5.4. Suggestions for further research

Renewable energy solutions and solar energy and related phenomena will certainly be studied quite a lot and from many different perspectives. There are always a number of new technical solutions on the market, some of which will become more common in the future and some will be marginalized by more efficient technologies. In the commercial sense, it is interesting to evaluate what kind of business opportunities in the future will be seen in the energy sector. It is particularly interesting to evaluate how the electricity market will change when increasing amount renewable energy is installed and connected to grid and also, how electricity purchase and sale transactions processes will change.

Secondly, this study found interesting phenomena in customer behaviour with photovoltaic systems. It is a known fact that photovoltaic systems are evolving all the time at an accelerating pace. There are constantly new technologies on the market, a higher efficiency, and so on. The market is at the same time a downward price level market. Some customers are expecting a future price level for their own systems, that is, it is assumed that the price of the system can be negotiated, for example, to level of two years of future. If the Systems Integrator does not agree to sell the solution so advantageously, the rational customer will compare how much savings the new solar PV system can offer compared to investment of few years after. It is assumed that the price level will in any case decrease in the future.

REFERENCES

Almendinger, Glen & Lombreglia, Ralph (2005). Four Strategies for the Age of Smart Services. *Harvard Business Review Oct 83:131 - 138*.

Annual Energy Outlook (2017). Market Study. Available from Internet: [https://www.eia.gov/outlooks/aeo/pdf/0383\(2017\).pdf](https://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf)

Binz C., Tang T., Huenteler J. (2017). Spatial lifecycles of cleantech industries – The global development history of solar photovoltaics. Elsevier. *Energy Policy* 101 (2017) 386-402.

Bocken, N.M.P & Short, S.W (2016). Towards a sufficiency-driven business model: Experiences and opportunities. Elsevier. *Environmental Innovation and Societal Transitions* 18 (2016) 41-61.

Bocken, N.M.P; Short, S.W; Rana, P; Evans, S (2014). A literature and practice review to develop sustainable business model archetypes. Elsevier. *Journal of Cleaner Production* 65 (2014) 42-56.

Business Finland (2018). Energiatuki. Available from Internet: <https://www.businessfinland.fi/suomalaisille-asiakkaille/palvelut/rahoitus/pk-ja-midcap-yrittajien/energiatuki/>

Collins S., Deane P., Gallachoir B., Pfenninger S., Staffell I. (2018). Impacts of Inter-annual Wind and Solar Variations on the European Power System. Elsevier. *Joule* 2: 1-15, October 17, 2018.

Cross S., Hast A., Kuhl-Thalfeldt R., Syri, S. Streimikiene D. (2015). Progress in renewable electricity in Northern Europe towards EU 202 targets. Elsevier. *Renewable and Sustainable Energy Reviews* 52 (2015) 1768-1780.

Davies, Andrew; Brady, Tim; Hobday, Michael (2007). Organizing for solutions: Systems seller vs. systems integrator. *Industrial Marketing Management* 2007 36: 183 – 193

Davies, Andrew; Brady, Tim; Hobday, Michael (2006). Charting a Path Toward Integrated Solutions. *MIT Sloan Management Review Spring 2006: Vol.47 No.3: 39 – 48*

DGS, Deutsche Gesellschaft für Sonnenenergie (2013). Planning and Installing Photovoltaic Systems. A Guide for Installers, Architects and Engineers. 3rd edition. Berlin: Routledge.

Energy Authority (2018). Electricity price comparison in Finland. Available from Internet: <http://www.sahkonhinta.fi/summariesandgraphs>

Energy Authority (2017). Julkaisu: Sähköverkkoon kytketty aurinkosähkökapasiteetti yli kolminkertaistui vuodessa. Available from Internet: https://www.energiavirasto.fi/-/sahkoverkkoon-kytketty-aurinkosahkokapasiteetti-yli-kolminkertaistui-vuodessa?redirect=https%3A%2F%2Fwww.energiavirasto.fi%2Fhome%3Bjsessionid%3DF5EE436B668A51E220324F2A0B21817D%3Fp_p_id%3D101_INSTANCE_o19kFDvrgZ2J%26p_p_lifecycle%3D0%26p_p_state%3Dnormal%26p_p_mode%3Dview%26p_p_col_id%3Dcolumn-8%26p_p_col_count%3D2

EIA, The U.S. Energy Information Administration (2017). International Energy Outlook 2016. Available from internet: https://www.eia.gov/outlooks/ieo/exec_summ.cfm

EIAS, European Institute for Asian Studies (2017). EU-China Solar Panels Trade Dispute: Settlement and Challenges to the EU. Available from internet: <http://www.eias.org/wpcontent/uploads/2016/02/EU-Asia-at-a-glance-EU-China-Solar-Panels-Dispute-YuChen.pdf>

EPC Contracts (2015). Utility-Scale Solar Photovoltaic Power Plants. A project developer's guide. Available from internet:

https://www.ifc.org/wps/wcm/connect/f05d3e00498e0841bb6fbbe54d141794/IFC+Solar+Report_Web+_08+05.pdf?MOD=AJPERES

Energy Transition Outlook (2017). Market Study. Available from Internet: http://www.ourenergypolicy.org/wp-content/uploads/2017/09/DNV-GL_-Energy-Transition-Outlook-2017_renewables_lowres-single_0109.pdf

Eriksson, Päivi & Kovalainen, Anne (2016). *Qualitative Methods in Business Research*. 2nd edition. Sage Publications Ltd.

European Commission (2017). EU Climate Action. Available from internet: https://ec.europa.eu/clima/citizens/eu_en

Finnish Meteorological Institute (2014). Reports 2014:5 Auringonsäteily Helsingin Östersundomissa. No. 2014:5

Forbes (2018). An EU law Change Could Render Home Solar Panels Worthless. Available from Internet: <https://www.forbes.com/sites/sap/2018/08/02/to-appreciate-the-value-of-digital-networks-look-to-the-skies/#b5597c15d5f9>

Gerlach A., Breyer C., Fischer M., Werner C. (2015). Forecast of Long-term PV Installations – A discussion of Scenarios ranging from IEA to the Solar Economy. Conference paper. 31st European Photovoltaic Solar Energy Conference, September 14 – 18, 2015, Hamburg, Germany.

Ghenai C., Merabet A., Salameh T., Pigem E. C. (2018). Grid-tied and stand-alone hybrid solar power system for desalination plant. Elsevier. *Desalination*, volume 435, 1 June 2018, Pages 172-180.

Glaser, B. and Strauss, A. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Chicago, IL: Aldine Publishing Co.

Goetzberger A., Hebling C., Schock H. W. (2003). Photovoltaic materials, history, status and outlook. Elsevier. *Materials Science and Engineering: R: Reports*. Volume 40, Issue 1, 1 January 2003, pages 1-46.

Goop J., Odenberger M., Johnsson F. (2017). The effect of high levels of solar generation on congestion in the European electricity transmission grid. Elsevier. *Applied Energy* 205 (2017) 1128-1140.

Green M. A. (2005). Silicon Photovoltaic Modules: A Brief History of the First 50 Years. Wiley Interscience. *Progress in photovoltaics: Research and applications* 2005; 13: 447-455.

Grönfors, M. (1982). Kvalitatiiviset kenttätyömenetelmät. Helsinki: WSOY.

IPCC, Intergovernmental Panel on Climate Change (2014). Social, Economic, and Ethical Concepts and Methods. Available from internet: http://ipcc.ch/pdf/assessmentreport/ar5/wg3/ipcc_wg3_ar5_chapter3.pdf

IRENA, International Renewable Energy Agency (2018 i). Available from internet: <http://resourceirena.irena.org/gateway/dashboard/?topic=3&subTopic=32>

IRENA, International Renewable Energy Agency (2018 ii). Available from internet: http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jul/IRENA_Off-grid_RE_Solutions_2018.pdf

Koskinen, Ilpo; Alasuutari, Pertti; Peltonen, Tuomo (2005). Laadulliset menetelmät kauppatieteissä. Vastapaino, Tampere.

Larjava, Kari; Aarniala, Marjatta; Honkatukia, Juha; Jussila, Jatta; Korhonen, Ilkka; Puhakka, Pentti; Tynkkynen, Oras; Helynen, Satu; Koljonen, Tiina; Lind, Irma; Mattila, Lasse; Savolainen, Ilkka; Sipilä, Kai; Syri, Sanna; Viinikainen, Seppo;

Similä, Lassi (2009). *Energy Visions 2050*. Kuopio: VTT Technical Research Centre of Finland Ltd

Matek B., Gawell K. (2015). The Benefits of Baseload Renewables: A Misunderstood Energy Technology. Elsevier. *The Electricity Journal* vol 28, Issue 2, March 2015, pages 101-112.

NASA, National Aeronautics and Space Administration (2017). Global warming from 1880 to 2016. Available from Internet: https://climate.nas.gov/climate_resources/139/

Navigant Research. Diesel Generator Sets: Distributed Reciprocating Engines for Portable, Standby, Prime, Continuous, and Cogeneration Applications. Available from Internet: <https://www.navigantresearch.com/wp-content/uploads/2013/02/DGS-13-Executive-Summary.pdf>

NREL (2015), Overgeneration from Solar Energy in California: A Field Guide to the Duck Chart. Available from Internet: <https://www.nrel.gov/docs/fy16osti/65023.pdf>

PVGIS (2018). Photovoltaic geographical information system. Country and regional maps. Available from Internet: http://re.jrc.ec.europa.eu/pvg_download/map_index.html

Radermacher R. (2017). Building energy research and the “duck curve”. Taylor & Francis. *Science and Technology for the Built Environment*, 23:7 1079-1079.

Rehman S., Alam Md. M., Meyer J. P., Al-Hadhrami L. (2012). Feasibility study of a wind-pv-diesel hybrid power system for a village. Elsevier. *Renewable Energy*, Volume 38, Issue 1, Feb. 2012, pages 258-268.

REN21, Renewable Energy Network for the 21st Century (2018). Available from internet: <http://www.ren21.net/status-of-renewables/global-status-report/>

Seel, J., Barbose, G. L., Wiser, R. H., (2014). An analysis of residential PV system price differences between the United States and Germany. Elsevier. *Energy Policy* 69 (2014) 216-226.

Spanggaard H., Krebs F. C. (2004). A brief history of the development of organic and polymeric photovoltaics. Elsevier. *Solar Energy Materials & Solar Cells* 83 (2004) 125-146.

SHB Resources (2017). Global Market Outlook for Solar Power 2015-2019. Available from internet: <http://resources.solarbusinesshub.com/solar-industry-reports/item/globalmarket-outlook-for-solar-power-2015-2019>

Short, S. W., Bocken, N. M. P., Barlow, C., Chertow, M., (2014). From refining sugar to growing tomatoes: industrial ecology and business model evolution. *J. Ind. Ecol.* 18 (5), 603-618.

Sioshansi F. P. (2016) Electricity Currents: A Survey of Current Industry News and Developments. Elsevier. *The Electricity Journal* 29 (2016) 71-75.

Solar power world (2018). Available from internet: <https://www.solarpowerworldonline.com/2018/03/german-solarworld-brand-files-for-bankruptcy-again/>

Syri S., Kurki-Suonio T., Satka V., Cross S. (2013). Nuclear power at the crossroads of liberalised electricity markets and CO₂ mitigation – Case Finland. Elsevier. *Energy Strategy Reviews* 1 (2013) 247-254.

UNFCCC i, United Nations Framework Convention on Climate Change (2017). Kyoto Protocol to the United Nations Framework Convention on Climate Change. Available from internet: <http://unfccc.int/resource/docs/convkp/kpeng.pdf>

UNFCCC ii, United Nations Framework Convention on Climate Change (2017). Paris Agreement. Available from internet: http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

van Sark W. G. J. H. M., Muizebelt P., Cace J., de Vries A. (2014). Price development of photovoltaic modules, inverters, and systems in the Netherlands in 2012. Elsevier. *Renewable Energy* 71(2014) 18-22.

Wise, Richard & Baumgartner, Peter (1999). Go Downstream: The New Profit Imperative in Manufacturing. *Harvard Business Review Sep-Oct Issue 83:133 - 141*.

Zakeri B., Syri S. (2015). Electrical energy storage systems: A comparative life cycle cost analysis. Elsevier. *Renewable and Sustainable Energy Reviews* 42 (2015) 569-596.

2017 The World Bank, Solar resource data: SolarGIS. (2018). Available from internet: <https://solargis.com/maps-and-gis-data/download/world/>