Department of Management Studies

Delimitation of technologies and impacts in focus in the Smart Energy Transition project

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Abstract

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Abstract
This paper specifies the scope of the research plan of the Smart Energy Transition project. Since the aims of the project are broad, we need to delimit the scope of our empirical analysis to particular technologies and particular kinds of impacts. The aim of this paper is to make (non-exclusive) delimitations that define the main empirical subject material of the project.

Keywords energy, energy transition, smart energy, smart energy transition, energy technology

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1 Introduction: The Smart Energy Transition project

Renewable energy sources combined with smart energy technologies (such as automation and energy efficient designs and devices) are potentially disruptive technologies because they change the way we produce, use and do business with energy. They are collectively envisaged to lead to a new and notably different energy system, which combines the rapid cost reductions in renewable energy, smart grids, metering, power storage, power-to-gas, power-to-chemicals, nearly zero energy buildings, and the Internet of Things. Smart energy solutions are expected to cascade into new business models and ecosystems and lead to radical shifts in the roles of producers, service providers and consumers.

The disruptions that the Smart Energy Transition (SET) consortium examines are driven by a convergence of several technologies, and they have consequences in multiple sectors. Although there is research on the impacts of individual technologies such as renewable energy sources (Richter 2013), or smart grids (Erlinghagen and Markard 2012) on the energy sector, there is a lack of studies that analyse the smart energy transition beyond energy production and distribution, and examine the opportunities and challenges for the wider economy.

The smart energy disruption is a global development. Despite Finland's past as a global innovation leader, the country has not been particularly advanced, e.g., in deploying solar and wind power or developing energy storage solutions (while in zero carbon buildings some promise is visible). The Smart Energy Transition consortium (SET) analyzes the ongoing global smart energy transition and its impacts on the Finnish economy and society, in particular the potential benefits for cleantech, digitalization and bioeconomy, the expected spearheads for Finland's future growth. The work consists of the following work packages:

- WP1 What are the rate, direction and impacts of the technological transition?
- WP2 Emerging value chains, business models and business ecosystems
- WP3 Analysis of institutions and industrial policy in the context of disruptive energy technology
- WP4 Competence development: learning from smart energy pilots and early users
- WP5 What are the short- and long-term policy implications of the disruption?
- WP6 How to support engagement formats and transition arenas in user-producer-policy interaction?

We envisage the disruption as a force driven by technological developments, even though many of these developments have been originally instigated by changing institutions and policy measures. Societal responses to these disruptive forces constitute the smart energy transition. The aim of the project is to help Finnish decision makers navigate this transition in a way that it benefits Finnish society as much as possible.

Smart energy transition refers to societal responses to disruptive changes in energy production, transmission, storage and demand. These responses aim to adapt to a more low-carbon economy that is able to make use of distributed and intermittent energy sources.

2 Aim of this paper

SET analyses a disruption that has been previously identified in broad contours, but which needs to be specified: what are the main drivers and enablers of the disruption and what are its main impacts? SET analyses how the Finnish economy could benefit from the disruption. Since the Finnish economy and energy market has strong international trade links, and the disruption is proceeding at a different speed in different countries, we need to pay attention to the geographical and temporal scope of our analysis. Since the disruption is likely to cause numerous impacts, we also need to decide which of these impacts we prioritize in our analysis.

Since the potential impacts are extremely wide, there is a need to narrow down the scope of the impact analysis to particular parts of the energy system and particular industries. Moreover, in order to identify plausible pathways through which the Finnish economy might benefit, we need to specify the way in which smart energy is disruptive and for whom, as well as define the scope of our search for promising business models and ecosystems.

This paper aims to define and delimit the technologies and industries that form the empirical focus of SET. It is not a presentation of the entire work plan of SET. Instead, we aim to delimit our work concerning the envisaged pathways through which the smart energy transition has impacts on the Finnish economy and society.

The main audience for this paper is our own SET consortium and related research projects. This paper can also serve as a basis when communicating with stakeholders and deciding whether we can respond to their needs, but this paper itself is not aimed for decision makers or other research users.

3 Previous research on the disruptiveness of new energy technologies

3.1 Previous research and commentary on the disruptiveness of renewable energy technologies

Several studies identify renewable energy in general, and often naming solar and wind power, as disruptive technologies that are likely to shape the future economy and the competitiveness of various industries:

- According to a McKinsey study (Manyiaka et al. 2013), renewable energy (solar and wind) and energy storage feature among the 12 technologies that will “transform life, business and the global economy” by 2025, alongside the mobile internet, the Internet of Things, 3D printing and others. However, their estimate of the potential economic impact of renewable energy (about \$0.2-0.3 trillion), is fairly low compared to the other selected disruptive technologies (e.g. Mobile Internet \$3.7–10.8) as well as to the estimated economic impact of energy storage solutions (about \$0.1-0.6 trillion).
- Stoiciu et al. (2014) have investigated the disruptiveness of various renewable energy technologies in Austria, Bulgaria, Germany and Romania, on the basis of (1) current and potential market share, (2) value proposition, (3) costs, (4) time to market, i.e., maturity of the technologies, (5) political, economic, social and technical barriers and (6) learning rates. They find solar and wind to be disruptive in forthcoming decades, but also mention e.g. biomass energy sources as disruptive technologies.
- Richter (2012; 2013) and Kungl (2015) have investigated the impacts of the recent growth in the German PV market on energy companies. They point out that the incumbent energy companies were late to react, as a result of which they have lost market share and profitability.
- The smart grid, a combination of existing electricity transmission technologies and advanced ICT solutions, has been identified as enabler to integrate new and more intermittent forms of energy generation into the grid and enable new products and services. Erlinhagen and Markard (2012) found that the smart grid development has brought existing large ICT firms into the electricity sector, which also forced energy companies to innovate. However, Lund et al. (2012) and Lunde et al. (2015) show that narrow conceptions of the smart grid merely in terms of electricity (as opposed to smart energy in a broader sense) can limit the scope action and the opportunities to benefit from the smart energy transition.

For SET, the **disruptiveness** of various technologies is an empirical studied in WP1 and WP2. Our starting point is in the disruptions caused by the increase in intermittent and distributed energy production technologies (wind and solar), which create the need for increased energy storage (including conversion to other energy carriers) and better management of loads. Digital technologies that enable such management are a part of this disruption since they enable better management of energy flows. At the same time, changes in energy usage patterns (less energy use for buildings, buildings as energy producers and potential storage sites, new transport systems and sources) are increasing the integration of buildings and vehicles in the energy system.

Previous research has not, to our knowledge, examined (1) the impacts of the convergence of several smart energy technologies or (2) the impacts of distributed, intermittent and integrated energy systems beyond the energy sector on other industries.

3.2 Ways in which technologies can be disruptive and for whom

The firm level is usually in focus when speaking of “disruptive innovation” (Bergek et al. 2013). Tushman and Anderson (1986) conceptualize technological discontinuities in terms of their effects on existing technological capabilities, classifying innovations as “competence enhancing” and “competence destroying”. Competence-enhancing innovations offer incremental improvements to firms’ existing capabilities, leading to cost reductions. In contrast, competence-destroying innovations render existing competences obsolete, and thus erode the advantage of incumbent firms. Christensen’s (1997) notion of disruptive innovation is different, since it refers to products and markets (Bergek et al. 2013). In Christensen’s terms, sustaining innovations help a firm offer better performing products to their existing customer base, whereas disruptive innovations help a firm to create products for non-customers, often ones who cannot afford existing products or are unwilling to pay for them (Christensen et al. 2015).

The energy system is addressed, e.g. by Sauter and Watson (2007), who take a broader approach to technological disruption, drawing on Hughes’ (1983) concept of Large Technological System to examine the systemic consequences of novel technological configurations like distributed energy production . They investigate the disruption caused by this innovative practice by comparing the ‘technical’, ‘non-technical’ and ‘control’ elements of the current and a new kind of more distributed energy system. Examples of non-technical characteristics include network ownership, generation ownership, new market entry, supply chains, consumer-supplier relations and skills, whereas control characteristics include regulatory settings, load management, wholesale market and finance.

Broader socio-technical systems are addressed in the multi-level perspective (MLP) (Rip and Kemp 1998; Geels 2002; Geels 2011), which examines system innovations and socio-technical transitions in terms of the interactions between three levels: technological niches, regimes and landscapes. In simplified terms: niches represent potentially disruptive novelties, regimes represent the technological capabilities and rules that stabilize the existing system, and landscapes are external to the socio-technical system (e.g. population growth patterns or climate change).

From the MLP perspective, the disruptiveness of technologies depends on the extent of external pressures on the dominant regime. While some of the early work emphasized the role of niche innovations in technological disruptions, external pressures on the regime are an important part of this model of technological change and link to the destabilization of regimes (Turnheim and Geels, 2012, 2013). Schot and Geels (2008) identified four potential ways in which interactions between these three levels can result in system-level transitions: (1) Transformation, where the incumbent regime adapts incremental innovations from niche innovations in order to adapt to pressures from the external landscape; (2) Reconfiguration, where niche innovations are more developed when the pressures emerge, and can be adapted as ‘add-ons’ to existing regimes, thus reconfiguring the regime; (3) Technological substitution, where the niche innovations are well developed and manage to replace the existing technological regime; and (4) De-alignment and re-alignment, where major landscape pressures disrupt the regime, leaving space for multiple niche innovations to compete and eventually for one of them to form a new regime. From the MLP perspective, niche innovations are disruptive of existing technological capabilities and the institutions governing them when combined with external pressures; and destabilization is named as the process through which this happens.

4 SET Scoping: Which drivers, enablers and impacts do we focus on?

SET investigates the changes caused by the smart energy transition against the general global backdrop of several driving forces: increasing global energy demand, climate change and other environmental concerns, technological development (efficiency, renewables and digitalization) as well as changes in policy interventions and institutions, business development and consumer behavior.

4.1 Which technologies are drivers or enablers of the disruption?

We envisage the main thrust of the smart energy disruption to emerge from the integration of energy production from diverse low carbon and renewable energy sources, which have three distinctive characteristics that represent a disruption vis-a-vis current trends:

1. Intermittency
2. Distributed and hybrid production
3. Deeper integration of buildings and transport into the energy system

Then alongside these driving forces, we recognise enabling technologies, which condition the change and increase the pace in which disruptive energy generation technologies are adopted. Enabling technologies can be found in other, more flexible forms of energy generation, conversion/ storage, energy efficiency in demand sectors, as well as smart automation across the energy supply chains. It is also worthwhile to distinguish between globally relevant and locally relevant energy sources.

Table 1. Driving and enabling technologies in focus for SET.

	Generation	**Conversion/ storage**	**Transmission**	**Demand**
Globally relevant	Solar PV Onshore (and offshore) wind, Hybrid energy generation systems	Heat pumps, thermal storage Power-to-X (gas, heat, chemicals, food) Lithium batteries Electric vehicles, gas vehicles	Smart automation Demand response	Reduction of demand of energy and peak power in buildings, Electrification of transport, MaaS nZEBs nearly Zero Energy Buildings, demand side management, self-learning systems and adaptive buildings Smart and low-energy appliances (e.g., LEDs, IoT)
Locally relevant	Heat and power as industry by-products, geothermal heat, hydro, existing heating and cooling networks	Local and system level storages	Existing heating and cooling networks	Local storages and demand side management

Some of these technologies and solutions are described next in more detail.

Solar PV and wind represent globally relevant solutions for energy production, and they are the energy generation technologies attracting the largest investment volumes worldwide. Today, with around 227 GW installed globally, PV can produce around 1.3% (ca. 275 TWh) of the current global electricity demand (IEA PVPS 2016), whereas the installed capacity of wind energy systems is about 432 GW, enabling the production of 840 TWh and 3.5% of global energy demand at the end of 2015 (GWEC 2016). Cost reductions of about 60% are expected from current cost levels by 2050 for both utility-scale and rooftop PV systems (Ahola and Ahonen 2016), which is expected to increase the share of solar PV in the global electricity mix to 16.7-29% by 2050 (Breyer et al. 2016). Long-term projections of the share of wind power vary significantly, from 4% to 31% of total electricity demand (Dukeov and Ahonen 2016).

Hybrid energy generation systems combine the above-presented solar PV with a gas turbine or some other energy production technology that is able to provide electricity during nighttime. On the way to renewables-based energy system, this is often an easily acceptable solution to rural locations, where only combustion power plants have been used: such an example can be found from Jordan where Wärtsilä is providing 10 MW solar PV plant next to already existing combustion power plant.

As concerns **conversion and storage technologies**, heat pumps and thermal storage are likely to gain traction globally. Heat pumps and the related geothermal heat systems are becoming relevant alternative for traditional heat power plants. Development of thermal storage solutions, such as deep water wells, are supporting this development: they are being more widely adopted to existing district heating and cooling systems, where they allow storing of excessive heat of summer period to be used during autumn and vice versa for cooling needs (Wigstrand 2010).

Lithium batteries are the primary solution for private households willing to increase their self-sufficiency and self-utilization of solar PV energy production. Currently, the system price level of lithium batteries for energy storage application is around 1000-2000 €/kWh (higher than for electric vehicles), but they are expected to decrease to increased mass-production for cars in forthcoming years (Nykvist and Nilsson 2015). In addition, new solar PV inverters are being equipped with battery systems that accelerates the uptake of lithium battery solutions in small and large-scale systems.

Power-to-X refers to various solutions for converting excess electricity from intermittent wind and solar power to fuels, chemicals or other products. As a main difference to lithium batteries, Power-to-X can store energy for longer periods of time and the storage capacity has no such price-related limitations as batteries have. In the simplest form, Power-to-Heat considers the use of heat pumps for storing the excessive electricity into the hot water. In Germany, Power-to-Gas technologies present considerable alternative for storing electricity into the existing gas network and selling it in the form of conventional natural gas. There CO2 air capture technologies can be utilized, making the natural gas manufacturing possible everywhere. Also direct production of hydrogen with excessive electricity will become more feasible with the possible uptake of hydrogen transfer infrastructure in Germany. X can also refer to liquids (such as fuels and chemicals) and materials produced with electricity and chemical synthesis; in principle, diesel fuel can be manufactured from carbon dioxide captured directly from air and hydrogen, but with notably higher price compared to the existing fossil fuels.

Demand response and smart automation are seen as important enablers supporting the transformation of the energy system from a centralized to a more distributed one. For example, in residential power distribution, digitalization is now visible through the use of Automatic Meter Reading (AMR) that allows remote monitoring of customer energy consumption with one hour resolution, use of variable tariffs and development of services around these options. AMR can be considered as a physical component of a smart grid, providing means for the automated control of active resources including distributed generation, energy storages and demand response (DR), which refers to the flexibility in the energy consumption (Koivisto et al., 2015). AMR also provides technical infrastructure for other third-party energy services motivating the efficient use of energy and for active management of the electric power quality (Logenthiran et al., 2012).

The reduction of energy and peak power demand in buildings is supported by increasing requirements for and development of nearly zero energy buildings (nZEB), i.e., buildings that have a very high energy performance. The general pathway to achieve an nZEB consists of two steps: first, reduce energy demand using energy efficient technologies. Second, use low carbon and renewable energies to cover the rest of the supply. In new buildings, especially the proportional share of the use of electricity is increasing; therefore, it is essential to pay attention on the electricity use in buildings. For the existing building stock, the transformation towards low carbon buildings requires improvement in thermal performance, as well. Future challenges in buildings are the integration of different systems into a seamless part of the whole energy system and the continuous optimisation of the building performance (within the scope of user requirements) using predictive algorithms. The question remains of which parties in society emerge to perform this integration.

> The SET project has carried out an expert Delphi survey and facilitated workshops focusing on the driving and enabling technologies of the energy transition. The technologies have been studied both in terms of global technology trajectories and the local adoption and integration of these technologies into the Finnish systems of energy production, distribution and use. Given that the SET project views integration a key phenomenon, the survey and the workshops produced an outlook of the joint implications of energy transition on four spatial scales: the scale of individual buildings, the scale of blocks and neighborhoods, the scale of city regions, and the national scale. Each of the four scales has been studied in terms of how technologies potentially materialize and what actions and which actors may support or inhibit these changes.

4.2 For whom are these energy technologies disruptive and in which ways?

The energy sector (energy suppliers, retailers and distribution system operators (DSOs)) is influenced by a decline in certain demand categories (heat and power in buildings), by distributed on-site solar power production (reducing external energy demand in buildings), and by intermittent energy production (creating fluctuations in energy prices and demand response business opportunities) and by the entry of new companies (small scale producers, ICT providers, demand response aggregators) into the energy market. In Finland, especially district heat providers are likely to be influenced in the short term, because of high fixed costs and declining demand. DSOs are already under pressure to change tariff structures given lower energy demand but sometimes higher capacity needs (Partanen et al. 2012). In the medium term, there is a widely perceived need to change the entire market and regulatory structure given the lack of incentives to invest in peak load capacity. On the other hand, climate targets and the declining cost of renewables are reducing the feasibility of large-scale coal-based CHP.

The ICT sector (hardware and software) experiences new opportunities in energy management, i.e., smart grids and related services (increased information flows on the status of energy supply and demand at any given time). Developments in the Internet-of-Things (IoT) can lead to smart appliances (including LEDs) that monitor the status of the electricity grid and manage power consumption accordingly. If the ICT and energy industries merge successfully, energy management might perhaps become the core of the energy system instead of energy supply?

On the other hand, ICT is also increasingly critical in the construction and real estate sector. Automation and control technologies, measurement technologies, data mining and data analytics, anomaly detection, integration of different energy sources and system optimization are increasingly important. Moreover, self-learning systems are emerging on building and system automation levels. These developments are already driven by regulatory requirements for nearly-zero-energy buildings. The need for automation is driven by increasing energy production in buildings and the need to maximize self-consumption (especially in Finland, with no feed-in-tariff). In the medium term, the need (and emerging market) for more flexibility in power consumption (demand response) increases demand for automation and control technologies. In the medium term, greater integration of buildings as an active part of the energy networks is also becoming important. In addition, systemic solutions for heat, cool and power storage are needed. This sector is also influenced by new business models created by integrated energy service companies that may have a disruptive influence on both energy and the construction and real estate sectors.

The transport sector has been envisaged as integrating increasingly with the power sector. This can be driven by an increase in the share of electric vehicles (and perhaps also natural gas vehicles). Smart charging and power storage in EV batteries are envisaged as options for responding to fluctuating electricity prices. Mobility-as-a-Service is a new concept which aims at reducing the need for private passenger cars. The service – enabled by mobile digital services – combines public transport and more tailored transport modes in an optimal way for consumers. The business models which require close cooperation between various actors are in their infancy and the direction of the development remains to be seen.

Existing and dedicated storage and conversion facilities: The use of existing storage can reduce the costs of energy storage ensuing from more intermittent production. In the short term, surplus power can be stored as heat in residential boilers and in district heating networks or via smart charging of electric vehicles. As the share of intermittent power sources grows, there is also increasing demand for converting power to gas (methane), power to chemicals (e.g., nitrogen) and in the future, also perhaps, power-to-food. Potential locations for such facilities can be in connection with existing facilities, e.g. biogas plants or LNG terminals.

Locally, particular technologies can be disruptive even if they might not be equally relevant globally. For example, energy from pulp and paper by-products can be important in major pulp producing countries but not elsewhere. Similarly, farm-scale renewable energy can be disruptive for small local electricity companies that mainly serve farms.

The ways in which the technologies are disruptive and the sectors that are influenced depend also on how energy policy and markets respond to them. For example, Verbong and Geels (2010) identified three alternative pathways for the electricity system, each of which represents a response to the challenge of decarbonizing the electricity system, but which imply different hierarchies in policy goals and strategies. Some scenarios maintain the status quo of incumbent actors, others would extend the scale of operation to a European supergrid, while yet others would decentralize the energy system and prioritize local actors. Verbong and Geels (2010) have shown that smart grid scenarios and pathways have significant implications for which actors gain power and profits in the new system configurations.

4.3 Geographical scope and timeframe for our analysis

The disruptive technologies described above are being adopted at different rates in different countries. Since the SET project is interested in impacts in both the domestic and export markets, we are not analyzing the situation only in Finland, where intermittent energy sources do not yet have a significant market share. Moreover, considering the common Nordic electricity market, as well as the advancing integration of the European electricity, gas and other energy markets, our analysis needs to define a set of geographical boundaries. In our analysis, we pay attention to developments in the following markets:

1. impacts on the domestic energy system
2. impacts on the energy systems in countries which are linked to the Finnish energy system (e.g. Nordic countries, Baltic Sea region)
3. impacts on the energy system in current and potential future major export markets
4. impacts of changes in these areas (1-3) on Finnish industries (domestic and export)

We have not yet decided exactly which markets will be analysed. In the SET project, institutional analysis linked to energy market and technology disruption focuses on Denmark, Germany, and the UK (WP3), whereas analyses of innovation systems (WP5) targets a broader market including e.g. the USA and the Republic of Korea. We also take into consideration existing cleantech export markets (Table 2).

Table 2: Major export markets for promising Finnish bioeconomy, cleantech and digitalization applications (FinPro growth programmes 2016).

Growth programme	Products and services	Main markets
Waste to energy and bioenergy	“entire value chain”	Asia, Africa, Latin America
Wood from Finland	sawn timber	China, potentially other markets
Cleantech Finland	bioenergy & biofuels, CHP&DHC, construction technology, energy production & distribution, marine & shipping, mining, recycling, solar energy, waste management, waste-to-energy, water technology, wind energy	Europe, Russia, India, China, Brazil
Mobility as a Service (MaaS)	digital vehicles, smart transport, mobility as a service	Germany, UK, Italy, Spain, USA, South Korea
Industrial Internet	processing of big data, communication between industrial equipment, real-time services and production processes	Germany, UK, Sweden, Denmark

The impacts of the smart energy transition depend on the timeframe of the analysis, as well. In the SET project, we analyse the impacts of disruptive smart energy technologies from three temporal perspectives:

- Short term (2020), i.e., five-year technology outlook
- Medium term (2030/2035), which is the timeframe of climate and energy policies
- Long term (2045), which is a timeframe capable of capturing pathways toward a new system configuration

5 Direct impacts on the Finnish energy market

The SET project is more interested in the indirect impacts of the smart energy transition. These, however, are partly mediated via direct and immediate impacts on the energy market and the business models of energy companies. These are within our scope, but not our only focus. Understanding them is also important for understanding impacts on other companies, the wider economy and society (see section 6).

5.1 Implications for the energy market

The smart energy transition requires adaptive energy markets. The technologies that enable smart energy transition are expected to cause at least partial integration of the power, heat and fuel markets. In particular, power-to-X, electricity storage and electric cars enable market integration. Energy market integration can have multiple benefits, such as increasing elasticity of demand, energy security and carbon neutral production possibilities across the whole energy sector. The market integration can also cause unexpected impacts on the energy markets. For example, the energy prices, quantities and market principles may change due to the technology transition. The following issues are likely to become relevant in the short to medium term:

- Market integration: The technologies that enable smart energy transition are expected to cause at least partial integration of the power, heat and fuel markets. This integration has impacts on the energy policies, markets and prices.
- Electricity market stability: The increasing share of fluctuating renewable energy sources is making the Nordpool power market more volatile. However, the smart energy transition will allow for the power to be produced and consumed at different times. This, in turn, balances the volatility of the markets.
- Market and policy models: As the share of zero marginal cost electricity production increases in the electricity markets, the current electricity market model faces challenges. Also, this imposes challenges for the current energy policies. Therefore, new market and policy models are required.
- Institutional implications: With a greater share of fluctuating renewable energy sources, it is relevant to consider whether access to markets is easier or more difficult for new and small players.

In the short term, impacts on the Finnish energy market are likely to derive from countries where intermittent renewable energy sources have a larger share than in Finland. European developments in renewable energy production lead to increased interest towards the Nordic electricity market, and the large Norwegian water reservoirs are envisaged as an appealing option for reserve capacity especially to the German markets. This would change the functioning of Nordpool profoundly and have major influence on the Finnish electricity sector.

5.2 Business models of energy and energy service companies

We take into account that new business models can be launched both by new market entrants and by large companies (cf. Bergek et al. 2013). Impacts on other companies are discussed in section 6.2.

Traditional energy companies have seen their business become less profitable (centralized production, CHP) as growth in demand has turned into decline. There are increasing pressures to reduce fossil-based production and loads are less stable due to intermittent power production. They are, thus, increasingly searching for new business opportunities in the following areas:

1. Renewable energy production: especially biomass, but also wind and solar in order to avoid losing market share as has happened in Germany, and they seek for new business models (e.g. selling solar from company-owned power plants like Helen or brokering production by small producers like Oulun Energia). The need to turn to renewables also leads to more radical moves: Fortum and ST1 are drilling for geothermal energy in Espoo, and studies for this purpose are underway in Tampere and Helsinki. Heat pumps are increasingly used and some companies are selling them to residential customers. Fuel suppliers like Neste, St1 and Gasum have also moved toward renewables (liquid biofuels and biogas).
2. Electricity retailers are also active in developing electric transport systems e.g. building a network of charging stations and related service concepts (Liikennevirta) and there are pilots underway in electricity storage (Helen's battery storage in Kalasatama).
3. Smart grid –based services are being developed in order to retain customers by helping them to monitor their consumption in more detail.

These developments raise several questions: Will the strategies and business models of vertically integrated energy companies change in terms of the relative importance of production, distribution and sales of electricity and heat? What about business models of other companies, such as specialized energy service companies? Such companies might participate in the integration of the energy sector with the real estate sector.

6 Implications for analysis of impacts on Finnish industry and society

The smart energy transition can have several types of impacts on the Finnish economy and society. For the SET project, the impact on the Finnish economy is one of our research questions, and therefore this section sets out hypotheses, which are used as a basis in our research. In the following, we examine envisaged impacts separately on the entire Finnish economy and businesses, and separately on specific sectors.

6.1 Impacts on the Finnish economy

In terms of macroeconomic impacts, it has been envisaged that an increased use of domestic energy sources would improve the trade balance. In particular, increases in energy efficiency are expected to improve competitiveness. A shift to low-carbon energy sources and energy efficiency is also seen to have the potential to create new jobs both within the domestic sector and in exports. However, the most important impacts are envisaged to occur in export markets, if Finnish companies can benefit from the global and European smart energy transition (Halme et al. 2014). Potential benefits can thus be categorized as benefits to energy users caused by changes in energy source and amount, benefits to energy producers, and benefits technology producers (Figure 1).

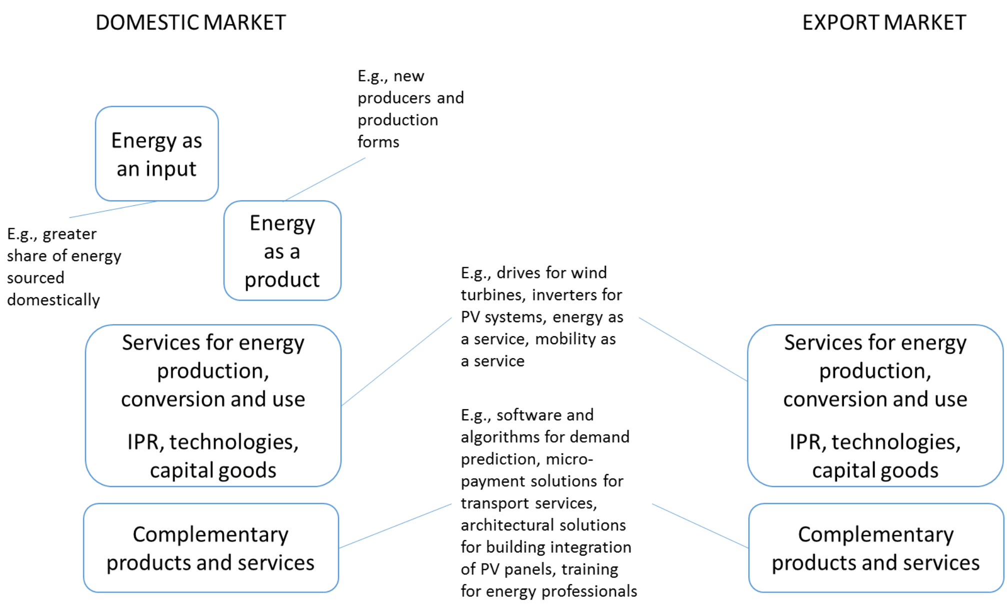

Figure 1. Examples of the types of potential impacts of the energy transition on Finnish businesses investigated by the SET project.

Finland's economy is very energy intensive, and still relies very much on production of raw materials such as steel and pulp. However, the structure of energy consumption in other European countries is quite different and the structural change already happening in Finland is changing the structure towards that in other EU countries (Figure 2). For example, the reduction in printing paper consumption due to digitalization has reduced the electricity consumption of the paper industry remarkably. The opportunities offered to the Finnish business by the decarbonization of energy have recently been summarized by Frost & Sullivan (Sitra, 2015). They identify transportation, energy systems, sustainable buildings, industrial processes, water, and waste management as the core market areas having opportunities for Finland.

From these perspectives, the transport and building sectors have been selected as the central foci of research in Smart Energy Transitions. Moreover, this offers export opportunities, as for example innovations in building automation or transport can be even more important for export industries than they are for the domestic market. However, the domestic market is considered to play an important role for providing demonstration and reference environments for companies with innovative products.

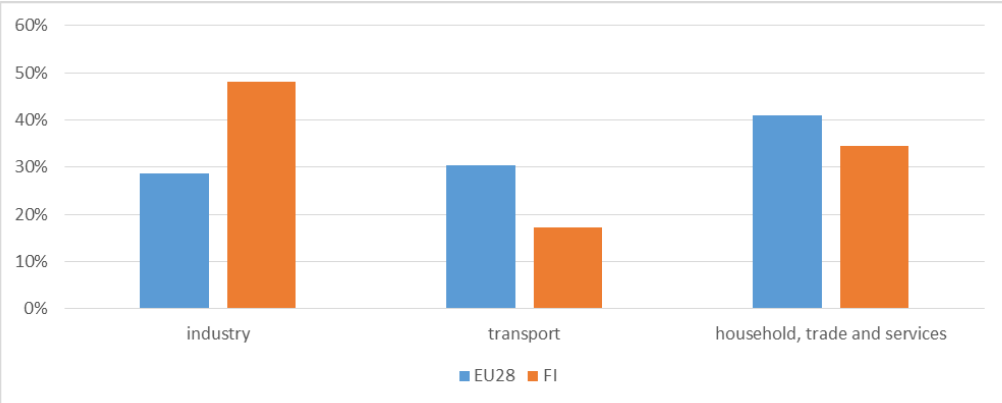

Figure 2. Structure of inland energy consumption, EU28 average and Finland (Source: Eurostat Energy online).

6.2 Impacts on Finnish businesses

New entrants and start-ups are agile and innovative, and therefore often early actors in the development of disruptive innovations (e.g. Hockerts and Wüstenhagen, 2010). Traditionally large incumbent companies have been considered to be too tied to the well-developed existing system and therefore suffer from inertia facing disruptions. However, there is growing evidence that new business models can be launched also by large companies (cf. Bergek et al. 2013). Examples of large incumbents changing in response to disruptions in the energy field include Neste, UPM and St1 moving into renewable fuels, as well as Fortum, Helen and Pöyry building solar energy businesses. The SET project investigates new business models by both old and new, large and small companies.

When considering where Finnish companies might have a competitive advantage and where value might be captured by Finnish companies, it is not only machinery and equipment, but also the related services and system integration that should be considered (see e.g. Shum and Watanabe 2009). We might not mass-produce PV panels but we might integrate solar systems based on imported PV panels, and we might even export such systems. However, it is important to make a careful analysis of value chains, in order to identify where value can be captured by Finnish companies given their size and factor cost structure.

In the SET project, we compile and analyze a database of Finnish companies, which benefit from the energy transition in different ways. The objective is to make a follow-up and analysis of companies and businesses affected by smart energy transition in order to answer e.g. the following questions:

- What industries are likely to grow? Does the disruption reinforce or weaken the situation of current business? For example, Neste Oil and ST1 gained markets when large multinational oil companies decided to exit the Finnish market.
- What opportunities are created where Finnish companies might enter? Where is value created? What are Finland's technological capabilities?
- How does the disruption influence large players: Markets are abroad, production is abroad, why would they stay and create value in Finland? E.g. Fortum is involved in wind and solar power, but outside Finland.
- To what extent do domestic markets and experiments serve as appropriate references for export market?
- We also examine under which conditions companies that are in an old line of business are able to adapt to change (e.g. Oilon)
- What is the impact on the spearheads of growth of Finnish economy: bioeconomy, cleantech and digitalization (see section 6.3.)

6.3 Impacts on specific sectors, especially bioeconomy, cleantech and digitalization

The Finnish government has defined bioeconomy, cleantech and digitalization as the new spearheads of growth. All these areas are broad and the definitions tend to vary. One of our hypotheses is that smart energy transitions have a connection to these spearheads and thus they present one pathway through which the transition might influence the success of the Finnish economy (Figure 3).

***Bioeconomy** refers to an economy that relies on renewable natural resources to produce food, energy, products and services. The bioeconomy strives to reduce our dependence on fossil natural resources, to prevent biodiversity loss and to create new economic growth and jobs in line with the principles of sustainable development.* (Finnish Bioeconomy Strategy, 2014)

Biomass-based energy is today's dominant form of renewable energy in Finland, but the potential for growth is limited especially on the global scale. Bioenergy can be complementary to other renewable energy sources. If countries to which we are exporting to plan to move to 100% renewables, there will also be demand for bioenergy solutions as reserve power. In these cases, it is likely that demand will focus on forms of bioenergy which are easy to store. Moreover, it is possible that a combination of biogas and power-to-gas as automotive fuels manages to combine the notions of bioeconomy with that of increased electrification of the energy system.

New business opportunities in bioeconomy are expected to be based increasingly on high added value products and services (Finnish Bioeconomy Strategy, 2014), which may affect the energy market in Finland (Figure 3).

In the SET project, we focus on the following aspects of bioeconomy/ impacts of smart energy on the bioeconomy: Biomass-based energy and structural changes in the biomass-utilizing industries will be taken into account in the energy market assessments. They will also be assessed in the analysis of companies and organisations affected by smart energy transition.

***Cleantech** refers to products, services and processes, which promote the sustainable use of natural resources while reducing emissions. Cleantech is not an industrial sector of its own but the markets for the products and services are found in all industrial sectors, especially from technology, energy and construction sectors.* (Ministry of Employment and the Economy, referenced in Kotiranta et al. 2015).

In the case of cleantech, we focus on energy-related cleantech. Issues to consider. Smart energy technologies such as renewable energy technologies and energy efficiency technologies are core technologies in the cleantech area (Figure 3).

In the SET project, we focus on the following impacts of smart energy on the cleantech industries: Emergence of organizational fields of renewable energy technologies such as solar energy. Development of nearly zero energy buildings and districts. Low-carbon mobility, including Mobility as a Service (MaaS).

”*In the **digital economy**, the logic of creating and 'snatching' value has changed over the course of the 2000s. Sectoral boundaries have blurred and the competitive situations of companies have shifted. Products and services have become more closely intertwined than ever before. The combinations of services and products in the digital economy are practically endless, as are the numbers of companies producing these services and products. Thus, competition between business ecosystems consisting of several companies has become more and more prevalent.*” (TEM 2013.)

Digitalization is a major enabler of smart energy disruption through better management of production and efficient use of energy. It offers numerous business opportunities for both new and incumbent companies (Figure 3). Digitalization is a generic development, which is also applied in all aspects of energy production, distribution and use. In particular, the increasing detail of monitoring and control technologies influences all types of energy usages. Our particular focus could relate to technologies supporting energy efficiency and demand response. A particular strength of Finland is the widespread existence of ICT capabilities, many of which are now freed by the decline of Nokia and can move into the energy industry.

In the SET project, we focus on the following aspects of digitalization/impacts of smart energy on digital products and services:

Mobility as a Service (MaaS): development of the field and business models that can potentially reduce energy demand via digitalization

Nearly zero-energy buildings and areas – managing intermittency.

Demand response and smart automation

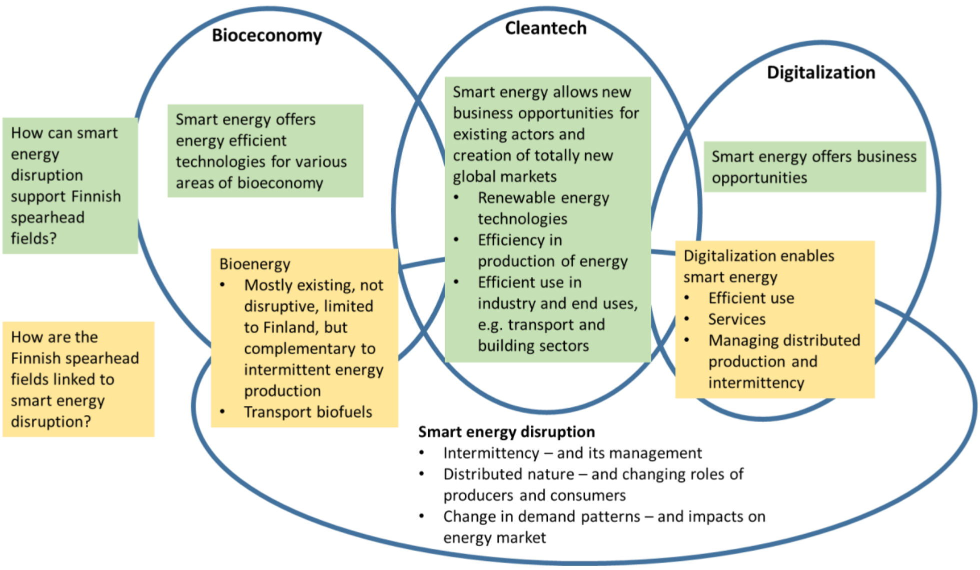

Figure 3. Main linkages of smart energy disruption to the three spearheads of the growth of Finnish economy. Research scope and delimitations of the Smart Energy Transition project.

Previous research has examined the impact of renewable energy on the energy market and energy companies in several countries (UK, Germany etc.). In this respect, SET makes an empirical contribution by examining the particular case of Finland, taking into account the interlinkages of its energy system to the Nordic and North European energy market.

There is also some research on ongoing and likely shifts in industry boundaries. But there is less research on the impact of the energy transition on other industries. SET makes a novel contribution here.

Some of the explicit delimitations of the project are summarized in table 3.

Table 3. Delimitations made in the SET project.

Technologies	**Included**	**Excluded**
Impacts on the energy market • **deriving from Finland** • **deriving from abroad**	Growing share of distributed and intermittent energy production -> impacts on energy companies' and other (new) energy producers'/ service companies' business models Impact on energy market and ongoing efforts for market reform (in collaboration with the ELTRAN project) (EL-TRAN 2016) Integration of energy and innovation policy	System modelling
Impacts on industries • **deriving from Finland** • **deriving from abroad** • **influencing export markets**	Housing, commercial and public real estate and construction Transport New products and services by other industries	Energy as an input for large process industries (pulp and paper, steel, chemicals)

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