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POLICY PATHWAYS TOWARDS ENERGY PROSUMER INNOVATION ECOSYSTEM – CROSS-COUNTRY COMPARISON FROM EUROPE

Master of Science Thesis

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ABSTRACT

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Energy field is in transition caused by political interventions and decreasing costs of renewable energy and ICT technologies. A new innovation ecosystem is being created around energy prosumers, new active market players, who produce part of their energy themselves. Electric vehicles, in-home batteries and ICT-driven business models like aggregation add possibilities to participate in the market. The transition from centralised energy system to a distributed one creates opportunities but also challenges for policy makers. Policy interventions are used for different purposes, like environmental targets but also developing economic competitiveness of the country. Policy instruments form policy mixes that steer the innovation ecosystem to a certain direction. The EU regulation creates a framework where countries are specialising in different technologies.

To structure the prosumer-related policy mix and see how they are deployed in practice, research questions of this thesis are: *What policies contribute to energy prosumer ecosystem creation from prosumer's point of view? How European countries differ in adopting these policies?*

For answering the research question, a cross-country policy comparison was conducted. Data was gathered from secondary data sources. Countries researched were Finland, France, Germany, Switzerland and Italy. Policies that were included in scope were chosen according to an initial review of relevant papers and evaluation of their comparability. The policies were structured from prosumer's point of view by using Rogers' Innovation Adoption Model. It was based on adoption process of new solar PV system and adding electric vehicle, demand response or battery to the system.

The results of the cross-country comparison show that the case countries have different policy mixes related to energy prosuming. Germany supports microgeneration and batteries but lags behind in smart metering. Italy has a developed market for other areas except aggregation and demand response. Finland has developed good market conditions but does not incentivise any prosumer technologies. France has centralised energy market and lacks smart meters but has established regulation for demand response and incentives for microgeneration and electric vehicles. Switzerland has a dispersed policy landscape as cantons' role is emphasised. It is a frontrunner in microgeneration and demand response but lags behind in smart metering. From the results, it can be seen that policy mixes could be further developed in each country to attain the potential prosumer innovation ecosystems have.

TIIVISTELMÄ

JUSSI VALTA: Poliittiset toimenpiteet energian tuottajakuluttajien innovaatioekosysteemien tukemiseen – maavertailu Euroopasta
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Energia-ala on suuressa murroksessa johtuen eri teknologioiden hintojen laskusta ja poliittisista tukitoimista. Pientuottamisen, älymittareiden, kysyntäjouston, sähkön varastoinnin ja sähköautojen kautta on syntymässä uudenlainen innovaatioekosysteemi, joka mahdollistaa kuluttajien osallistumisen sähkömarkkinoille uudella tavalla. Siirtyminen hajautettuun energiajärjestelmään johtaa lainsäädännön ja politiikan haasteisiin. Poliittisilla toimenpiteillä on monia eri päämääriä, kuten ympäristön suojelu ja taloudellinen kasvu ja kilpailukyky uusilla markkinoilla. Kansantalouden kannalta voi olla viisasta panostaa kilpailukykyyn strategisilla osa-alueilla, joskin Euroopan unionin säädökset tulee huomioida eri teknologioiden tukemisessa.

Tämä työ jäsentelee tuottajakuluttajiin liittyviä poliittisia toimenpiteitä ja vastaa seuraaviin tutkimuskysymyksiin: *Mitkä poliittiset toimenpiteet vaikuttavat tuottajakuluttajiin keskittyviin innovaatioekosysteemeihin? Miten eri Euroopan maissa näitä on toteutettu?*

Työn tutkimusmenetelmänä käytettiin politiikkavertailua, joka suoritettiin sekundääristen tietolähteiden avulla. Maat, joiden politiikkayhdistelmiä tarkasteltiin, olivat Suomi, Ranska, Saksa Sveitsi ja Italia. Tarkasteltavat politiikkasäädökset rajattiin tutkimalla, mitä ajankohtaisia kysymyksiä tuottajakuluttajiin liittyy tällä hetkellä. Lisäksi niiden vertailtavuutta arvioitiin. Säädökset jäsenneltiin tuottajakuluttajan näkökulmasta käyttäen pohjana Rogersin innovaatioiden adoptointiprosessia. Mallissa kuluttaja ottaa käyttöön aurinkopaneelijärjestelmän ja liittää siihen kysyntäjouston, sähköauton tai/ja akun.

Työn tulokset osoittavat, miten erilaisia politiikkayhdistelmiä maat ovat implementoineet. Saksa tukee sähkön varastointia, sähköautoja ja pientuottamista, mutta se ei ole tuonut älymittareita tai kysyntäjoustoa kuluttajamarkkinoille. Italia on edelläkävijä muissa teknologioissa ja ratkaisuissa, mutta sen kysyntäjoustomarkkinoita ollaan vasta luomassa. Suomi on edelläkävijä kysyntäjoustossa ja älymittaroinnissa mutta pysyttäytynyt markkinaehtoisissa ratkaisuissa teknologioiden edistämisessä. Ranskalla on hyvin säädellyt kysyntäjoustomarkkinat ja se tukee pientuottamista. Siltä kuitenkin puuttuu vielä älymittarijärjestelmät ja alhaisen sähkönhinnan vuoksi varastointi on kannattamatonta. Sveitsin kantonijärjestelmä vaikeuttaa kokonaiskuvan luomista, mutta kysyntäjousto ja pientuotanto ovat hyvin säädeltyjä ja tuettuja. Älymittareita Sveitsi ei ole vielä ottanut käyttöön. Tuloksista voidaan päätellä, että poliittisilla toimenpiteillä painotetaan eri teknologioita eri maissa. Ekosysteemin kehittämisen kannalta olisi järkevää, että maat täydentäisivät niiden politiikkayhdistelmiä puuttuvien teknologioiden ja sovellusten kohdilla.

PREFACE

Writing this thesis has been an interesting journey. Sometimes it felt like jumping on a moving train because especially electric vehicles develop so rapidly right now. Experiencing this phase of these technologies in Brussels was special due to the discussions on the Clean Energy Package of the European Commission. It was released only a couple months before this work was started.

I would like to thank professor Saku Mäkinen and Kirsi Kotilainen for steering me in the process of making this thesis. I would also like to thank Joona Turtiainen and others from Nordic Energy Office in Brussels for advices on the topic. In addition, I would like to thank my friends in communities FC Juhuu and '9 ½' for continuous support even from distance. Finally, I would like to thank Sanni for supporting, listening and motivating me during the long journey.

In Brussels, 10.11.2017

Jussi Valta

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ABBREVIATIONS

ACER	Agency for the Cooperation of Energy Regulators
AMI	Advanced Meter Infrastructure
AMM	Automated Meter Management
AMR	Automated Meter Reading
CEER	Council of European Energy Regulators
CPP	Critical Peak Pricing
DER	Distributed Energy Resources
DR	Demand response
DSO	Distribution System Operator
EC	European Commission
ESCO	Energy Service Company
ETS	Emission Trading System
EU	European Union
EV	Electric Vehicle
FIP	Feed-in premium
FIT	Feed-in tariff
HEMS	Home Energy Management System
ICT	Information and Communication Technologies
IS	Innovation System
LCOE	Levelized Cost of Electricity
NRA	National Regulatory Authority
nZEB	nearly Zero Energy Building
PPA	Power Purchase Agreement
PV	Photovoltaic
R&D	Research and Development
RE	Renewable Energy
RED	Renewable Energy Directive
RES	Renewable Energy Sources
SC	Self-consumption
TM	Transition Management
ToU	Time-of-Use
TPO	Third Party Ownership
TSO	Transmission System Operator
VAT	Value Added Tax
V2G	Vehicle to Grid
VPP	Virtual Power Plant

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1. INTRODUCTION

1.1 Background

Energy field is experiencing a big transformation as countries are determined to answer to the challenge of global warming. The EU (European Union) has a long-term goal of decreasing its total carbon emissions by 80% by 2050 in comparison to 1990 level (European Union, 2012). It has made commitments that in 2030 it will increase the share of renewable energy sources (RES) in its final consumption up to 27% in total. For electricity sector, this means shares of approximately 50%. The energy sector has traditionally been included in "network industries" with telecommunication, water and transport (Daly, 2016). These all have been characterised by natural monopolies that have been diluting with more liberalised, yet often regulated, competition. Adding distributed energy resources (DER) in the energy system revolutionises the old top-down structure of the field and brings different kind of player: "prosumers", into the value chain (Schleicher-Tappeser, 2012).

Prosumers were introduced by Alvin Toffler (1981) as customers' response to industrialised mass markets. Due to increasing resources and needs, customers started to want customised and differentiated products. During recent years, prosumption has become again into scope of research due to new technologies like 3D printing and sharing content on web (Ellsworth-Krebs & Reid, 2016). In the context of energy, prosuming refers to customers who are active in the market by producing, storing and selling energy. By adding an in-home battery, they can increase their autonomy from the grid but also act as a flexibility resource by providing grid services. Being active in the market means also co-creation by which prosumers become important part of the ecosystem development.

Prosumer technologies like solar photovoltaic (PV) and electric vehicles (EVs) have been developed in politically protected niches until recently. Now they are getting cost competitive and entering to the main stream. They can be seen as disruptive innovations in relation to the old business models of the energy sector. Utilities are more and more becoming big data specialists to enable flexibility and integration of DERs in the grid (Markard & Erlinghagen, 2012). A whole ecosystem is being built around these technologies and different companies attain different strategic positions. Aggregators are needed in handling DERs cost efficiently, solar PV suppliers and installers manage the uptake of microproduction, and EV manufacturers try to attain value through battery diffusion. Complementing technologies like smart thermostats, boilers, applications, remote controls and displays offer opportunities for niche players. Business model innovations come through new partnerships and acquisitions like in the case of Tesla and SolarCity (Frankel et al, 2014).

The context of the thesis is shown in figure 1. Because energy prosumer policies bring vast energy field into residential sector, this thesis takes macro, meso and micro level into consideration.

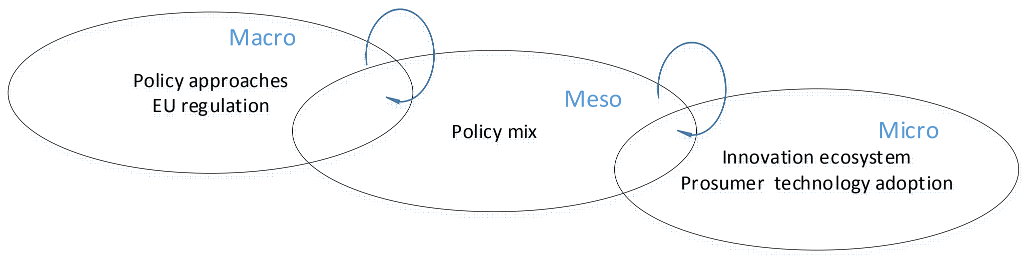

Figure 1. *Context of the thesis (modified from Kotilainen et al., 2016).*

The EU regulation affects countries' policies according to climate targets, economic situation and other wide socio-technical trends. Political agenda pushes now energy transition, which means a shift away from fossil fuel usage. Usual framing of energy policies is the 'energy trilemma', meaning that governments have to choose between energy security, low costs and sustainability. This thesis highlights innovation creation, and therefore following policy approaches are handled: industrial policy, environmental policy, innovation policy and transition policy. These approaches have different objectives and they frame the policy instruments differently. Chosen policy approaches deal with the transition in different ways. Transition policies thrive this disruptive socio-technical change whereas industrial policies enforce the current regime's position and thrive for incremental change (Alkemade et al. 2011). Innovation policy aim to create new competences and networks and environmental policies aim at environmental protection.

Countries have introduced different kinds of incentives for energy prosumers. Policies depend on policy strategies that countries adopt. Sustainable technologies have potential of integrating these objectives in policy mixes (Rogge & Rechardt, 2013, p. 19). These happen in the meso level, which determines the practices and rules regarding the prosumer ecosystem. The lowest level of the system include the prosumers and how they react to the policy mixes. In this thesis, the policies are framed as prosumer journey where different policies affect different steps of technology adoption.

1.2 Research questions

This thesis handles residential prosumers since they are set in the focus of EU's Energy Union and reflect well the challenges the energy transition brings along (European Commission, 2017b, pp. 4-6). For example, prosumers have consumer's status and need different kind of informing and other policies than cooperatives and commercial prosumers who may have professionals taking responsibility. The first objective of this thesis is to structure policy interventions that affect the development of the energy prosumer ecosystem into a relevant and comprehensive form. The first research questions of this thesis is:

RQ1: What policies contribute to energy prosumer ecosystem creation from prosumer's point of view?

The second objective is to explore, what kind of decisions has been made regarding the studied public policies. The EU harmonises the regulation and in principle companies act in one single market. However, in the energy field, the single market is still developing. Countries may emphasise adoption of different technologies because of different environmental reasons and political objectives. This thesis combines also the strategic innovation management aspect into the picture. If the policy targets' motivations are unclear, there is a danger of creating needless incentives that could be covered by different, less costly, policies. On the other hand, if people's opinions are not taken into consideration and the technology diffuses quicker than the regulation, there will be a problem of 'regulatory disconnection' that has appeared strongly in cases of AirBnb and Uber, for example (Butenko, 2016). The second research question is:

RQ2: How European countries differ in adopting these policies?

These questions are answered by studying policies in Germany, France, Switzerland, Italy and Finland. This is conducted with a cross-country policy comparison. As the influence of the EU is important in the energy field, the results also show the approaches the EU has on the different policies. To emphasise the consumer approach, this thesis uses Rogers' (2003) Innovation Adoption Model to structure the regulations and incentives that affect the prosumer. In addition, earlier literature of related to energy prosumers has concentrated in separate technologies and their regulations. This thesis concentrates in the most common prosumer technology solar PV, but adds enabling technologies like EVs, storage and DR into the scope. These technologies are interconnected and form the ecosystem of distributed energy resources (DER).

1.3 Structure

The thesis is organised as follows: Second chapter will describe issues in governing innovations and innovation ecosystems. It introduces the approaches on which prosumer policy mixes are being built. The methodology chapter describes the policy scoping process and data collection methods. Fourth chapter includes the results and discussion. Discussion is added to the results because in that way is easier to demonstrate the dynamics between different policy options. The conclusions chapter will wrap up the results, discuss the methodology and look forward to next challenges for research.

2. INNOVATION AND REGULATION

2.1 Factors of innovation diffusion

2.1.1 Incremental and disruptive innovations

"Innovations are processes where new or value adding products, processes, materials and services are established and repositioned to the places they are suitable" (Rubenstein, 1989). Traditionally innovation theories emphasis technological innovations and are categorised to incremental and disruptive innovations (Markides, 2006). However, business model innovations play increasingly important role in companies' innovation activities and often beat pure technological innovations (Chesbrough, 2007, p. 12). Disruptive innovation can create remarkable competitive advantage to companies. Companies can either choose the strategy of first-mover or second-mover. Being first-mover may help to occupy the whole market and bring a monopolistic position by controlling resources. Being frontrunner means also high costs and risks because it has to develop the new business model from scratch. Being a second-mover can bring some free-rider benefits by imitation, learning on the market and saving from research and development (R&D).(Schilling & Esmundo, 2009)

Technological innovations

The roots of incremental vs. radical innovation typology are in technological innovations (Dijk et al., 2015). Incremental innovations usually keep the same market and marketing approach. They are based on the existing knowledge, technology or products of the company (Schoenmakers & Duysters, 2010). Often they are low level of risk and developed by small-scale experiments and problem solving inside the organisation (Bessant et al. 2014, p. 1284). They focus on improving products that mainstream consumers value (Dijk et al. 2015). Better fuel efficiency of engines is a good example of incremental technology innovation (Berninger et al., 2017). In some industries, this is highlighted whereas other industries have much faster innovation cycles. For example, the new generation of smart phones comes much faster to the market compared to energy production or new cars (Canzler et al. 2017, p. 31).

Technological innovations are disruptive to the competitors when they propose new products and value propositions that do not fit in the producers competences and consumers' current behaviours (Markides, 2006, p. 22). There are many examples of incumbent companies having troubles managing disruptive innovations (Magnusson et al., 2003, p. 4). Their aim is usually to achieve the dominant design that is approved by the whole industry and only incrementally improved. The mainstream consumers regard disruptive innovations worse in key functions but some consumers value some new features (Dijk et al.

2015, p. 278). Abernathy and Clark (1985) divide the technology linkage of innovations by disrupting or conserving competences.

Another way that highlights the technological side of innovations is examining the change on component level linkages and the components themselves. Disruptive innovations change also the role and choice of components that are used. For example, energy storage may change the way grids are needed in the energy system. Incremental innovation typically keeps the same linkages between components but enhance their performance. In addition to these innovation types, Magnusson et al. (2003) introduces architectural and modular innovations. Architectural innovations keep the same type of components but change their interfaces and the way they are used. In modular innovations, new components are introduced but the linages between them remain the same.

Business model innovations

Companies have to develop business model innovations aside product innovations. If the competitor has same product but better business model, they will capture the profits from the market (Chesbrough, 2010). Business model innovators do not necessarily create new products or services but instead change the way they are delivered to the customer and this change can be disruptive or incremental. Garcia and Calantone (2002) divide business model innovation into three categories: newness to the firm, newness to the industry and newness to the customer. Business models have many different definitions depending on what the author is highlighting and what is his or her background. In a much used work, Timmers (1998) highlights information flows, Chesbrough (2007) value creation and capture. Aside product-oriented innovations, Tukker (2004) classifies business model innovations into use oriented and result-oriented models.

Breakthrough innovations, like integration of internet in cell phones to transportation sector, can change business models disruptively. In general, they change the value network and bring along business models that come outside company's usual business paradigm (Biber et al. 2017, p. 12). Sharing economy has many implications from disruptive innovations. Uber, AirBnB and other companies that have changed the business models in very traditional sectors, are good examples of business model innovations that pose challenges to regulation. Biber et al. (2017) claim that regime-shifting innovations involve combination of new business models that leverage a breakthrough technology.

Incremental business model innovations develop the existing model but do not create discontinuities. Bucherer et al., (2012) take the case of new vehicle insurances as an example. In their approach, new business models can be disruptive either for the industry or for customers. For example, Better places, a Danish EV car sharing company tried to change both of them.

2.1.2 Innovation adoption

MacVaugh and Schiavone (2010) divide the adoption of innovation into three domains. On micro-level, the adoption depends on learning conditions. On meso-level, the adoption depends on social conditions and macro-level depends on technological conditions. The micro-level refers to personal adoption of a technology. Each domain has to be thought and evaluated, since they perceive the innovation adoption differently. Individuals evaluate the benefits and costs of change through their relationships and other community members. Norms, values and hierarchies are shared within other people and affect the desirability of different technologies. On macro level, there is an advantage for first movers to gain the dominant design. Microsoft Office software is one example of such development. On a broader scale, this can mean technological lock-ins that makes it harder not using a certain technology because of important complementary products are based on one technology. Within this kind of development there are whole industry clusters grown which are embedded in the social structures. (MacVaugh & Schiavone, 2010)

For personal adoption, which is the approach of this thesis, the most common framework of innovation adoption is Rogers's (2003) innovation adoption model. According to, the innovation decision is a process which stages are knowledge, persuasion, decision, implementation and confirmation (see figure 3). Customer chooses after every stage, whether he/she will continue to the next step. The process is essentially an information-seeking and processing activity. Each step aims to reduce uncertainty and communicate the advantages of the innovation by the right communication channels. Generally, mass media is better in giving the initial awareness and spreading information of the innovation whereas peer-to-peer communication is more effective in shaping attitudes towards the innovation.

Home energy systems are strategic purchases that take big proportion of household budget, long-term commitment and high involvement in the process. Common factor of such durables is that buying decision is complex especially if the price is perceived high. Difference to frequently purchased items is that there is less possibility to try the product beforehand and learn from errors. Compared to a car or a house, energy systems and their use can also be less familiar for the customers. (Koklic & Vida, 2001)

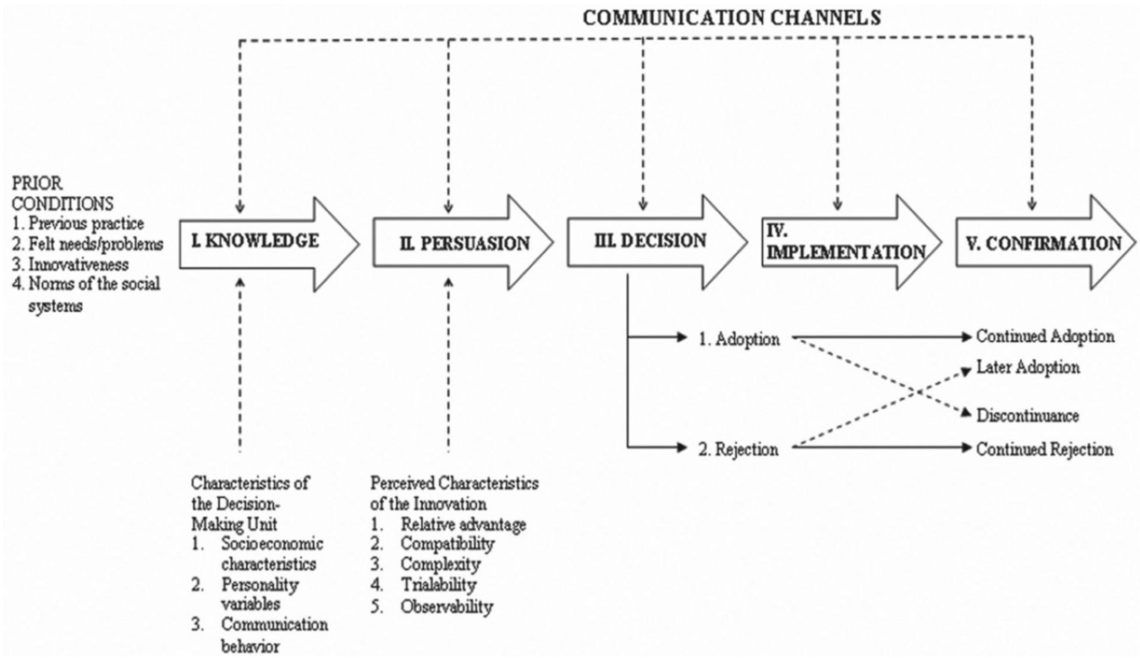

Figure 2. *Innovation adoption process (Rogers, 2003).*

Innovation adoption process begins when customer realises the existence of the innovation, understands how it functions and how to use it efficiently. Gaining information is usually framed by personality variables and socio-economic characteristics. Usually people are selective to information and pick to ones that suit their opinions and interests. Some researches see that individuals seek actively for information whereas some say that individuals come aware of innovations more through coincidence. There might be a need for the innovation before the awareness of the innovation is created or the innovation suits a problem that is not conceptualised yet. Some customer segments are more probable to adopt technologies and therefore act as important target groups for marketers and policy makers. (Rogers, 2003)

Persuasion is a stage where customer evaluates the innovation and its attributes and forms an attitude towards it. At this phase, the individual starts actively seeking and processing information of the idea. Ability to imagine the future use of the innovation is important for the planning of the adoption. For this purpose, he/she seeks more customised information, which the mass media usually cannot provide. According to Rogers (2003), the diffusion determinants at his stage are relative advantage, compatibility, complexity, observability and trialability. Relative advantage depends on the earlier experience customer has on the similar technology and how much he or she has put resources in learning it. Here, the individual perception of the advantages is more important than the objective advantage. Switching costs can be perceived bigger if one has used some time to overcome complexity issues related to the adoption. If the innovation is perceived difficult to understand and use, customer will probably reject it. Compatibility means the closeness of the innovation to customer's earlier experiences, needs and values. Trialability refers to the possibility to experiment the innovation. Observability is the degree of visibility of the value and benefits of the innovation.

Persuasion leads to decision of adopting or rejecting the innovation. Adoption can happen also partially, because people often want to try the innovation before the final decision. A possibility for small trial decreases perceived uncertainty and accelerates innovation diffusion. Sometimes it is enough if a peer has tried the innovation. In these cases it is also important whether the lead user or demonstrator is a so-called opinion-leader (von Hippel, 2005). (Rogers, 2003) Even though the perception of the innovation might be positive, he/she may still reject the innovation. This situation has been studied in the KAP-gap (knowledge-attitude-practice) literature. This literature is often related to Ajzen's (1985) Theory of Planned Behaviour that attempts to explain the links between values, beliefs, attitudes intentions and behaviour.

In implementation phase, the customer does the purchase and continues to evaluate the usefulness of the innovation. Implementation leads to routinisation where new idea becomes part of his/her habits and everyday life. Customer might still be uncertain about the innovation. Therefore, he/she gathers more information on the usage and operational problems it has. Innovation might also be used in a different manner than was originally intended by the inventor. This re-invention come from user's modifications and changes to the innovation. According to Rogers (2003), invention is a good word for describing this change because it changes the inventor's idea of the innovation. Re-inventing happens especially when innovation has many applications, it is implemented to solve a wide range of problems or there is strong local pride of ownership. However, manufacturers often create products which are not easy to modify or even repair (von Hippel, 2005).

In confirmation phase, the decision is already made but he/she is still looking for more information on the innovation. This information either reinforces or creates need to reverse the adoption decision. A discontinuance of use can be divided in two categories: 1. Replacement and 2. Disenchantment. Replacement happens usually in sectors where innovation cycles are fast and the new innovation just replaced the older innovation. Disenchantment is decision to reject an idea because of dissatisfaction or poor performance. In addition, wrong usage can push to rejection, which has been observed especially in late adopter segments. Shih & Venkatesh (2004) extend the model to the usage phase of the innovation by looking at frequency and ways of usage.

Adopter Segments

Customer segments are a common theme in marketing studies. This research area studies consumer characteristics, demographics and how they change in time and experience (MacVaugh & Schiavone, 2010, p. 199). The segments are showed in figure 3. The first adopter segment, innovators, are characterised as technology-oriented risk-takers. They have more resources and are closer to scientific groups developing the technologies than other segments. The next group, early adopters, have the most influence in the opinions of later adopter categories (Rogers, 2003). They are more careful in their choices than innovators and usually they are well educated and informed. They are a very important part of the technology learning and shaping because they create new knowledge and conventions regarding the technology. As they are interested in the technology itself, they can also become co-producers of it. They share experiences and solutions through peer-observation, where people tend to have different needs and resources. That diversity makes innovating efficient because probability of reaching the needed knowledge is big (von Hippel, 2005).

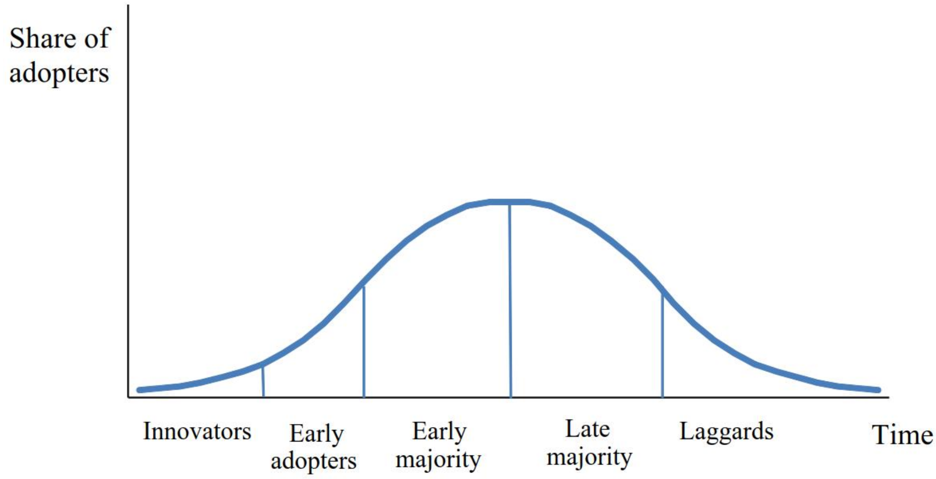

Figure 3. *Adopter segments (Rogers, 2003).*

Early majority are the first to adopt technologies in a more mass-market oriented manner but they do not have same opinion leadership as early adopters. Moore (2002) calls the difference between early adopters and early majority 'the chasm' as it separates the visionaries and pragmatists who have different expectations on the technology. Pragmatists value ready products and turnkey solutions. Usually the diffusion of a technology accelerates after a certain stage when it has sufficient market scope. The diffusion spreads progressively upon one market from early adopters to majority and laggards. Late majority are relatively conservative who form the average participants. They might have less financial resources and lower social status. Last group are the laggards who are sceptical on new technologies and have an aversion to change. (Rogers, 2003)

2.1.3 Prosumers

Prosumers are "people who produce many of their own goods and services" and according to Toffler (1981) there are many reasons to this. People have more time besides work, and they are more educated. Workforce is expensive and do-it-yourself practices are seen as self-actualisation, which brings satisfaction and better products. According to Kotler (1986), there are two types of prosumers: "The Avid Hobbyist" and "The Archprosumer". The first ones mainly produce to exchange but makes some products also for own use.

The latter refers to people who prefer to make almost everything by themselves thus avoiding the mass consumption society.

Prosuming changes the usual value chains as customers' role is expanded to create part of the value creation. The idea behind prosuming is self-service. In prosuming context it does not mean less service but facilitating participation and fulfilling individual needs (Bremdal, 2013; Kotler, 1986). Prosumers see that they get more value from networking than acting within one value chain. Typical examples of value networks come from web domain and programming. Users are able to add their own work in shared platforms, like Wikipedia, Linux-based software, 3D-printing applications, Lonely Planet and Trip Advisor (Daly, 2016; IEA, 2014).

In the energy field, the definition of the prosumer is typically relatively simple, like: "consumer of energy who also produces energy to provide for their needs, and who in the instance of their production exceeding their requirements, will sell, store or trade the surplus energy" (Ford et al., 2016). Parag and Sovacool (2016) adds also the use of smart appliances, communication technologies, EVs and battery storage capacities for flexibility services in the definition. Difference to current demand response (DR) markets, for example, is remarkable as prosumers step from being reactive to price signals to being active service providers to the grid. Prosumers' influence in the market has to be highlighted as they affect and provide value not only to themselves but also to others: neighbours, network operators and the society.

Energy prosumers are seen differently by emphasising differently the technicality and human aspect of their involvement to the energy market (Olkkonen et al. 2016). The more technical approach in literature links prosumers to intelligent systems such as EVs and smart houses. When smart houses are linked to demand side response that supports the electricity system, difference between energy production and home automation dilutes. Furthermore, when prosumers are bundled together by an aggregator, they can act as virtual power plants, which can be valuable resources to the electricity system.

The more behaviouristic approach of literature includes studies in energy communities and behaviour. It highlights the legal framework in which prosumers act. Prosumers can be seen as "active customers" highlighting consumer rights that they need from being separated from utility-scale energy production (Roberts, 2016). Bleicher and Gross (2015) see prosuming as co-development of RES within inventors and users. Olkkonen et al. (2016) refer to prosumers also as producer-consumer-citizens since they can have a distinctive impact in the community they act.

Some researchers combine these approaches. According to Shandurkova et al. (2012) prosumer is an economically motivated entity that consumes, produces and stores electricity and energy in general; optimises the economic and to some extent the technological, environmental decisions regarding its energy utilisation and becomes actively involved in the value creating effort of an electricity or energy service of some kind. Meanwhile they also change the usage patterns of energy by changing the values that are related to energy consumption (Ellsworth-Krebs & Reid, 2016).

Motivations to invest in own energy production is a vastly researched topic. Balcombe et al. (2013) did a research on microgeneration adoption and categorise the motivation factors as finance, the environment, security of supply, uncertainty and trust, inconvenience and impact on residence. Karakaya et al. (2015) see in their case study that in grid parity situation in southern Germany, environmental reasons and gained independence from electrical suppliers are important motivators. IEA report (2014) on residential prosumers mentions also status and prestige and interest in technology as motivators.

In literature on energy prosumers focuses not only on electricity but also heat and transport (Ellsworth-Krebs & Reid, 2016). This limitation depends on the article's approach. Possible technologies energy prosumers can use are solar PV, micro wind energy, geothermal, small scale CHP (e.g. biogas) or hydropower (Brange et al. 2016; Ellsworth-Krebs & Reid, 2016).

2.1.4 Prosumer activities

Prosumer participation in the market is coming more significant as technologies and regulation open new areas of the energy market for them. The main activities that are now in sight are handled in this chapter and are shown in figure 4.

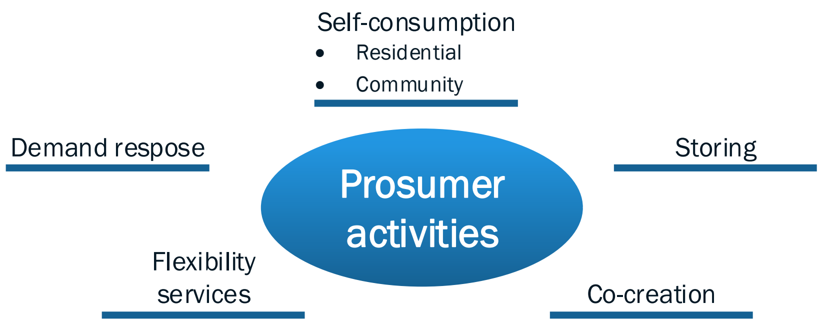

Figure 4. *Energy prosumer activities.*

Self-consumption

Prosumers produce part of their own consumption with different microgeneration technologies. Most common technology is solar PV installed on roofs. Typically, the production levels with solar PV is approximately 30% (Schill et al., 2017). Rest of production is fed into the grid, stored or sold (IEA, 2014). Self-consumption (SC) is relatively new model because until recently all own production was fed into the grid and remunerated with a feed-in tariff (FIT) or net metering. The FIT used to be clearly above the normal wholesale price of electricity and is still is given for tens of thousands investor homeowners. With FIT model, prosumers continue to buy electricity from the utilities like before (IEA, 2014). Self-consumption works in very different dynamic and incentivises to buy smaller installations especially if own consumption is small whereas FITs incentivised to buy as many panels as possible (Schill et al. 2017).

Community self-consumption

If the prosumers are not active themselves, there is also a possibility that they can join a prosumer program running in their neighbourhood (Ford et al. 2016). Community project is a way for people to get together and think how they can develop their energy usage collectively. One example is a project where community is investing together in a wind farm or other bigger plant nearby (Ford et al. 2016). There are also many examples of initiatives where a micro grid is created between households and people use their productions and storages collectively. Community micro grids are nowadays built on campuses, suburbs, harbours or other bigger entities. They are seen from the distribution system operator's (DSO) perspective as one single connection point. Micro grids can have benefits like added resilience, decreased losses and increased efficiency of the delivery systems (Adil & Ko, 2016; Koirala et al. 2016). Technologies that can be used on a community level are mostly the same, but bigger, as at household level.

Demand response

Shifting consumption from darker to sunnier times of the day can mean, for example, washing cloths during the day or adjusting thermostats so that they forecast the weather. This changes usage patterns, knowledge, and values towards flexible and greener models (Ellsworth-Krebs & Reid, 2016, p. 1992). It is similar to implicit DR, which happens when consumers decide to choose dynamic pricing for their energy contract. The consumers are exposed to time-varying electricity prices or network tariffs. However, in these contracts consumers are not participating in balancing or ancillary service markets (Bertoldi et al., 2016, p. 3).

Storing

Storing energy is a key for further integration of renewable energy (RE) in the grid because it is intermittent in its nature. Prosuming storage is called "prosumage" (producing, consuming and storing) (Schill et al. 2017). Storing is usually done by installing a battery in the house and charging it with own production that is not immediately used. Companies like Sonnen are building services like trading on top of the batteries (Ford et al. 2016). The level of activeness towards the system depends on how much smartness is integrated to the storage and how it reacts to the market price signals. Firstly, the storage may only focus on maximising self-consumption rates and not looking at market prices. Secondly, the storage may have system-oriented shifts in charging by looking at market prices.

Thirdly, the storage can interact with the market with flexibility services (Schill et al., 2017, p. 147). Storing can be done also in the battery of an EV but then the electricity is not necessarily used in the house but for transportation. When batteries and EVs do charging in a controlled way, they do not create peaks to the system (Pérez-Arriaga & Knitte, 2016, pp. 292-293).

Flexibility services

Flexibility services can be delivered through Virtual Power Plant (VPP) business model. When entering the energy market individually is not economically or technically reasonable, it can be done by an aggregator. An aggregator gathers many households into one entity that can offer controlled demand shifts in the market. Aggregator is acting on the same level as a retailer but delivers two-way transactions. The flexibility is offered to the DSO or Balance Responsible Party (BRP) (EnergieKoplopers, 2016). Applicable technologies that can be aggregated are fridges, boilers, heat pumps, thermostats and other appliances that do not have to be on constantly or have little impact on people's everyday life. In Vehicle-to-Grid (V2G) solutions, EVs and batteries can provide flexibility services by feeding electricity to the grid when car is parked and electricity prices are high. Missing infrastructure and standards, skepticism of consumers, like concerns about car batteries being charged when needed are issues that come up when as they become more mainstream (Steinhilber et al. 2013). The prosumer connections and activities related to the grid are illustrated in figure 5.

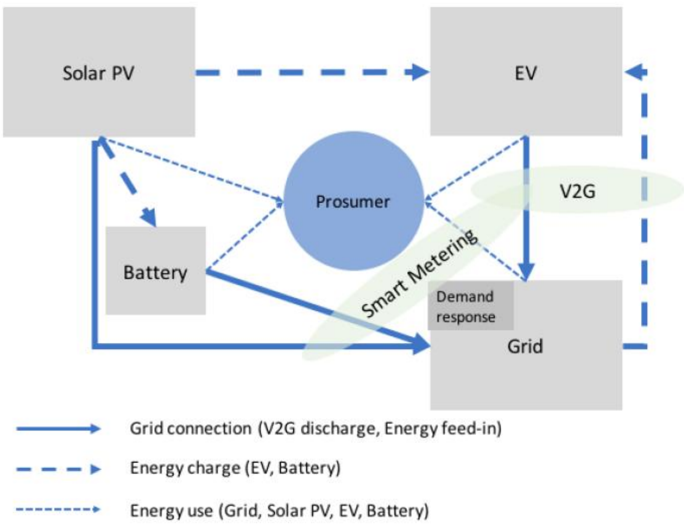

Figure 5. *Prosumer activities related to the grid (Kotilainen et al., 2017).*

Co-creation

Prosumers are also co-producers who engage in development of the production and business models through co-creation (Bremdal, 2011; Olkkonen et al., 2016). As innovations come from a network of players, the innovation process opens for many actors. Democratised knowledge, harder control of expertise and ideas and venture capital have diminished borders of innovation and companies have shifted from closed innovation processes into open ones. However, not all industries, like nuclear power generation, are willing to open their innovation processes. (Chesbrough, 2003) Co-creation is an active, creative and social process, based on collaboration between producers and users that is initiated by the company to generate value for customers. It allows use of customers' creativity, improves customer relationships and enables the company to adapt market trends.

Innovation process can be divided into two main steps: the contribution of novel ideas and selection of best ideas that are further elaborated. O'Hern & Rindfleisch (2008) created a typology of these two tasks as illustrated in figure 6. The contribution activity ranges from being fixed to company's own processes or being open to everybody. Selection part ranges in a similar way from company's own decision to power of the customers.

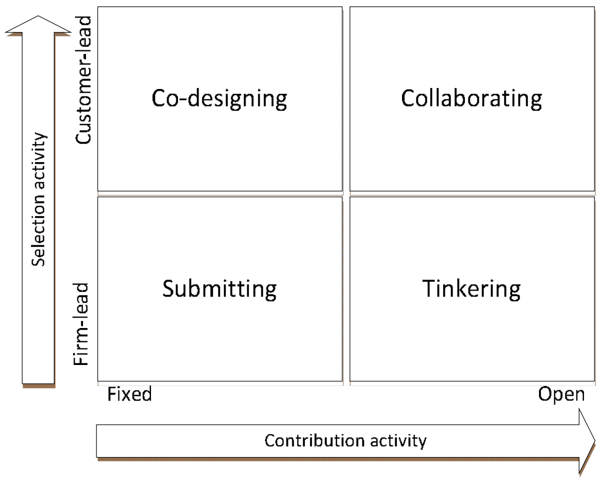

Figure 6. *Types of customer co-creation (O'Hern, M. S., & Rindfleisch, 2008)***.**

Collaboration is a process where customers have power to create and choose best innovations. For example, open source software like Linux works in this way. Tinkering means that customers make modifications to existing products and these changes are taken into account when company releases the next version of the product. In co-designing, customers provide new ideas to the company, which then typically lets customers vote for the best models. Submitting often takes place by company's invitation for new ideas. Ideas are formatted in a way the company wants and the company also has the full power to choose the innovations.

This framework is relevant to the energy field because people producing their own energy are also developing their production. Yet, co-created ideas can be somewhat harder to implement because the grid requires standardised interconnections and the appliances are regulated in many ways. Prosumer co-creation happens most commonly by inviting user to take part in product design processes and by gathering information on user preferences related to temperatures, heating, bathing and showering. Some homeowners go further to technical issues like modifying and designing technical details or posting results on online platforms. (Bleicher & Gross, 2015)

2.1.5 Innovation ecosystem

Gomes et al. (2016) define innovation ecosystems as “a set for the co-creation, or the jointly creation of value.” Adner (2006) describes them as “collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution.” They are composed of interconnected and interdependent networked actors, that include the focal firm, customers, suppliers, complementary innovators, advertisers finance providers, universities, research institutes, standardisation organisations, customers and regulators.

The concept of an innovation ecosystem is replicated from biology. Essential aspect of ecosystems is that everything is interconnected and all actions have complex feedback loops to other species. Companies have to manage their innovation processes in complex environments where the success of a product is dependent on the success of other players too. Creation of value happens by offering it to the customer but also by sharing it with other ecosystem actors. (Iansiti & Levien, 2004) Using other companies’ resources and integrating to other companies form innovations that are hard to imitate. Company strategy should be formed so that the consequences on the whole ecosystem are analysed. Iansiti and Levien (2004) takes Yahoo, who controlled the internet ecosystem, as an example of a too aggressive ecosystem leader. By making tough deals with their dot-com partners, it weakened their profitability and in that way lost important players from the ecosystem they were dominating. As innovations depend often on the whole ecosystem, the first-mover position is challenging because of the uncertainty of external environment and players (Adner & Kapoor, 2010).

Different players have different strategies in the innovation ecosystems. Iansiti and Levien (2004) form a matrix of possible strategies (see figure 7). Role depends on the relationships to other companies and the turbulence of the environment. If the company shares many assets with other companies and operates in a turbulent environment, it should aim to take the keystone strategy. Leading the ecosystem means solving major technological problems and offering a stable technological framework and business opportunities to other companies. The keystone company also determines the ‘design rules’ of the ecosystem by standardisation of modules and their connections (Mäkinen & Dedehayir, 2012). Common example is Google’s way of leading its ecosystem by gathering information of its by-products (Iyer & Davenport, 2008). If the environment is relatively stable and the market is mature but the company operates a complex network, it can take the role of a physical dominator. By that, the company aims to integrate vertically or horizontally and capture large part of the network. If the relations to suppliers and complementary firms are clear but the field is in flux, a niche position may be the strategy to follow. In commodity strategy, the relations to other actors are less important. (Iansiti & Levien, 2004)

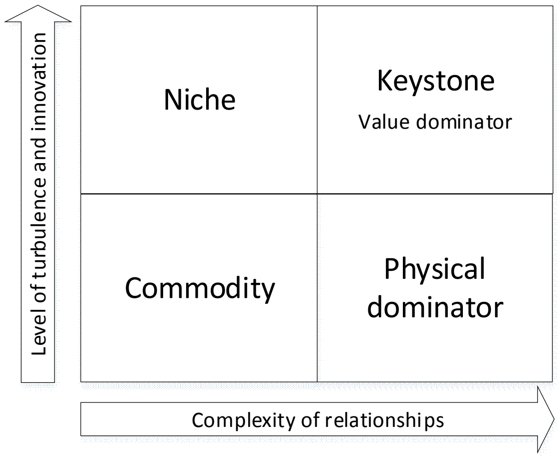

Figure 7. *Roles in an innovation ecosystem (Iansiti & Levien, 2004).*

Each company has its own customers, suppliers and complements depending on their position in the ecosystem. Figure 8 shows a simplification of the relationships a focal firm can have in an ecosystem. Being a complementor means having a product that enables customer to gain better value from focal firm's product or service. The positions of the firms are not stable. Ecosystems evolve as the firms feed-off, support and interact with each other while offering services and products to each other. The co-evolution of them is best seen in ecosystems where complementors and component makers form their own sub-systems. Sub-systems have their own development phases that are controlled by the platform leader who connects the different sub-systems together. (Iansiti & Levien, 2004; Mäkinen & Dedehayir, 2012)

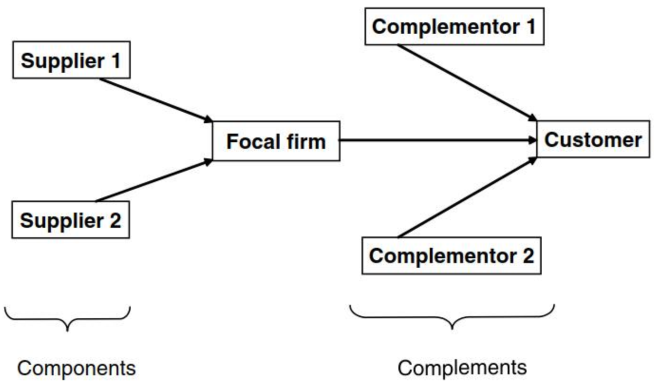

Figure 8. *Generic schema of an innovation ecosystem (Adner & Kapoor, 2010).*

Adner and Kapoor (2010) divide external environment's challenges into complement and component challenges. If suppliers fail to adopt required components, the focal firm has a bottleneck in its ecosystem's value chain. In the same way, if complementors fail to create complementing technologies, focal firm's product is less valuable for the customer. These challenges are also a way to gain competitive advantage based on learning curves.

Solving technological problems within the ecosystem partners create processes that are hard to imitate.

Besides the endogenous factors, there are also exogenous factors that influence the innovation ecosystem development. These include social, economic and technological changes in the environment. Adner and Kapoor (2010) describe the importance of external actors on both sides of the supply side with the example of AirBus' A380. This airplane was so much larger than earlier plane models that it required timely cooperation and performance by airports, regulators and component suppliers. If the technological changes converge outside the focal firm's ecosystem, the original ecosystem may broaden its scope to attain a part of the new development. The external development may also produce a competitive ecosystem, which attract module developers out from the earlier dominant ecosystem. (Mäkinen & Dedehayir, 2012)

2.1.6 Energy prosumer ecosystem

Ecosystem framework is relevant to the energy transition since it emphasises the connections of every actor and the need for complementary innovations (Adner & Kapoor, 2010). Energy field is changing, as it is getting more and more integrated with the transportation and information and communication technologies (ICT) sectors. In addition, the energy field itself is in integration as heating and cooling technologies are being electrified and therefore more connected to other electrified functions of the systems. (Canzler et al. 2017; Erlinghagen & Markard, 2012) The challenges electricity sector faces are in many ways the same for transportation and heating sectors, for example stranding assets, decarbonisation and changes in the distribution channels. The opportunities are also connected. By connecting EVs to the grid, it is possible to diminish grid congestions produced by intermittent RESs. Combining offers of solar PV, storage and DR into a package can add capacity usage of whole system.

The ongoing energy transition can be described as a shift from this top-down supply system to a multi-level exchange system (Schleicher-Tappeser, 2012). The traditional grid system is formed of five components: energy source, generation, transmission, distribution and end user (Richter, 2012; Rodríguez-Molina et al. 2014). It is characterised by centralised energy production, one-way communication, small amount of data and censors, manual control and only a few user choices. In the past, power generation units kept on growing for better efficiencies and economies-of -scale. Large number of customers made it easy to predict the demand and behaviour patterns. Distributed energy system, on the other hand, means distributed energy generation, two-way real-time communication and extensive control systems (Zame et al. 2017). It may also include locational pricing (Schleicher-Tappeser, 2012).

The market functioning is formed by an innovation ecosystem built around prosumers' DERs. Depending on the business context, the focal firm of the ecosystem may be the solar PV installers, solar service firms or prefabricated home manufacturers (Strupeit & Palm, 2016). Complementors and suppliers depend on the focal firm and may not have been created yet. To reach the potential of the ecosystem, these interactions should develop and bottlenecks solved. Issues for these interactions between complements and components include:

- Smart meters and appliances are necessary for real time flexibility but replacing old meters require a functioning DR market. If there is no demand for smart meters, their diffusion is slower. (Knight, 2016, p. 8).
- Intermittent RES and big loads like EVs and heat pumps increase the need for flexibility in the system. If their diffusion stays low, need for DR stays smaller. These factors also create a saturation point for the DR market (Arteconi et al., 2016).
- Developing grid scale energy efficiency eats consumer DR market (Knight, 2016, p. 8).
- The profitability of batteries and DR is dependent on the deployment of the other (Pérez-Arriaga & Knitte, 2016, p. 40). DR is less incentivised when having invested to an energy storage.

The way the grid architecture will shape is also a political affair, since it will shape not only technological innovations but also power relations between different actors. More decentralised generation, distributed grid intelligence and active balancing in distribution network will change big utilities' current strong position in the market. The incumbents have different approaches to the prosumer ecosystem. Some are resisting the change and shaping policies and regulatory framework to be supportive for their resources (Geels, 2014). In the energy transition, they build on their strengths like data ownership, pricing and relationships and partnerships (PwC, 2010, p. 28). Prosumer technology choices are highlighted on the distribution system level, where new investments have traditionally been done according to the peak demand. Network operators' customer contacts have been limited to the grid connection phase, disruption calls, metering and billing but now they are starting to manage different complex data sets. Now they face a new situation where the old business-as-usual model will lead to extent investments and new smart solutions are required to make the system sustainable (Pérez-Arriaga & Knitte, 2016, p. 46).

New entrants from other sectors like transportation, telecommunications and big data firms start to cooperate and compete in the energy regime (Canzler et al. 2017). They are interesting actors in the energy field that has long been seen as monopolistic industry (Daly, 2016). Usually they have less difficulties to adopt new technologies in disruptive changes (Adner & Kapoor, 2010). On the other hand, energy is still highly regulated field, which gives advantage to incumbents. New entrants may alter the strategic positions of the companies in the ecosystem that is illustrated in figure 9. Transportation sector with EVs is linked to prosumer ecosystem through smart charging, V2G business model and battery infrastructure. EVs are now bigger investments than solar panels so they may become the physical dominators of the ecosystem (Rubel et al. 2017). Accordingly, development of battery manufacturing is currently an important piece of EV diffusion but affects also the solar PV industry.

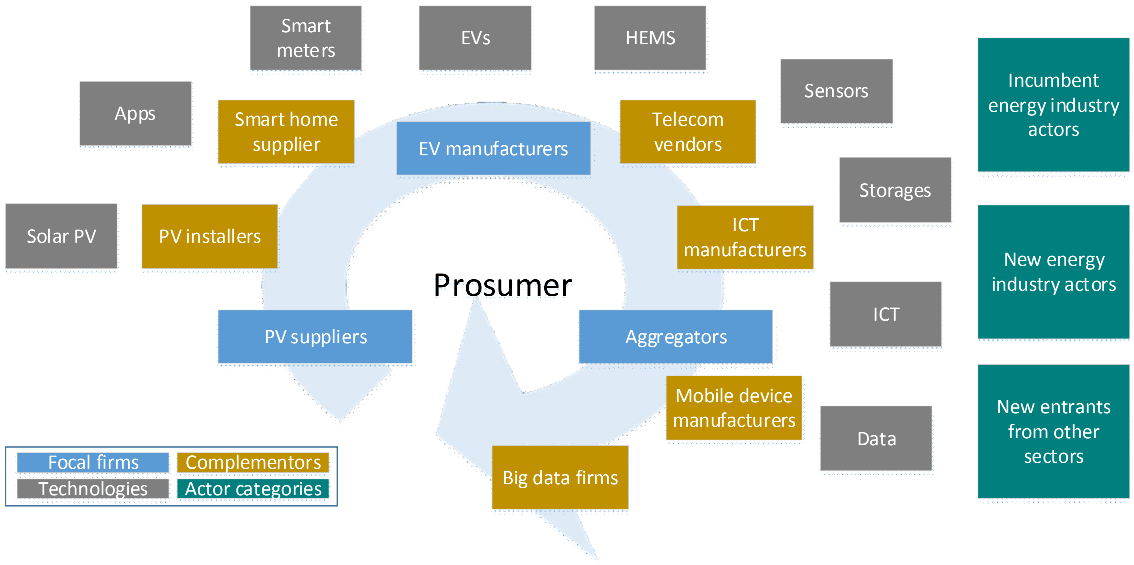

Figure 9. *Prosumer innovation ecosystem with technologies, focal firms and complements (adapted from Kotilainen et al., 2016).*

ICT sector, which is strongly entering the market, functions as an accelerator of the regime shift by enabling DR and aggregation (Markard & Erlinghagen, 2012). Aggregators can control and optimise the combinations of technologies can become the value dominators without owning much hardware themselves. They also handle interfaces to customer DERs and system operators. Sensors, applications, smart meters and other software based technologies form possibilities for niche strategies that have not existed in the energy field in this extent. Design rules and standardisation face local solutions but offer also possibilities of leveraging the niche to bigger markets.

2.2 Policy interventions

According to de Lovinfosse & Varone (2004), public policies are “intentionally coherent decisions or activities taken or carried out by public -and sometimes private- actors, whose resources, institutional links and interests vary.” Public policy aims at channelling the behaviour of a target population by the help of public effort to solve the decided problems. Policies can be rules or otherwise influencing mechanisms, which impose obligations, create incentives or build up capacity of the target group. Incentives are defined as: “Rewards or penalties designed to induce one set of economic agents to act in such a way as to produce results that another economic agent wants” (Black et al., 2017). The policy design can be broken down into four elements that are shown in figure 10 (Sorrell et al., 2003).

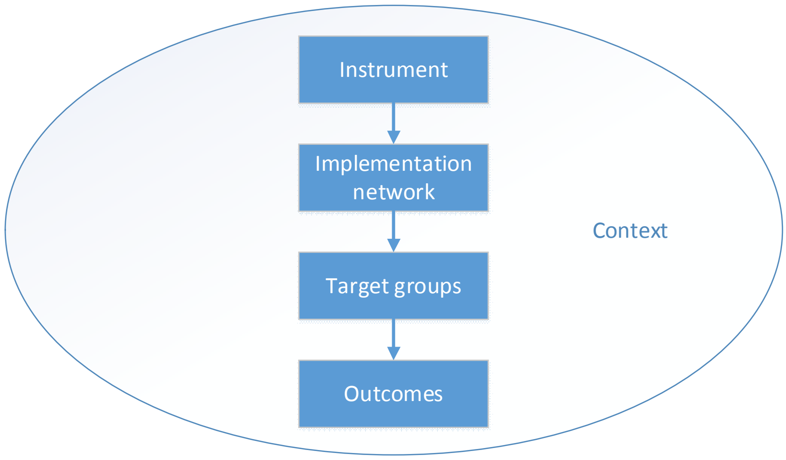

Figure 10. *Policy design elements (Sorrell et al., 2003).*

Instrument is a new legislation, law, regulation or an initiative in order to achieve a certain objective. Implementation network includes private and public actors who have to be mobilised to implement the policy. In a multi-level policy context like the EU, the intermediaries, like National Regulatory Agencies (NRAs) between different levels play important role. Target groups are individuals or organisation that the policy influences directly or indirectly. Outcomes and objectives are the effects the policies are desired to have. In most cases there are several objectives and different stakeholders see them in different ways. Outcome is determined by the analysed potential change to the current situation the policy can create. For example, cost-benefit analyses are essential but often challenging to implement. The context of the policy includes economic, political and cultural factors that create circumstances and impose constraints for it. (Sorrell et al., 2003)

Success of the policy design depends on many details of the instruments (Mir-Artigues & del Río, 2016, pp.275-276). Some elements are instrument-specific but some are common for all instruments. In energy field, eligibility of old plants, location specific support, duration of the support and the flexibility of the support level are important risk factors for investors. These elements can steer investments and whole system towards either centralisation or decentralisation. In addition, the way support costs are burdened has an effect on overall electricity price. Rogge and Rechardt (2013, pp. 13-15) add also more general features to policy design: stringency, level of support, predictability, flexibility, differentiations and depth.

Measuring policy success is a subject that has been researched a lot but has not been fully answered. The criteria of a good policy intervention is context specific and depends on the sector company size, level of implementation and incentive design (Rademaekers et al., 2012, p. 93). For example, transportation policy interventions are evaluated regarding emission and pollution differences, health outcomes and alternative policies and technologies and even knowledge spill overs (Deshazo et al. 2017, p.20). In the field of RE, the indicators are effectiveness, efficiency, equity, institutional feasibility and replicability (IRENA, 2012). According to Jaffe et al. (2005, p. 170) innovation policy's success is uncertain and difficult to measure and is often not quantitatively measured. Ex-ante measurements are especially difficult in long periods like in the case of climate mitigation. However, general principles can be given. Following list is modified from Rademaekers et al.'s list (2012, p. 11) company strategies in mind. Incentives should

- work in long-term but also supporting near-term investments,
- affect firms' profitability and competitiveness,
- be transparent, simple and action orientated
- give pressure from supply chain (effective especially for small companies)
- linked to well-known programs like ISO certificates or common reporting schemes and
- provide support to qualify for incentives is important especially for SMEs.

The broadening context of policies and interoperability of them is making the evaluation of policy mixes more difficult. Policy mixes include many political objectives but also many administrative domains, like transportation, environment, fiscal and climate policies (Kivimaa et al., 2017). Borrás and Edquist (2013, p. 18-21) combine the policy instruments to actions of Innovation System functions. Sorrell et al. (2003, p. 63) mention that policy mix approach creates a situation where success of one instrument is dependent on timing and the other instrument's success. A multi-criteria analysis is usually conducted with a matrix with quantitative or qualitative analysis (Sorrell et al., 2003, pp. 24-25).

Multi-level governance

Multi-level governance in the EU context is defined as "system of continuous negotiation among nested governments at several territorial tiers – supranational, national, regional and local" (Hooghe & Marks, 2003). In public policy literature, the EU has brought up a new kind of theoretical aspects of division of governance, which is different from the one concerning independent nations, the United Nations and NATO, for example. The EU includes complex relations between governments and the cohesion and integration-driven policy. Subsidiarity is one of EU's priorities meaning that decisions should be done as close as possible to the citizens as far as the objectives can be met in that way. The EU has a strong influence on the other levels of governance and may be used in questions that handle specific matters where multi-purpose national bodies are not working on.

Nations have delegated some duties to the EU through different treaties with the Lisbon treaty being the most important one. Competences in the energy field are divided between the member states and the EU as stated in the Treaty of the EU and Treaty of Functioning of the EU and their amendments. The EU steers their policies through directives, guidelines, research and funding and affect directly via energy saving standards and the emission trading system (ETS). Different types of EU laws are treaties, regulations, directives, decisions, recommendations and Commission communications (Lane, 2015). (Bommel & Bregman, 2013; SGTF, 2013)

Member states can decide their own energy mixes, support schemes and taxing of energy but they have to follow the EU directives. Also bilateral energy relations outside the EU belong to member state competencies (European Commission, 2012). The interpretation and implementation of different EU regulations may differ between countries. Many path dependencies like earlier investments and cultural habits shape the regional implementation. For example, Scandinavia has traditions of consensus-driven policy and strong legislation whereas in southern Europe informal connections are important. In addition, some countries give more legal and administrative power to regions than others do. The importance of regional level can vary from being a federal state to a sole administrative level to a uniform state. Meanwhile part of the national power has been shifted to Brussels, in some cases the regional power has increased. This is the case especially in regions with strong lobbying power. (Keskitalo, 2010)

2.2.1 Industrial policy approach

Industrial policy has many different definitions depending on the country and time. Often industrial policy is pursued through many policy instruments, like infrastructure provision, public procurement and defence an employment protection. Because of this vagueness, industrial policy has not clear taxonomy (Warwick, 2013, p. 17). However, throughout the different definitions and rationales, the goal of industrial policy is competitiveness, economic growth and productivity growth (Aiginger, 2007, p. 320). It is also a way of solving problems in certain industries and allocating resources to macro economically important fields. In this thesis, the widely used definition of Pack & Saggi (2006) for industrial policy is adopted: "Industrial policy is any type of selective intervention or government policy that attempts to alter the structure of production toward sectors that are expected to offer better prospects for economic growth than would occur in the absence of such intervention."

Important aspect in strategic industrial policies nowadays comes from the internationalisation of manufacturing process and the shift to service-based business of many industrial manufacturers (Warwick, 2013, p.11). These trends lead to thinking of value chain positioning which is illustrated in figure 11. As labour costs in industrialised countries have increased, firms aim to cover the parts of the value chain that require more educational workforce and in general use more human rather than natural capital. Automation is yet again changing this landscape as companies are relocating the production due to decreasing importance of labour costs.

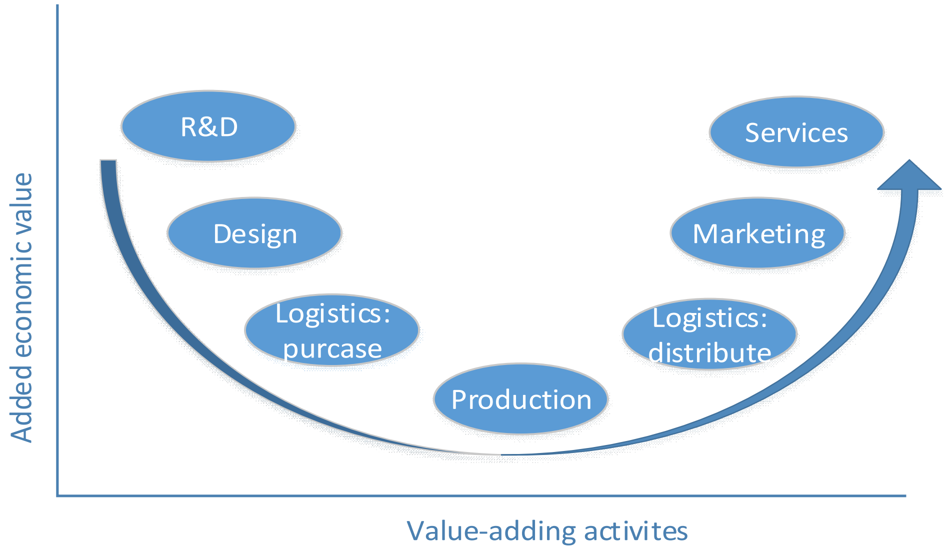

Figure 11. *Economic value of activities in a traditional value chain (modified from Warwick, 2013, p.12).*

One approach is targeting certain sectors in attempt to create "strategic industries" with industry-specific interventions, subsidies or trade barriers. Weiss (2011) describes this kind of technology-specific activity as 'promotional' approach. This strategy was clearly seen in the traditional approach of industrial policy, where governments gave subsidies or other state aid to mainly domestic manufacturing industry (Warwick, 2013, p. 29). There is no lack of arguments against such policies. Economists warn politicians of inefficiencies that comes from picking winners, policies are prone for corruption and international rules leave little space for national policy interventions (Rodrik, 2004, pp.36-37). However, there are reasons for adopting such technology-specific policies. They are often popular because they disperse the costs of focused benefits (Jaffe et al., 2005, p. 169). Some authors also claim that they are needed for creating sustained knowledge, market distortions avoidance and path dependency (Groba & Breitschopf, 2013, p. 16). Weiss (2011, p. 3) note the need for subsidising risk-taking activities. Nowadays, the attempt in sectoral policy is to help infant industries to gain access to financial markets and certain economies-of-scale by clustering policies (Aiginger, 2007, p. 316).

Opposite of sectoral policies are horizontal measures that are set to improve business conditions in general. Weiss (2011, pp. 3-4) describes this kind of activity as market-based approach. Governments may aim to facilitate and creating supportive framework for business by correcting externalities, providing information and infrastructure. Strategic trade policy through subsidies is another way of supporting industries (Warwick, 2013, p. 21). If two exporting countries compete on the same markets, either one of them or both may give subsidies to the exporting industry for winning the trade deals.

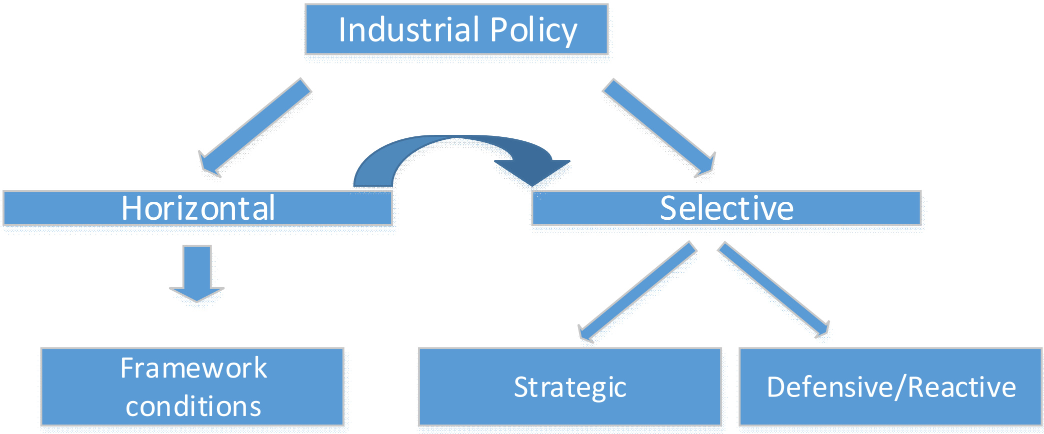

Figure 12. *Typology of industrial policies (modified from Warwick, 2013)***.**

Another way of categorising industrial policies is by the orientation towards technological and societal changes. In other words, industrial policy may be defensive and reactive towards landcape changes to protect workplaces. Some policies prevent industries of dying for political reasons. For example, automotive industry got a lot of subisdies in the USA after 2008-2009 financial crisis. Other policies promote change through inducing innovation, new entrants, spoinoffs and new capbilities. Warwick (2013) also divides the selective policies into strategic domains or technologies in which country should focus and create competitive advantage.

2.2.2 Innovation policy approach

National innovation and technology policy aims to create national competitive advantages and productivity growth. It creates preconditions and framework for generating inventions and supports research and knowledge creation. National innovation strategies identify fields where country has potential to thrive economically and socially. (Meissner, 2014) It includes wide range of activities, which depend on the country and its technological development. It covers many areas from intellectual property rights to support for new business and policy on basic research. Meaning of technology and innovation policy depends on country’s development and priorities. More developed countries aim to be on the cutting edge of innovation whereas less developed countries aim to facilitate the adoption of innovations from abroad. In general, there has been a shift from R&D policies towards markets and commercialisation of innovations. It means that technology and innovation policy definition has widened to cover the whole innovation diffusion process and markets have gained more attention.

In environmental policies, the cost of externalities are internalised in a way or another. Innovation policies are somewhat other side of the coin compared to environmental policies (Jaffe et al. 2005, p.165). It sees technology change from the angle of internalising the external benefits of the technology adoption. This means benefiting from the front-runner position and learning efforts. Adopting a less pollutive innovation can be costly for the first adopters, and since the costs are decreased by policy intervention. Innovative firms can create new knowledge that other firms and society benefit from. As the diffusion and user base continues to spread, new adopters receive relatively higher value of it than earlier adopters do. Basis of this hypothesis is that both users and producers learn and make improvements to the technology during the diffusion process. (Jaffe et al., 2005) Of course, the precondition of policy interventions is that the private actor has problems in achieving the objectives on its own and public sector can help with it (Edquist, 2014).

Usual categorisation of innovation policies throughout the innovation diffusion happens within technology-push policies and demand-pull policies (Grubb, 2004, p. 10). Technology-push approach would support research and demonstration stages of innovation cycle through public R&D programs. The proponents of technology-push policies think it is better to support technologies in the market only when their costs have already decreased. The change in policy related to the innovation cycle and innovation policies is shown in figure 13.

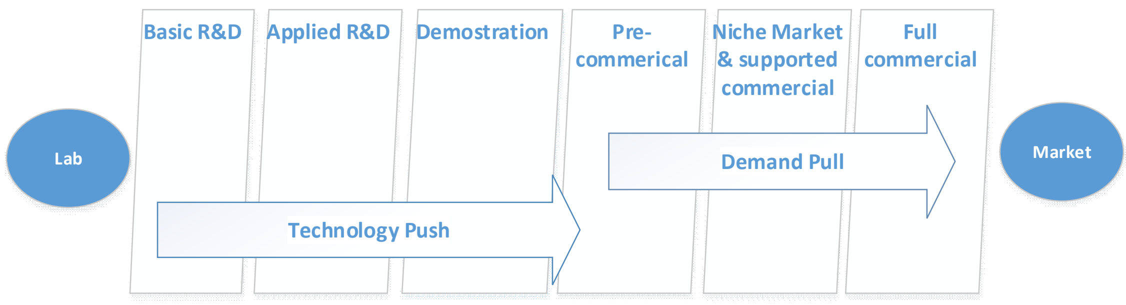

Figure 13. *Policy instruments in different sections of an innovation cycle (adapted from Bürer & Wüstenhagen, 2009 and Grubb, 2004).*

Demand-pull refers to commercialisation and bringing the innovations to the market. Proponents of this approach think that technological change comes with economic incentives that push business sector to act. They also highlight the different market barriers for innovations to emerge in the markets (Grubb, 2004, p. 9). As the performance of the innovation gets to the level of incumbent technologies, the policy instrument changes to more market-based one that allows it to be fully commercialised. On the maturity level, the technology can fully compete and aim of public policies is to form a level playing field for all players in the market.

Co-creation and networking policies

Framing innovation processes as linear processes, where the input and output can be measured, has gained a lot of criticism. Base of this thinking is in methodologies of accounting and economics, amongst others, which do not allow deeper analysis on the innovation process. Usual measurements are, for example, patent counts and gross domestic product per capita (Yawson, 2009, p. 3). Such straightforward thinking is in contrast with the systemic nature innovation processes. Understanding of innovation processes as iterative and interactive processes has during recent decades start to affect policymaking (Meissner, 2014). According to Smits and Kuhlmann (2004, pp. 6-9), innovation policy planning include nowadays non-linear innovation models, open innovation, rise of systems approach, growing need for public-private partnerships, rise of uncertainty and need for learning. Networks and social dimension is easily forgotten in the policy planning (Meissner, 2014).

Innovation ecosystem includes non-linear interrelationships, different systems, niches and pathways that come together (Yawson, 2009, p. 4). For example, managing interfaces and providing platforms for learning and experimenting are examples of systemic policies that support these trends (Smits and Kuhlmann, 2004, p. 12). Under the research framework of Technological Innovation Systems (TISs), business ecosystems are studied from the functions point of view (Bergek, et al. 2015). These functions are processes, which are central to the success of the TIS. They include entrepreneurial activities, knowledge development, knowledge diffusion, guidance of search processes, market formation and resource mobilisation (Hekkert et al. 2007). These functions highlight the importance of communication and knowledge creation.

Different TISs interact and sometimes development of complementary TISs enforce both sides. Knowledge sharing is important source especially for service innovations (Meissner, 2014). Proximity has an positive effect on linkages between buyers, suppliers and other institutions (Meissner, 2014). The EU supports these “smart specialisations” also in the name of cohesion policy (Carayannis et al., 2017). Timing is important aspect in ecosystem creation because the relationships and environment changes over time.

Von Hippel (2005, Ch. 8) discusses aspects of innovation policy from point of view of open innovations. Firstly, intellectual property rights are an aspect that may become a barrier for co-innovation practices. Although rearranging property rights is challenging and not probable, effectiveness of patenting can be questioned as well as the policy effects they produce. Companies can use patent thickets to create entry barriers and competition in their sector. Secondly, companies create constraints in product modification. Own modifications could be enabled by regulating products to certain direction. Thirdly, ownership of distribution channels hinders the competition efficiently and therefore the content and channels should be separated. Fourthly, traditional economic aid for R&D goes to companies themselves and not the lead-users who are increasingly important sources of innovation.

Regulating disruptive business models

Sometimes business model innovations are so disruptive that they conflict with the current regimes. Recent examples of these innovations come from the sharing economy business models, which have changed transportation and housing sectors. Level of the innovation is important because not all disruptive innovations cause problems with the current regulation. The normative approach of policymaking determines how to react to different disruptive innovations. If the country has ambitions on being an innovative frontrunner, it might choose to encourage or at least not to restrict new businesses. One option is to do nothing and let the old business model and regulatory structure decline. Other option is to accommodate the new business and reform the existing legislation for it or create entirely new legislation (Biber et al. 2017).

Biber et al. (2017) gather a toolkit of four policy strategies. First option is to block the new business model totally and preserving the existing business structures. Second option is to let the new business to proceed without interfering and imposing the incumbent business to restructure. Third option is allowing the new business models but imposing them with certain rules that are set to the incumbents too. The fourth and last option is to develop a new legislative framework and structure of business where all players have neutral conditions.

2.2.3 Environmental policy approach

Environmental policy aims at environmental protection and reducing industry's effect on nature and environment. Knoepfel (2006) states that it aims at assessing the state of environmental pollution, evaluating this pollution in relation to the threat it poses to human welfare and ecosystem and controlling pollution activities by means. Idea of including external costs to economic growth and production and thereby to prices is an essential aspect in environmental policies. Example of such externalities is pollution that a factory creates but does not necessarily pay for. Instead, rest of the society pays this cost (Popp et al., 2010). There are two way of dealing with the externalities: internalising the costs of polluting to the factory or limiting the pollution by regulation. Factory might have to install new equipment or change their products or inputs of the process. (Jaffe et al., 2005)

Basic categorisation of environmental policies is division to command-and-control and economic instruments, which is widely used in public policies also on more general level (Borrás & Edquist 2013; Rogge & Rechardt 2013).

Command-and-control instruments, the "sticks", are used for creating market conditions for sustainable products. They are rules and directives, like emission restrictions, that form the framework in which interactions in the market and society take place. They are typically backed with threat of sanctions if they are not obeyed. People focusing on the hierarchical side see that the sanctions are the most important aspect of them, while others see the normative authority as the main outcome (Borrás & Edquist, 2013). Normative authority means that regulation steers our ways of thinking on the desired outcomes. There are positive and negative sides with the use of these tools. As they are performance standards that explicitly tell what kind of technology should be used, they are not dynamic and responsive (Groba & Breitschopf, 2013). Even though regulation has been efficient in giving the desired outcomes, it has also proven to be resource intensive, both for regulator and regulated companies (Rademaekers et al., 2012, p. 50). Lately they have decreased their popularity because they have not guaranteed enough investments and can cause technological lock-ins (Groba & Breitschopf, 2013). Furthermore, they are made to form a level playing field for all actors but this might not be suitable for smaller companies for bureaucratic reasons and lack of resources (Rademaekers et al., 2012, p. 98). For this reason, there are administrative incentives, such as, reduced inspection frequency, which can induce also smaller companies. Patenting is also a possible way to induce innovations especially on the less mature technologies but also has effects of hindering innovations (von Hippel, 2005).

Economic instruments, also called as the “carrots”, strengthen the market-based drivers to lower emissions (Vedung et al., 1998). They can be encouraging and promoting certain activities but they can also be disincentives restraining certain activities like polluting. Examples of market-based policies are ETS, public investments and tax credits, public funding, investment subsidies and infrastructure provision. They entail a risk of creating lock-ins and pathways for technologies that once seemed the best option but did not turn out to be on. Some also claim that these incentives are not efficient because companies regard access to them difficult and think that eco-innovations with business sense do not need subsidies (Rademaekers et al., 2012, pp. 41-42).

Third category with less attention are soft instruments, which include voluntary actions, recommendations and labelling. In some contexts, they are also named as Information tools because their aim is to shape general knowledge and opinions (Vedung et al 1998). Information plays and important role in technology diffusion and is underprovided by the markets (Jaffe et al. 2002, p. 8). Especially early adopter face large private learning costs alongside other costs (Jaffe et al., 2005). Companies have different motivations for informational incentives. On one hand, they communicate environmental plans themselves for stakeholders and marketing purposes. On the other hand, rankings, awards and recognition schemes by external actors may work as good benchmarking tools and influence stakeholders (Rademaekers et al., 2012, ch. 3.3.5).

As it becomes clear, some instruments are more imposing than others, making it possible to range the instruments according to their coerciveness (see figure 14). However, the stringency is finally determined by the way an instrument is designed, implemented and enforced (Persson, 2007).

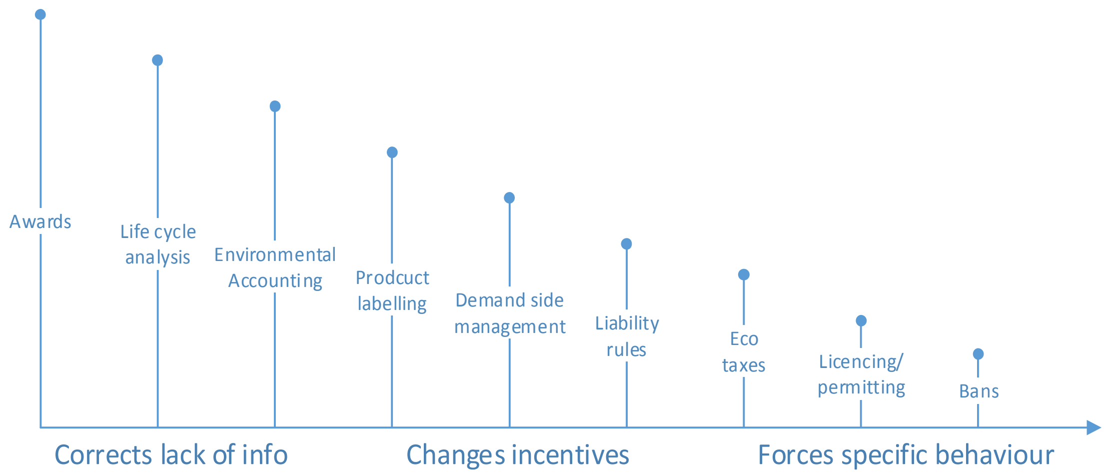

Figure 14. *Stringency of environmental policy instruments (Persson 2007 modified from Barde 2002).*

The development of environmental policies can be divided into three waves according to the same three dimensions. Until 1980s, the paradigm supported traditional command-and-control regulation. However, regulation affected mostly the end-of-pipe products and was questioned in the 80s as ineffective and costly. The second wave introduced market-based instruments like pollution charges, taxes and tradeable permits. The third wave in the 90s brought soft instruments like labels and voluntary approaches as reputation of the companies in environmental matters started to become increasingly important (Persson, 2007; Rademaekers et al., 2012) .

2.2.4 Transition policies

Transition policy is a relatively new governance type, which aims to create disruptive innovations that enable making system-wide sustainability transitions. It is based on framework of Transition Management (TM), a research field that studies how to steer systemic changes (Kemp & Loorbach, 2007). It emphasises bottom-up developments by coordinating self-organised experiments and other types of learning processes. Experimenting helps to decrease uncertainty and avoid locked pathways. It has also an adaptive approach that supports co-evolution and self-organisation (Rotmans, 2006). The final aim of transition policy is to change current regime's industries to sustainable ones. Therefore, economic growth is not the primary target. (Alkemade et al., 2011)

Transitions can be steered by politics to certain directions but full control is practically impossible. Steering happens with coherent actions on different layers of governance: strategic, tactical and operational (Kemp & Loorbach, 2007, pp. 5-6). The strategic level holds top-down policies by which authorities set long-term goals, commitments and visions. Strategic level actions affect profound structures of the system so that the system can sustain changes and is not only reacting to them. Liberalisation of the electricity markets is a good example of such structural change. Tactical level includes processes of agenda building, negotiating, coalition building and networking. The operational level steers the pathway from bottom-up by experimenting, project building and implementation. Experience-based learning and feedback loops show the way to most sustainable pathway. Policy makers should get information from the experiments and then continue the transition in small-scale solutions. Experiments also spread ideas, values and attitudes on macro level, which have an effect to the political regimes. Transition policies work in a new transition arena, which is outside regular short-term policy cycles. (Berninger et al., 2017)

The transition policy instruments can be divided into two categories: “niche support” and “regime destabilisation” (Kivimaa & Kern, 2015). The niche support policies are somewhat traditional innovation policies that allocate resources for R&D and create market conditions for innovations. The system transition is initiated in a safe niche environment, which is protected from competition of the bigger market players. Experiments and initial projects may offer a steep learning curve but do not in themselves guarantee market readiness and success. The difference between the initial demonstrations and market readiness is often called the “death valley” (Schot & Geels, 2008, p. 538).

Policies that destabilise the current regime can be used to reinforce the Schumpeterian “creative destruction”. These policies are typically command-and-control regulations that strict for example polluting or limit some products from markets (Berninger et al. 2017). They put pressure on the regime actors and put them on the same level as niche players. Social network movements by changing ties of regime actors and government changes the political agenda. Withdrawing support for dominant technologies, like fossil fuels can further accelerate the transition (Kivimaa & Kern, 2015).

Path creation is important part of transition policies and is used to un-lock path dependencies. These paths enable to overcome regime shift barriers like regime’s economies-of-scale production, cumulative learnings and existing networks of actors (Schot & Geels, 2008). The process of a path creation is done in three steps. Firstly, a vision for a potential solution is created and communicated. Secondly, the actor groups, like researchers, lead-users and producers network with each other and increasingly with regime actors. Thirdly, path upscaling involves constant learning which steers it towards the vision. A new path is created when:

1. Actor networks are being established,
2. There have been triggering points like new supportive legislation done,
3. The course of the pathway is simultaneous and the pathway options are narrowed down,
4. Course is self-reinforcing and
5. The path-creation produces lock-ins and established practices. (Sydow et al. 2012; Berninger et al. 2017)

There has been also criticism towards transition policies. Visionaries initiate the transitions but their work has not got enough attention in the research. Also, transition policies face many political challenges that make their implementation messy and difficult (Meadowcroft, 2009).

2.2.5 Policy mixes

A policy mix is defined as set of different and complementary instruments to address identified problems (Borrás & Edquist, 2013). Policy mixes are a result of a process in which the instruments are debated and chosen (Flanagan, Uyarra, & Laranja, 2011). A profound building block of the policy mix is the policy strategy. Rogge & Rechardt (2013) define policy strategy as combination of policy objectives and principal plans for achieving them.

In most cases, policymaking is a set of compromises that adjust to existing policies. New goals and instruments are being “layered” on top of old policies. The goals may remain the same but the instruments for achieving them change (“drift”). In addition, it is possible that the goal changes without change in the instruments (“conversion”). These solutions built on old goals or instruments produce often incoherent policy mixes (Howlett & Rayner, 2007). The policy problem articulation determines the instruments that create the pathway towards the vision. Same target can be tackled in many different ways. For example, developing ICT sector has been done by attracting foreign investments, supporting own private sector’s industrial R&D with public grants or by creating public research activities (Borrás & Edquist, 2013).

The instruments have to be aligned with each other so that their interactions are mutually reinforcing. The analysis of policy interaction includes identification and evaluation of the consequences different policies have together. Instruments’ target groups and their activities may be different and change during time. Elements between instruments that should be analysed are scope of interactions, nature of their goals, timing, operation and implementation processes. This process is illustrated in figure 15. (Rogge & Rechardt, 2013; Sorrell et al., 2003)

Figure 15. *Policy instrument alignement (Sorrell et al., 2003).*

Firstly, the scope of policies is estimated by the degree of who are affected. This can be divided into main target group and the identification of indirectly affected groups. Scope can also be evaluated on level of activity or technology (Sorrell et al., 2003, pp. 57-58).

Secondly, the policy objectives of different instruments are analysed by their degree of compatibility. These targets are accompanied with road maps and strategic action plans (Rogge & Rechardt, 2013). In theory, all RE policies try to reduce emissions, but their logic of doing so can include conflicts. Finding common objectives in energy field is challenging because different stakeholders have different interests and approaches. These objectives are summarised in table 1 by each policy approach studied earlier. Inconsistent targets can result in inefficient policies, and therefore the targets should be integrated. (Kivimaa, 2008) The objectives may be in conflict if other instrument's target undermines other's target. The objectives can be also reinforcing if one objective reinforces or complements other achievements. This happens if two instruments target different aspects of the same problem. (Sorrell et al., 2003, pp. 58-60)

Thirdly, the operation of the instruments on the target groups are estimated qualitatively through relative size and importance of each incentive, the likely response of the target group and evaluation of which incentives will dominate. There can be overlapping effects and an instrument can become redundant by another one. This happens when one policy is considered adequate to get to the objective. For example, having restrictions on some products and subsidies on other products may not be necessary. Policies can also operate counterproductively or be neutral or complementary. (Sorrell et al., 2003, pp. 60-61)

Fourthly, the implementation phase should be designed so that regulators tasks can be compatible and same work do not have to be done twice and responsibilities are clearly addressed. Complex and insufficient structures may cause inefficiency for results. Especially in technical fields like renewable energy, legislators should cooperate with the innovators to ensure the policy implementation and the market functioning after the policy intervention. (Sorrell et al., 2003, pp. 61-62; Rogge & Rechardt, 2013)

Finally, the timing of the instruments includes responses to triggers and policy sequencing. Flexibility and policy predictability form a trade-off and a tension regarding the timetable (Sorrell et al., 2003, pp. 62-63). This also relates to the innovation phase the technology is in (Rogge & Rechardt, 2013).

Table 1. *Policy approach comparison.*

Policy	Industrial Policy		Innovation Policy		Environmental Policy			Transition Policy	
Objectives	Competitiveness, economic and productivity growth		Mostly economic goals like competitiveness and productivity growth but also sustainability and other societal issues		Protecting environment			Replacing current regime to a more sustainable one.	
Typology	Horizontal	Sectoral	Technology push	Demand Pull	Economic incentives, "carrots"	Command-and-control, "sticks"	Information, "sermons"	Creative	Destruction
Instruments	Market deregulation, indirect tax policy, exchange rate policy, R&D tax credit…	State aid, tariff protection, , export promotion, public procurement, clusters policy…	Public R&D, grants, demonstrations, investment subsidies, tax breaks…	FITs, standards, tax credits, CO2 trading, public procurement, auctions, RCTs…	Levies, tax breaks, tradable green certificates, capital allowances, removal of subsidies	Performance requirements, emission caps, permits, standards, bans…	Education, training, statistics, labelling…	R&D funding, demonstrations, tax breaks, SME networks, education, labels…	CO2 caps and taxes, new legislation, removal of subsidies, new committees…
Sources	(Warwick, 2013)		(Bürer & Wüstenhagen, 2009; Rogge & Rechardt, 2013)		(Rogge & Rechardt, 2013; Vedung 1998; Persson 2007)			(Berninger et al. 2017; Paula Kivimaa & Kern, 2015)	

Moving from one instrument to a mix of policy instruments means classification of main instruments and complementary instruments. It helps at creating the policy mix from different perspectives. Looking at common typologies show that these categories are different in nature and policy inclusion is varies. For example, command-and-control policies are included in regime destruction policies; financial incentives are included in all categories in other policy approaches. Division of industrial policy to horizontal and sectoral policies is a distinct from others, yet useful categorisation for other approaches as it defines the scope of policies. By the instrument categorisation, closest approaches seem to be innovation and transition policies by looking at the timing of the policy according to technology's market readiness.

2.3 Regulating energy prosumer ecosystem

This chapter aims at combining the earlier literature from innovation theories and policies. It connects the typologies of policy approaches in prosumer innovation ecosystem and the introduced ecosystem strategies. It also structures the policy interventions from the prosumer's point of view.

Countries that adopt the industrial policy approach related to prosuming, want to make use of their country's resources but not necessarily make big changes to the regime position. If they aim at physical or value dominator position it would mean creating competiveness by controlling value networks but also developing own manufacturing. Value chain position is important in regard the energy ecosystem. If large companies control certain part of the value chain, new entrants have to ally with incumbents (Hekkert et al., 2007; von Hippel, 2005). Aiming to this position requires horizontal policies lowering entry barriers and transaction costs. Difference to the earlier energy business with just handful of players is vast. Opening innovation spaces is happening by platform business models, which are utility adopt more and more (Parag, 2015). The downside of creating only horizontal policies is that the formation of complex supply chains and complementors may be difficult when the future of the market is unclear.

Countries emphasising innovation policy aim at competitiveness but include also societal issues in the strategy. They may specialise to certain technologies in which they already have relative advantage and knowhow. The innovation policy approach indicates that technologies should be under different political intervention in different stages of the lifecycle. Solar PV and different communication technologies like smart meters, are already relatively mature and market ready. Other products, like energy storages, are still more on the niche side but becoming mainstream quickly. Systemic effects of the policies and complementary technologies should be thought when planning these policies. Networking are cluster policies are important when attaining the value of these technologies.

The transition policy approach adds disruptiveness to innovation policy approach. It highlights the importance of destabilising current regime by command-and control policies. Because it emphasises bottom-up movements, direction is most notably decentralisation of the whole system, which easily means restructuring of tax collection and new rules with infrastructure. The aim is to replace the fossil fuel generation, which means that widespread RE should win the incremental fossil fuel developments. In that sense, this strategy is connected to commodity-oriented but also niche-oriented strategies. Transition is systemic and aside energy sector, building and transportation sectors apply policies that impose manufacturers to change their products. Through niche creation, it is possible to create acceptance for new sustainable technologies, like DR solutions but also networking within different actors.

Environmental policies have similar targets as the transition policy approach. However, changing regime actors is not necessarily in its agenda. It mainly aims at decreasing heavily the use of fossil fuel generation and avoiding excess investments in grid lines. It is therefore leaning towards commodity and physical dominator strategies. Command-and-control regulation works as a destabilising force but more importantly imposes better energy efficiency by internalising pollution costs to consumer prices. Added information for consumers means they realised the environmental and monetary value of sustainable choices better.

The next chapters will look at the effects of regulation from prosumer's point of view. Policy mix is concretised in customer's innovation adoption process. Aim is to show the strengths and weaknesses of the national innovation ecosystem policies. A policy instrument that is missing from the process or not aiming towards same target may result to overall inefficiency (Howlett & Rayner, 2007). Journey is linked to innovation ecosystem theory by seeing prosumer actions and policies as complementors and suppliers. In principle, each phase of prosumer's adoption process relates to the earlier phase's success.

The framework of this thesis, illustrated in figure 16, starts with the knowledge phase, which includes political decisions that are seen as prerequisites for the prosumer ecosystem. In a way, they enable the prosumer journey to begin. They are technology-neutral policies and merely regulative in nature. In the energy field the tendency is away from "natural monopolies", so these policies are deregulating the market and opening new options for consumers.

Policies in the persuasion phase are merely sectoral policies as they steer consumers to choose certain technologies. They are a mix of informational, regulatory and financial policies that affect the decision by either excluding or incentivising different technologies. They affect the fixed costs of the purchase. Informational policies aim to inform consumers on different technologies but they can also be used to support energy efficient solutions in general. In this customer journey, the financial policies are divided into ones that affect in the purchasing phase, namely investment subsidies, and ones that affect the usage phase. Investment subsidies are usually technology specific and include different conditions on the support. However, their impact in the energy market is less imminent since they do not affect prosumer's behavior during the usage phase.

Implementation phase policies are a set of regulatory and financial policies that affect the operational costs and benefits of the technology. These policies are typically technology-neutral as they include regulation like how to interconnections are handled, how multi-family houses get involved, does RE have a guaranteed access to the grid, how the network tariffs and taxes affect the usage of the system. However, these policies can change according to different system sizes and technologies. These policies determine how well the prosumer is engaged with the product.

The policies in the confirmation phase are technology specific policies for complementing technologies, namely batteries and EVs. It also holds aggregation regulation, which is an enabler for many different technologies on the DR side. Aggregation regulation is in principle technology neutral policy that includes valuation of flexibility by different resources in the energy market.

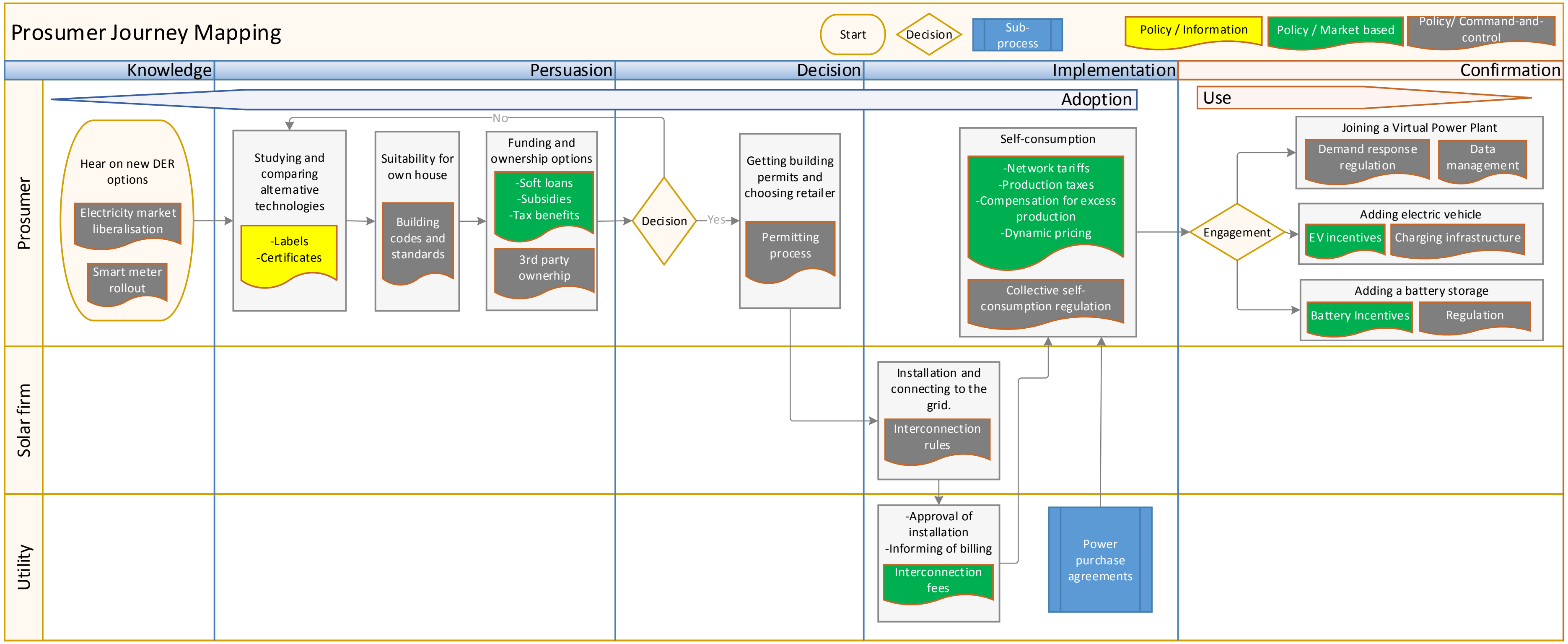

Figure 16. *Prosumer journey and regulation related to each step.*

It should be mentioned that the process is indicative and includes many feedback loops that are not as linear as the process introduced suggests. Here presented prosumer journey is not the only possible way to enter the prosumer ecosystem. EV adoption as well as participation in DR may lead in investing to own solar PV panels, for example. In addition, there are so-called passive prosumers who have not been actively seeking to invest in DERs. They have bought a house or an apartment that has already had microgeneration or has a leasing contract to one but not especially sought for such a functionality (Ford et al. 2016). The choice of concentrating on the micro production purchase is done for simplifying the process and because according to the general definition of prosumers, own production is element that every prosumer has and other DERs are accompanying it (see Ch. 2.1.3.). Finally, the process is also simplified by leaving out possible services, as consultations, utilities and third party actors can have along the prosumer journey.

3. RESEARCH METHODOLOGY

3.1 Methodological approach

The aim of this study is to compare prosumer related regulation and incentives in different European countries. Cross-national comparisons of public policies are conducted for different reasons like understanding how national contexts and ideologies affect the successful implementation of certain policies (Dupiuis & Biesbroek, 2013). Hua et al. (2016) notice that comparative policy studies are important for global RE studies as they observe also the policy learning effects between countries. They can provide understanding of the fundamental drivers of policy-making and how they are impacting the world (Dodds, 2012).

The thesis takes a pragmatist approach since the research questions demand and twofold approach. On one hand this thesis aims to collect and compare the policies objectively, meaning it takes merely a positivist approach. Assumption is that researcher is independent, value-free and is not affected by the subject researched. (Saunders et al., 2009) On the other hand, the research explores how the policies affect the prosumer innovation ecosystem, which demands more realist approach. In realism, researcher interprets the research issue and sees the findings are probably true (Healy & Perry, 2000).

The research questions demand also a combined research strategy. Comparing policies means merely a deductive approach but studying the ecosystem formation demands an inductive approach. Inductive research describes the problem rather than proofs a hypothesis. Inductive approach is needed because of the novelty and nature of the research subject. Prosumer ecosystem has been studied from each sub-system's point of view and policy studies are always context specific (IEA, 2014). The prosumer ecosystem is only now being created as prosuming has not been the paradigm for a long time. As there is only short time of data on the effects of the prosumer related policies, a cross-sectional time horizon is chosen. Policy analysis usually relies on historical developments with longitudinal or synchronic approaches (Dupiuis & Biesbroek, 2013, p. 3).

As the research questions look answers to question "what?", the country comparison is not a pure case study, which usually answers to questions "why?" and "how?", but a comparative research. As a notion to reader, the studied countries are still called as 'case countries'. For the limited resources, the research is conducted as secondary data research. Secondary data can be categorized into documentary and survey data (Saunders et al. 2009). Documentary data is typically used aside primary data collection but can be used also on its own in business history research, for example. Documentary secondary data include both written and non-written materials, but this thesis is only based on written material (Saunders et al., 2009, p. 258). Primarily, this thesis is based on information found in industry reports provided by European industry associations and regulatory institutions on the national and EU levels.

When sources vary a lot, evaluating data source quality is important. Saunders et al. (2009) propose a three-step evaluation process for secondary data sources.

1. Assess overall suitability, like measurement validity and coverage of data to research questions and objectives.
2. Evaluate precise suitability, like validity, reliability and measurement bias, of data for analyses needed to answer research questions and meet objectives.
3. Judge costs and benefits in comparison to other alternative sources.

Especially the second step in this process is important for this thesis because industry association reports are presumably biased towards their political agenda. However, they are in some cases also the most detailed source of information on the European level because their mission is to have good connections to all member states. Comparing industry papers to governmental sources can indicate which reports are of high validity. On the other hand, governmental papers may be overly conservative in their opinions.

Coverage of these reports is important to check country by country because the federal level information may not be accurate in all parts of the country. For example, Switzerland and Italy have delegated important duties to cantons and regions so the federal level indicators may show only the average information.

3.2 Case countries

Due to limited time and resources, the scope was limited to five countries, namely Switzerland, Finland Germany, Italy and France. The case countries are also the same as in a wider research project conducted within Tampere University of Technology and the University of Tampere. The countries represent well-developed countries with strong industries and welfare. This reduces confounding factors that arise from effects that cannot be distinguished from another factor (Kitchenham et al. 1995). Having a similar environment under the EU influence also helps choosing dependent variables for each policy instrument discussed. However, there are also many differences between countries. Firstly, geography of the countries vary remarkably, which also explains partly their energy mix choices. Secondly, they vary in their elements of the socio-technical regime: energy policies and regulation, energy production profiles, public perception of RE and knowledge and routines (Berninger et al. 2017). Yet, they are all integrated in the European energy market and all except Finland are situated in the heart of the central European markets. Creating the Energy Union under the European Union legislation harmonizes the regulation but national energy policy strategies remain different.

Swiss electricity system is experiencing changes in the amount of hydropower, nuclear energy and RE. Decision to phase out nuclear energy increases intermittent energy supply in the energy mix (SEDC, 2017). Many Swiss DSOs are owned by municipalities and forced to build and incentivise RE within local prosumers (Hüsser, 2016, p.25). The VPP tiko is a frontrunner in smart grid solutions in Europe and a good example of Swiss innovativeness in the DR side (Tiko, 2017).

Italy is Europe's second biggest market of solar PV. It has a history of energy saving policies and it is a frontrunner in smart metering. Its electricity mix is based on natural gas and it decided to phase out its nuclear plants after the Chernobyl catastrophe in 1986. Its share of RE in 2015 of total energy consumption was 17.5%., which means it has surpassed its target for 2020 (17,0%) (Eurostat, 2017). It has one of the highest prices of electricity in Europe, which also makes it attractive market for self-consumption and energy storage businesses. It has had challenges in integrating islands to mainland and integrating northern parts of the country to the south. (IEA, 2015)

Germany became the frontrunner of RE with the help of EEG starting in 2000. After the events in Fukushima in 2009, it decided to phase out from nuclear power before 2022. Its share of RE in 2015 of total energy consumption was 14.6%. and the target for 2020 is 23,0% (Eurostat, 2017) Electrification of the powerful car industry steers also the way of Germany's prosumer ecosystem.

Table 2. *Case country information (Ahola, 2015; Altenhöfer-Pflaum, 2014; Berninger et al. 2017; Castello et al. 2015; Hüsser, 2016; Kaaijk & Durand, 2016; Tews et al., 2016)***.**

	Italy	**Finland**	**Germany**	**France**	**Switzerland**
Electricity generation mix, top 3 (IEA 2015)	Gas 40% Coal 14% Hydro 16%	Nuclear 36% Hydro 26% Biofuels & waste 16%	Coal 44% Nuclear 14% Wind 13%	Nuclear 78% Hydro 10% Wind 4%	Hydro 58% Nuclear 35% Biofuels & waste 4%
PV installations in 2015	298 MW	5 MW	559 MW	850 MW	300 MW
LCOE of unsubsidized PV (Huld et al., 2014)	0,12 €/kWh	0,22 €/kWh	0,17 €/kWh	0,15 €/kWh	0,15 €/kWh
PV installations total	18,9 GW (end of 2015)	20 MW (end of 2015)	38,6 GW (end of 2014)	6,6 GW (end of 2015)	1,36W (end of 2015)
Current political agenda	High energy prices, energy market liberalisation.	Dependency of imports. Future role of CHP plants and biomass.	North-south grid expansions. Nuclear phase out by 2022. Social acceptability of rising electricity prices.	Reduction of nuclear to 50 % of electricity mix. Financial problems of sector players.	Nuclear phase out by 2025. Declining hydro.
Country-specific factors (IEA 2017)	First EU country to install smart meters. Nuclear phase out in 1980s.	Dark long winters. Expansion of nuclear capacity. Integration in Nordic-Baltic market.	Home ownership rate only 52,5%. Strong car industry.	Highly centralised energy sector.	Utilities typically owned by municipalities and relatively small.

Finland has a relatively centralised energy regime based on nuclear energy and CHP plants for electricity and heat (Berninger et al. 2017). RE comes mainly from bioenergy due to strong role of forest industry. Finland's position in the north makes use of solar power challenging. It is reliant on electricity imports during peak demand periods but commissioning of Olkiluoto 3 plant will ease the situation. It is part of the common Nordic electricity market Nordpool. Its share of RE in 2015 of total energy consumption was 39.3%., which means it has surpassed its target for 2020 (38,0%). (Eurostat, 2017)

France has a highly concentrated electricity markets with regulated tariffs. Renewable energies are less established compared to its neighboring countries. It aims to lower its use of nuclear energy to 50% of its electricity usage by 2025 and on the same time increase the amount of RE (IEA, 2017b). Its share of RE in 2015 of total energy consumption was 15.2%. and the target for 2020 is 23,0% (Eurostat, 2017).

3.3 Policy inclusion

Choosing the policies affecting prosumers was done according to their relevance and comparability. For finding out the relevance, recent prosumer-related reports, position papers and articles were gathered and occurrence of different policy actions was listed (see table 2).

Table 3. *Initial policy papers and articles for policy inclusion.*

		IEA, 2014	Masson et al., 2014	Eurelectric, 2015	CEER, 2016	European Commission, 2016	Keles et al., 2015	SolarPowerEurope 2016	SEDC, 2016	BEUC, 2016	Roberts, 2016	Valles et al., 2016	Tews et al., 2016	Daly, 2016
Smart meter diffusion	9	X		X	X	X	X		X			X	X	X
Market liberalisation	4	X	X							X			X	
Dynamic pricing	7	X		X	X	X		X	X				X	
Battery incentives	3					X							X	X
Electric vehicle incentives	3	X				X	X							
Standardisation and certifications of technology	4					X			X			X	X	
Transparency and understandibility of the tariffs and incentives	6	X		X	X					X	X	X		
Tax reduction	3								X		X		X	
Soft loans	3								X		X		X	
Grants	3	X		X									X	
Authorisation procedure	7	X				X		X	X	X	X		X	
Connection fees and taxes	6	X	X			X				X	X		X	
Demand response and flexibility compensation	9	X	X	X	X	X			X		X	X	X	
Self consumption compensation	10	X	X	X	X	X	X	X				X	X	X
Compensation of excess production	8	X	X		X	X				X	X		X	X
Network charges and other levies	13	X	X	X	X	X	X	X	X	X	X	X	X	X
Taxes on self-consumtion and production	10	X	X	X			X	X	X	X	X		X	X
Other compensation mechanisms (e.g. aggregating or P2P)	8	X	X	X	X	X			X		X	X		
Data security	4					X			X			X	X	

Already published cross-country comparisons IEA, 2014; RES Legal, 2017; Veum et al., 2016, steered the choices related the possibilities to make a cross-country comparison. The comparability of policies is not always easy to implement because in some countries the policies are implemented in different level. Local-level policies, like information campaigns were excluded. If the policy is usually state-level, like grants, it was still included in the scope. Standardisation was mentioned in many papers but is related to many issues and hard to compare and therefore it was left out of the scope. 'Transparency of incentives' or 'policy stability' was mentioned in many papers but it is also difficult to compare between countries, so it was leaved out of the scope. Dynamic pricing was also mentioned in many papers but it is handled under market liberalisation since offering different pricing schemes is related to market opening. After going through the data, they were narrowed down into 16 topics. Tax benefits, soft loans and grants were gathered under 'investment aid' and data management, and explicit demand response and data management were handled in Aggregation chapter.

The research was conducted through secondary documentary data, and this has to be taken into account when evaluating the validity of the results. The outcome is not exhaustive in a way that it would include every support system for RE. Political interventions that affect prosuming more indirectly include, for example R&D grants for companies, ETS, carbon taxes and policies affecting education and consumer awareness in general.

3.4 Data collection

The data used in the thesis is secondary data. Main data sources were European-level industry associations and advocacy organisations and reports for European Union institutions. Research reports conducted for the European Commission or the European Parliament were done by research centers like Smart Grid Task Force (2015) and consortiums (Veum et al., 2016) or regulatory bodies, like CEER (2017). Used associations were, for example, BEUC (2016), Eurelectric (2015), EuroBAT (2016), Smart Energy Demand Coalition (2017), SolarPowerEurope (2015) and Client Earth/Greenpeace (Roberts, 2016). European Commission's online database on country-specific regulation was also useful but not always accurate (RES Legal, 2017). Full list of sources is in table 4.

Academic journals were used in cases where the data was not accurate enough or needed more explanation. This sequence was due to the delay of academic publications. In the fast moving energy field, these publications tend to lose their accuracy even though they provide more in-depth analysis on many developments. They were used more as a source when describing the regulatory measures investigated. These papers were searched from Google Scholar and Web of Science with search words from each sector. For example, regulation of battery storage was searched with words "energy storage" and "European Union". The data is complemented and validated with information from national and regional sources like utility websites and consumer helping websites. This kind of search from sources in German and Italian sources was not done due to language barrier, which is taken into account when evaluating the validity of the results from these countries.

Table 4. *Used secondary data categories and sources.*

Source	Italy	Finland	Germany	France	Switzerland
Governmental / international organisations	Castello et al. 2015 RES Legal, 2017 IEA, 2016b Veum et al., 2016 AF-Mercados EMI, 2015 Cambridge Economic Policy Associates Ltd, 2017 IEA-PVPS, 2016 European Commission, 2015 IEA-HEV, 2016	Finnish government, 2017 IEA, 2017a Ahola, 2015 RES Legal, 2017 AF-Mercados EMI, 2015 Energiavirasto, 2017 Eurostat, 2017 European Commission, 2015 Bertoldi et al., 2016 SGTF, 2015 Sähköinenliikenne.fi, 2017	RES Legal, 2017 Marzocchi, 2016, p. 28 Veum et al., 2016 SGTF, 2015 IEA, 2017	de l'Elpine, 2017 RES Legal, 2017 Hespul 2015 Courtel 2017 Kaaijk & Durand 2016 Bertoldi, Zancanella, & Bozakiss, 2016 SGTF, 2015 Ministère de l'Environnement de l'Énergie et de la Mer, 2016, 2017	EDNA, 2016 OCEN 2013 IEA, 2013 Canton de Geneve, 2017 Hüsser, 2016 RES Legal, 2017 IEA-HEV, 2016
Interest group	Dunlop & Roesch, 2016 BEUC, 2016 ACEA, 2017 Eurelectric, 2015b	Eurelectric, 2015b SEDC, 2017 FinSolar, 2017 ACEA, 2017 Lehto, 2016	BEUC, 2016 Eurelectric, 2015b SEDC, 2017 Dunlop & Roesch, 2016 ACEA, 2017 Tietge et al. 2016	SEDC, 2017 Eurelectric, 2015b	SEDC, 2017 AEM, 2016
Academic	Valles et al., 2016	Erlinghagen et al., 2015	Tews et al., 2016 Valles et al., 2016 Strupeit & Palm, 2016	Valles et al., 2016	
Other	Mayr, 2016			CMS, 2015a EcoInfos, 2017	CMS, 2015b SIG, 2017 Romande Energie SA, 2016

The aim was to gather the most current information of the regulation and incentives used in the countries. This is because the regulation is changing rapidly across Europe due to the liberalisation of the energy markets and changes in DER technology prices. Therefore, data from sources published before 2016 were checked and used only if more timely information was not available.

3.5 Data analysis

The thesis is divided into chapters of different parts of the energy prosumer ecosystem. This ecosystem is structured within different phases of an energy prosumer journey, which starts with installing own energy production and then extending the system with EVs, batteries and DR. The journey model is common way of demonstrating the purchase of residential solar PV system. It is used oftentimes by utilities, help centers or associations when explaining the bureaucracy steps (e.g. Caruna, 2017; Dunlop & Roesch, 2016; EcoInfos, 2017). Customer journey enables quick digesting of the process, addresses complex non-linear nature of the journey, generates ideas and discussion and encourages to work with diverse teams (Ortbal et al. 2016).

The phases of the journey are derived from Rogers' innovation adoption model (Rogers, 2003). The prosumer actions illustrated in this thesis are modified from the solar PV customer journeys used by utilities mentioned earlier. Each policy instrument is attached to certain prosumer activity. The indicators should measure the actual phenomenon (Carmines & Woods, 2005). Each policy has its own indicators that replicated from the data sources used. Besides availability, relevance and comparability steered the indicator decisions. Analysis aims to describe the policy pathways countries take. The data of each regulatory issue from each country is summed up in an Excel table in the Discussions chapter. There, it is also evaluated within a three-level scaling, modified from BEUC (2016), IEA (2014), Veum et al. (2017) and Ranchordás (2015).

4. RESULTS AND DISCUSSION

4.1 Phase 1: Knowledge

4.1.1 Liberalisation of the energy markets

Bringing new innovations to the market happens by removing barriers for competition. Especially prosumer innovations needs working retail markets where consumers have real options and utilities develop different products and energy services. Before the liberalisation of the energy markets, the utilities in Europe were, and in some cases still are, monopolies that are owned by the state (Barrett 2017). Political actions on institutional changes related to market liberalisation include grid access rules, network pricing, risk management, market transparency and consumer protection (Markard & Truffer, 2006). Unbundling DSOs from generation activities ensures that all actors have access to the network. CEER (2015) measures market functioning by low concentration, low market entry barriers, close relationship between wholesale markets and retail prices, range of offers like DR, availability of comparison tools and consumption data, switching rate and consumer protection. Reforms to achieve liberalisation are summarised in table 5.

Table 5. *Energy market reforms (Jamasb & Pollitt, 2005).*

Restructuring	-Vertical unbundling of generation, transmission, distribution, and retail supply activities -Horizontal splitting of generation and retail supply
Competition and Markets	-Wholesale market and retail competition. -Allowing new entry into generation and retail supply
Regulation	-Establishing an independent regulator -Provision of third-party network access -Incentive regulation of transmission and distribution networks
Ownership	-Allowing new private actors -Privatising the existing publicly owned businesses

The basic idea is that only generation and supplying electricity are to be profitable businesses. The rationale for market liberalisation derives from increased competition, efficacy and innovation. Open markets are seen as a prerequisite for development of the supply and DR. Concern is that vertically integrated suppliers, who own both generation and supply, do not have an incentive to offer energy efficiency and DR products because they want high wholesale prices (Eurelectric, 2015b). On one hand, market liberalisation has created new roles in the market, enabled new entrances and increased decentralised production. It has increased the amount of strategic alliances and innovation networks. On the other hand, it has also brought the guiding principle of profits and shareholder value to the energy market (Verbong & Geels, 2007, p. 1031). As the electricity is mainly a commodity business, in theory the strong players should have advantage in the market place and increase their market share. In practice, the results of market liberalisation have been hard to predict and vary across countries (Gencer et al., 2017).

The implementation of the liberalisation means steering a systemic change, because effects of the change will affect every actor of the system. State will have less power to the energy market as state-owned monopolies are privatised and an independent regulatory authority is assessed. Markard and Truffer (2006) see market liberalisation as a fundamental change in the electricity innovation system. They see it has created a shift from incremental and technology-oriented innovation more radical and customer-oriented product innovations. More generators come as the grid access is authorised. Transmission system operators' (TSO) and DSOs' role is to be neutral market facilitators. Customers get more options of supply and pricing. (Jamasb & Pollitt, 2005)

Dynamic pricing

The biggest impact of market liberalisation for consumers is changed energy bill. If prices reflected the actual scarcity, the prices would rise during times when the demand is high and supply is low. Current dynamic pricing schemes do this in different ways. In static Time-of-Use (ToU) pricing, the hourly prices are set beforehand with the help of overall market prices during these times. ToU pricing can be adjusted to reflect seasonal changes, daily changes or peak load. Critical Peak Pricing (CPP) is an event-based scheme in which the price is increased for short periods. It is typically used for larger industrial customers. In real-time pricing, the price is updated constantly and communicated to the consumer. Dynamic pricing requires defining the price zones since demand, supply and grid congestions happen in different geographical areas. This kind of system is called a nodal pricing system (Jong et al., 2017, p. 19).

Implementation of dynamic pricing is a systemic change that affects people's everyday life and companies that implement it. Consumers' motivation for choosing dynamic pricing and changing habits to save energy require understanding of the effects their actions have. Therefore, consumers should be provided with clear information of the contracts (Eurelectric, 2017). Smart meters and other automation is required to be in place at the supplier and consumer. Suppliers need to adopt new ICT-based technologies and processes. Dynamic pricing helps to follow consumers load profiles and can therefore reduce retailers' market hedging and revenues (SEDC 2016). Local pricing zones would create better price signals for new investments but changes in the zoning also uncertainty (Jong et al., 2017, p. 19).

The effect of liberalisation of the energy markets on energy prices is debatable when big portion of the energy bill goes to taxes and surcharges. One of the rationales of liberalisation was to drive the prices down but different political supports combined to electricity bills have diluted the effect the customer would otherwise would have seen. In fact, the cost of energy itself has come down in average by 7 % between 2008 and 2014. The rise of taxes and levies (+47%) and network charges (+18%) have actually increased the final electricity bills of consumers (Eurelectric, 2015b). The household retail prices in the case countries are shown in figure 17. Prices in Germany are one of the highest in Europe alongside Denmark and Belgium, prices in other countries are lower (Eurostat, 2017).

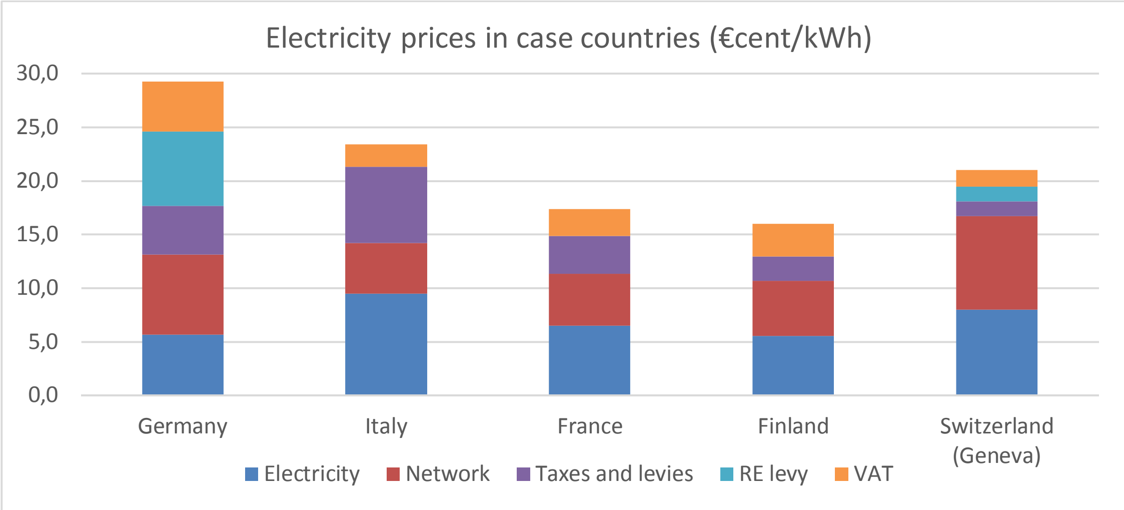

Figure 17. *Electricity price formation (own elaboration from Bourgault et al., 2016; Energiavirasto, 2017; Eurelectric, 2015a; Eurostat, 2017; SIG, 2017).*

High prices may hinder the electrification of transportation and heating sectors, which reduces DR possibilities within their functions. On the other hand, high consumer prices can drive energy efficiency and self-consumption as their profitability increases. Taxes and network charges may become a driver for efficient use of energy in a grid-wise manner if they are priced dynamically (Eurelectric 2017). However, keeping them as fixed proportionate in the bill only reduces that kind of responsive effect.

In theory, market liberalisation should thrive innovation and new entrants to the market. This has also been proven empirically as markets that were opened earlier have in average more competition and customer engagement (ACER, 2015). It is a horizontal policy instrument, which enables innovation ecosystem to develop. It, however, requires informational policies alongside, so that consumers get better involved. The challenge is that support for RE has decreased wholesale prices and created difficulties for companies to predict the market. In that sense the policy has not been very coherent.

Approach of the European Union

Market liberalisation has been driven in the Electricity Market Directives of 1996, 2003 and 2009. These directives include rules like non-discriminatory grid access, designating regulatory authority at national level and founding of ACER. Member states have had a lot of freedom in implementing the measures (Barrett 2017). Alongside national market liberalisation, the EU has pushed cross-border trading and transmission. Now it is forming an Energy Union for harmonising the energy markets to a single European-wide energy market (European Commission, 2017b). Mechanisms set to achieve this are: free entry to generation, unbundling TSOs and DSOs, funding new interconnections between countries, technical arrangements like cooperation in DSO-TSO levels and joint energy markets like the NordPool in Scandinavia and the Baltic countries.

Table 6. *Market liberalisation in case countries.*

	Market liberalisation description	Amount of generators and suppliers (Eurelectric, 2015b)	Households with dynamic pricing (ACER, 2015, p. 27)	Source
IT	Liberalised markets. High interconnectivity and standard offers still dominate market.	Main generation utilities: 3 Electricity retailers: 412	Over 75% have ToU pricing.	(BEUC, 2016; Cavasola & Ciminelli, 2017)
FI	Liberalised markets.	Main generation utilities: 4; Electricity retailers: 70	50-75% have ToU pricing.	(Energy Market Authority, 2016)
DE	Fully liberalised, increasing competition, broad choice of offers.	Main generation utilities: 4; Electricity retailers: >1000	Under 25% have ToU pricing.	(BEUC, 2016; Eurelectric, 2015b)
FR	Competition is open but EDF and its subsidiaries own almost all generation, transmission and distribution. Still regulated prices.	Main generation utilities: 1; Electricity retailers: 183	50-75% have ToU pricing; under 25% have CPP.	(CMS, 2015a)
CH	Liberalisation undergoing, smallest customers cannot choose supplier yet. ElCom regulates fees.	Very fragmented electricity market with over 900 utility companies. 6 utilities own 80% of generation capacity.	N/A	(CMS, 2015b)

4.1.2 Smart meters

Smart meters are "advanced meters that identify consumption in more detail than conventional meters and communicate via a network back to the utility for monitoring and billing purposes" (The Climate Group, 2008). They are replacing the old manually read electricity meters. The concept of smart metering can be categorised to different technologies and terms. AMR (Automated Meter Reading) means that the utility can receive the information from the meter from distance. The benefit is mainly that the utility gets the billing information from distance and the information flow is only to the direction of the utility (Rashed et al. 2014). AMM (Automated Meter Management) means that information flow is bidirectional so that distance control of the valves, for example, is possible. AMI (Advanced Meter Infrastructure) is a larger entity of software and displays and supplier business systems that measures, collects analyses and communicates the information to all parties. AMI is regarded as an important building block of the smart grid infrastructure. (Zhou & Brown, 2017, p. 22; Barth et al., 2014, p. 20)

Smart meters enable new pricing schemes for utilities and regulators. Before diffusion of smart meters, real-time pricing was implemented only to industrial customers who could participate to DR. Smart meters enable remote control of appliances, load limiting for DR and communication with other intelligent devices. (Rashed et al. 2014) They can facilitate more RE to the grid since they give more information to the DSOs on the fluctuations and imbalances of the grid. For the early adopters of smart meters, the desired outcomes of the smart meter rollout include reducing carbon emission, gaining competitive advantages in the global market, increasing customer awareness and activity by more information and simplified supplier switching processes (Zhou & Brown, 2017).

The challenges of the rollout lies in the constantly developing technology, unclear needs and privacy issues. Smart meters have different standards caused by different strategic interests of technology providers, utilities and governments. Some standards are open for everybody, whereas choosing other standards means dependency on certain suppliers (Erlinghagen et al., 2015, p. 1254). The first smart meters installed in 2001-2007, for example in Italy, were based on proprietary standards, which have now a large installed base. However, the new standards are more open and will probably gain bigger share of future meters. Utilities have to analyse future needs of the grid and how advanced meters they want to install. Reaching distant users and adding data exchange adds costs. The average cost of delivering smart metering system is from €200 to €250 per customer (European Commission, 2014a).

Implementation is usually done by DSOs who also take care of the metering. DSOs are responsible to plan the functional requirements and communication standards within the frames the governments choose (Erlinghagen et al. 2015). DSO remuneration regulation is important factor in the smart meter diffusion, because the large financial burden of the rollout. Regulation may include quality incentives that allow DSOs to raise network tariffs. Technology providers, like Sensus, Landis + Gyr, GE Energy and Elster, have naturally a big role. These examples are either European or have manufacturing capacities in Europe (Zhou & Brown, 2017). The communication network ownership goes to either the utilities or third party actors like mobile phone operators. Role of ICT sector will only keep on growing in energy sector, which makes it a challenging environment for incumbent players. (Erlinghagen et al. 2015)

Some countries have chosen mandatory regulatory measures for smart meter rollout as some countries have chosen partial or conditional policies. Naturally, the more binding policies have been more effective (Zhou & Brown, 2017). Early adoption of smart meters influences the pathway of technology development but includes also a risk of missing the technical standards that are developed after the adoption. The speed of the rollout determines also the target group of the policy. Residential segment may need other policies to support the rollout, such as information on the benefits of the new technology. For example, in Finland DSOs are obliged to provide customers in-home displays on their electricity consumption. Social acceptance is dependent on the fears of privacy violations, increased electricity bills and loss of control of electricity usage (Krishnamurti et al., 2012).

Approach of the European Union

Directive on the Internal Energy Market 2009/72/EC (European Union, 2009) says that at least 80% of the consumers shall be equipped with intelligent metering systems by 2020. The Clean Energy Package from 2016 states that consumers who do not have a smart meter should be able to have one when wanting to engage in dynamic pricing.(European Commission, 2017b)

Table 7. *Smart meter rollouts in case countries.*

	Smart meter rollout	Operator	Financing	Source
IT	99% by 2020, first European country to do the rollout.	DSO	Network tariffs and DSO resources	(Valles et al., 2016)
FI	100%	DSO	DSO	(Erlinghagen et al., 2015)
DE	Big consumers, new generation facilities. Expected diffusion rate by 2020 is 23 %. Finalisation for all consumers is expected in 2032.	Meter operator/DSO	Under study	(Tews et al., 2016; Valles et al., 2016)
FR	Rollout started in 2016, to be completed in 2021.	DSO, upon customer's agreement	Network tariff	(de l'Elpine, 2017; Valles et al., 2016)
CH	80% by 2025	N/A	N/A	(EDNA, 2016)

4.2 Phases 2 and 3: Persuasion and Decision

4.2.1 Building codes

Renewing the building infrastructure is slow since only a couple percentages of buildings are being renovated or rebuilt yearly. To accelerate the trend of energy efficient buildings, regulation can impose building codes on lower energy consumption, zero energy buildings and energy audits. Challenge is to change the current paradigm of concentrating on the up-front investment costs in the construction field (Berninger et al. 2017). Long payback times of energy efficient solutions have not been attractive investments for customers and construction companies who already struggle with high upfront costs. Usually construction companies are not responsible for the life-cycle costs of the houses. In addition, energy efficient solutions require deep cooperation within actors in the project development, which has not always been a common practice in the field. (Berninger et al. 2017)

Building codes address the potential issues RES have in buildings, such as, noise, visual and environmental impacts. (Sawin & Flavin, 2006, p. 23) Some regulation makes sure that buildings and infrastructure is suitable to the RES installations. Especially older buildings are not designed so that there would be space for solar panels, water heaters or charging equipment for EVs. The idea is that building codes affect the building construction phase and building materials.

Typically, the building codes set annual limits in energy usage. A downside of total consumption measurements is that timing of the energy usage has no weight in the regulation, which can hamper smart DR solutions. Sorri et al. (2016) offer some practical examples of building codes that has or could have an impact on DR. Regulation defining the readiness of buildings to accommodate DR could mean spaces for bigger boilers for heat storage. Seasonal and peak-time power usage requirements would result in lower peak demands. Timing energy use according to own production could be encouraged by synchronising instructions. Power management inside the building could be steered towards lower peak loads. (Sorri et al., 2016)

Building codes consist of a set of mandatory minimum energy performance requirements designed to regulated energy use in buildings (IEA, 2013). In that sense, they are command-and-control type of policy instrument. There are also voluntary aspects in the building code regulation.

The implementation network is often complex because of the fragmentation and locality of the construction industry. Level of implementation depends on the country but is usually done on the local level. (Berninger et al. 2017, ch. 3.2). Building permits are used when builder or renovator is applying for building licence. Building project developers can hire private experts in building inspections. On the macro level, standards are also an object of battles between organisations. Naturally, they can be used to restrict technology developments by unfavourable regulations. Different stakeholders who all have different interests in the technological development are creating standards: technology providers, users, complementors, standard development organisations, standard advocates and governments (Markard & Erlinghagen, 2017). At worst situations, the construction and energy policies may be misaligned. (IEA, 2013, p. 11).

Approach of the European Union

Directive of Buildings’ Energy Efficiency 2010/31/EU sets that new buildings that are used and heated regularly should be so-called nZEBs (nearly Zero Energy Buildings) in the near future. For public buildings this requirement starts in 2018 and other buildings in 2020. However, the directive leaves open questions of how much exactly of the consumption has to be produced on-site and how much of it has to be RE (Talus et al. 2016). Energy Efficiency Directive 2012/27/EU states that member states should renovate at least 3% of buildings yearly and energy distributors and retailers should have 1,5 % savings by energy efficiency.

Table 8. *Building codes related to prosumers in case countries.*

	Building codes and other requirements	Source
IT	Regions are responsible for building permits. All new buildings have to integrate RES-E and RES-H. (e.g. 35 % of warm sanitary water, at least 2 kW for 100m2 house)	(Castello et al. 2015, RES Legal, 2017) (IEA, 2016b, p. 9)
FI	No need for permits if the device does not affect environment or urban landscape remarkably. Different coefficients for different primary energy sources.	(Finnish government, 2017)
DE	PV plants are a subject to building law but roof-mounted PVs do not require permission. Energy Conservation Regulations (EnEV).	(RES Legal, 2017; Tews et al., 2016)
FR	PV plants do require a notification but not a building permission. Réglementation Thermique (RT): New buildings obliged to have RES-H; existing buildings have to improve their efficiency until 2020.	(RES Legal, 2017; Hespel 2015)
CH	Cantonal duty. Usual installations do not require building permissions but notice to municipality is necessary. Min. 20% of heat has to come from RE.	(OCEN 2013; IEA, 2015)

4.2.2 Labels and certificates

Standards and other product properties are informed to investors and consumers by different labels and certificates. Their aim is to promote energy efficiency and influence property developers (IEA, 2013). Some governments can require labelling that indicates how environmentally friendly products are or how much RES they use. They can be both regulatory measures but in essential, they are informational policies, which allows consumers to make better decisions. Their aim is to raise awareness and knowledge among all stakeholders: consumers, developers and public procurement offices but also designers, architects and other parties in the supply side. There is typically a highlighted dimension in a product or a service that is otherwise difficult to measure or estimate by the consumer.

Certificates are important in industry growth by giving credibility and quality measures. Finnish heat pump organisation SULPU is a good example of industry association that was able to solve quality issues by installer and product certifications and training (Berninger et al. 2017). Mir-Artigues and del Río (2016) say that densification of local suppliers and installers, better training of the labour force and greater standardisation of the systems can further reduce system prices. Labels and certificates facilitate the change in the market but do not guarantee any outcome and are therefore suitable as a complementary policy instrument. Implementing a certification or label scheme poses costs that have to be allocated to public or private actors. (Shailendra et al., 2013)

The implementation of the labels and certificates affects all stakeholders in the product supply chain as customers are integrating the label information in their purchase decisions. This demand effect will then alter the up-stream supply chain by improving building materials and processes. After the building is registered and rated, there may also rating on the usage of the building by measuring energy bills and meters. (EC-DG Energy, 2014)

Approach of the European Union

Directive 2010/31/EU of Energy Performance of Buildings mandates that the energy performance rating is shown when selling or renting the house. In addition to houses, the Eco-design Directive 2009/15/EC regulates the minimum energy performance and Energy Labelling Directive 2010/30/ of products like refrigerators, air conditioning, lightening and vehicles. The Energy Performance Labels of building are implemented differently by the EU member states. The EU is developing a new sustainability performance measures to value the full Life Cycle Assessment (European Commission, 2017a). The Clean Energy Package includes voluntary smartness indicator, which informs on building's capacity to use ICT to optimise operation with the grid (Council of the European Union, 2017). Directive 2009/28/EU states that certification and qualification schemes should be available for installers of different RES.

Table 9. *Labels and certificates in case countries.*

	Labels and certificates	**Source**
IT	SEU certificate for RE systems; lowers general levies of the system. Installer training programmes and mandatory certificates. Energy Performance Building Certificate (2009), EPBD Energy Performance Certificate (2009), Passive House - ZEPHIR (1990).	(Castello et al. 2015, RES Legal, 2017) (Dunlop & Roesch, 2016, p.89)
FI	Voluntary certifications for installers and construction companies. Energy Performance Certificate (2008), Nordic Ecolabel (Swan) (2009), Nearly Zero Energy Buildings	(Finnish government, 2017; IEA, 2017a; Lehto, 2016)
DE	Big emphasis on safety regulation and certificates. PV plants require Solar Keymark certificate. Trainings and obligatory registrations for self-employed installers. Passivhaus, Zukunft Haus: Energy performance certificate.	(Marzocchi, 2016, p. 28; RES Legal, 2017; Tews et al., 2016)
FR	A lot of effort in certificates and assessments due to building insurance policies. Big Certisolis TC, CSTB, QualiPV Elec for electricians and QualiPV Bât for roofers. Bâtiment Basse Consommation.	(de l'Elpine, 2017, p.31; RES Legal, 2017)
CH	CECB (Certificat énergétique cantonal des bâtiments), Minergie.	(IEA, 2013)

4.2.3 Investment aids

Access to capital is often named as a big barrier for RE diffusion (e.g. Balcombe et al., 2013, p. 658). Contrary to the conventional energy sources, high upfront costs with low operational costs are typical for most RES. Once the initial investment is done, the system produces energy with very low operational costs. Same logic works for heating, energy efficiency and EVs. Alternative business models like leasing and contracting are increasingly introduced to the market. Possible financing methods are summarised in table 10. As the technology is still relatively new to many financial partners, RES are often regarded as a “new asset classes” by the banks. Spreading knowledge is one way of reducing the high upfront costs of RES. (Overholm, 2015)

Table 10. *Funding possibilities (Mir-Artigues & del Río, 2016).*

Origin of funds	Modality	Residential	Non-residential
Self-financing	Cash	Own savings	Internal funds
	Debt	Bank loans, home loans, specific loans	Bank loans
Third-party financing	Lease	Operating lease	Operating lease
	PPA	n.a.	Service contract

Tax incentives

Tax incentives can include tax credits and reductions to sales taxes and VAT. Taxation can also be used for property tax exemptions. Benefits as a policy instrument are related to the price signals they create to customers and obviation of governmental regulatory decisions. Tax reductions also allow governments to set limits on the amount they spend on the policy. The weaknesses of tax incentives is possibility of free riders who would do the investment decision anyway, incapability to decrease consumption and the fact that their effect on creating technology diffusion cannot be guaranteed because actual demand might not be increased. In addition, they have to be devoted to certain technologies and in that sense politics will be picking the winners. (Carley, 2011)

Grants

Grants are monetary assists provided by the government that do not have to be repaid. Usually there are conditions, like battery storage or DR applications on getting the grant like fulfilling certain standards. Sometimes they are used to allow banks to offer low-interest loans for RE systems. For the consumer, grants are simple and transparent. (IRENA, 2012; Tews et al., 2016) Downside is that the subsidy amount may increase prices. The subsidy can be calculated as a proportion of the cost or the capacity of the system installed and there may be a limit on the total support given.

Soft loans

Usually residential prosumers take a loan in combination of 20-40% share of their own equity. Loans may be connected to the FITs if they exist but normally they are just conventional loans with interest rate of 3-7%. Countries can guarantee low interest loans for RE investments when the interest rate can drop to 1-2% (Mir-Artigues & del Río, 2016). In addition, government loan guarantees can reduce financial risk and therefore lower the interest rate. This effect can be more seen in bigger investments. In developed countries, the loan possibilities are relatively good, but capital costs still vary a lot between countries. In developing countries, microfinance is an important tool.

These instruments are not mutually exclusive but often work as combined policies. Financial instruments at the investment phase have been categorised as secondary instruments (Mir-Artigues & del Río, 2016, p.275). Their effectiveness and success has been tied to primary instruments, like FITs. Now that the prices of RES have come down, they are connected to other complementary policies like information and regulatory measures. The effect of subsidising the investment itself may be effective especially in the circumstances where profits of the use are uncertain. Subsidies that are paid straight on the purchase are seen more efficient and easier for the dealer. (Bauner & Crago, 2015). They are also safer for the government as future electricity market and technology cost trends are less important than with subsidies that apply at the use phase. In addition, subsidising the investment does not affect the market as much as production subsidies.

Direct subsidies and tax exemptions require technology choosing from the government, which they are not perhaps willing to do. On the other hand, they enable supporting certain technology combinations. Current trend is that solar PV is bought in combination with other services or technologies like smart thermostats or energy storage (Dunlop & Roesch, 2016, p. 38). However, controlling the business models by supporting certain solutions may hinder innovativeness and long-term contracts with energy service companies (ESCOs). For example, targeting tenants, housing companies or leasing firms demands different designs. Rebound effects, like reduced demand and prices for fossil fuels should also be considered (Carley, 2011, p. 278). National government can implement grants but more often, they are applied on the lower governmental levels like regions or municipalities. Taxing is state-level competence.

Approach of the European Union

Member states have freedom to choose how they implement the investment subsidies, but they have to be accepted by the EU. The EU strives for reducing market distortions and creating level playing field for all technologies (European Commission, 2017b, p. 11).

Table 11. Financial support for investment in case countries.

	Grant	Soft loans	Tax reductions	Source
IT	Capital subsidies differ regionally.	N/A	Reduced VAT of 10% instead of 20% and reduced real estate tax of 0,4%.	(Castello et al. 2015; RES Legal, 2017)
FI	No grants for residential installations.	Can be financed with home loans, rates 0-2 %.	45 % tax reduction from the work component when installation done as retrofit to existing buildings.	(Ahola, 2015; Motiva, 2017)
DE	30 % grants from KfW-bank with requirement for a storage system or DSM-enabling technology.	Loan programs from 1 % annual interests connected to battery incentives from KfW bank.	N/A	(Tews et al., 2016)
FR	Grant of 400€-300€/kWp for self.-consumption installation.	Many commercial possibilities.	Materials have decreased 10 % VAT	(EcoInfos, 2017)
CH	Up to 30 % of installation cost, 500 CHF/kWp. Implementation varies between cantons, e.g. Genève offers 1200 CHF + CHF 500/kW for solar panels.	Usually financed by increasing mortgages: interest rate: 0,8%-1,5%.	N/A	(Canton de Geneve, 2017; Hüsser, 2016)

4.2.4 Third party ownership

McKinsey counts that service-related costs like financing, customer acquisition, regulatory incentives and approvals represent half of the expenses US customers paid in 2014 (Frankel et al. 2014). The shares in the case countries are shown in figure 18. It is clear that bringing these costs down have still potential to reduce to total costs of solar PV.

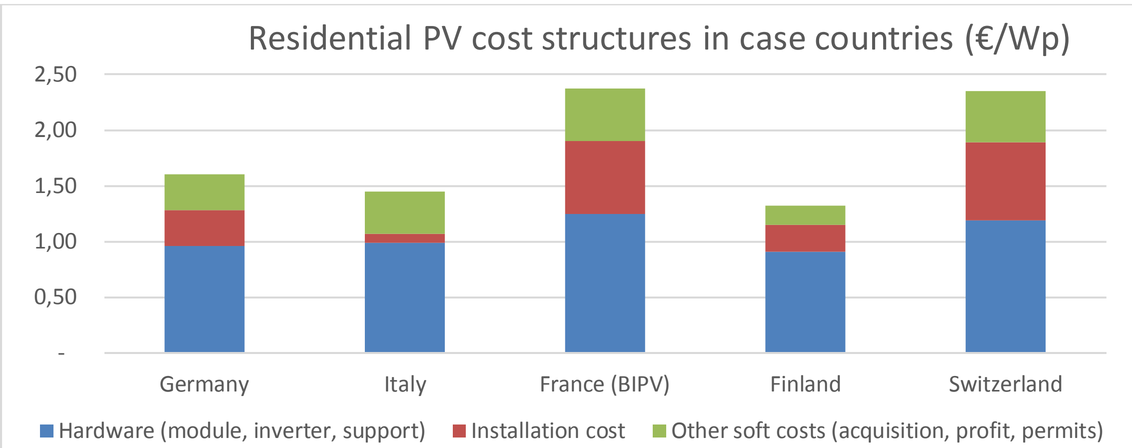

Figure 18. *Solar investment cost break-down in case countries (Ahola, 2015; Altenhöfer-Pflaum, 2014; Castello et al., 2015; Hüsser, 2016).*

Policies can encourage other financing and ownership models that address these problems (Berninger et al. 2017). Juntunen and Hyysalo (2015) say ownership models can be divided into local ownership at the production site or ownership outside the site. In developed countries, the traditional on-site ownership is normal. Third-party ownership (TPO) and financing model, shown in figure 19, is popular especially in the US markets. Idea is that solar service company plans, installs, owns and maintains PV systems for the customer and takes care of the financing. These TPO contracts include Power Purchase Agreements (PPA) like fee-for-service contracts or leasing possibilities like "rent-a-roof" contracts. In PPA model, the system and installation is free for the consumer but he pays a monthly bill that the developer uses to finance its business. They have different payment structures that are fixed or they can vary according the production. In some contracts, the consumer can purchase the system after certain period. Leasing contracts are common in car industry and office equipment. In them customer pays also a monthly fee for the system and not the production. Similar kinds of models are used by ESCOs in the field of energy efficiency and DR (Berninger et al 2017).

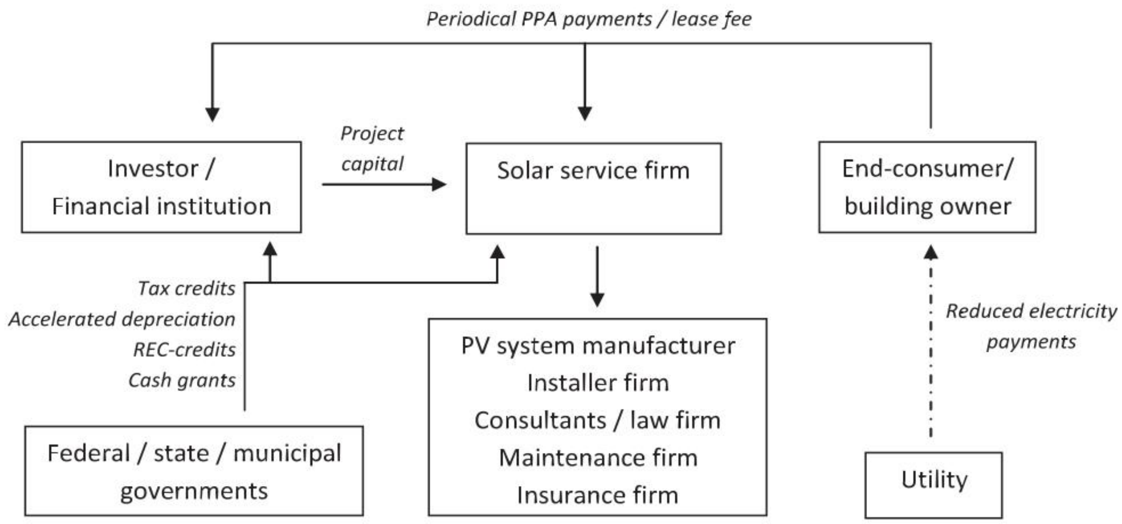

Figure 19. *Financial flows in TPO models (Strupeit & Palm, 2016).*

Benefit of the business model comes from the easiness of the service, which makes TPO models attractive to customers who are less engaged to the process and have less disposable income. TPO models decrease the complexity and risks of the investment, decrease upfront costs and effort on permitting and maintenance of the system. On the other hand, this efficiency is formed by learning efforts of whole business ecosystem that is often based on current technologies likes solar, and can in that way form lock-ins regarding other innovations like DR. Good financing conditions require often proven track record of successful projects which means use of the same technology also in the future. (Overholm, 2015)

TPO models have not diffused to Europe as they have in the US, which can be explained partly with policies. TPO companies in the US have had often close relationships with regulators and utilities, which has ensured transparent processes and stable regulatory framework (Overholm, 2015). TPO companies should be able to work legitimately without having to be classified as a utility. Other reasons are related to FIT system and financing possibilities. In the US, success of leasing and PPA contracts is based on tax credits and accelerated depreciation for solar assets, which bigger companies benefit from. To reach these benefits the service provider has to have large customer base, which forms also an entry barrier to the market. Electricity rate structure and level, and relatively high transaction costs of permitting, which is done more efficiently by companies than individuals, are other reasons for success. In addition, weak possibilities to get low-interest loans can push people to use TPO business models. (Strupeit & Palm, 2016) Possible barriers to TPO contracts come from national property regulation that need to allow fixed assets in privately owned property. Issues like responsibilities for damages and mortgage loan conditions have to be sorted out. In addition, leasing contracts may become difficult when the tenant of homeowner moves. (SolarPowerEurope, 2015)

Approach of the European Union

The Electricity Directive 2009/72/EU states that electricity markets should be open to all market participants and people should be able to choose their suppliers freely. Third parties should have similar rules to access the grid. In the Energy Efficiency Directive, the EU encourages municipalities to use integrated energy performance contracts and developing market for energy services (European Union, 2012).

Table 12. *Third party ownership in case countries.*

	Third party ownership models	Source
IT	Allowed but with conditions for net metering program 'Scambio sul Posto'	(IEA-PVPS, 2016)
FI	3rd Party ownership possible and several funding options available. PPAs, crowdfunding, renting with fixed prices. Some utilities provide financing for panels.	(Ahola, 2015)
DE	PPAs authorised but not common in residential market.	(Dunlop & Roesch, 2016; Strupeit & Palm, 2016)
FR	Legal framework uncertain. Used in commercial and industrial sectors. Leasing is a common instrument with own Energy Financing Company Sofergies.	(de l'Elpine, 2017)
CH	Practically not existing in Switzerland.	(Hüsser, 2016)

4.3 Phase 4: Implementation

4.3.1 Interconnection rules and costs

Issues regarding the grid connection include permission to interconnect, system size limitations, bureaucracy process, delay times and cost allocation of the reviewing, connections and grid upgrades. Grid connection rules are seen as efficient complementary regulation that supports prosumer diffusion. (Tews et al., 2016; Barth et al. 2014) It is command-and-control type of regulation that can be either horizontal or technology specific. In principle, all parties should have equal possibilities to interconnect and participate in the market but increasing interconnections require new kind of grid planning on the TSO/DSO level. Grid connection rules are in a way an indication of the openness of the energy market. Grid connection is guaranteed by legislation in some countries, which means that the DSOs have obligation to connect DERs to network. There may be also requirements for the grid operator to communicate the timetable of permitting, costs and compatibility checks. Priority dispatch is a mandate that RE supplies are integrated into energy systems before supplies from other sources (IRENA, 2012). There can be also solar or wind maps available that tell where it is easiest and most clever to install RES (IEA, 2014, p. 67).

In some countries, the costs of grid connection and applications are allocated to prosumer either fully or partly. This is often determined by the capacity that is being installed by the prosumer. In a way, it is prosumer's contribution to network's stability. If prosumer can reduce the peak production load to network by self-consumption, the grid fee may also be reduced. (Mir-Artigues & del Río, 2016) In some countries, a legislation guarantees that the connection is done for free or it is at least partly recovered for the prosumer. In addition, the grid extension costs have to be taken into account. They can be tricky to allocate to a few prosumers because strengthening the grid benefits other ratepayers too. Even though prosumers get a guaranteed connection to the grid, the obligation to buy electricity does not necessarily exist. If there is not a purchase obligation, prosumer has to find a retailer to whom to sell the electricity. Finding a retailer is not usually a problem but the price the utility will pay might differ from one company to another.

Desired outcomes of grid connection rules are cost efficiency and short delays. When the market is new and there are no rules regarding the interconnection, the evaluation of every project is long and technical requirements are not streamlined and standardised. Even if there are laws that require energy companies to do the interconnection, there is not necessarily the experience to do it. As the industry is still relatively young in many places in Europe, the interconnection experiences and capabilities vary a lot also between municipalities and regions. (Olkkonen et al. 2016) In some countries, the interconnection procedure may be only a quick check that everything is appropriately done whereas in some countries the costs and delay times may become a barrier for prosuming. These issues are, however, more common in commercial and industrial segments than residential segment (Barth et al. 2014). Interconnection rules are important facilitator for further prosumer diffusion because perceived difficulty of the investment is often a barrier in the later adopter segments. Simplicity is often very important to big majority of consumers. If the procedure is difficult, the value and role of TPO solutions rise like happened in the US (Strupeit & Palm, 2016). The priority dispatch encourage developing the electricity system but may also lead to higher system costs (Jong et al., 2017, p. 22).

Approach of the European Union

Before the Clean Energy Package in November 2016, The European Union mentions priority dispatch of RES as a desirable option. Now the European Commission proposes to end priority dispatch for producers of over 500 kW capacities, which therefore does not affect residential prosumers. Article 12 states that grid should be planned so that maximum 5 % of RES is curtailed. The 2009 Renewable Energy Directive (RED) says that small customers should be ensured a simplified and less burdensome authorisation procedures (European Commission, 2009).

Table 13. *Interconnection rules in case countries.*

	Interconnection procedure	**Cost allocation**	**Source**
IT	Hassle free priority grid access with little delays. Some local authorities may apply own rules and delay permission. DSO must connect the plant within 30 day.	Upgrade costs recovered from network costs.	(BEUC, 2016; RES Legal, 2017)
FI	Law does not regulate the grid connection procedure so it depends on the DSO. No timeframe but unreasonable delays are covered (max €3000). Non-discriminatory criteria but no priority access.	Grid operator can ask a reasonable price for the connection but is not obliged to pay for grid upgrades.	(Ahola, 2015; RES Legal, 2017)
DE	Hassle free priority grid access and purchase. Grid operator is obliged to offer the installations without delay. Only 70% of capacity can be fed into grid or the system has to be also remotely curtailable.	Upgrade costs recovered from network costs.	(BEUC, 2016; Tews et al., 2016)
FR	Grid operator has to deliver connection plan in 6 weeks and installation after 2 months of the acceptance. (18 months for bigger) Unclear if there will be a limit for SC systems.	Connection costs approximately 180€/kW. Exceptoin form Linky smart meters. Plant owner pays grid extensions.	(Courtel 2017; Kaaijk & Durand 2016; RES Legal 2017)
CH	Grid operator checks the connection in 30 days. Non-discriminatory criteria but no priority access. Differences depending the DSO.	The costs for grid connection are borne by the energy supplier.	(RES Legal, 2017)

4.3.2 Indirect benefit from self-consumption

Self-consumption (SC) has become more and more popular way of integrating RES to the grid as the costs of RES have reached grid parity in several countries. The financial benefit of SC comes from savings in the electricity bill. The retail price of electricity is formed of three components: electricity, taxes and network costs, which all entail about one third of the bill (Eurelectric, 2015a). Electricity part includes the production in power plants, trading and selling to customers and the customer service of utilities. Network costs are the transport costs, which cover the costs of delivery of electricity to homes and construction and maintenance of power lines and other infrastructure to do it. Rest of the bill includes taxes and other levies like RE support costs or support for vulnerable customers. In countries like Germany and Denmark, which have introduced a lot of RE, this part is relatively bigger than in other countries (Eurelectric, 2015b).

In many countries, the excess electricity fed into the grid gains only the wholesale price, which is often not enough to be financially attractive. In some cases, there can be a feed-in premium or tariff but the levels of them have come down during last years. In addition, a limit on the amount of electricity fed to the grid may reduce system sizes. The SC rates for residential homes are usually around 30 % depending on country (Keles et al., 2015).

The change of the business case from FITs to SC is illustrated in figure 20. The line A refers to the difference between levelized cost of electricity (LCOE) price of the own production and the retail price of electricity. The line B refers to the difference between the LCOE price of own production and the FIT price, which is set to be slightly higher than the LCOE price. For example in Germany's case, prosumer self-consuming saves the 29 cents of retail price by SC but on the other hand loses the FIT of 12 cents. Remaining 17 cents resembles the net benefit the prosumer gains. Since network tariff formation and taxation are the cornerstones of profitability of the SC model, they are studied more in detail in the following chapters.

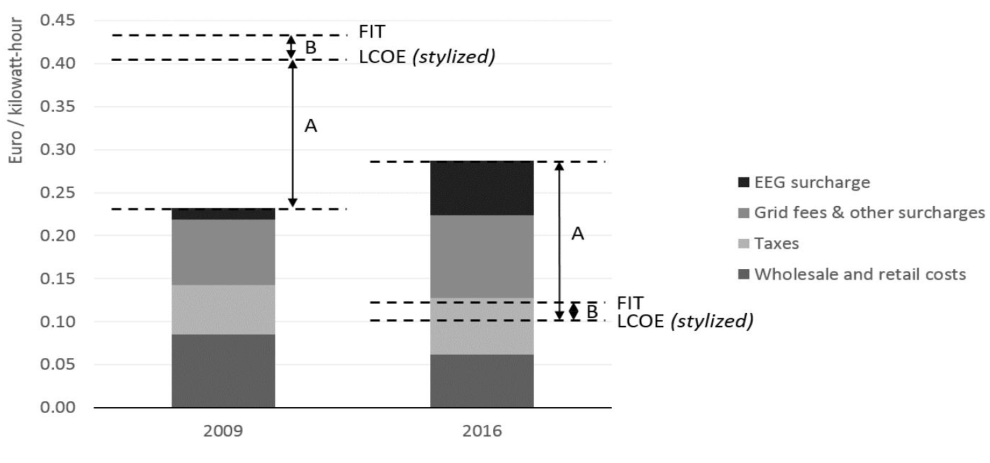

Figure 20. *Change from FIT remuneration to SC business model (Schill et al. 2017).*

The aim and tools of SC are debatable. SC is a better solution for grid stability than FIT or net metering. Most importantly, SC is a driver of flexibility that is well aligned with DR, battery storage and other smart solutions (European Commission, 2015). However, some point that the SC rate should be maximised whereas others highlight the importance of prosumer's activity in the market. According to BEUC (2016) "isolated system", like houses with high SC rate, would not provide that. In addition, the decreases in tax revenues and network charges cause problems for DSOs and the state.

Network tariffs

Increasing amounts of smart appliances, storage, EVs and microgeneration are reasons network tariffs are being now re-designed or re-evaluated in Europe (CEER, 2017). As RE has a decentralised nature, the emphasis is moving away from a grid serving only unidirectional electricity flows. As prosumers produce their own energy, less grid is used but fluctuations increase. With volume-based network tariffs, prosumers pay less network charges than regular consumers do. However, prosumers use the grid as back up because going off-grid requires very big capacities of storage. Independency from the grid is a possible future in some areas when battery price get down (Baker et al. 2016). In this sense, there is a possibility of so called "death spiral" for utilities if no structural changes are done (IEA 2014). Although there are concerns of this phenomenon within utilities, some policy makers address that small changes in ratemaking can answer it.

Objectives of ratemaking can be divided into sustainability, economic efficiency and protection principles (AF - Mercados EMI 2015). According to CEER (2017) the general objective of rate planning is to achieve cost reflectivity, non-distortion for innovative solutions, cost recovery for DSOs, non-discriminatory for different kinds of consumers, transparency, predictability and simplicity.

Most European countries have still volume-based tariffs at the distribution level, but some countries, like Spain and the Netherlands have shifted into capacity-based charges (CEPA, 2017). The benefit of capacity-based tariffs is that they reflect well the actual network costs, which are derived from the peak demand requirements. The disadvantage of them is that they do not encourage energy efficiency and punish low consumption hous eholds. As a solution, some countries have introduced hybrid pricing that take both, volume (€/kWh) and capacity (€/kW) into account. Also a fixed charge (€/period) or dynamic pricing schemes are possible. The more the network component remains fixed, the more the incentive to react to the market supply weakens. (Picciariello et al. 2015; Valles et al. 2016) Different rate options are listed in table 14.

Table 14. *Different ways of charging network costs (CEER, 2017).*

Tariff structure	**Explanation**	**Advantage**	**Disadvantage**
Fixed charge or contracted capacity charges	DSO determines certain fixed level that can be based on e.g. installed capacity. (€/day; €/month; €/year)	Simple, stable and predictable. Can signal capacity costs.	No signals of long-term costs. Does not encourage energy efficiency.
Capacity usage based tariff	Charged retrospectively according to highest used capacity.	Incentivises lower peak power usages.	Does not encourage lowering energy consumption. Bad for SC business models.
Energy usage based tariffs	Relative to the energy taken from the grid. Also called volumetric tariff. (€/kWh)	Acceptability of consumers. Encourages energy efficiency.	Uncertain revenue for DSOs. Does not reflect always the system peaks.
Static ToU tariffs	Certain hours have higher charges according predicted peak hours of the network.	Makes planning of flexibility easy.	Don't take into account intermittent RE production, use of storage and DR.
Dynamic ToU tariffs	Price bands can change on day-to-day basis or more frequently to reflect e.g. very hot or cold days.	System benefits. SC and storage to avoid peak hours.	Risk of simultaneous responses, e.g. with EVs.
Interruptible tariffs	DSO can interrupt system usage of its customers for security and system reasons. Used for e.g. electric heaters or freezers.	Easy to invoice, predict and compare flexibility options.	Does not encourage decreasing energy consumption or peak usage.

The profitability of the SC model depends heavily on the network tariffs. Yet, there has to be a systemic approach on the tariff design because they also affect the network and different technologies. In fact, the same incentives that influence prosuming patterns may have an opposite effect on the network system. The combined price signals from higher network tariff and lower electricity price may eradicate each other's effect. For example, low wholesale prices during sunny days may incentivise to load batteries and EVs, but also congest the grids. Cost reflectivity is therefore important for sustainable grid development.

Capacity-based tariffs can encourage battery investments that can lower the peak demand. Solar PV would be installed to reduce to peak consumption and home appliances would be controlled so that, for example washing machines and electric saunas are not on at the same time. On the other hand, EVs and DR require high capacities if they are to be a fully used as flexibility resources (Honkapuro et al. 2017, pp.45-52). Implementing different prosumer market models like peer-to-peer, prosumer-to-grid and prosumer community models (Parag & Sovacool 2016) require certain amount of interconnections between prosumers, which means that minimising capacities is perhaps not the optimal solution. Another issue that has to be thought is public acceptance of the changes. Cross-subsidisation effect happens when more of these costs are allocated to non-prosumers.

The implementation network normally consists of European-level directives, the local energy regulator, DSOs and end-users. Regulators create a regulatory framework according to the European directives that NRAs implement for the DSOs. In some countries, DSOs can decide the tariff structure themselves. Remuneration regulation of electricity distribution for the DSOs is the other side of the issue. Regulating DSOs is a regulatory issue because DSOs are natural monopolies. In practise, NRAs follow how much network operator gets revenues. Allowing and incentivising them to be innovative on DR and storage, for example, depends on the regulation. Valles et al. (2016) suggest profit sharing schemes as well as accelerated depreciations and longer regulatory periods for new framework.

Network tariffs create conditions in the whole electricity system and are therefore technology-neutral. Even though the rules may be same for all technologies, the way of implementing the network tariffs affects how the prosumer ecosystem will shaped up since it will support other technologies more than others. This policy should be accompanied with information policy instruments because consumer do not necessarily understand the effect of different appliances on the peak demand.

Approach of the European Union

Directive 2012/27/EU of Energy Efficiency Directive states: "Network tariffs shall be cost-reflective of cost-savings in networks achieved from demand-side and DR measures and distributed generation, including savings from lowering the costs of delivery or of network investment and a more optimal operation of the network". (European Union, 2012)

Table 15. *Network tariff regulation regarding self-consumption.*

	Network tariffs	**Self-consumption costs**	**Source**
IT	Fixed + capacity (34 %) + energy (66 %); Nationally almost uniform. Tradition of having progressively increasing energy part. Change towards capacity and fixed pricing.	Under 20 kW systems' self-generation exempted from grid costs. Bigger gradually exempted. Small fee of 15-45 € depending on system size to cover management and control.	(Veum et al., 2016; AF-Mercados EMI, 2015, p. 114; CEPA, 2017)
FI	Fixed (50%) + energy (50%); Depends on the DSO.	No grid tariffs on SC.	(AF-Mercados EMI, 2015; Energiavirasto, 2017)
DE	Fixed (20%) + energy (80%); each DSO sets own tariffs.	No grid tariffs on SC.	(Tews et al., 2016; Valles et al., 2016; Veum et al., 2016)
FR	Fixed (6 %) + capacity (14 %) + energy (80 %); Nationwide uniform; voltage and optional TOU	No grid tariffs for SC.	(EcoInfos, 2017; Valles et al., 2016)
CH	Volumetric tariffs.	No grid tariffs on SC.	(Hüsser, 2016; SIG, 2017)

Taxes and levies

Energy has always been an efficient way of collecting taxes and on the same time to controlling energy consumption and incentivising energy efficiency. Now that the energy field is in transition, also ways to tax it are under changes. Besides taxes, consumers pay surcharges for RE support in some countries. Other surcharges include RES and CHP premiums, nuclear decommissioning, support for vulnerable consumers, energy efficiency support, security of supply surcharges and many other fees. Usually industrial electricity consumers are exempted from them, which increases the burden on residential consumers. (Eurelectric, 2014)

The needs for updating the energy taxation and collecting levies arise from three reasons: decrease of demand and incentivising flexibility and energy storage. Firstly, taxes and surcharges are often carried out as fixed €/kWh consumed, which means that self-consumption as well as energy efficiency decrease state's tax revenue. The revenue loss is even bigger when the RE subsidies, like FITs, are funded from electricity charges. Profitability of self-consumption business model is dependent on the tax level consumers and prosumers pay. This cross-subsidisation issue has arisen debate in Germany on the social acceptability and affordability of the whole energy transition (Tews et al., 2016). The FIT model does not have this issue because it does not decrease energy consumption. In some cases also the FIT is taxed as revenue (IEA, 2014, pp. 47-51). On the other hand, the investor of a self-generation has paid taxes while buying the equipment and installation (SolarPowerEurope, 2015). Secondly, the fixed €/kWh does not incentivise DR. The amount of taxes is kept the same no matter what the price of the energy component is. Thirdly, energy storing is not currently taken into account in the taxation and may be taxed twice, both when storing electricity from the grid and when feeding electricity back to the grid. Storing energy is different from normal usage of energy and it can be used for adding flexibility to the grid in many ways.

The Value Added Tax (VAT) is another issue that has to be taken into account. For consumed energy, it is paid as a percentage of the energy cost. Common options for electricity tax reform are roughly: fixed €/kWh and fixed percentage of market price. One option is to carry the taxes as a fixed charge monthly or annually (Pérez-Arriaga & Knitte, 2016, p.117). The benefit of this solution would be that it does not distort short-term market signals. However, equal sum to all consumers would not be fair to less-consuming people. In addition, high share of fixed part of taxes and levies in the electricity bill hinders DR and the development of energy storing.

If the tax would be counted as a percentage from the energy bill like the VAT is, the fluctuation of retail price would increase and encourage storing and DR activities. For example, a 40% tax on electricity price would mean that consumer's tax payment is

- 4€/MWh, when electricity is 10€/MWh
- 20€/MWh, when electricity is 50€/MWh
- 80€/MWh, when electricity is 200€/MWh (Smart Energy Transition, 2017)

VAT on the self-consumed electricity is another issue. Usually small residential prosumers are not obliged to pay VAT on their electricity production but bigger installations it may affect and this affects collective self-consumption. In general, products that are made only for own use are however often exempted from VAT. There are also exempts on small-scale businesses that are not regarded as main businesses for the owners. Factor that can affect the VAT rules lies also in how the investment is shared and what is the individual investment and revenues. (Talus et al. 2016) If the self-produced electricity is due to VAT, the profitability of the investment can change dramatically. On the other hand, the exemptions on VAT in the purchase and installation phase saves money that the prosumer can invest elsewhere immediately. In 2013, there was a case in Austria which feeding excess electricity to the grid was regarded as economic activity and therefore VAT duties. The European Court of Justice decided that he was obliged to calculate VAT output of his production but on the other hand could exempt the VAT from the plant procurement. (Talus et al. 2016)

These kinds of measures are possible in creating conditions for more flexible usage of electricity. However, their political acceptability is questionable and therefore hindering the change. Questions that remain to be answered include: How the change will affect different consumer segments? Which price level the tax would be linked? How the total the tax is designed so that total tax burden does not increase or decrease too much? (TEM, 2017)

Approach of the European Union

Electricity taxes are harmonised by the EU but member states have freedom to implement their own taxes. Directive 2003/96/EU states that taxes should not distort competition or the single market (European Union, 2003). It sets a minimum tax level of 1,0 €/MWh for residential use. In practice, member states apply much higher taxes for electricity. In addition, there does not seem to exist barriers of implementing a %-based tax (Borenius, 2017).

Table 16. *Taxes and levies related to self-consumption in case countries.*

	Retail bill	**SC taxes and levies**	**Source**
IT	Consumer taxes and levies 9,2 €c/kWh. Levies volumetric for residential consumers but partly fixed for non-residential users.	Charges for systems above 20 kW.	(Valles et al., 2016; Veum et al., 2016;)
FI	Consumer taxes and levies 5,3 €c/kWh. RE surcharge from state budget, does not affect electricity prices directly.	Generation less than 100 kVA is liberated from electricity tax. Owning PV system isn't regarded as business activity but the income from surplus electricity regarded as personal income	(Ahola, 2015; Eurostat, 2017)
DE	Consumer taxes and levies 16 €c/kWh. All consumers pay 6,9 €/kWh surcharge for RES.	EEG surcharge of 40 % for installations over 10 kW. No taxes on SC.	(Tews et al., 2016; Valles et al., 2016; Veum et al., 2016)
FR	Consumer taxes and levies 6,1 €c/kWh.	No taxes on SC. FIT revenue not taxed	(Valles et al., 2016)
CH	Consumer taxes and levies 4,3 €c/kWh. All consumers pay little 0,013 CHF/kWh surcharge for RES.	No taxes or charges on SC	(Hüsser, 2016)

4.3.3 Collective self-consumption

Peer-to-peer market means that prosumer is selling directly to another customer without the utility in the middle. Theoretically, it means that people share part of their own hardware and information for a common purpose. Usually this means so-called "over-the-fence usage of production prosumers can sell their production to nearby consumers in multi-apartment blocks or shopping centres. This framework is especially useful for apartments and tenants because now they face difficulties in getting active in prosuming markets (Veum et al., 2016). Problem is that joint production site of a building may have to use the common grid before being used. In this way, the consumers in the apartments have to pay the taxes and network fees.

Allowing collective SC means a set of regulatory measures. Usually prosumer has to be one legal person and the SC has to be done close to the production. Important factor is whether the limit is the apartment or the connection to distribution system. The size of the installation, community and how many persons it includes may affect the amount of taxes to be paid for the electricity they produce onsite (Talus et al. 2016). Other questions lie in (1.) Is there a possibility for habitants to view the metering data? (2.) Can the utility offer and charge for the billing and metering services? (FinSolar, 2017) and (3.) Is the producer also a 'supplier' of electricity with obligations of suppliers? In addition, adding a storage to the system is not discussed in current regulation (Courtel, 2017). Housing company acts should be taken into account and participants should also have an option not to participate (TEM, 2017, p. 35).

Aim of legalising collective SC is to unlock this investment potential for RES for multi-apartment houses and tenants. Allowing joint ownerships of SC plants also allows optimising the location, maintenance and use. (Talus et al., 2016) It would open new service business models for smart micro grids. In addition, it would reduce the cross-subsidisation effect between residential prosumers and ordinary consumers who have not had a chance to become prosumers earlier. Distance between the use and generation determines how profitable the scheme is for the prosumer and the utility. With longer distance, the benefits for the utility diminish but SC rates can increase for the prosumer. On the other hand, collective SC reduces revenues from network costs. In addition, people living in more dispersed areas would not have the same possibility and their relative proportion of network costs would increase.

As a more radical market formation, peer-to-peer markets get independent from the gird by a bottom-up movement. (Parag & Sovacool, 2016) These marketplaces have a resemblance of sharing economy platforms like Airbnb or Uber by creating a virtual grid and trading electricity among the community members. It forms a market place where prosumers and consumers can directly sell and buy electricity and other services and in this way cutting the utility from the value chain. The market may include long-term contractual relations between players. One part might generate while other party stores the energy. If these markets form autonomous units, the question of responsible of security of supply arises. The blockchain technology is already used to handle transactions in such microgrids (Hasse et al., 2016).

Creating collective SC is a change that affects a wide network of actors. DSO and a possible third party would organise the metering so that it is possible to meter apartment-level and community-level prosumption and consumption. Information delivery and management are important pre-requisites for this because inhabitants may have several different retailers. Use of data hub for this should be discussed. In addition, real estate market, building codes as well as housing company acts set framework for collective SC. (TEM, 2017).

Approach of the European Union

The Clean Energy Package requires Member states to ensure that prosumers can participate in the energy markets through local energy communities, which are protected to compete against large-scale players (European Commission, 2017b). A closed distribution system is possible for industrial areas, for example, but usually not for residential areas (European Union, 2009). European Commission has approved a feed-in premium for a joint PV installation in Denmark, which several different housing communities built together. Assumption was made that the PV installation di not exceed 6 kW per household. Therefore, it can be assumed that EU legislation approves support for joint cooperatives (Talus et al. 2016).

Table 17. *Collective self-consumption and peer-to-peer possibilities in case countries.*

	Description of regulatory framework	Source
IT	Not yet common in residential sector but promising possibilities in the scheme SEU (Sistema Efficienti die Utenza) having similar tax incentives as for residential solar.	(Dunlop & Roesch, 2016)
FI	No established legislation. Unclear points: taxes, availability of consumption data, can DSO take a fee for the service,	(FinSolar, 2017)
DE	Direct delivery to nearby consumer without using the grid is allowed. The prosumer can choose if he will use the grid or sell the energy directly with bidirectional meter.	(Veum et al., 2016)
FR	Legislation for collective SC came in 2017 into force. Producers and consumers have to be part of a same legal entity, but the type of entity is free. Installation cannot exceed 100 kW. Network tariff levels are still unclear.	(Courtel, 2017)
CH	Collective SC is part of new Energy strategy 2050 and under discussion. Now, collective SC is possible in apartments.	(AEM, 2016; Romande Energie SA, 2016)

4.3.4 Compensation for electricity fed into the grid

Mostly the excess production is remunerated by the wholesale price, which reflects the value of energy in the electricity system. The final remuneration is typically negotiated private PPAs. They are sales contracts between two parties where contract lengths, prices and contract structure vary (Dunlop & Roesch, 2016, p. 90). However, the remuneration can be also done by net billing or other measures which can be adjusted to different prices and charges.(Mir-Artigues & del Río, 2016) Timing of the production and usage comes more and more important in the future as flexible pricing can change the old paradigm of fixed energy prices. This will be taken into account while installing the RES at home by facing the solar panels towards east or west. Suddenly not only southern façade is important. For example, in South Africa the remuneration of energy producers is increased by factor 2.7 for the period between 16.30-21.30. (Mir-Artigues & del Río 2016; IEA 2016)

Feed-in tariffs

FITs are common incentives for RE producers in situations where the self-generation cost is above grid parity. They are regarded as the main instruments that are combined with other, secondary instruments, like purchase obligations. FIT is the price that RE producers receive for each kWh they sell to the grid. It is higher than the wholesale price but the level depends between countries. Many design elements are particular to FITs and can be used to achieve different targets. For example, the policy can impose or induce to use local components or installers (Mir-Artigues & del Río, 2016). In general, the most common design questions are:

- Which price the FIT is tied to and is it revisioned periodically?
- Does different plant capacities, locations or installation styles have different support levels?
- Are there limits on capacities that are eligible for the scheme?
- Is there a cap and/or a floor in the FIT that can not be overtaken?
- What is the eligibility period of the FIT? (Couture et al. 2010; Mir-Artigues & del Río, 2016)

Advantages of FITs include security for the investor, low transaction costs, performance-based costs and adjustability in the initial phase. They support technologies different stages of maturity. They incentivise to maximise the production when there is no cap on production. In addition, they do not reduce the amount of taxes and network charges carried from energy bills. Seen disadvantages include market distortion, cross subsidising effect and weak controllability if badly designed. By themselves, they do not solve the issue of high upfront costs. They also require continuous and long-term policy commitment. They do not encourage competition between project developers and create reliance on policy. (Couture et al. 2010, pp.11-12) In addition, FIT are not compatible with storages as they guarantee the same price for selling electricity at all times (Schill et al., 2017).

The main challenge in the policy design is to set and maintain a support level that is not too costly but still effective in encouraging new investments. Too high FITs have also brought speculative players in the market who are there only to rip off the subsidies and not planning to stay and develop the field. (Mir-Artigues & del Río, 2016) Decreasing the levels has had a big impact on the market. In Germany, for example, even the possibility of decreasing the FIT seems to have an effect. This dynamism was seen in 2012 due to a FIT system that looks at monthly PV capacity increases and then may decrease the FIT by 0,5%. The level of the compensation became closer to the wholesale price than the retail price, which explains the overall decreasing trend of installations (Tews et al., 2016).

The implementation of the FIT depends on the country. Utility's role in the implementation can be increased with purchase obligation that requires them to purchase the production of eligible installations. The financing of the FIT programs is buried to consumers, either through tax budget or a levy included in the electricity price. For example, Germany and Denmark include the support costs in the electricity price. Spain has had a hybrid of these methods. Other options are financing through carbon auction revenues or utility tax credits. (Couture et al., 2010, p. ix) Including FIT to the retail price increases consumer prices sometimes remarkably. It encourages energy efficiency and SC but it also buries costs on often more vulnerable consumers. High electricity prices also encourage using fossil fuels for heating and transportation. In that way, also their use as flexibility assets will be lower and so the whole ecosystem misses potential flexibility sources.

Net metering and billing

Shift to self-consumption has brought net metering and net billing as more popular ways of incentivising RE production. However, these terms include many different variations and meanings. In net metering scheme the kilowatt-hours injected to the grid are valued the same the electricity consumed from the grid, namely as retail price. In practice, the meter turns backwards when there is electricity fed in to the grid. If only one register is used, the actual production and consumption amounts remain unknown. (Hughes & Bell, 2006) The billing period is an important design element in this policy. Oftentimes the period is 2-3 months but in Denmark, for example, it is one hour. Shorter the period is, more it encourages to use own production. Longer the period between meter readings is, more there will be flexibility for the prosumer and in a way more subsidy given by the system. (BEUC, 2016) Some countries use metering period of one year, which does not incentivise to demand side response at all. The advantage of the net metering policy is its simplicity for the consumer due to a simple billing arrangement.

The Danish net metering model is close to the net billing system in the way that it incentivises bigger SC rates. In net billing, the electricity fed to the grid is most often valued as the wholesale price so the compensation for excess production is often just some cents per kilowatt-hour. In practice, prosumer net billing measures difference between the value of consumption and production. If the remuneration is done on the real-time wholesale price, the length of the billing period does not matter.

Remuneration instruments are usually adjusted to certain technologies because they have different cost and production structures. Technology neutral models like green certificates are also used in some countries but there is a general shift towards SC models. In principle, remuneration policies are financial instruments that affect the profitability of DR and energy storing. They also affect the amount of network tariffs and taxes paid. Net billing incentivises to increase self-consumption as much as possible if the remuneration is below retail price. Net metering incentivises to install as much capacity as possible if the excess production is remunerated but it does not incentivise DR. Dynamic pricing and ToU tariffs can further strengthen this effect since the wholesale price goes down when sun is shining and all PV systems get to their full production. According to Masson et al. (2014) it remains unclear whether time-based pricing is good for prosumers or not. Renewables decrease the market prices when they are widely deployed. On the other hand, dynamic pricing with large amounts of PV production leads to higher demand side response and use of storages.

Approach of the European Union

In principle, EU states are not allowed to support certain technologies from state funds in a way that distorts domestic and international markets. If the aid is governed by somebody else than state, they are, however, possible. (KPMG, 2014) State aid guidelines calls for shift to auction-based systems but systems under 500 kW are exempted of these measures and may still be part of a FIT or premium system (European Commission, 2014b). Net metering is not directly mentioned but regulators are against it (ACER & CEER, 2017) .

Table 18. *Direct production compensation in case countries.*

	FIT / FIP	Net metering/billing	Source
IT	PPAs. Sales decreased after "Conto Energia" was phased out in 2014.	'Scambio sul posto' net billing scheme is applicable for plant sizes of 20-200kW. Yearly netting period. ToU price.	(Castello, S., Tilli, F., Guastella, 2015; European Commission, 2015; RES Legal, 2017)
FI	PPAs.	N/A	(Ahola, 2015; European Commission, 2015)
DE	<90% of production applicable for FIT. Level depends on site and capacity, approximately 10 €ct/kWh. Rest PPA or spot market price (4-5 €ct/kWh).	N/A	(RES Legal, 2017)
FR	Integrated installations have almost double FITs, approximately 23 €ct/kWh. Others have about 13 €ct/kWh.	N/A	(CRE, 2017)
CH	Revenues from excess PV electricity injected to grid approximately 15 €ct/kWh. Long waiting list for the FIT and with only 100 MW of new contracts (2015). Big differences between cantons.	Some utilities.	(Hüsser, 2016; RES Legal, 2017)

4.4 Phase 5: Confirmation

4.4.1 Aggregation

Demand response can be divided into two categories, explicit and implicit DR. Implicit DR, sometimes called "price-based DR", means that customer chooses a time-variant electricity pricing and acts according to that (SEDC 2015). In explicit DR, households' loads are aggregated and their resources are traded in the wholesale, balancing and capacity markets. In practice, it means that some consumer appliances are controlled through home energy management systems or smart meters. Consumers can receive payments if they act upon aggregator's request.

The types of aggregators in the residential market segment are *demand aggregator* and *generation aggregator*. Demand aggregator controls different devices like water boilers, smart thermostats and air conditioners. Their availability and maximum temporal powers are relatively low but heat pumps combined with boilers are suitable for longer services like peak shaving (Eid, et al., 2016). Demand aggregator can use bi-directional DERs like batteries and EVs with smart charging. This brings along many optimisation problems related to charging costs, rewards and incentives on supply and demand shifts and patterns on usage and loading. Generation aggregator controls different distributed generation units like prosumers' solar PV production combined to smart inverters. (Ikäheimo et al. 2010) V2G solutions and batteries offer flexibility with bi-directional devices. Batteries offer availability and work instantaneously when wanted. (Plancke et al. 2015)

Rationales of DR programs are reduction in total power consumption and generation by decreasing the need for peak demand supply. Adding flexibility to the grid decreases the need of capacity mechanisms. DERs have a short start-up time, which enables quick response and a robust output for example, when a bigger production unit breaks down. In addition, aggregators bring actors together and offer value by overcoming information barriers, reducing transaction costs and coordination of market participants. (Pérez-Arriaga et al. 2016) It empowers consumers to energy efficiency, brings new players to the market and helps to integrate more RES to the system. Retailers who engage in the aggregation market do so because low wholesale market prices have lowered the value of their generation portfolio and pushes them to explore new business opportunities. Owning inflexible generation like wind or nuclear energy increases balancing costs but do not provide the retailer to gain from high market prices. Also new independent entrants form a threat to retailers but on the other hand create also market and consumer awareness. (SGTF, 2015)

The disadvantage is that if badly implemented, a synchronised DR may actually increase the pressure in the grid when many consumers react to price fluctuations on the same time. The geographical distribution of DERs may not be favourable from the system's perspective (Schill et al., 2017). In addition, central and local balancing will eat each other's business. (Schill et al., 2017; SEDC, 2016) Suppliers have also criticised independent aggregation for reducing their revenues and taking responsibility of imbalance they create (DNV-GL, 2017). Societal barriers in making aggregation possible in the residential loads is related to consumer preferences and privacy concerns. People do not often like that they lose control of their devices and possibility of surveillance of their actions. In the EV segment challenges of aggregation are related to charging sequences, duration and rates (Carreiro et al., 2017). For the business developers the high upfront costs, risk of failure and decrease in known revenues form barriers of entrance for retailers to step in the aggregation market. Efficient aggregation requires economies-of-scale on the residential level to influence the supply level. The sums are small when all participants divide them. For example, in the US customers received 33$ savings per year but enabled to avoid 140 megawatts of generating capacity. (Pérez-Arriaga, et al. 2016) Swisscom aggregator tiko has over 10000 customers in Switzerland. It offers approximately up to 250 euros per year savings if customer joins his/her storage in tiko's virtual power plant (Tiko, 2017).

The implementation network of explicit DR is complex and requires cooperation between TSOs, DSOs, retailers, aggregators and end-users. Electricity supply must provide ancillary services to the grid, which ensure that DSOs and TSO can maintain frequency stability and voltage control in the grid. DSOs normally determine the demand volume that should be altered in a certain period. The aggregator gets this information and chooses the end-users that agree with the proposed DR program. Then aggregator informs DSO what capacity end-users are ready to provide for the market. (Carreiro et al. 2017)

Rules and market design

Many countries have still DR regulation that suits only large fossil fuel generation units and big consumers like steel factories (Eid et al., 2016). Important attributes of the DERs include direction of the load, size (kW and Kwh), time and location (see figure 21). The flexibility markets where DERs can participate vary from short-term ancillary services keeping grid stable to long-term capacity markets balancing big fluctuations in supply and demand. The temporal characteristic can be defined by the maximum duration the DER can sustain its maximum power. For example, a 10 kW battery and capacity of 50 kWh can sustain 5 hours at its peak capacity. The regulations on DR were designed according to fossil-fuel generators and can remain up to 12-60 hours in some countries. If the minimum bid to get into the market is for example 50 MW, it efficiently blocks residential loads from the DR market. (SEDC, 2017)

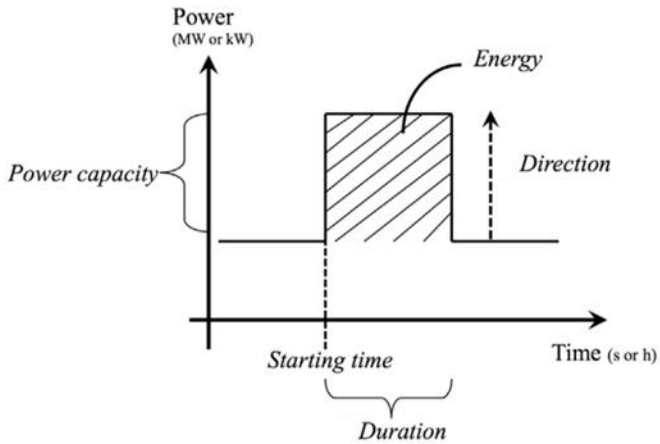

Figure 21. *DER attributes for flexibility services (Eid et al., 2016).*

DR including aggregated loads may be authorised offer in electricity markets but more detailed regulatory framework is often needed to lower the legal barriers. The definition of aggregator's role in the market clears their tasks (Bertoldi et al. 2016). In advanced markets, the aggregators can act independently from utilities and in that way create a new business unit in the electricity market. Obviously, the businesses of DR and electricity selling are contradictory to each other and in that way may reduce the options to ones that are favourable for the retailer. On the other hand, more regulation brings more administrative costs, which may be market barrier especially for smaller companies (NordREG, 2017).

The measurement, verification standards and compensation mechanisms should be suitable for DR. One essential element is setting an expectation baseline, which tells how much DR is produced compared to so-called normal consumption (SGTF, 2015, annex 5). Important product elements include communication protocols, transparency of methods how DR is measured and penalties of non-compliance to agreements. Requirements should be proportionate to customer capabilities, payments fair and penalties reasonable (SEDC, 2017). Experiments and demonstrations of aggregating business are valuable because they help to find best practices on which a stronger legislation will be built and clear up the way to technical standards that enable innovations.

Data management

Consumer data provision and access are key barriers for DR (Pause et al., 2016). Data exchange between aggregators, retailers and BRPs helps to control the actions of each party. As the smart grid diffuses, the amount of information that comes from the grid use increases dramatically. Eurelectric (2016) categorises the data into three main categories, namely

1. Smart meter data
2. Smart grid data
3. Smart market data

Smart meter data includes consumer identification and his/her consumption and production data. Consumer chooses who is allowed to use and process this data. Smart grid data comes from smart meters, censors and others and is used for grid monitoring and includes voltage, frequency and power quality data. The smart market data is the wide set of data coming from other sources related to the grid, for example, smart appliances, EVs, weather forecasts and price information.

From consumers point of view the change to earlier is remarkable because earlier the data exchange did not really even exist except the billing and reading the aggregate consumption. Current meters can give the information on the customer behaviour with high accuracies. Even though the meter does not necessarily show the use of appliances separately, it is possible to analyse their usage patterns from the cumulative energy consumption data. This kind of data is valuable also for third party actors like insurance companies. Giving information requires mutual trust from consumers (Michaels & Parag, 2016).

Regulations regarding smart meter and data ownerships are important innovation facilitators (Zhou & Brown, 2017). They allow innovative use of information for new business models by democratising the information of the system (von Hippel, 2005). Data sharing is a horizontal instrument that can be used for different technologies and business models, like aggregation. Like the electricity value chain, also the data handling is changing from bilateral exchange to open data. Some countries are moving towards centralised data hubs where it is distributed to different players. Some countries are staying in decentralised models where the DSOs, for example, are responsible for data management. The centralised model is efficient for new players in the market since it reduces transaction costs on information exchange. However, centralised data management is also more vulnerable against cyber-attacks than the decentralised model and takes several years to be implemented. Defining the tasks and responsibilities of a neutral market player is essential (SGTF, 2016, p. 13). Eurelectric (2016) sees there is no "one size fits all" solution but the centralised data hub is *"increasingly relevant to smarter energy systems".* National institutional differences seem to be so big that it is difficult to evaluate which model is the best for prosumer ecosystem development.

Approach of the European Union

Regulation level concerning aggregation on the EU side has been low (Pause et al. 2016). The Clean Energy Package aims to correct this and states that consumers should have fair conditions with aggregators and a possibility to get contracts with aggregators without acceptation of the customer's supplier. It requests member states to define frameworks for independent aggregators and handling DR as a resource like all others in the energy markets. Article 4 states that small RE plants do not have balancing responsibilities but shall have access to balancing markets. Article 7 states that the minimum bid size should 1 MW. (European Commission, 2017b) These issues are already noticed in the Energy Efficiency Directive (2012/27/EU), where the EU member states are required to achieve 20% energy efficiency gains at all levels of the energy value chain. In addition, the directive says that network regulation and tariffs should not prevent network operators or retailers to make DR services available. The directive on the internal energy market 2009/72/EC (European Union, 2009) says that TSOs should facilitate end-user and aggregator participation in reserve and balancing markets.

The EU General Data Protection Regulation 2016/679/EC (European Union, 2016) sets overall requirements for consumer data and its movement. It addresses tasks of data subject, controller, processor, recipient of data, data protection officer and supervisory authority. For example, consumers have the right to access and control his/her data from the third parties that are using it. In addition, they have to be asked for a permission to use the data and inform of any data collection and usage beforehand. Regulation has to be in place in the member states by 25th of May 2018.

Table 19. *Aggregation regulation in case countries.*

	Aggregation regulation	SEDC grade (2017)	Data management	Source
IT	No framework for aggregated DR in place. Changes ongoing.	3/20	Centralised data platform for all participants. DSOs are responsible for metering process.	(SEDC, 2017; Bertoldi et al 2016; SGTF, 2016)
FI	DR and aggregation possible but exists mainly in large scale due to minimum bid size. Aggregators service providers to retailers.	14/20	Centralised data platform for all participants. Customers control their authorisations by using Data hub services via their utility's web pages.	(Bertoldi et al 2016; SEDC, 2017; SGTF, 2015; SGTF, 2016)
DE	Aggregation via retailers only. Residential sector not active yet but industry and commercial yes. Discussions on opening secondary and tertiary reserves to DR.	10/20	Customer data will be stored in each smart meter device. Customers' access to their data is planned to be available during 2017.	(SEDC, 2017; SGTF, 2015; SGTF, 2016)
FR	Balancing mechanisms, ancillary services and capacity mechanisms open to aggregated DR. Independent aggregation enabled. Changes done in 2016.	18/20	DSOs are responsible for data protection and must ensure customers access to their data. Processes between customer, DSO and third parties of DSOs and third parties not yet solved.	(Bertoldi, et al. 2016; SEDC, 2017; SGTF, 2015; SGTF, 2016)
CH	Balancing service providers are allowed to aggregate loads without permission of BPR. No tariff incentives.	16/20	No info	(SEDC, 2017)

4.4.2 Energy storage

Energy storage enables further integration of RES, balances the system and provides security of supply. It also decreases energy prices and their volatility. In addition, prosumers can offer ancillary services via an aggregator and shave peak demand by arbitraging, namely feeding electricity in to the grid when the prices are high and storing when it is cheap. (RMI, 2015) In low-voltage grid areas, they can also provide back-up power in case of a blackout. (EuroBAT, 2016; Ugarte et al., 2015)

On the residential level, "behind the meter" batteries can increase the self-consumption rates from 30% up to 60-70%. The ultimate solution in sunnier areas is to add sufficient capacity and to go off-grid totally. However, increasing self-consumption rates from 65%, the cost per kWh increases quite rapidly because the system has to sustain longer periods of no sun (Schill et al., 2017, p.149).

The market of in-home batteries is still relatively small, but the growth in certain countries like Germany is significant. Reductions in battery costs continue and second-life use of

EV batteries may reduce the prices further (Schill et al., 2017). Several regulatory changes are needed to make energy storage sustainably profitable and market-ready. On the general level comprising all storage methods, the key barriers to batteries' participation in the energy market are lack of a clear definition of energy storage, ownership of batteries by DSOs and TSOs, double grid fees and taxes for stored electricity, financial compensation for curtailed energy, lack of compensation for ancillary services and the lack of dynamic pricing. (EuroBAT, 2016; Ugarte et al., 2015)

Other DER-related regulation and general ratemaking influence the profitability of storing. Incentive for owning a battery at home depends on the retail price of electricity. Clear difference between self-produced cost and retail price can induce to invest in storage and in that way to optimise further own energy usage. Net metering does not incentivise battery ownership because the monetary value of self-consumption remains same at all times. Same thing applies with high FIT levels. Energy-based tariff systems favour the use of storage for minimising the use of the grid but not that much for providing flexibility. Capacity-based tariffs would incentivise storage purchasing, because lower peak demand would reduce the network tariff. This would lead to usage of storage connected to big loads likes EV charging. On the other hand, smaller network capacities limit bidirectional DR. (Ugarte et al., 2015) Priority dispatch may be a bottleneck for storage since it allows feeding the RE to the grid always.

In total, incentivising residential energy storage is a matter of market design and incentives and it involves practically all players in the market. The role of DSOs is still unclear, because unbundling requirements prevent them from owning storages. On the market design level, they will be in charge of the network costs, which is also matter of governmental decisions. Taxation of storages is currently not taken into account besides pumped hydro, which leads to double taxation. In some cased the government offers subsidies and low interest loans for the investment and this is done by the energy ministries and relevant banks, like in Germany. Subsidies can be connected to certain demands. For example in Germany, the SC rate has to be over 50 % (Schill et al., 2017).

Approach of the European Union

EU Battery Directive 2006/66/EC aim in minimising batteries' environmental damages by restricting the use of certain materials, such as mercury and setting framework for recycling. Batteries are also related to EU Waste Legislation, Water Framework Directive and RED. (European Commission, 2009) The new Clean Energy Package highlights dynamic pricing and that storages should have same possibilities to participate and to be rewarded than other flexibility services like DR and flexible generation. According to it, national frameworks should incentivise DSOs to procure especially DER-based services to support the system but they are not usually allowed to won them. (European Commission, 2017b). Batteries were not even mentioned in the earlier Electricity Directive from 2009. (European Union, 2009)

Table 20. *Battery incentives in case countries.*

	Battery incentive	Source
IT	50% tax reduction	(Mayr, 2016)
FI	No specific incentives for battery storages.	(Ahola, 2015)
DE	KfW bank provides low interest loans for batteries up to 2000 €/kW. Rebates for under 30 kWp systems of up to 25% of costs. Market size 128 MWh in 2016. Condition of feeding max 50% of installation's capacity to the grid.	(RES Legal, 2017; Schill et al., 2017; Tews et al., 2016)
FR	No incentives. Just a couple hundred batteries declared.	(de l'Elpine, 2017)
CH	In some cantons.	(Hüsser, 2016)

4.4.3 Electric vehicles

Mobility is important part of the whole energy system and decarbonising traffic and reducing its air pollution are remain big challenges. EVs are complementary products for DERs because of their batteries, which have potential to offer flexibility to the system. According to some studies, cars are parked almost 95% of the time, for which they could be used for flexibility services to the grid. V2G and vehicle-to-home solutions are being designed in order to use car batteries to smoothen peak demand, reducing electricity cost and increasing reliability of the grid. (IEA-HEV, 2016)

Several policy instruments are used to fasten up the diffusion of EVs. Policies regarding EVs can be divided into purchase incentives, use and circulation incentives and waivers on access restrictions. Several countries offer incentives to buy an EV by offering so-called registration subsidies, namely rebates or tax incentives. (Sierzchula et al. 2014) For example, in Norway, which has been a frontrunner in EV adoption, these have included tax exemptions from vehicle registration, ownership and VAT. In addition, there are direct rebates and scrappage programs for changing old cars to newer ones. Circulation subsidies are used regarding the use of the EV. In Norway, vehicle licence fees are lower and EVs are exempted from road tolling, ferries and parking tickets in public parking areas. Regulation can also offer other incentives, like in Norway's case, faster routes by offering bus lanes for EV cars. (Bjerkan et al. 2016) In addition, tailpipe emissions standards affect EV diffusion indirectly (IEA, 2016a).

Charging points are regarded as a prerequisite for larger diffusion of EVs. Public provision of charging points can help in the beginning of the diffusion. There are two types of charging points: fast charging points, which are mostly situated in public areas like parking lots and shopping centres and slow home chargers. A European wide standard (type 2) is used in home charging points, which works with lower capacities. The EU states that over 22 kW chargers are fast chargers and under 22 kW slow chargers. One charging point costs approximately 1000e and costs of installation and cabling. Either the housing company or the inhabitants pay charging points in apartments. Regardless of the organisation, the metering has to be personalised. EVs are often leased by a company, which then builds also a charging point for the customer. (Motiva Oy, 2017) The charging has to be done smartly because of the power levels needed, which means there has to be real-time communication and management.

EV diffusion is expected to follow Rogers' model of the diffusion of innovations. Different policy instruments suit different people, which can be taken into account when designing the policy mix. Green et al. (2014) see that early adopters are less interested in design and technological performance but rather on environmental performance and efficiency. Bjerkan et al. (2016) did a study in Norway, in which they found that incentives on fixed costs appealed men, older people, Tesla owners, and later adopters who mostly live outside Oslo. Income is thought to be an important factor but also different results are obtained (Li et al. 2017). This is taken into account in California, where high-income families do not receive the EV rebate and charging stations have minimum targets for deployment in low-income areas (Farrell, 2017).

The implementation of EV policies affects a network of players. Typically, dedicated ministries implement the financial subsidies that are applied by private investors or companies. There can be a new organisation initiated by the ministry for this purpose. (Tietge et al. 2016) Cities implement and bear mostly the costs the new EV rules for traffic, like toll payment exemptions, and parking spaces with the chargers (Milne, 2017). Car manufacturers and utilities have to cooperate in the V2G business models and technology. Suitable smart meters are provided by DSOs. Aggregation rules are part of the electricity market regulation.

EV diffusion creates a need to accelerate the development of the smart grid and metering infrastructure. As the diffusion continues, need for smart charging and DR increases, which poses pressure on dynamic pricing, network tariffs and tax reforms. Depending on the valuation of peak demand, EVs may incentivise the use of storage in the charging stations. On the other hand, storage at home for EV charging would decrease the need of V2G solutions.

Approach of the European Union

In the Alternative Fuel Directive, the EU sets a target for 800 000 public charging stations in Europe by 2020. The Clean Energy Package included a proposal for EVs by requiring a pre-cabling for every third public parking space. Focus of these targets are in urban areas. Manufacturers have to comply mandatory CO2 emission targets and EVs get a "super credit" in these calculations. From 2021 onwards, the average target is 95 g CO2/km. EVs are treated as zero emitters. (EU, 2014)

Table 21. *Electric vehicle incentives in case countries.*

	EV incentives	Charging infrastructure incentives	Source
IT	Exempt of ownership tax for first 5 years. After 5 years, 75% reduction compared to ICE cars. Many regional incentives.	50 million € fund was dedicated in 2014; max 50% of costs could be covered with it. 2000 stations were in 2015 but Ministry of Transportation planned to build 20000 more in 3 following years. Enel has been active in V2G solutions.	(ACEA, 2017; IEA-HEV, 2016)
FI	Minimum rate (5%) of the CO2 based registration tax for EVs. Government proposes now a subsidy of 2000e.	4,8 million € public support by Ministry of Employment and the Economy. Earlier 35% rebates for charging points.	(ACEA, 2017; LVM, 2017; Sähköinenliikenne.fi, 2017)
DE	4000€ bonus for EVs. 3000€ for PEVs. Exempt of ownership tax for first 5 years. Exemption of emission inspection, low-interest loans.	Private-public partnership funding. E.g., Electro Mobility Model Regions funding program has invested 90 million of public and 80 million of private money in charging stations. 16 550 slow chargers and 1 403 fact chargers in 2016.	(ACEA, 2017; IEA, 2017; Tietge et al. 2016)
FR	6000€ for cars of 0-20 gCO2/km. If replace old diesel car + 4000€	Private-public partnerships. 16 000 public charging points now, 100 000 in 2020. 50 million funded by ADEME. Tax credit of 30 % of costs for private people. Rebate of 50% of costs for multi-housings.	(Ministère de l'Environnement de l'Énergie et de la Mer, 2016, 2017)
CH	No federal policy for EVs. Exemption of car import tax. Each canton has their own policies. E.g., Geneva exempts ownership taxes for 3 first years.	Public-private partnerships. 3200 charging points by the end of 2015.	(IEA-HEV, 2016)

4.5 Summary of country regulations

The results of the case country regulations and incentives are gathered in table 22. There is used a three-level scaling that is similar for all studied policies. Regulations, financial incentives and information policies are categorised in the following way on the same scale. The meanings of the values are:

- * = No regulation in place. A financial punishment. Low emphasis on informational policies.
- ** = Regulation exists but the implementation still unclear. No incentives or only small incentives in place. Standard implementation of informational policies.
- *** = Regulation well implemented. Incentives in place. Strong emphasis on informational policies.

The table should be read as an overview of policies and not an explicit evaluation of them. The effect on prosumer's technology adoption of building codes and labels is, for example, difficult to evaluate because the same policy may benefit one but restrict another company or consumer. In addition, the effect of standardisation, system size limitations and bureaucracy is different for different companies. In general, less bureaucracy requirements is better for smaller companies but may be beneficial for larger and exporting companies.

The knowledge phase is relatively well in place in Italy. Italy has had smart meters for nearly 20 years now. Due to high price of electricity and southern location, Italy has good conditions for residential solar PV. Market liberalisation has been done even tough consumer prices are still partly regulated. Consumer incentivising in the persuasion phase is less strong. Investment subsidies and third party ownership regulation are done on the regional level and some incentives exist. The implementation is done relatively easy for the customer. Italy is still subsidising residential solar PV production but the level of subsidisation has come down significantly since the beginning of 2010s. For the high price of energy, it is a prominent market for batteries, which are also subsidised. The framework for aggregation is currently being under discussion and implementation, but Italy is somewhat a latecomer in DR. In overall, opening the aggregation regulation can create dynamic innovation ecosystem where all technologies are included.

In France, the market is still very centralised even though the market is legally liberalised. Diffusion of prosuming is hindered by low electricity prices that are still regulated. Smart metering is only now being rolled out. The persuasion phase has strong emphasis in France as certificates have a big role, solar PV gets investment subsidies and building permits are easy to gain. Currently, also the purchasing procedure is stable but lately it also included many delays (Barth et al., 2014, p. 8). PV systems can earn FIT but also self-consumption is now possible. France is investing in EVs through governmental subsidies. It is also one of the frontrunners in aggregation and DR. The emphasis has been in industrial side but now also consumers are getting involved. However, it does not subsidise residential batteries, which have bad profitability due to cheap electricity. The centralised nature of the energy market and price regulation hinders innovation ecosystem creation. The keystone player EDF is in controlling position regarding standards and complements. The situation may change if the regulated consumer prices in France end. National car manufacturers like Renault are investing in smart grids and aggregation.

In Germany, the market liberalisation is implemented even though the "big four" utilities have still large market share. Smartness of the grid is lagging behind since German chose to rollout smart meters in a selective way. The persuasion phase directs consumers to combine solar PV with batteries as the rebate has this condition. In addition, many certificates and building codes steer the market players. Germany has shifted from the incentives that supported business logic of FITs to self-consumption, which is relatively profitable for the consumer. On the other hand, high electricity prices hinder the overall electrification of the energy system and create pressure to change the rate structure of network tariffs and levies. Besides the relatively low FIT, consumers have still stable regulatory framework for investing in own production. The regulatory framework for residential DR is only partly opened but players like Sonnen are frontrunners in that market. Currently, EVs are getting relatively strong support from the government, which was not earlier the case. Germany's FIT support led to high and widespread competence in the solar industry (Strupeit & Palm, 2016, p. 130). The structure of the market for DR and EVs may be different to local and installer-lead solar PV market, as they require more digitalisation, synchronisation and economies-of-scale. In addition, car manufacturers' are big organisations with long supply chains, which means they are not as agile as small RE companies.

Finland has implemented the European directives concerning market liberalisation and smart metering. The market conditions support also dynamic pricing and connecting own production to the grid. Finland has never subsidised residential solar PV except tax reductions on the installation work. Due to long winters and low electricity prices, the residential self-consumption or storing are not profitable. EVs do not get big subsidies in Finland, but some schemes are being planned. In overall, the approach is to support level-playing field by opening the regulation for different technologies. Even though the markets are not so big in Finland, this enables smart grid solutions to arise and spread in export markets. System wide electrification is encouraged, which can be indicated from the popularity of heat pumps, for example (Heiskanen & Matschoss, 2017, p. 2).

In Switzerland, the electricity market reform is still under way but opening will be implemented in coming years for residential consumers, too. Smart meter rollout is lagging behind in most cantons. Investment in solar PV is subsidised and conditions are also otherwise in place. RE production is given a FIT but self-consumption model is more relevant because of a long queue for the FIT. The regulatory framework for DR is one of the most advanced in Europe and there are also some residential markets in place (Tiko, 2017). Batteries or EVs are not subsidised on the federal level but some cantons support them. Due to fragmented governance of the subsidy policies, it is hard to get a coherent picture of the Swiss prosumer ecosystem. However, federal subsidies for own RE investments and good regulatory conditions for DR have created a good backbone for EV diffusion. Prosumers have had their say in the development, as many utilities are municipality-owned and politically steered. The decision of reducing nuclear power and declining hydro energy will accelerate the prosumer ecosystem development.

No case country is supporting energy prosumer ecosystem in all dimensions. Germany is supporting own production, batteries and EVs but lagging behind in smart metering and DR regulation. France is a frontrunner in DR and EVs and supportive in own production but has not yet implemented smart meter rollout or battery subsidisation. Italy has history of supporting energy efficiency, PV production and smart meters but is opening its DR markets only now. Finland has stable and open electricity market with smart metering infrastructure in place but is not particularly pushing towards own production or in-home batteries. Switzerland is one of the leaders in DR and own production even tough smart meter rollout is not done and the market liberalisation is also underway.

Table 22. *Summary and brief evaluation of case country policies.*

	Policy	Italy		France		Germany		Finland		Switzerland	
Aware-ness	Market liberalisation	Yes	***	Yes but not effective	*	Yes	***	Yes	***	Ongoing	**
	Smart meter rollout	Yes	***	Rollout began 2016	**	Selective rollout	*	Yes	***	Only some cantons	*
Persuasion	Investment aid	Some regional grants, reduced VAT	**	Small grants and VAT reduction	***	Grants if DSM/ storage connected	***	Some tax reductions	**	Grants	***
	TPO allowance	Allowed with condi-tions	**	Some but uncertain framework	**	Available but not common	**	Available but not common	**	Available but not com-mon	**
	Building codes	Permission local activ-ity; RE requirements	**	No permission need; RE requirements	***	No permission need	**	No permission need	**	No permission need; RE requirements	**
	Labels and certificates	For installers	**	Very common	***	Very common	***	Voluntary based	*	No info	
Implementation	Interconnection process	Priority access	***	Access procedure regulated	**	Priority access	***	Hassle free but DSO dependent	**	Access procedure regulated.	**
	Interconnection fees	No fees	***	Connection fee	*	No fees	***	Possible connection fee	**	Possible connection fee	**
	Self-consumption	Possible	***	Possible	***	Possible	***	Possible	***	Possible	***
	Collective self-consump-tion	Scheme available but not common	**	Legal framework sketched	**	Direct deliveries allowed	**	Under discussion	*	Under discussion	*
	Taxes and levies	Surcharge if > 20 kW	**	No	**	Surcharge if > 10 kW	**	No	**	No	**
	Network tariffs	Capacity fee increasing. Small fee on SC	**	Mostly volumetric. No costs on SC	***	Mostly volumetric. No costs on SC	***	Division negotiable. No costs on SC	***	Mostly volumetric. No costs on SC	***
	Compensation of excess energy	PPAs	*	Moderate FIT, higher for BIPV	**	Low FIT	*	PPAs	*	Moderate FIT	**
Confirmation	Aggregation	Framework being created	*	Well regulated DR market	***	Partly opened DR market	**	Mostly opened DR market	**	Well regulated DR market	***
	Electric Vehicles	Tax benefits	**	Strong rebates and tax benefits	***	Rebates and tax benefits	***	Some tax benefits	**	Some tax benefits	**
	Batteries	Tax reductions	***	No	*	Investment subsi-dies	***	No	*	Subsidies in some can-tons	**

The support is now moving from technology-specific financial support towards creating regulatory frameworks for different kinds of solutions. When thinking of general condition building, there is no one-size-fits-all type of solution. Roughly said, whatever policies are introduced, there are winners and losers. Different effects on DERs are summarised in table 23. For example, incentivising lowering peak demand would mean capacity payments. However, this is not in line with the target having flexible demand with efficient DR and added infrastructure for EVs.

Table 23*. Horizontal policies' effect on DERs. "+"=positive,"–"=negative, "+/-" positive or negative, "N"=neutral (extended from Honkapuro et al., 2017).*

				Network tariffs		Taxes + levies	
		Smart metering	Dynamic pricing	Volumetric	Capacity-based	Volumetric	Progressive
Self-consumption		+	+/-	+	+/-	+	+/-
Demand Response		+	+	N	+/-	N	+
EVs	Uncontrolled	+	-	+	-	+	-
	Smart charging	+	+	N	+	N	+
	V2G	+	+	N	+/-	N	+
Storage		+	+	N	+/-	N	+

Explanations of countries' decisions can be derived also from their energy mixes. Italy's energy mix is highly dependent on gas, which is regarded as relatively flexible source of energy. France's electricity comes mainly from nuclear energy, which is less capable to respond to demand fluctuations. In Germany, the political decisions have supported residential prosumers the furthest, a decision made together with the phase out of nuclear energy. Finland has a diverse energy portfolio but its energy production is connected to its large steel and forest industries. Switzerland has decided recently to also phase out nuclear power so it is increasingly dependent on imports.

5. CONCLUSIONS

5.1 Results

The objective of this thesis was to explore and structure the role of public policies in the creation of energy prosumer ecosystems. The literature review handled different policy approaches related to energy transition and theories of innovation adoption and ecosystems. The context and the content of the study are shown in figure 22. To gain more information in this context, following research questions were formulated:

RQ1: What policies contribute to energy prosumer ecosystem creation from prosumer's point of view?

RQ2: How European countries differ in adopting these policies?

These questions were answered by two phases of research. Firstly, a data collection through different secondary data sources was conducted and different policies were structured as to different phases of energy prosumer journey. The policies emphasised solar PV purchase process, which was seen as the cornerstone of the ecosystem. Secondly, a cross-country comparison of selected policies was conducted from different secondary sources. Selected case countries were Italy, Germany, Switzerland, France and Finland.

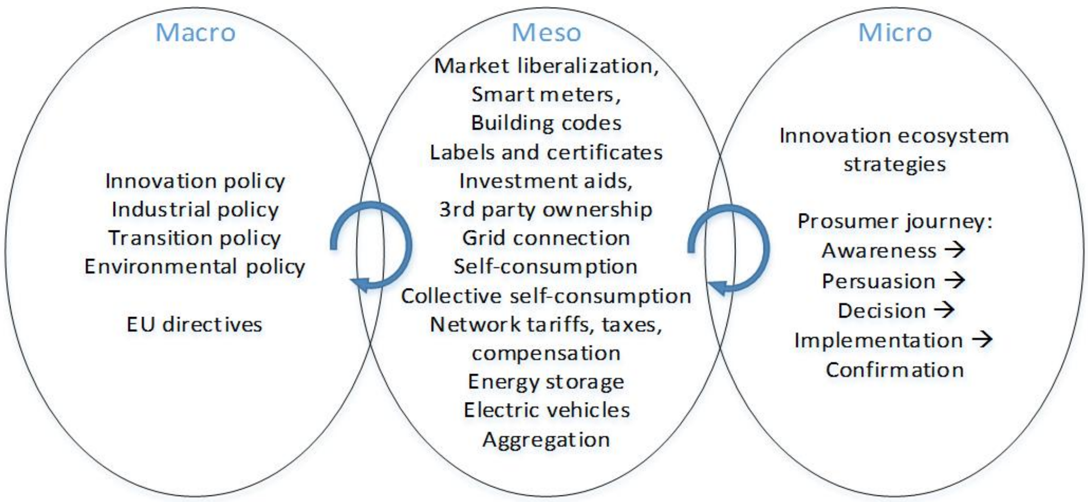

Figure 22. *Research context structured into research areas.*

Prosumer policy instruments were divided into five phases of the prosumer journey. Firstly, smart meter rollout and market liberalisation are prerequisites or enablers for the prosumer adoption. Secondly, policies that steer prosumer choices are investment aids, third party ownership, building codes and standards, labels and certificates. They work in the persuasion phase and reduce the soft costs of the investment. The implementation phase policies are grid connection procedure and costs, individual and collective self-consumption regulation, network tariffs, taxes and compensation for the excess electricity fed into the grid. The confirmation phase policies are regulation on aggregation, batteries and EVs.

Results show that the case countries have adopted different policy mixes relative to energy prosumers. Italy has emphasised smart meter rollout even though its demand response regulation is not established. It subsidises also batteries and has also good circumstances for storing and SC due to high electricity prices. France is a global frontrunner in DR and incentivises EVs but is a follower in solar PV market due to low electricity prices and relatively low FITs. For the same reason, also battery market is practically non-existing. Germany is closest of having incentivising policies in place for the whole ecosystem. It has technology-specific financial incentives for EVs and batteries and grid parity for solar PV because of high electricity prices. However, it is follower in smart meter adoption and DR. Finland emphasises creating good market conditions by having smart meters, well-functioning markets and regulation for DR. It has not adopted financial incentives for any technology and the diffusion of DER is still low. Switzerland has emphasis in solar PV and its DR regulation is one of the most advanced in Europe. However, it has not rolled out smart meters and has no federal policies for EVs or batteries.

5.2 Contributions of the study

Theoretical contribution

This thesis brought together different policy approaches that relate to the energy transition. Although policy mixes have been widely researched, a comprehensive comparison of policy fields and approaches has not been done. Earlier studies have done comparisons between environmental and innovation policies (Jaffe et al., 2005; Popp et al., 2010; Rogge & Rechardt, 2013) and transition and industrial policies (Alkemade et al., 2011). It is useful to see which objectives and typologies can be used when creating a systemic policy mix. These different typologies correspond well with the overall categorisation of Groba and Breitschopf (2013, p. 17).

In earlier studies, the energy prosumer related policy instruments have mainly concentrated to technology specific approaches (e.g. IEA, 2014; Tews et al., 2016; Valles et al., 2016). This thesis brought micro production, DR, batteries, EVs as well as energy efficiency standards into the same study. This brings a more coherent picture of the innovation ecosystem where these technologies are more and more interconnected. On the same time, it contributed to the missing knowledge of policy mixes related to innovation system development (Rogge and Rechardt, 2013, p. 35). It structured policy mix according to consumer adoption process by combining Rogers' technology adoption model. To author's knowledge this has not been done before in the context of residential solar PV. This approach highlights linkages between different policies and actors from consumer's point of view. It also adds a practical point of view to TIS framework's approach of system relations.

Thesis also connects the common environmental policy typology of market-based policies, command-and-control policies and information policies into the innovation adoption process (Borrás & Edquist, 2013). Even though the prosumer journey still miss validation, this approach enables seeing, which policy types affect in which phases of the adoption process.

Contribution for policymakers

For the policy makers, this thesis highlights the importance of systemic approach in the policy mix design. The consumer perspective helps to add coherency by taking every step of the process into account. Technology adoption is a process in which one weak part may become a barrier even tough other polices in the process are effective. It offers information on the differences of political frameworks between the case countries. Although the EU is harmonising the legislation, national differences remain big. Countries have different business environments for DR, self-consumption, EVs and batteries.

Countries should find a policy mix that would incentivise prosuming, storing and electrifying transport and heating. Energy transition to clean technologies happens on many frontiers and technologies are increasingly interconnected. As the prices of energy storage, solar PV and EVs are coming down fast, implementing financial incentives for them is challenging. Earlier mistakes of windfall profits to investors from solar and wind industries increase policymakers' carefulness. Alongside technology-specific incentives, creating market conditions for aggregators' business models is increasingly important and timely. Updating value propositions for DSOs, BRPs and generators so that they support the development is essential at this point. The business ecosystem benefit from healthy and striving partners. Data ownership and framework of smart metering are big questions of the future where the EU has an increasingly important role. It also determines the future of ecosystems if aggregators become the value dominators in the ecosystem.

As noticed earlier, no country has adopted a policy mix that would have strong and incentivising policies in place for each step. From ecosystem's perspective, this would be desirable. On the other hand, different pathways for the prosumer ecosystem are logical because they derive from countries' socio-technical system and these have to be taken into account in policymaking. Missing policy intervention is not necessarily a barrier for the innovation system development, like in the case of missing smart meter rollout in Switzerland and Germany. In addition, some technologies, like DR and batteries, have similar functions, so supporting both may not be efficient. Finally, it must be indicated that policy recommendations require research on the effectiveness of the policies in creating the ecosystems.

Technology solutions where countries seem to be furthest from supportive regulations that would enable dominant designs are third party ownership models and collective SC. These business models have a lot of potential for further RE diffusion in democratic way. These businesses are perhaps more scalable than house segment as apartments are somewhat similar everywhere. On the other hand, new technologies like blockchain, may still affect radically the development of these business models.

Other practical contribution

For information search, this thesis lists many information channels that are also regularly updated. It lists interest groups, international organisations and other sources that concentrate in different regulations.

Table 24. *Contributions of the study.*

	Theory	Policy	Business and other
Macro	-Policy approach comparison	-Cross-country policy comparison with strengths and weaknesses.	-EU directives and proposals on each policy topic
Meso	-Energy prosumer policy mix structuration	-Policy areas to concentrate in the future. -Application of customer journey as a policy mix design tool	-Illustration of customer journey applicable for company strategies
Micro	-Innovation adoption process for energy prosumers.	-Customer processes and segmentation as a part of policy making	-Lists of information sources for policy analysis -Policy comparison for finding new markets

For companies acting in the prosumer ecosystem, it gives a tool to analyse consumer's journey, which leads consumers into the ecosystem's market. Different companies can adapt the approach to their needs and ecosystem strategy. Different partnerships between car manufacturers, solar companies, aggregators, utilities and smart home providers are emerging. As the ecosystem positions have not yet been cleared out, companies have to think their strategies and resources' potential for them. The ecosystem theory from Iansiti and Levien (2004) and Adner and Kapoor (2010) can work a basis for the ecosystem strategy elaboration. Car manufacturers may figure the prosumer journey starting from electric car adoption and aggregators from DR from consumers who are not willing to invest in own microgeneration. These companies have to adopt knowledge of regulation in other fields if they want to capture value stream outside their sector.

5.3 Assessment and limitations of the research

Most important limitations of qualitative studies are related to their reliability, construct validity, internal validity and external validity (Yin, 1994). Yet, the roots of this division are in quantitative research paradigm, and therefore it does not necessarily correspond well to qualitative studies. As the research question of this thesis was merely "what?", it takes a positivist approach to the topic. According to Lincoln and Guba (1985), the more relevant criteria in positivist qualitative research are *credibility, confirmability, dependability* and *transferability*. This chapter aims to evaluate the reliability and validity of this thesis within these terms.

Dependability

Dependability is a contextual way of evaluating the reliability of the study. Reliability is typically used in positivistic quantitative studies to evaluate the repeatability of the research. On the other hand, in case studies reliability issues arise from unstructured information and researcher's own interpretations (Bell & Bryman, 2015, p. 400). In this thesis, no interviews were taken so the issue of interpretation is more related to researcher's choices in data collection. Healy and Perry (2000) propose criteria for the evaluation of trustworthiness of the chosen methods in realism paradigm. Most notably, they refer to ability to audit the research process. In this thesis the data sources for each country were listed in the beginning. The general sequence of finding and using data was explained. For repeating the same data collection in the future, it has to be taken into account that not all reports and databases are updated or published annually and cannot therefore be used in similar way. For instance, IEA's prosumer-report and BEUC's self-consumption report are special reports published only once.

Confirmability

Confirmability evaluates how neutral the results are from the researcher. The results should not reflect preferences of the researcher but the sources of information (Shenton, 2004, p. 72). This can be increased by triangulation and detailed description of the methods used. In the sense of confirmability, this means including the raw data, like notes or statistics, data reductions, reconstructions and their processes in the study. Methodological description may include two trails: one that describes the development of the theory related to the research question and one that describes the how the data accumulated during the research process (Shenton, 2004, p. 72).

In this thesis, the criteria of choosing the studied policies and countries is explained in the methodology chapter. Describing the initial exploration of new policy papers and reports explained why each policy was chosen. Search and use of data sources was explained and language barriers mentioned.

In addition to researcher's own decisions and interpretations, the objectivity of data sources themselves has to be evaluated. As the data was mainly collected from secondary sources that are tightly related to policy making there is a danger of following a path of certain political agendas. Using many different sources reduce this risk. In addition, papers of SEDC and IEA, for example, have been widely cited in literature, which indicates they are rather reliable sources. Yet, also these organisations have some political agenda behind them.

Credibility

Credibility refers to internal validity of the study. It shows how well the chosen method suits measuring the abstract concept and research questions. Lincoln and Guba (1985) state that credibility is the most important factor in ensuring trustworthiness of the study. This thesis was conducted from secondary sources, so validity should be evaluated from content validity and construct validity. In addition, criterion-related validity is relevant as the policies were compared with each other.

The content validity measures how adequately and comprehensively the chosen measure reflects the topic. To reach content validity, firstly, the entire domain of the research context should be specified. Secondly, suitable measures ae selected. (Carmines & Woods, 2005) In this thesis, the theory was reviewed in a broad perspective with different policy approaches and innovation ecosystems. The broad theoretical approach is justified knowing that energy prosumer policies are part of wide socio-technical change that happens in different national contexts. Concentrating only in innovation and industrial policies would have addressed the ecosystem creation as they share the similar policy targets. Environmental and transitions policies, however, add other policy targets into the policy mix.

The construct validity is based on the theoretical build-up of the study. It tells how well the theory built is measured (Healy & Perry, 2000). It is especially important in cases where the theory has not yet been established. Researcher merely formulates predictions on the empirical indicators based on theoretical expectations. Problem exists if this theoretically driven prediction does not align with the actual phenomenon. (Carmines & Woods, 2005) In this thesis, this issue can be connected to the use of Rogers' innovation adoption model to structure the policy mixes and innovation ecosystems. Clearly, it has its strengths but also weaknesses. Strengths include simplicity, visibility and consumer focus. The five steps of the process have been validated in earlier and in overall, the model surely resembles prosumers adoption process. However, the separate activities and stepwise structure where each step has to be overtaken for continuing to the next one do not necessarily fit to the practice. On the contrary, France and Germany, for example, show that smart meter rollout is not required for established micro production or DR. Studying innovation ecosystem from the perspective of customer innovation adoption model can be justified but is not necessarily fit for the purpose throughout. For example the TIS model is a more comprehensive approach that looks at the connections also from the companies' perspective (Hekkert et al., 2007). However, the consumer perspective add and interesting perspective in the ecosystem policy mix planning.

The criterion-related validity indicates how well the chosen criteria measures the actual phenomenon (Carmines & Woods, 2005). Method of choosing the compared policies was explained in the methodology chapter. These indicators were based on the relevance and availability of comparable data. These indicators could have been more systematically evaluated from the innovation ecosystem functioning point of view. Now, the brief evaluation in table 22 shows merely the existence of the policy and does not evaluate its effect on ecosystem's success. However, the evaluation of policies is somewhat subjective even if it is systematised to a certain criteria. Subsidies and incentives have dynamic effects that are not only positive to the ecosystem creation. For example, subsidy-lead boom-and-bust cycles have been very challenging for solar industry's supply chains.

In general, the credibility of the research design could have been ensured with more in-depth research on each country. This could have been done with interviews with national experts like Imbert et al. (2017) did. The amount of countries would have been smaller and in that way the research would have missed the larger picture of energy transition in Europe. Another critique of the chosen research method is the short time scale that was included. Energy is now a fast moving industry where also regulation changes rapidly. For example, the reductions in FITs show how quickly policies can change in the RE industry. Longer time-scale with only one or two countries would have enabled studying contextual factors more in detail. That would have enabled answering to questions "how?" and "why?", instead, this thesis answers to question "what?"

Transferability

The external validity means the generalisability of the results to other contexts (Saunders et al., 2009). In quantitative research approach, generalisability is improved with large samples. In qualitative studies the criteria is different because the sample size is smaller and context is more important. Transferability of the findings requires therefore similar contexts in other countries. Lincoln and Guba (1985) state that making a "thick description" of the contextual factors increases the transferability of the study.

This thesis described the contexts on the macro level by describing countries' energy mixes, possible effect of industry, current energy policy agenda, RE targets, LCOE price of solar PV and current PV diffusion. These aspects affect the prosumer policy mixes and should be thought in other countries if similar investigations are to be done. However, also contexts of each policy on the national level is important and this thesis did not analyse them. In principle, the context often determines the functionality of the policy. For example, in Germany the important role KfW-bank is not comparable with other countries' circumstances. Yet, the research method of cross-country comparison increases the transferability of the research since it requires comparable and standardised data.

5.4 Future research

The future research avenues this thesis forms can be structured in macro, meso and micro levels. On the macro level, a more detailed study on policy strategies could aim answering, why countries pursue different policy strategies. For example, how disruptive change the country is implementing and what strategies current regime actors have to take in the transition. Policy landscape influencing would be another prominent way of studying policy strategies. According to Geels (2014), it is a topic under Transition Management that requires more research. Regime resistance of incumbent utilities may form the policies into more incremental approaches and in that way sustains their strategic positions in the ecosystems. The ecosystem actors are creating political coalitions and, for example, dynamic pricing, energy poverty and data security are questions that divide the field to supporters and opponents. Ecosystem members from transportation, energy and ICT fields may participate in different coalitions. Furthermore, research on the regulatory interactions between these fields would tell companies, which regulations they have to take into account when entering the other industry.

On the meso level, a longitudinal study of the formation of national prosumer ecosystems would be an interesting approach for studying networking between different fields. Regulations, like smart home labels for buildings, can be seen as drivers for these formations. It should also be highlighted that the technologies also compete with each other. Relations of policy mix and development of the prosumer ecosystem remains an interesting research topic. This approach could combine different value layers Schleicher-Tappeser (2012) described. Regulatory barriers and drivers for flexibility, like balancing responsibilities and roles in different system levels affect other policies, too, but these dynamics have not been researched yet.

This thesis built the prosumer journey, which was derived from utilities' web sites where similar journeys were presented. The prosumer journey should be validated and elaborated through interviews. The usage phase should be an important part to research as consumers' activity finally determines the benefits of the technology to the system. For example, the Use-diffusion model of Shih & Venkatesh (2004) could work as a frame of customer engagement. Another way to continue is to study the effectiveness of the policies. This requires elaborating valid indicators that not only measure the diffusion of DERs but also many other issues around them. For example, the DER integration costs and grid development are issues to be taken into account.

New technologies' like blockchain and V2G solutions will continue to change the ecosystem dynamics and affect the regulation. Research on new entrants should consider socio-technical compatibility of the new technologies and the current regime. For example, seasonal storage solutions and their fitting into the distributed energy regime will be one of the questions to be answered in the future.

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