Österbottens förbund
Pohjanmaan liitto

Regional Council
of Ostrobothnia

SMART ENERGY SYSTEMS RESEARCH PLATFORM

SESP

PROJECT REPORT

FUTURE ENERGY MARKET SYSTEMS:

SMART AND FLEXIBLE ELECTRICITY MARKETS

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30.4.2019

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1. INTRODUCTION

This report is an output of the Smart Energy System Platform (SESP) project. The aim of the report is to shed light on future energy market systems, especially in electricity markets, by firstly deepening understanding on distributed energy resources (DER) and their role in energy market transition. Secondly, regulative issues such as policies and regulation-related barriers are addressed. Thirdly, the report focus on the different market mechanism and the roles of existing and emerging new actors on the future energy markets. The report serves as a deliverable related to the SESP project's Work Package 9 (ABB case, Market Models). The report also provides inputs to the Work Package 7 Deliverables D7.4 (Policy paper on optimal electricity pricing models for prosumers) and D7.5 (Customer Value Insight Platform Guideline Tool Kit – CVIP).

As the technology behind energy production is developing in accelerating steps, at the same time the whole world is facing crushing facts about the climate change and what it requires from the people. The IPCC's (Intergovernmental Panel on Climate Change) climate report tells us that the energy field, among the others, is in crucial part to cut the greenhouse gas emissions thus trying to keep the global warming in 1,5 Celsius degrees comparing to the pre-industrial level. (IPCC 2018). This will change the whole field fundamentally and will affect to how the energy and electricity is produced, transferred and consumed.

The main reason for changing energy field is to prevent the climate changes. Energy sector makes almost 80 % of the greenhouse gasses in the European Union (European Parliament 2018) hence there is willing to get rid of coal-based energy production. Simultaneously technology is developing and making energy production that bases on renewable energy, such as wind turbines and photovoltaic panels, that is cheaper and more appealing (IRENA 2018). Because the demand and supply of electricity must be in balance, weather-based production requires flexibility and adjustable reserve electricity in the energy system (Partanen, Viljainen, Lassila, Honkapuro, Salovaara, Annala, Makkonen 2014). On the other hand, governmental subsidies for renewable energy production have disturbed the markets hence in Finland the price of electricity has decreased. This has led to that many traditional production plants, especially combined heat and power plants, have gone unprofitable thus shut down (Energia Uutiset 2018a). Unfortunately, many of the shut down production plants had a lot of good qualities for flexibly and adjustable production. This has led to problems in the electricity system that need to be resolved in the markets in order to maintain the security and retain the continuous of the needed electricity. (Fingrid 2018).

In addition, with the governmental subsidies, also the energy politics and legislation has intrinsically a huge effect to how, when and what will happen with the electricity industry. Each nation has their own policies and legislations, but also EU and its Energy Union aims to guide its members to keep the climate change at 1,5 Celsius degrees and secure the supply of energy (European Commission 2015).

The change in electricity industry does not stop at new energy generation types. As the small energy sources become cheaper, it will also appeal new parties to the markets. Consumers are already trending about their own renewable installations with photovoltaic panels, small combined heat and power or small wind turbines (Richter 2013). But it can be seen in the markets that also companies out of the electricity industry are willing to invest to their own production. These productions can be smaller photovoltaic panels in the office roof to reduce the electricity bill (Yle 2018), or even Mega Watt sized wind turbine parks to reduce the carbon print of the whole world-wide brand (IKEA 2015). This has also led to new products and parties in the market, for example many companies buy a part of their electricity with different kinds of long-term Power Purchase Agreements (PPA), where the power plant can be on the roof of the factory, but capital investor owns the plant and sells the produced electricity to the factory with long term agreements (Energiauutiset 2018b).

There are lot of different ways to implement distributed energy resources and it causes different challenges and benefits to each shareholder. Implementation of local energy markets requires innovations in several different fields. The innovation areas can be divided in customer applications, market services and control services. In this report the focus is on the market services and will focus only on electricity as fuels and heat are left out of the topic.

2. DISTRIBUTED ENERGY RESOURCES

Distributed energy resources (DER) refer to smaller energy generation units and energy storage units that are located usually near the consumption. Generation can be divided to residential sector and commercial and industrial sectors where the used technology may differ based on the location and the need. Different technologies can be for example solar photovoltaic panels (PV), wind turbines (WT), energy storages, combined heat and power units (CHP) and in the future, energy storages and small nuclear power-based generation with Small Modular Reactors (SMR) (EPA 2018; Energiauutiset 2018c).

For electricity companies and system operators distributed energy sources causes challenges as the increased amount of power input points and intermittent nature of most renewable generation makes the ensuring of the network balance and the security of supply more complex. Because the demand and supply of electricity must be in balance, flexibility and adjustable reserve electricity is required in the energy system. In addition, todays distribution networks have been planned only to transfer power from production to consumption and distributed power input points can change the dynamics of the network which may lead to a shift in power direction. As the flow direction changes, it also makes challenges to the control of the tensions in the various parts of the network (Kauhaniemi 2006; Partanen et. al 2014; Jenkins, Allan, Crossley, Kirschen & Strabac 2000).

Information and communication technologies are required to apply to the network system thus making the grid "smart". Smart grids make a better integration of renewable and distributed energy generation possible and can lead to savings in future network investments. This will open new opportunities which can lead to new business models with additional customer value creation or new ancillary service offerings. To enable effective management in local energy markets smart grid operations are essential. To provide more accurate data, smart meters are required to improve the quality of balance settlement. This also enables service providers to develop innovative and user-friendly services for customers. Accurate data of supply and demand is essential for different market stakeholders and makes efficient market operations possible (Teknologiakeskus Oy Merinova Ab 2015; CEDEC 2014; Meyn, Barooah, Busc, Chen & Ehren 2015; Van Halewyck, Verstraeten, Strobbe & Develder 2014; Koirala, et al. 2016).

In addition to big energy utilities, also household level customers are interested in investing in their own energy generation and storage units. Thereby consumers may evolve to prosumers that are one part of the grids generation and will actively participate in the energy markets and their role could be essential (FinSolar 2018.) As the customers involvement is increasing, new opportunities, innovative products and services open which has led to discussion about local energy communities and local energy markets. Local energy markets make the utilization of different distributed energy resources possible, and eases some challenges considering the volatile electricity production which requires more flexibility inside the grid. As the other prosumers can offer surplus electricity they generate, other users can offer flexibility to the grids through, for instance, demand response services and, even further, through energy storage services. With demand side management it is possible to use the grid more effectively as it makes possible to shave the peaks in the demand and relieve congestions in the grid. This requires new ways to interact with other actors in the system thus will open new market places for new actors like aggregators and Virtual Power Plants (VPP) and possibilities to current Distribution System Operators (DSO) and further to Transmission System Operator (TSO) (Mengelkamp, Gärttner, Rock, Kessler, Orsini & Weinhardt 2017).

As the new services goes available for consumers, it allows them to participation in demand response activities, which can increase the grids' flexibility. As different kinds of storage units are slowly becoming more common (Energy Live News 2018) DSOs and TSOs have increasing set of tools to response the increasing demand to manage the grids' flexibility (Timmerman 2017).

2.1. Microgrids

The architecture and functions of microgrids vary wherefore there are no one specific definition for it. Basically, microgrid is a limited group of multiple low or a medium voltage distributed generation, load and storage units operating as a self-coordinated system. Microgrids are a part of future self-healing smart grids as they have islanding capability to reduce outages. It consists of interconnected renewable and traditional energy sources and is often connected to the distribution grid at a point of common coupling thus for the DSO perspective it occurs as a single, flexible and controllable entity. There is no definition for microgrids size and it can vary, but usually it is considered to be a small part of low or medium voltage distribution network (Lo Prete & Hobbs 2016; Laaksonen 2011; Stadler et al. 2016; Soshinksaya et al. 2014). Microgrids are the main components of local energy markets and enables the opportunity for peer-to-peer energy trading. (Zhang, Wu, Zhou, Cheng & Long 2018).

To function, microgrids requires a variety of components. In simple terms, the foundation of microgrids are distributed energy resources (DER). This includes distributed generation, storages or active loads. Secondly, a physical network is required to connect all the DER and consumers. In order to operate and control distributed energy flows, via integrated communication, an advanced control and demand response technology is needed (Soshinskaya et al. 2014).

The ownerships of microgrids can be divided into three different designs. In the "*DSO monopoly microgrid*", DSO owns the grid and all the responsibilities and costs of maintaining the microgrid falls to the operator, but so does also the benefits. Normally this occurs in non-liberalized markets where the DSO owns the distribution and retail of the energy. In "*Prosumer consortium microgrid*" single or multiple consumers own different distributed energy sources thus benefits from the produced energy via lower electricity bills or revenues when supplying the grid with the surplus electricity. "*Free market microgrid*" is operated by different stakeholders like DSOs, prosumers or consumers. This means that there has to be a central controller to operate the microgrid. Since this type of microgrid is driven by many different stakeholders, also the possible benefits are shared between them. (Schwaegerl, Tao, Mancarella & Strbac 2009; Soshinskaya et al. 2014).

Although microgrids do not have any standards for size, usually they can be divided in low voltage and medium voltage microgrids. In low voltage microgrids the network customers are smaller and the production is based on small-scale generation. This includes typical households with own small-scale generation. It can cover the whole low voltage network or it can be formed by only some consumption points of the network. Medium voltage microgrids are naturally formed by larger consumption or generation units. These can be for example wind farms or industrial estates (Soshinskaya et al. 2014).

2.1.1. Revenue streams

Microgrids open different opportunities for new value streams. Stadler et al. (2016) found four major value streams. These are based on *Demand response, Power exports, Resilience against outages and Local energy markets.*

Demand response means that the end-users make changes in their electricity consumption in response. This change can be motivated with the price of the electricity or with some incentives to lower electricity consumption at times of high wholesale market prices or when system reliability is jeopardized (Shartiatzadeh, Mandal & Srivastava 2015). In practice, this can be done by reducing energy consumption through load curtailment strategies such as peak shaving, or by shifting energy consumption to different time periods. Both can be done either changing the consumption directly or with household automation or by taking advantage of onsite generation and storage resources.

This requires contactless Automatic Meter Reading (AMR) and good data connection between the retailer or system operator and customer. (Stadler et al. 2016, Van Halewyck et al. 2014; Roadmap 2015).

One of the value streams is power export. Prosumers can also get revenues via exporting the produced surplus power to the grid. However, for example in Finland the price of electricity consists of three key factors; the price of power, the price of transmission services and taxes. When exporting (selling) the produced electricity to the grid it consists only the price of power. This means that when prosumer uses the own generation, it saves the price of power, price of transmission services and taxes, but when prosumer sells, one gets back only the price of electricity. This make it unprofitable for the prosumer without any Feed-in-Tariffs or bigger incentives for households at the moment (Stadler et al. 2016; Energy Authority 2018).

Revenues can be achieved also with resilience against outages. Increased reliability prevents economic losses in case of power outages in the main grid. This can be caused by increasing price in the wholesale market due to power shortage or losses in production (Nooij, Koopmans, Bijvoet 2007). Although the value is problematic to quantify, this is a significant advantage of microgrid concept. DSO gets fines if the blackout prolong itself but also industry stops without electricity. One method to evaluate the lost value is Value of Lost Load (VoLL). VoLL estimates the cost to the customer per unit electricity not delivered, or the price that customers are willing to pay to avoid disruptions in the power supply. Different customers have different consequences thus it is required to take the nature of the consumer into account. For companies, power outtakes cause three different kinds of damage. The loss in production, the losses caused by increased electricity prices and thirdly, some goods and inputs may be lost. For example hot steel in a steel plant may cool down and have to be reheated. For households the damages intensify in two different ways. The loss of goods as if the power outtake takes long and for example the content of freezer goes bad or the loss of possibility to spend one's leisure time as wanted. (Stadler et al. 2016, Nooij et al. 2007).

The fourth revenue stream is local energy markets which is focused on the chapter 2.2.

2.1.2. Barriers

Although microgrids provide a lot of benefits and possibilities they still have some challenges and obstacles. Soshinskaya et al. (2014) groups the challenges into four categories: technical, regulatory, financial and stakeholder.

Technical challenges can be caused by the technology components, switching from grid-connected to island mode, protection and power quality problems and control issues. Dual-mode operation allows microgrids transition from grid-connected operation to island mode. During the transition the reliability of the energy needs to be maintained. Also reconnecting back to the distribution grid causes challenges as synchronization of the two different grids requires right timing to close the switch. Transition causes also imbalances between generation and load, which requires improved voltage and frequency controls in the microgrid. These problems are typical at component level and are caused by the volatility of weather-based generation or by frequent load shifting. (Soshinkskaya et al. 2014).

The major regulatory challenges are due to interconnection rules of distribution grid and microgrid and issues with bi-directional power flow. To implement microgrids, well-designed regulatory frameworks are essential. Then frameworks can provide guidance, integration and interconnection rules to the distribution network. Also, every country has its' own legislation which naturally causes differences and challenges for the microgrid design. Legislation can also limit the economic attractiveness with for example unfavorable taxation. The problems with the regulation of bi-directional flows causes challenges to the ability to feed surplus power to the main grid which naturally affects the utilization of smart networks and local markets. Regulatory challenges are focused more in the chapter 3.2. (Soshinskaya et al. 2014).

Expensive technology and its' high costs that accumulates in advance causes microgrids' main financial challenges. However, the technology behind DER solutions develop rapidly which can be seen in more powerful and better-quality products and with better price hence the economic attractiveness of microgrid solutions is rising. As the prices and power generation per unit has been rising rapidly in PV and WP technologies, storage technology is still in quite an early stage thus expensive and not very cost-effective. Many technologies are still very subsided which distorts the development of the markets. On the other hand, new technology might not be so easy to sell without the subsidies thus would not get enough resources to develop further to cost-effective version. Also some energy incentive industries are subsided with cheaper electricity that makes investments for own DER less appealing. However, in the long run technologies must be cost-effective without any incentives (Soshinskaya et al. 2014).

Problems considering self-interest problems, consumer engagement and trust are the major stakeholder challenges. For DSOs and energy utilities local energy markets causes discrepancy because the more their customers produces their own electricity and the more they sell it between other prosumers, the less they need electricity that utilities produce and DSOs transfer. At the same time local market designs can open up new business opportunities for all stakeholders but also bring new players to the opening markets with new products and services. When engaging the consumer, the consumers must be convinced that they and the whole local community understands the benefits that microgrids allow. For local consumers the understanding about the different levels of financial and environmental benefits of microgrids can be challenging thus the whole concept needs to be explained and clarified to gain social acceptance and trust within the community. Local communities need several prosumers to work thus the idea must reach the whole community. There can be also a lot of challenges if there have been failures with same kind of efforts in the past (Khattabi, Drenkard, Dierschmann, Dimeas, Moutis 2009; Soshinskaya et al. 2014).

2.2. Local energy markets

Interconnected microgrids can enhance the balance of supply and demand and strengthen markets' effectiveness while enabling end-users to trade electricity with other end-users in other microgrids instead of trading just inside their own microgrid or feeding produced electricity to the distribution grid. The local energy market is a marketplace where prosumers and consumers are able to trade electricity among each other and utilize local energy resources effectively. In addition, this eases the utilization of intermittent renewable generation to the energy system as the volatility even out. Local energy markets can restrain the market power of traditional power utilities, particularly when the local market is formed from customer owned microgrids (Koirala et al. 2016, Kilkki et al. 2018).

Interconnected microgrids produce value streams to market participants by lowering the energy costs and by promoting the use of local energy resources. Local energy markets are not limited to markets between different microgrids but also a single microgrid can be considered as a local energy market. Moreover, local energy markets do not have to be geographically contained, since aggregating loads from customers in different locations and offer the capacity to the wholesale and balancing markets can be done through virtual platforms (Koirala et al. 2016).

To operate local markets, there are options with different structures and possibilities and within, different threats and opportunities. However, basically all local market structures aim to optimize the utilization of renewable local energy resources, allow local energy trading, provide new services and strengthen customers' role on the energy markets. In different market scenarios, the stakeholders have different roles and new players, such as aggregators will enter the markets. Local markets can be connected to the wholesale markets, balancing and reserve markets. To ensure effective utilization of different resources between interconnected markets, active information between different market participants is required. In addition, transparency in the markets is essential. This will ensure non-discriminatory local market operation and participation of all market stakeholders (Kilkki et al. 2018). Interaction between local, wholesale and retail markets can be seen in Figure 1.

Figure 1. Concept and Interactions of local market (Kilkki et al. 2018).

There are various possibilities for trading mechanism and for example pricing and billing can be done in different ways. Blockchain technology has been emerged as a promising solution which might need further studies. Trading mechanisms and market designs are focused more in the chapter 4.1. (Mengelkamp et al. 2017a.)

2.3. Distributed Energy Resources in Finland

In Finland Energy Authority collects the data about small-scale (less than one megawatt generation capacity) generation. In total, the small-scale capacity at the end of 2017 was around 178 MW in

Finland and it is rapidly increasing (Energy Authority 2018). The production technology and their capacities can be seen in the Table 1.

Production technology	**Capacity 2017 (MW)**	**Capacity 2016 (MW)**
PV	66,2	27,2
Wind	17,5	15,5
Bio	16,3	15,3
Hydro	36,2	34,2
Diesel	38,2	37,4
Other	3,3	2,8
Total	**177,7**	**132,4**

Table 1. Small-scale production in Finland (Energy Authority 2018).

The biggest share and increase go to PV-production with around 66,2 MW capacity, which is over 140% more than at the end of 2016. During the 2018 small scale PV-production capacity is expected to break 100 MW limit thus it is continuing the rapid increase which is probably because of the decreasing prices of the technology, increasing price of electricity and the flexibility and ease of installation of the gear. However, if over one megawatt plants are considered PV capacity is around 70MW, WP 2000MW and Hydro 3000MW, where the WP capacity is rapidly increasing as building of plants with combined capacity of 340 MW is in progress and there are published new WP projects with almost capacity of 15 500MW (Finnish Wind Power Association 2018).

3. REGULATION IN ENERGY MARKETS

Currently European Union has set energy rules at the European level, but in practice it has 28 national regulatory frameworks. Each nation has its own targets for energy sector and also the European Union has its own targets for it member countries. Basically, there are three economical ways to guide the energy markets into preferred direction: taxation, subsidies and emission trading. For prosumers and furthermore for microgrids, the regulation in each country varies and decides how prosumers are compensated for their surplus electricity. There are a few different ways to compensate the prosumer. It is possible to use net-metering schemes, where the electricity exported to the grid is metered and the same amount is reduced from the electricity bill, or the prosumer sells the surplus electricity with current whole sale market price to the DSO or electricity company. The worst case for the prosumer is that one does not get any compensation from the surplus electricity. (Winkler, Ragawitz, Isi 2016). The way of compensation affects significaly how profitable it is for prosumers to invest on their own DER. The ability to sell the surplus electricity and receive benefits from it is one of the most important features of the microgrids and local energy markets. Hence it is very important to develop well-functioning regulation that allows stakeholders to use, invest and benefit from microgrids and DER. (Mendes, Nylund, Annala, Honkapuro, Kilkki, Segerstam 2018). In EU countries, European Commission has suggested Energy Union package in 2015 to balance energy politics and to develop them in Europe (European Consilium 2018).

3.1. Energy Union

The Energy Union has three main objectives; To ensure security of supply, competitiveness and sustainability to its Member States' energy sector. To achieve these objectives, the Energy Union focuses on five individuals, but mutually supportive dimensions: Energy security, solidarity and trust; the energy market; energy efficiency as contribution to the moderation of energy demand; decarbonization of the economy; and research, innovation and competitiveness (European Commission 2015). As a part to achieve these targets EU aims for integrated energy market. Integrated energy market "*creates more competition, lead to greater market efficiency through better use of energy generation facilities across the EU and produces affordable prices for consumers*" (Energy Union Package 2015).

The secure of supply does not only mean own energy generation, but also dependence of import energy outside EU and its disruption to prevent dependency on one main source. Currently over half of the used energy in EU is import energy, and this takes over one billion euros each day (Energy Security Strategy 2018.) To reach these priorities EU has its own energy and climate targets for the years 2020, 2030 and 2050. The target for 2020 is so called 20/20/20 where EU is targeting to increase renewable energy sources to 20 %, reduce the greenhouse gasses from 1990 levels by 20 % and improve energy efficiency by 20 % by the year 2020. Target for 2030 is to reduce greenhouse gasses 40 %, increase the use of renewable energy sources to 27% at minimum, to improve energy efficiency 27-30 %, to increase the interconnection rate of European electricity grids to 15 % when 15 % of the produced electricity is transferable to other EU countries. The long-term goal of the 2050 target is to reduce greenhouse gasses 80-95 % from 1990 levels. (European Commission 2018.)

Internal energy markets are in key role to deliver security of supply and integrating variables renewable energy sources. This requires market design that provides for coordination of capacities at regional level, storage and more flexibility in demand response, enabling consumers to better participation in markets and allowing energy to be exchanged across borders without barriers. Hence the EU regulation considers increasingly to all the Member States (European Commision 2015). Because investments to energy generation includes risks caused by large initial investments for long term, the objective of the strategy is also to send a strong signal to the market, encouraging private investment in new pipelines, electricity networks, and low-carbon technology (Energy Strategy 2030 2018).

3.2. Policies and Regulation Barriers

To enable the efficient use and development of microgrids and local energy markets, the regulation and policies are in significant role. The major problem is the absence of clear regulation considering local energy markets. There might be conflicts between who owns and manages the distribution infrastructure in microgrid networks. Especially when microgrid intersects with local distribution network. (Mendes et al 2018). In some cases, there is difficulties to define who owns the distributed generation capacity. One major problem considers the regulation of the ownership and furthermore maintenance responsibilities of the generation units that serve a whole community but are only installed to some households (Wouters 2015). Koirala et al. (2016) founds out that energy cooperatives are one solution for the ownership structure where members share the revenues and benefits of local microgrids. Microgrids often need additional infrastructure which might cross publicly or privately-owned property thus there needs to be a clear regulation for electrical supply installation (Wouters 2015).

To function, the prosumers of local energy markets must be allowed to sell surplus electricity and receive monetary or some else benefits from it. Otherwise there is no use to produce electricity and specially to give it to others. That is why there must be an appropriate regulation considering the selling of prosumers' surplus electricity to the grid or trading it with other users. Public policies should support local offer of customer-centric services, rather than discourage it. One major issue is due to the taxation. For example, in Finland, when buying, the price of electricity is a combination between electric power, electricity taxes, value added taxes and transmission services. When prosumer sells the surplus electricity, one gets only the price of electric power. Hence the financial benefits of selling the surplus is only around 30% compared to the cost of buying. For prosumer's point of view this makes the investment for micro-production equipment more unprofitable and undesirable. In legal aspect it is already possible to compensate also the transmission service costs. However, electricity taxation is a bit more problematic because the excise duty on energy products is largely harmonized within the European Union. This sets the boundary conditions under which a member state must impose its electricity taxation. However, it could be possible as member state could apply for a national derogation, which is permitted by the first paragraph of Article 19 of the Energy Tax Directive. Value added taxation is not possible to compensate in net billing, because the law explicitly prohibits the sale of prices and taxes in sales and barter situations (Aapio 2017).

Customers' load control can inflict conflicts of interest. The flexibility customers can offer, could be utilized for balancing power markets or ancillary services market or use to maximize utilization of local generation capacity. Thus, the responsibilities and rights need to be clearly defined between the balance responsibility parties including if third-party intermediary is controlling the loads (Mendes et al 2018). Due to the voltage stability problems and to ensure safe operation, islanding is often prohibited. To utilize the microgrid with its' full potential regulators will have to push regulatory frameworks that facilitate compliance with bi-directionality requirements, particularly at the point of common coupling (Wouters 2015; Soshinskaya et al 2014).

Many energy projects have to go through long administrative procedures and the time from planning through approval and permission to final product might prolong. Instability and sudden changes in policies creates an additional risk for investors. For example, the uncertainty who pays for connecting DER to the distribution network and for possible grid reinforcements. Transmission and distribution networks have been designed for unidirectional power flow. Regulators have to consider how new regulations or adjustments in the old ones facilitate and serve best for grid's bi-directionality. (Ali, Li, Hussain, He, Williams, Memon 2017; Soshinskaya et al 2014).

For housing companies regulation allows the utilization of small scale generation only for property electricity. This means that the residents cannot save electricity or utilize emission-free generation compared to companies, farms and other households. This cuts a huge potential as there are, for instance, in Finland almost 90 000 housing companies with 142 000 different buildings that could have own small scale generation. The current regulation causes that housing company's own generation that goes through the housing company's electricity meter to the residents, is treated in regulatory point of view similarly as electricity from the distribution network. Hence savings with taxes and transmission are lost. To enable small scale utilization in housing companies, the residents should act as small producers through their shareholdings in the joint power plant. Legislation should allow the computational distribution of small scale generation within the property network to be used by shareholders for their own electricity trading periods. The length of the balance period is currently one hour and in the future will be 15 minutes. The amendment to the measurement regulation may allow the invoicing and balance settlement of small producers to be based on computational data. This would enable the building of internal energy communities within real estate networks, with the help of smart metering data and computer software. (Auvinen & Honkapuro 2018).

There is also difference how the prosumers production is measured and compensated in Finland. All the meters cannot compensate the surplus electricity behind different phase where the demand is. This leads to that there might be, for example 2kWh surplus on phase one fed to the grid at the same time when phase two is still buying the same amount of energy from the grid because the meter cannot compensate the phases with each others. Hence the benefits can be radically different basing on where the prosumer lives and what kind of meter the local DSO provides. (Auvinen 2019).

In Finland, companies are encouraged to invest on small-scale production with investment subsidies. However some energy incentive industries are also subsided with smaller energy taxation that leads to cheaper electricity that makes investments for own energy production equipment less appealing.

4. FUTURE MARKETS

Reduced energy costs and CO_2 emissions are few of the main objectives of the energy markets. Although microgrids are often identified with different names such as energy communities, virtual power plants or local energy markets, all of them have same kind of target and technical principle: to form a marketplace where prosumers and consumers can exchange electricity with each other and this way use the local (renewable) electricity as efficient as possible. In order that future local markets can function, flexibility and new services are in key role. This lead for new roles for stakeholders and has a huge impact for how the prices are formed and how the markets work (Koirala et al. 2016)

4.1. Market and pricing mechanism

Local energy market mechanism should be a combination of balancing and pricing mechanism to optimize the use of local energy markets and their energy production. This requires common bidding language and format between the electricity communes' prosumers and consumers to available trading electricity at variable prices. Because local electricity market contains its' own characteristics the design of the market must take into account the configuration of the local power system, characteristics of market participants and the objectives of the stakeholders. Also, the competition in the market, the trading horizon and dispatch intervals should be considered because they impose different optimization problems. Microgrids consist mainly small-scale generation, thus there should be minimum and maximum allocations of energy. To function properly, markets should send price signals according to the available electricity. If there is a shortage in the market, prices rise, and if there is a surplus, prices go down. When the local market price is lower than the wholesale price, it is profitable for consumers and prosumers. As the local energy markets' benefits can be seen, customers' and prosumers' interest and commitment towards the local market development will increase. (Mengelkamp et al 2017, Ampatziz et al. 2014).

With local electricity markets there are a few critical issues and different approaches in the implementation of the market mechanism. For functional market mechanism the main components that need to be defined are the format of the bids, the clearing rule, the pricing rule and the information the market participants have access to. In addition, the time horizon is an essential part as the electricity markets consist of day-ahead and intraday markets. Day-ahead market is dependent on accurate forecasting of supply and demand. With such an intermittent characteristic as weather-based generation has, shorter trading horizon enables more efficient utilization of DER. With shorter trading horizon, imbalance settlement is more stable because there is less imbalances between predicted consumption and actual consumption. If the imbalances cannot be met in the local market, then it is among top priorities for DSO to dispatch energy resources with fast response for real-time power balancing and reliable operation. (Mengelkamp et al 2017; Du, Deng, Sheng, Xiao, Qu 2016; Ampatziz et al. 2014; Vytelingum, Cliff, Jennings 2008).

In energy markets the clearing price can be determined by uniform or discriminatory pricing. With uniform pricing, the clearing price is derived from the aggregation of supply and demand bids, hence all transactions have the same price. With discriminatory pricing, each transaction has a different trading price according to matched supply and demand bids. When the information of the market participants is private, discriminatory pricing reduces market power and with uniform pricing revenues and prices increase (Smith 1967; Wolfram 1998; Xiong, Okuma & Fujita 2004).

Local electricity markets can have different market designs. Mengelkamp et al. (2017) presents a centralized order book market and a direct peer-to-peer (P2P) market. With the P2P market design, prosumers and consumers trade between each other with orders made on a pay as-bid basis individually, randomly and anonymous. Buyer is in every time slot randomly paired with prosumer until the buyer has produced all of one's electricity or is paired with all potential sellers. The buyer is paired with the prosumer, if the bid price is equal or higher than the asking price of the prosumer. Buyer pays the bidding price and the matching energy amount is determined by buy and sell order's minimum amounts. If the buyer's bids cannot be paired with any prosumer's selling bids, the wanted electricity must be attained from the external market with the grids' electricity price. For the trading period of one time slot each bid is fixed and renewed in every trading period. Because consumers and prosumers have a limited amount of tradable electricity, the sequence of pairing in matching algorithm is relevant and orders are randomized to avoid competitive advantages. (Blouin & Serrano 2001; Mengelkamp et al. 2017).

As with the peer-to-peer market every payment is individual with a different price, with order book market all the successfully purchases are made with the market clearing price. This is because the order book market is executed with a double-sided auction market with discreet closing times. All the bids (buy) and asks (sell) have to be submitted to public order book. The lowest bid that still can be matched with the aggregated supply, determines the market clearing price. All consumers pay the market price to the sellers. If the consumers cannot buy all the needed electricity from the local market prosumers, the rest must be bought from the external retail market. On the contrary, if prosumer cannot sell the produced surplus to local markets or storage it, it must be sold to the distribution grid. When P2P markets do not need any central authorities, order book market design requires a central unit or a platform that could aggregate the bids and clearing prices. (Mihaylov, Jurado, Van Moffaert, Avellana & Nowe 2014; Vytelingum & Ramvhurn 2010; Kok, Roossien, MacDougall, Van Pruissen, Venekamp, Kamphuis, Laarakkers & Warmer 2012; Mengelkamp et al. 2017).

There are two types of agent bidding strategies; the zero-intelligence bidding strategy and intelligent agent bidding strategy. The zero-intelligence agents decide on a price limits either for buying or selling electricity in every trading period. The price limit is randomly assigned within designed boundaries. Boundaries can be that prosumers will not sell electricity below the feed-in tariff and consumers will not pay more than the grid electricity tariff. This will lead to that only economic reasons are taken into account and for example higher usage of local renewable electricity is forgotten and agents will not take into account any info about the past auctions. Intelligent agents learn from their past auctions and attained results of trading. They update the ways how they place bids basing to the received incomes as prosumers and costs that hit them as consumers. (Lamparter, Becher, Fischer 2010; Vytelingnum et al. 2010; Mengelkamp et al. 2017).

4.2. Impact for Stakeholders

4.2.1. Transmission System Operator

Transmission System Operator (TSO), e.g. Fingrid, is responsible for the technical functionality and dependability of the national electricity system. It also manages the nationwide balance operation and prepares the nationwide imbalance settlement in an appropriate manner that is equal and non-discriminative of any party of the power market. TSOs are interacting with the high-voltage network thus smaller microgrids might not have much impact to TSOs role. In the future local energy markets can offer their capacity and flexibility to the balancing energy markets via aggregating services which might open new interactions with TSO (Fingrid; Kauniskangas 2013; USEF 2015).

4.2.2. Distribution System Operator

Distribution System Operators (DSO) are obligated to maintain and develop the grid, to connect the production plants to the users and to transmit the electricity. DSOs are responsible for the grids' condition and quality of the electricity to the customers (Energy Authority). A customer can choose the producer, but not the DSO, because of the regional monopoly of DSOs (Kauniskangas 2013). As microgrids and local small-scale production becomes more common, the role of DSO might evolve as new opportunities and duties might open. Microgrids will not remove the need for distribution grids but on the contrary DSOs enable local markets to participate in, for example, conventional electricity market which enlarges the opportunities of microgrids beyond islanding and trading only inside one market. The DSOs' role in the local markets can vary based on the local market structure as the DSO could take a role of local market operator and ensure the local marketplaces' function and secure the supply inside the local market. At the same time DSOs get more tools and flexibility to operate as local energy markets' prosumers surplus electricity, demand response and possible storages enter their flexibility. In other hand, new technology can cause a need for increased grid capacity and weather-based electricity generation causes more need for flexibility. (Timmerman 2017).

4.2.3. Prosumers and Consumers

Prosumers and consumers are in essential role as self-generated electricity and demand response services and their users make the local energy market possible. As end-users are rarely aware of energy industry and they do not know about the possibilities and limitations, the service providers, energy suppliers and DSOs are responsible for offering the needed ancillary services and applications. In addition, all the offered ancillary services and applications should be user-friendly and should not decrease the daily comfort level of end-users' life, but still enable the participation of different local energy markets without preventing the use of electric equipment at any given time.

Prosumers and consumers energy management applications will be on key role as they enable users to optimize their energy usage but also gives to DSOs or aggregators flexible capacity with demand response services for the network balancing. Energy users just have to have motivation, such as smaller energy bills, to give DSOs or aggregators access to their flexible capacity (Timmerman 2017).

4.2.4. Suppliers, Aggregators and Service Providers

The suppliers procure electricity from energy utilities and traders and then sells the acquired electricity to their own customers. The profit is made with the difference in costs between buying and selling. Most of the local energy markets are part of a distribution grid where the end-users are also able to receive electricity from the grid additionally to the self-produced energy. Weather based production leads to imbalances with consumption and production for time to time thus consumers have to compensate their electricity surplus and/or deficit it with suppliers or other service providers. At the same time suppliers can enhance prosumers' surplus production for their own supply portfolio (USEF 2015; Kilkki et al. 2018).

The new business models and new market opportunities give chances to suppliers to expand their businesses and become an aggregator for local energy markets and deliver the electricity and flexible demand response from one microgrid to another (USEF 2015).

Suppliers are not the only market actor that can take the role of an aggregator, but also in addition different local energy market operators or energy service providers can find new opportunities with aggregating. Aggregating enables prosumers to participate into the market and maximize their use of their flexible resources and surplus generation without taking risks that are involved in electricity market operations. Hence aggregators are an important link between local energy markets and conventional electricity marketplaces such as intraday, day-ahead and balancing markets. With enough different prosumers, aggregators can provide more reliable flexibility from multiple resources. Aggregators can open new tools for DSO when for example one microgrid entity has enough generation capacity, it could be disconnected from the distribution grid for short periods if there is a need for up-regulation in the balancing markets. (USEF 2015).

As the technology behind households' energy generation is developing and making energy production cheaper and more appealing, more prosumers will enter to the grid giving suppliers and aggregators more available capacity. Developing technology also enables different service providers new business models, as electricity generation comes available for anyone with enough capital. Different companies can install PV-plants on the roofs of their real-estates. Also different kinds of long-term Power Purchase Agreements (PPA) have emerged to the markets, where the power plant can be on the roof of the factory, but capital investor owns the plant and sells the produced electricity to the factory with long term agreements. For traditional energy utilities this will add competition and for microgrids more capacity will emerge.

5. SUMMARY AND CONCLUSIONS

Electricity markets are facing a significant change in the future as production, transfer, consumption and even future revenue streams might drive paradigmatic changes. As the technology behind small-scale generation becomes cheaper and available for everyone, more and more distributed generation and power inputs will enter to the grid which has developed to transfer power from production to consumption. The distributed input points can change the dynamics of the network which may lead to a shift in power direction. As the flow direction changes, it also makes challenges to the control of the tensions in the various parts of the network. For electricity utilities and system operators distributed energy causes also challenges to ensure the network balance and the security of supply because of the intermittent nature of weather-based generation. Flexibility and adjustable reserve electricity is required in the future energy system. Information and communication technologies are required to apply to the network system thus making the grid "smart". Smart grids make a better integration of renewable and distributed energy generation possible and can lead to savings in future network investments.

As customers and prosumers are more involved to the markets, new opportunities and innovative products and services open. Microgrids and local energy markets has been discussed as a solution for utilizing the different distributed energy sources and easing the challenges considering the volatility of weather-based electricity production which requires more flexibility inside the grid. As the other prosumers can offer surplus electricity they generate, other users can offer flexibility to the grids through, for instance, demand response services and, in the future, through energy storage services. With demand side management it is possible to use the grid more effectively as it makes possible to shave the peaks in the demand and relieve congestions in the grid. This makes prosumers and consumers role in the future electricity markets essential.

There is not a specific definition for microgrids architecture and functions because they vary, but basically microgrid is a limited group of multiple units of low or medium voltage distributed generation, load and storages operating as a self-coordinated system. In the future microgrids could be a part of self-healing smart grids operating with islanding capability to reduce outages. It consists of interconnected renewable and traditional energy sources and is often connected to the distribution grid at a point of common coupling thus for the DSO perspective it occurs as a single, flexible and controllable entity. Microgrids open opportunities for various new value streams. Four major ones; demand response, power exports, resilience against outages and local energy markets were discussed. Microgrids still have some challenges and obstacles which were categorized to technical, regulatory, financial and stakeholder based.

Regulation and policies are in significant role of utilizing the efficient use and development of microgrids and local energy markets. The major problem is the absence of clear regulation which can lead to conflicts between different stakeholders. There are also challenges due to interconnection rules of distribution grid and microgrid and issues with bi-directional power flow hence regulatory framework could be needed. Then it could provide guidance, integration and interconnection rules to the distribution network. Legislation can also limit the economic attractiveness with for example unfavorable taxation. The problems with the regulation of bi-directional flows causes challenges to the ability to feed surplus power to the main grid which naturally affects the utilization of smart networks and local markets. Microgrids' prosumers must be allowed to sell surplus electricity and receive monetary or some else benefits from it. Otherwise there is no use to produce electricity and specially to give it to others. Public policies should support local offer of customer-centric services, rather than discourage it. Also, the rules and benefits should be same to everyone and not dependent on the location of generation and the local DSO who has local monopoly. There are a lot of unused DER potential with the housing companies that enter the local energy markets with their flexibility and surplus if they would be allowed to utilize their own generation better. In Finland, companies are encouraged to invest on small-scale production with investment subsidies. However, some energy incentive industries are also subsided with smaller energy taxation that leads to cheaper electricity that makes investments for own energy production equipment less appealing.

Flexibility and new services are in key role to enable future local markets function. This has a huge impact for the role of different stakeholders and market mechanisms. Functional markets need defined bid format, clearing rule, pricing rule and information for the market participants. For intermittent generation as weather-based is, shorter trading horizon enables more efficient market function as the imbalance settlement is more stable because there is less imbalances between predicted consumption and actual consumption. If the imbalances cannot be met in the local market, then it is among top priorities for DSO to dispatch energy resources with fast response for real-time power balancing and reliable operation.

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