Peer to Peer Smart Energy Distribution Networks

Document ID:	**P2P-SMARTTEST-WP2-D2.2**
Deliverable Title:	**D2.2 Regulatory, Business, Technological, and Social Enablers and Barriers of P2P Energy Transfer**
Responsible beneficiary:	**University of Bath (UBAH)**

On 07/05/2014 the Project Coordinator submitted the proposal for the call for proposal H2020-LCE-2014-3. The Specific Call is contemplated in the Work Programme 2014-2015, 2020-LCE-2014-2015/H2020-LCE-2014-3. The Project with the contract number 646469 has been declared awarded in the framework of the Specific Call.

Start Date of the Project:	1 January 2015
Duration:	36 Months
Dissemination Level:	Public

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 646469

Document Information

Document ID: P2P-SMARTEST-WP2-D2.2

Version: 2.2

Version Date: 2016/10/31

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Security: Public

Approvals

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Coordinator	Ari Pouttu	UOULU	31.10.2016	
Management Committee	Ari Pouttu	All partners	28.10.2016	

The purpose of this document is to define a consistent set of working procedures, processes and best practice guidelines in order to ensure highest quality standards of the project outcomes.

Document history

Revision	Date	Modification	Authors
V1.0	17.10.2016	Pull together the results contributed by responsible partners	Furong Li, Zhipeng Zhang, Yueqiang Xu, Petri Ahokangas, Maria Kopsakangas-Savolainen, Eloisa Porras
V2.0	26.10.2016	Revision after Partner's (ENDESA) comments	Furong Li, Zhipeng Zhang, Yueqiang Xu, Petri Ahokangas, Maria Kopsakangas-Savolainen, Eloisa Porras
V2.1	28.10.2016	Revision after Management Committee's comments	Furong Li, Zhipeng Zhang, Yueqiang Xu, Petri Ahokangas, Maria Kopsakangas-Savolainen, Eloisa Porras
V2.2	31.10.2016	Final version for submission	Furong Li, Zhipeng Zhang, Yueqiang Xu, Petri Ahokangas, Maria Kopsakangas-Savolainen, Eloisa Porras

EXECUTIVE SUMMARY

Our electricity system today was designed around a centralised market, where large power stations generate energy, national retailers buy and sell this energy and the whole system is balanced on a national scale. This market is rather complex and involves a number of differing participants, including transmission system operators (TSOs), distribution system operators (DSOs), retailers, and generators.

Nevertheless, as the energy system changes, current business models of these entities become outdated. DSOs' current business models are to recover network operation and investment costs through the use of system and connection charges. Although there are wide differences in charging methodologies among EU countries, the underlying factors determining their revenue streams are the same – network investment is the main option for meeting peak demand and making money. Current business models thus cannot provide adequate incentives for DSOs to move towards smarter energy grid and guarantee they can survive in the energy revolution.

Recently, there has been a rapid growth in distributed energy resources (DERs) such as distributed generation and energy storage connecting to the distribution network and micro-generation and flexible loads at the premises of end users. Estimates reveal that renewable energy sources based on solar, wind, geothermal and tides can meet a large portion of the energy demand. These resources are not actively utilized at the distribution system by distribution network operators, retailors or energy service providers, as there are no active markets in place to incentivise DERs at the edge of the grid.

With the increasing penetration of DERs, incumbent DSOs, retailers and new service providers are presented with unprecedented opportunities and challenges to manage infrastructure costs, customer engagement and reduce energy costs. The key challenge to facilitate demand response and deployment of DERs is to put in place new business models and local and regional real-time market solutions that would actively involve, not only DSOs, but all the rest of actors of the electricity market: Consumers, ESCOs, and Retailers. As a result, new business models and market mechanisms are required to take the full advantage of DER from substantially increasing interactions between people, energy service providers, retailers and the system.

This report aims to understand where we are today, identify enablers and blocks, pave the way for developing new business models for the ecosystem, and provide a baseline position to demonstrate the benefits from introducing innovative new business models. More specifically, this work establishes an understanding of differing enablers, limiting factors/barriers and challenges in the context of P2P energy market in particular. Four aspects of the influence have been investigated. From the regulatory perspective, although various countries in EU tend to have rather differing

governmental supports and regulatory environments, the barriers of limitation on customers' access to the energy market and regulatory compliance burdens on licensed energy entities have been particularly discussed. On commercial side, influencing factor such as business case risks and uncertainties for small retailers, access to funding, and the conflict of interests among market participants have been identified. Technologically, the lack of monitoring on distribution levels, the lack of half-hourly settlement for individual customers, system instability caused by increasing penetration of local resources and ICT maturity have been investigated. Finally, this report looks at today's social challenges for P2P trading and new business models, the general lack of customer engagement and privacy and data protection issues have been examined.

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LIST OF ABBREVIATIONS

EU	European Union
P2P	Peer-to-Peer
ICT	Information and Communication Technology
DER	Distributed Energy Resource
DSO	Distribution System Operator
ESCO	Energy Service Company
DR	Demand Response
WP	Work Package
TSO	Transmission System Operator
DG	Distributed Generation
DSM	Demand Side Management
FIT	Feed-In-Tariff
VPP	Virtual Power Plants
MNO	Mobile Network Operator
VAT	Value Added Tax
B2B	Business to Business
B2C	Business to Consumer
BRP	Balancing Responsibility Plant
PV	Photovoltaic
MME	Ministry of Employment and Economy
ICES	Integrated Community Energy System
GB	Great Britain
HV	High Voltage
EHV	Extra High Voltage
LV	Low Voltage
EV	Electric Vehicle
SG	Smart Grid
AD	Active Demand

1 INTRODUCTION

To ensure Europe produces world-class science, removal of barriers to innovation makes it easier for the public and private sectors to work together in delivering innovation. Horizon 2020 (The EU Framework Programme for Research and Innovation) is implemented and backed by Europe's leaders and the Member of the European Parliament. By coupling research and innovation, Horizon 2020 is helping to achieve the goal with its emphasis on excellent science, industrial leadership and tackling societal challenges. P2P-SmartTest project is one of the Horizon 2020 projects.

P2P-SmartTest project investigates and demonstrates a smarter electricity distribution system based on the regional markets and innovative business models enabled by advanced ICT. It will employ Peer-to-Peer (P2P) approaches to ensure the integration of demand side flexibility and the optimum operation of DER and other resources within the network while maintaining the energy balance, second-by-second power balance and the quality and security of the supply.

The objectives of this project are:
(1) To investigate and develop alternative business models for DSOs, ESCOs, Suppliers and Consumers for P2P energy trading to capture the whole supply chain value while maintaining second-by-second power balance, maximizing Demand Response (DR) and DER utilization and ensuring supply security. The magnitude of benefits from introducing P2P energy trading is quantified and the required changes in technical, commercial and regulatory arrangements will be identified. (This corresponds to WP2.)
(2) To evaluate existing ICT technologies and new ones for P2P energy trading. The focus is on investigating the last-mile technologies, which support inter- and intra-MicroGrids operation, also the backbone telecom infrastructure is considered, which is critical for intra CELLs operation and data exchange with transmission network operators. (This corresponds to WP3.)
(3) To develop P2P advanced optimization techniques to provide efficient P2P energy market trading, while considering the new business models and ICT technologies. In order to fulfil a real integration of the flexibility of demand and DER management using P2P, the whole market domain will be explored including products/services to be traded and certification mechanisms to be implemented. (This corresponds to WP4.)
(4) To develop alternative P2P based control paradigm of distribution networks, integrate probabilistic and predictive control functions to enable and facilitate the P2P based energy trading and better network operation under extremely dynamic and uncertain conditions, and model of dynamic demand for operational functions of P2P smart distribution networks. (This corresponds to WP5.)

This deliverable is part of WP2.

In this report, the key regulatory, business, technological and social enablers, limiting factors/barriers, and challenges have been investigated: 1) distribution network control, operation and planning; 2) the market dominance by big suppliers, government interventions in tariff setting and green subsidies; 3) communication network and ICT utilization operation and management within and between each player; 4) commercial and regulatory arrangements and mechanisms, particularly allow ESCOs, Aggregators, service providers and Prosumers to optimise the return for their customers access many markets across the entire supply rather than a small fraction of the markets. The purpose of this investigation is to provide a coherent view on the enablers, limiting factors/barriers, and challenges at the local, community and regional levels, which will be fed into WPs 3, 4, and 5.

2 REGULATORY ENABLERS AND BARRIERS

This chapter provides a short overview of the regulatory issues facing P2P energy transfers. The aim is to analyse the enablers and barriers/limiting factors resulting from current (or possible future) regulatory arrangements to peer-to-peer energy transfer. It is acknowledged that countries within the EU have rather differing regulatory frameworks, we have selected Finland as an example of discussion in the chapter, though majority of the factors are also applicable in other EU countries.

Economic barriers can be categorized from the viewpoint of economics as being brought on by market or non-market failures. In economic theory, regulation can be seen as welfare increasing if it is enacted to address a known market failure. Sometimes regulation that affects the normal functioning of the market is implemented for other reasons and regulation in itself can be seen as a barrier. Here we categorise all barriers related to enacted or missing regulation as regulatory barriers.

In this work, regulation itself refers to all forms of taxes, subsidies and legislative or policy measures that affect prices, market entry and other functioning of the market. The peer-to-peer energy transfers are connected both to the competitive electricity retail and wholesale markets and the non-competitive distribution of electricity. Peers are here defined in a very wide sense as any loads or generation (or both) aggregated or not which may be owned by households, small firms or other instances (e.g. shared assets, cooperatives).

Possible regulatory measures that might benefit the adoption of P2P energy transfer, i.e. regulatory enablers will be discussed in this chapter first. Then, we will discuss the existing regulatory issues and barriers relating to P2P and look at possible future regulatory barriers.

The regulatory environment consists of policies and legislation that are enacted by several different actors. For instance, in Finland the regulation of energy related matters is under the Energy Authority (Energiavirasto), but building codes, taxation and competition can fall under the control of different institutions. In Finland the regulatory framework is also increasingly connected to international developments as the Nordic regulators are aiming for more harmonised electricity markets [1].

In Finland, the main regulatory authority is the Energy Authority, which supervises among other things the electricity market and is the national emissions trading authority. It also promotes renewable energy and energy-efficiency. The Energy Authority is also responsible for procuring the necessary capacity reserves to ensure supply and demand balance at all times [2].

Electricity retailing does not require a license or registration in Finland and there are no regulated tariffs for retail supply that have to be approved by the Energy Authority or any other authorities. The electricity retailers in Finland may be under the obligation to supply. There are 64 retailers with the obligation to supply within at least one distribution network area of responsibility. Although the electricity retailers may be obligated to supply, the electricity retail prices are not regulated in Finland [2].

There are some ties between electricity providers and distributors in Finland and some regulation has been imposed to unbundle some operations in the electricity market. The Electricity Market Act forces utilities to unbundle any electricity network operations from other electricity trade operations. The network operations must be legally unbundled from electricity generation and trade operations if the annual transmitted quantities exceed certain limits. As an example of the more general tendency of unbundling of operations, two large energy generating companies Fortum Power and Heat Oy and Pohjolan Voima Oy (PVO) sold their shares of the Finnish TSO Fingrid in 2011 as part of the requirements of the Internal Electricity Market Directive. There is no requirement for ownership unbundling of the DSOs in Finland and most of the legally unbundled DSOs still belong to the same group of companies as electricity retailers and/or generators. For example, a generator or a retailer can be the parent company of the legally unbundled DSO, or a group of DSOs can own an electricity retailer [2].

The Electricity Market Act (9.8.2013/588) sets many of the rules regarding electricity markets in Finland. The Electricity Market Act (9.8.2013/588) aims to achieve reliable electricity supply, competitive electricity prices and reasonable service for customers. The Electricity Market Act defines the rules for obtaining operator licenses, supplier switching, billing, metering etc. According to the act electricity network operations must be legally unbundled from electricity trade operations and electricity generation if the annual quantity of electricity transmitted to the customers through the network operator’s 0.4 kV distribution network has been 200 GWh or more during three consecutive calendar years. In 2015 there were 35 DSOs over this limit and over half of the total number of DSOs (46 of 80) have already legally unbundled network activities [2].

In Finland, customers have a right to have access to their consumption data for free and the customer’s permission is required for sharing their information to other parties [2]. Data availability and transparency are important also to possible P2P solutions.

The Electricity Market Act also assigns the Finnish TSO Fingrid the task to develop information exchange required for trade and imbalance settlement. As a part of this task Fingrid has set out to establish a datahub in Finland [2]. A datahub is a centralised information exchange system which enables all players in the market to access data shared between consumers, retailers and DSOs.

Regulation in the electricity market has to be such that price signals reach the market participants correctly. This is important in the future as more flexibility is needed. There must be room for also higher prices so that the market participants can react properly, leading to adequate short-term responses and long-term investment decisions [1].

Previous literature dealing with barriers in relevant areas was examined in order to find possible barriers. The literature reviewed included among others studies looking at barriers in energy efficiency and demand response. To some extent it is possible to make use of the literature covering barriers and enablers from other areas such as demand response, energy efficiency and new technology adoption for example. The same approaches can be used at least partially in this context as well. The listing of barriers and enablers used here is not a comprehensive or theoretically oriented classification of them, but instead aims to be as detailed as necessary without going too deep into technicalities of business models, technology or legal issues and cover enough of the different types of issues related to peer-to-peer energy transfer within the limited scope.

On a larger scale the barriers and enablers of P2P energy transfers are tied in with the development of the smart grid technology. Smart grids enable controlled smart delivery of electricity and sharing of relevant consumption and other information in order to enhance reliability and even overall efficiency of the system. Peer-to-peer energy transfers are a part of smart grid enabled possibilities and as such face similar hurdles and are partly driven forward by same new demands. There are several possible benefits to increasing demand response (DR) and different DR programs, for example by reducing local demand peaks and need for network investments [3]. Increased trading of local production and demand can have similar positive effects. Possible positive externalities may give reason to enact subsidies or other measures that enable wider and faster adoption of new types of distributed generation (DG), demand side management (DSM)/DR and P2P solutions.

Chai and Yeo [4] have looked at barriers to energy efficiency and categorize the barriers in their systemic framework according to the stage at which the barriers exist. It pointed out that the differing culture and legal traditions of countries have affected the extent of their regulatory and legislative measures regarding energy efficiency. This will undoubtedly be the case with P2P energy transfer as well. Different regulatory and legal environments in different countries will have an effect on the possible measures and the associated barriers and enablers. Here the focus is mainly on Finland and the Nordic market. Although the focus is on a specific market, the key barriers and enablers can be considered to have relevance in other markets as well.

Microgrids are also a concept relevant to the discussion of P2P energy transfer. For a discussion on how to define what a microgrid is and different types of microgrid models see e.g.[5]. The work in [5] suggests a three-part categorisation of microgrid business models. The models are: Free Market, Prosumer and DSO Monopoly models. Free Market and Prosumer models require more regulatory and financial support according to them. Integrating distributed resources to microgrids can bring about many positive effects for the consumers and for the system [5]. According to them subsidies and national and EU funds have had a role in ensuring the success of first microgrid tests and have yielded positive results with certain microgrid business models. They also point out that legislation also limits the use of microgrids currently in some countries. Usually the limitations are connected to rules regarding main grid connections and power flow considerations. This may be caused by incumbent utility opposition to microgrid integration in to the main network.

The profitability of some new solutions is dependent on the electricity prices. Different subsidies and tariffs can affect the pricing and thus the profitability of, for example, selling electricity back to the main grid or P2P trading. There has been attempts at creating emissions trading that would set emissions permit fees on the price of non-renewable energy sources, but so far the emissions permit prices have been so low that they have not increased the prices to the extent that was planned [6]. There are also subsidies for renewable energy sources. For example, as a part of the climate change mitigation goals wind power has been subsidised with a feed-in-tariff (FiT), but only a set amount of capacity has been approved to receive it [6].

Wind power investments have been supported in Finland and new plants have received subsidies. During the period 2013—2015 new projects could receive an extra incentive if the project was completed fast. The guaranteed price for these projects was 105.3 euros per MWh. After 2016 the guaranteed price is 83.5 Euros per MWh. This guaranteed price will not be paid if the three-month average price in the market goes is below 30 € per MWh [6]. As some peer to peer solutions may depend on sufficiently high energy prices in order to become economically viable, different subsidies and regulations affecting prices may affect their adoption.

Peer-to-peer energy transfers can be thought to include also demand response (DR) trading. Considering DR as a part of this framework, the benefits and also driving factors are more numerous. The benefits of demand response have been widely discussed and agreed upon, but as [7] points out the fair distribution of these benefits is a challenging issue. They go on to study a possible method for a fairer DR scheduling scheme in a market-based approach, which is also of interest in the peer-to-peer energy exchange context.

Aggregation is necessary if small scale production and DR are to participate in the market at the moment. The need for aggregators in the Nordic market arises out of the current market structure where participation requires a minimum size for bids. Aggregators can be divided into different types, according to the distributed energy resources they aggregate (be it demand response or distributed generation resources). [8] defines three types of aggregators: production, demand and commercial aggregators. Production aggregators group together small generators in order to generate economies of scale in accessing the markets. Virtual Power Plants (VPP) are an example of these types of activities. Demand aggregators work as intermediaries between small consumers and for example retailers and distribution companies. The consumers in these setups may own storage or production resources. Commercial aggregators buy and supply locally generated electricity and are responsible for maintaining the balance [8].

Predictions and possible future scenarios include

- Centralized vs. distributed
- How will institutions, different players and systems cope with fast changes
- New technologies and new uncertainties and security concerns

[9] listed possible changes and driving forces in the energy industry and generally in the society affecting future energy systems in the end report of the Roadmap 2025 –project, which aimed at creating a future vision of the development of the Finnish electricity market. One of these changes mentioned was that the regulation by the EU will increase. Other relevant possible changes listed include:

- Electricity consumption will not grow in Finland (or only moderately if energy intensive production returns)
- Locality and community spirit will increase
- Climate change related changes:
    - no more fossil fuels
    - certificates of origin will also be extended to cover also electricity products
- Energy independence will become increasingly valued
- More EU level regulation
- Security issues will become more important
    - Cybersecurity concerns
    - security of supply

Regarding regulatory future points of interest, [9] mentioned TSO/DSO roles, energy storage (especially ownership and usage) and how regulation will be able to adjust to the rapid changes. One future scenario they consider is that end-users separate from the main grid into their own microgrids. The risk is that regulation will not allow the active participation DSOs in owning, servicing and operating these microgrids. They also mentioned possible future shocks that might affect the development of the future energy system. These include possible shock such as: EU breaks down and regulation will become completely national again and disruptive new innovations (e.g. in hydrogen energy or energy storage or carbon capture).

There are many different proposals for the future of the electricity system and markets. Competition between different technical solutions and system models brings with it some degree of uncertainty before the de facto standards of the future system start to emerge. Different models have varying levels of centralization for example. Experiments based on the blockchain technology are based on a decentralized system. One example using blockchain in the energy context is SolarCoin where renewable energy is used to create an electricity backed currency [10].

2.1 Enablers

- Taxation
- Pricing (e.g. innovative tariffs or net metering)
- Regulatory requirements
- Information
- Well defined regulation periods and objectives

Table 1 Identified existing and possible enablers to P2P energy transfer

There are some rules and regulations governing network charges in Finland (for example connection fees for small scale electricity generation and annual charges for electricity generators connected to the grid) [2]. The Electricity Market Act (9.8.2013/588, 6:56 §) includes provisions on network charges collected from electricity generation. The connection fees for small-scale electricity generation (<2 MWA) may not include the costs caused by strengthening of the existing network and may only include direct costs of connection. The network charges have to be smaller for the production side than those collected from consumption side. Annual network charges for electricity generators connected to the below 110 kV network may not exceed 0,07 cent/kWh [2].

Small electricity producers in Finland received a tax break on May 2015. The changes allowed small producers freedom from responsibilities and taxes related to electricity production. So called micro-producers are now exempt from electricity production taxes [14].

Renewable energy sources receive some subsidies. Companies can get investment subsidies and households are eligible for tax credit on installation work costs [11].

- **Taxation**
  - Tax credit for households on installation work costs [11]
  - Tax breaks for small scale (micro) production [11]
  - Subsidies [12]
  - Tax credit for households on installation work costs
  - Tax breaks for small scale production

- **Pricing**
  - Implementation of net metering [13]
  - Clearer pricing information
  - Services detailing price and other relevant information
  - DIY and other hobbyist communities and the information and support they provide

- **Information**
  - Information availability
  - Transparency of regulation and legislation
  - Predictability of regulation and taxation

- **Regulatory requirements**
  - Stated regulatory objectives are aligned with increasing role of peer-to-peer energy transfers
  - Well defined regulation periods and objectives
  - Responsibility to transfer (for DSO) [12]
  - Building regulations (E-number for energy efficiency) [12]
  - Other policies requiring standardized smart home/house technologies in all new buildings (see e.g. Visio 2035 Energiateollisuus)

From the perspective of time periods, Table 2 below has lists both current enablers and potential future possibilities.

The regulators vision and goals can work as an enabler, if the regulator is committed to implementing regulation (or conversely deregulating) in way that increases reliability etc. That is to say if the perceived benefits of increasing P2P transfers align with current regulatory and policy goals.

	Aggregator	Consumer/ Prosumer/ Community	DSO	Retailer	MNO
Current					
Tax credit for households on installation work costs [11]		X			
Tax breaks for small scale (micro) production [11]	X	X		X	
Subsidies [12]	X	X	X	X	
Responsibility to transfer (for DSO) [12]	X	X	X		
Building regulations (E-number for energy efficiency) [12]	X	X		X	
Possibilities					
Lowering investment barriers for households (possibility), already available for some forms of micro-production [11]		X			
Net metering [13]	X	X	X	X	X
Other policies requiring standardized smart home/house technologies in all new buildings (see e.g. Visio 2035 Energiateollisuus)	X	X	X	X	X
Increased information	X	X	X	X	X

Table 2 Enablers and their relations to different actors

There may exists positive feedback loops or critical points for certain enablers. Increased information may drive more adoption and more awareness and decrease uncertainties related to P2P energy transfer. Positive feedback effects have been observed with adoption of energy efficiency projects [4].

Information availability can help increase solar power adoption in Finland [15]. Smart Grid Task Force (2015) lists several enablers for flexibility services which are relevant for P2P energy transfers as well [16]:

> "• *Regulation & codes*
> • *Market rules and processes*
> • *Grid and retail products & tariffs*
> • *ICT technology and standards*
> • *Smart appliances and smart meters*"

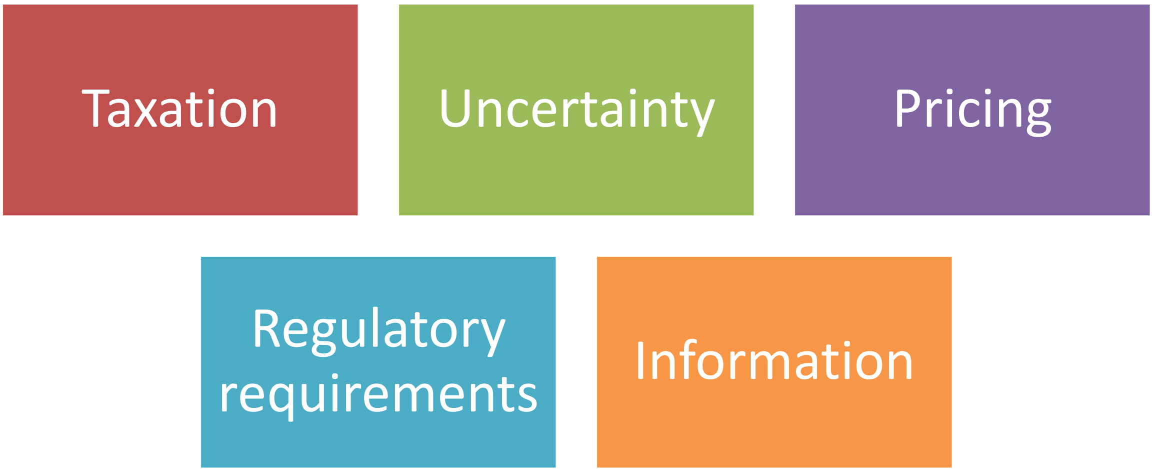
Smoothing peaks in demand is becoming increasingly important as more variable renewable energy production is coming online. Smart grid technologies can enhance the overall efficiency of the system by intelligently managing loads and smoothing demand peaks [17]. Peer-to-peer energy transfers can bring benefits if it also helps make it possible to smooth out peaks in demand. Regulatory environment may continue to improve for P2P energy transfers if they can be part of the solutions to problems regulators aim to correct.

P2P energy transfers should aim to enable wider deployment of distributed energy production and utilization of the distributed resources, as there are many positive effects to increasing DG and DER. Distributed energy resources can displace energy sources with high environmental and health effects. [18] determine how these resources can be placed and deployed in the right time to optimize the marginal displacement of air emission with high adverse effects mentioned above. Pesola et al (2010) point out that distributed generation can create new opportunities for energy entrepreneurship and new valuable additional services can created.

[3] presents a survey of DR potential in the smart grid setting and covers enabling technologies and systems. Enabling technologies related to DR and smart grids are still advancing and their availability is increasing. This may bring more benefits from new and existing DR programs [3]. Advances in smart systems for exchanging information and controlling loads are key to peer-to-peer solutions as well. The economics of the adoption are important in order to capture the societal benefits in their fullest.

Some example regions have made local renewable energy production a marketing point that is connected to the regions brand image [11].

2.2 Barriers



Taxation

Uncertainty

Pricing

Regulatory requirements

Information

Table 3 Identified barriers to P2P energy transfer

- **Taxation**
  - Issues in net metering (VAT and increasing complexity of billing) that may make adoption not feasible;
  - Thresholds may create barriers
  - Unexpected changes in taxation

- **Pricing**
  - Strongly in favor of self-consumption (incentive might be needed, cf. net metering);
  - barriers to trying innovative tariffs (legality and visibility);
  - Feed-in tariff

- **Uncertainty**
  - Transparency of regulation, legislation and rules regarding
  - Regulation difference between b2b and b2c
  - Differences between areas (not all retailers that buy electricity from small producers/prosumers operate everywhere in Finland for example)
  - Reliability of technical solutions [18]
  - Reliability of savings projections [18]
  - Data security and privacy
  - Trust

- **Regulatory requirements**
  - Long delays caused by bureaucracy when beginning small scale production [13]
  - Unbundling requirements may rule out experiments with some types of new energy systems
  - Balancing responsibilities: Capacity aggregators / other ESCOs need to become BRPs for some services

- **Information**
  - New entrants offering services have problems gathering information about customers prior to market entry; access to data and data quality [19]
  - Billing information issues – format regulations differ between areas
  - Access to information/Cost of acquiring information

	Aggregator	Consumer/ Prosumer/ Community	DSO	Retailer	MNO
Uncertainty	X	X	X	X	
Regulatory requirements					
Bureaucracy and permits [13]		X			
Balancing responsibilities	X		X	X	
Taxation	X	X			
Issues in net metering (VAT and increasing complexity of billing)	X	X	X	X	
Information					
New suppliers and entrants offering energy services have problems gathering information about customers prior to market enter [19]	X				
Access to information/Cost of acquiring information		X			
Pricing					
Strongly in favour of self-consumption	X	X			
Innovative tariffs (legality and visibility)	X		X	X	
Data security and privacy	X	X			X

Table 4 Barriers and their relations to different actors

2.2.1 Issues Regarding Peer to Peer Trading

The wholesale market is considered a competitive market and as such it is not under any strict regulation. The study on wholesale market performance in Finland done by Gaia consulting. According to the report there may be problems with asymmetric information between the public and large producers and that may affect the functioning of the market.

One of the biggest barriers to P2P electricity transfer is the sizable difference in favor of self-consumption of electricity [11]. The Ministry of Employment and the Economies working group on small scale energy production [12] found in their report that small producers may face challenges, for example technical, when trying to connect to the main grid.

The price of electricity is currently so low that selling solar power to the market is not profitable in a business setting [6].

The sector report of renewable energy in Finland in 2015 [6] states that, in order to drive more investments to renewable energy and small scale business in them, there has to be clarity regarding taxation, subsidy policies and transparency decision making in the long term.

Bionova Consulting also did a report on net metering [16] for the Ministry of Employment and Economy. The report lists challenges for the market driven development of small scale production and net metering:

- Government subsidies and taxes are unreliable and unclear for small producers
- The bureaucracy related to beginning small scale production takes too long compared to the benefits that can be gained
- Terms and procedures for billing are not accessible and easy to implement

Auvinen et al. [13] also argue that small producers may have problems finding buyers and receiving fair prices.

The liberalization of the retail market, increasing demand response and DG are going to put pressures on the existing DSOs and their current operating models. For example, the report by the MEE [21] visions the roles of DSOs changing from the traditional network maintenance and operation towards that of a market facilitator [21].

Lewis [19] points out that there are concerns relating to the role of DSOs in the developments of new services. If DSOs are allowed to provide additional services, they may have an advantage compared to new entrants. DSOs could spread costs of service between the competitive market and their monopoly business and use their existing knowledge of the network developments to create an uneven playing field in the market for new smart services. Another barrier to entry for new suppliers is the difficulties in getting the customer information required for the switch. Datahub, increasing smart metering systems and moving to a more supplier centric system are mentioned as some ways to decrease hurdles for new entrants [19].

2.2.2 Issues in Small Scale Production

For households participating in peer-to-peer energy transfer is tied in with becoming energy producers themselves i.e. so called prosumers. One way to becoming a prosumer is to invest in solar photovoltaic panels (solar pv). There are some barriers against the adoption of solar power in Finland. According to Haukkala (2015) some of the key reasons for low solar energy deployment and usage in Finland are the missing financial support and beliefs and attitudes relating to usability of solar energy in the north. Solar power is not a prominent part of the Finnish energy policies yet, which reflects the pessimistic general attitude towards solar energy in Finland. Haukkala (2015) interviewed several actors in the solar energy sector in Finland. According to the participants there is a widely held belief in Finland that photovoltaic (PV) solar or thermal solutions are not viable in Finland due to the low amount of sunshine. Other issues and barriers mentioned in the study were political will, incumbent electricity companies, grid monopoly, storage systems and the functioning of the current market system and support systems.

Policies and regulation can help support or act as obstacles for developments in energy production. The Finnish energy policy has in place some subsidies for different renewable energy sources. There have also been changes made to the taxation of production in order to support new more localised small production. The report by the MME [21] examines the different possible alternatives for the future Finnish energy policies building on the current situation.

A discussion paper by SITRA [13] lists barriers for small scale production in Finland. They argue that the benefits related to small scale production are not well known in Finland and that the technical requirements for connecting solar power systems to the grid are unclear. In addition, the Feed-in-tariff has a minimum plant size (100 kVA) which has ruled out all small scale production from the incentive system [11,13]. The Ministry of Employment and the Economies working group on small scale energy production [12] also found in their report that small producers have problem with permits and struggle with hard (and varying) rules that increase costs and cause delays to projects. Building permits can also be an obstacle for small scale production [15].

Small scale power production is eligible for investment subsidies. Currently the Ministry of Employment and the Economy grants investment subsidies to small scale solar, wind, hydro and landfill gas power plants. Wind power, biogas and wood fuel powered plants are supported by a feed-in tariff. Ministry of Agriculture and Forestry subsidises energy production on farms which have additional business activities in order to encourage energy related businesses in the rural areas. The investment subsidy is 10—35 per cent of the total investment. Other subsidies or tax breaks to energy production or installations include feed-in tariffs and tax credit for domestic expenses [11, 21].

The taxation of smaller power plants was changed in May of 2015 so that the maximum size of the power plants exempt from the tax was increased from 50 kVA to 100 kVA. Also over 100 kVA power plants became eligible for the exemption if their total production stays below 800 000 kWh per year [21].

Solar power is one of the renewables that has not received as much attention in the energy policies. Finland has been one of the few EU-countries that had not implemented any support policies for PV solar. Only investments by the public sector and companies have been able to get support through renewable energy support systems. There is no support for investments made by private citizens besides the tax credit for domestic expenses.

The economic incentives for investing in small scale production of electricity are presented in Table 5.

Size of the investment	Positive	Negative
Small house (< 5 kW)	Higher price of electricity from the market	Usually a low percentage of the energy produced is consumed at the location
	Savings from network fees and taxes	Higher unit costs (compared to larger systems)
		Smaller subsidies (tax credit for domestic expenses) in comparison to the industry projects (energy support)
Company/large property (> 10 kW)	Often a high percentage of using self-produced energy	Lower electricity market price compared to households
	Smaller unit costs (compared to smaller systems)	
	Larger subsidies (energy support) compared to households (tax credit for domestic expenses)	

Table 5 Economic incentives for investing in small scale production of electricity [11]

2.2.3 Taxation and Policy Issues

The electricity tax was increased by 100 per cent in Finland in 2011. The income tax was lowered in 2012 and currently Finland has a competitive income tax compared to other Nordic countries. The electricity tax has two levels in Finland. Manufacturing industry, commercial greenhouse cultivation and some data centres are entitled to the lower tax class 2 and other are taxed according to the higher tax class 1. The tax level in class 1 is 2.24 cents/kWh and 0.69 cents/kWh. Other taxes and fees levied on electricity are value added tax (VAT) and the strategic stockpile fee [22].

Currently households and private citizens can only get a tax credit for the installation costs of the solar systems, but there are no other subsidies offered for households for installing solar power systems. Companies are eligible for investment subsidies [11].

Reasons and motivations for starting to produce power locally include the savings and wanting to move to renewable energy sources. Prosumers can use, for example, solar power. Solar power has a highly variable output and small producers that are aiming to produce mainly for their own consumption may have situations where the consumption and production do not meet. Net metering is a way to deal with the occasional surpluses and deficits. In net metering the power taken from the network can be offset in the billing later by supplying surplus electricity back to the network. [22] investigated net metering of small scale electricity production for the Ministry of Employment and Economy. The report studies the possible effects of different ways of implementing net metering with small scale production of electricity. Possible barriers to the net metering include taxation issues (current laws prohibit certain ways of setting value added tax on the sales of the generated electricity) and increasing complexity of billing. It can also raise issues regarding equal treatment of customers as network companies could impose resulting costs on the customers who do not have their own production capacity [22].

Koirala et al. (2016) present the concept of integrated community energy systems (ICESs) and look at how local systems could integrate distributed energy resources. They also discuss current barriers and possible enablers. Although the framework is different the issues are somewhat similar: "Existing and persisting problems include tax issues associated with the use of distribution grid for local consumption. Community energy labeling and different tariff design for the energy produced from ICESs might help in local consumption of the energy."

Taxation can consist of many different parts (three in Finland) and the responsibilities can be hard to interpret [15].

2.2.4 Other notes on barriers

Considerations of income distribution effects might also have to be taken into account when assessing possible barriers and enablers. Subsidies that encourage peer-to-peer energy transfer solutions might have regressive income distribution effects. The redistributive effects of Feed-in-Tariffs in Germany for example have been shown to be regressive [23]. Possible regressive effects may require additional scrutiny and policy interventions and hinder fast adoption and vice versa.

Regulation affecting only financials of demand side management and similar interventions may not be enough as there are also considerations such as convenience that in some cases matter more for behaviour change [24].

Goulden et al. (2014) point out that in the current system it is easy to treat households as merely consumers and frame their choices through the energy consumer role. In this frame certain options may be left outside of consideration for example. It is possible then that the implementation of new technologies (e.g. smart grid) do not necessarily lead to active participation of households and not all possible gains can then be realised from them.

Policy and regulation planning require good data on current capacities and future potentials. Vihanninjoki (2015) looks at distributed generation of energy and electricity in Finland. He points out that it is hard (or even impossible) to get accurate data on certain types of distributed small scale production capacities and potentials. This is partially due to the difficulties in defining what distributed generation is and what the defining characteristics of it are. [26] and [27] have looked at the economics of solar PV systems and how they are affected by time-of-day pricing and tax-credits. The effect of time-of-day pricing is dependent on the peak and off-peak prices and net metering.

3 COMMERCIAL ENABLERS AND BARRIERS

The best approach to analyze the barriers and enablers for P2P-Trading from a commercial point of view is to take advantage of the experience from other peer-to-peer businesses. The concept of the peer-to-peer marketplace is well known since the rise of the internet and has become an important feature in the growth of the collaborative economy.

The value proposition of a peer-to-peer business consists on creating a match between a peer owning a certain resource and a peer in need of that resource, at the right time and with reasonable transaction costs.

Matchmaking is often realized through the deployment of an online platform or marketplace where consumers can post their offering and/or needs, and find the offerings and needs of others. The individual consumers provide the services and consume the services, while the company acting as Market-maker, provides the platform for making the matches, the rules or regulations and the payment mechanisms. The success of a peer-to-peer business can be then identified with the success of the marketplace.

The commercial obstacles and drivers to develop any peer-to-peer business are much related with the regulatory and technical ones. In addition to those, for P2P-Trading particularly, the inherent hurdles to unlock the flexibility of the demand or the well-studied barriers for local energy markets, must be added.

Even if we assume that the upcoming technological progress will allow the P2P business model to become more convenient and flexible, and that the Regulation will evolve to facilitate the participation of the demand in the market and the implementation of a P2P-Trading, there are still many challenges to achieve a successful business.

3.1 Enablers

The drivers to facilitate the P2P-Trading are naturally defined by its barriers. The target should be the creation of a strong value proposition by increasing the revenues and decreasing the investments.

As mentioned before, every enabler of the flexibility of the demand and of the sharing economy will help the P2P Trading Business Model. Additionally, every regulatory or technological barriers that were got over, will help to build a more feasible commercial proposition for the P2P-Trading.

As stated by the European Commission [28], the consumer participation can be increased through intermediation and collective schemes. In that sense, the P2P Trading scheme is a strong enabler by itself, as it combines:

- consumers engaging in collective self-generation and cooperative schemes to better manage their energy consumption and
- intermediary companies like energy services companies or aggregators, emerging to help consumers achieve better energy deals while relieving them from administrative procedures.

Besides, there are several drivers that come directly from the way of implementing the P2P Trading and that are been addressing mainly in WP4. From those, we want to mention the following:

- Define standard products to be traded in a P2P fashion
- Define standard contracts between the Market-maker and the prosumers
- Establish feasible procedures for the Measurement and Verification process
- Establish a simply and transparent procedure for the settlement process
- Establish a Market Design with current market players instead of new incomers to minimize the required investment and the compensations.

3.2 Barriers

The barriers could be grouped in 4 items that will be discussed in the next four sub chapters.

3.2.1 Weak Value Proposition

The P2P Trading business model has two sides who need to be successful: one is formed by the prosumers, who buy and sell their generation/consumption (exchange energy) and the other one is the Market-maker who provides and manages the P2P Platform.

From the side of the prosumers participating in the P2P Trading, there have been many investigations on the motivational factors that drive the engagement of customers in a collaborative trading. But what is not under discussion is that saving money is at the top of the list.

According to this, a key factor to develop P2P Trading is the ability to create monetary incentives for the consumer either by getting new revenue sources or by reducing the cost of their electricity consumption.

But the fact is that, nowadays in Europe, there are regulatory difficulties to reflect benefits in the electricity bills. Whenever retail contracts were more consistent with wholesale market prices, this will allow suppliers to offer supply contracts that incentivize consumers to reduce their consumption when it is economically profitable.

But even in that situation, it would still be difficult to predict which would be the economic benefit for a customer to become a prosumers able to trade energy with other prosumers.

From the side of the Market-maker, most of the peer-to-peer businesses have a similar approach to generate revenues. They charge a fee for every transaction done through the P2P Platform. In addition, they usually complement their revenue through sponsorships or advertising models.

However, to build a powerful business is essential to maintain the fee for participating as a seller or buyer as low as possible. This allows the marketplace to develop as much liquidity as possible. If we agree that the P2P energy exchange is a service of a low added value, the key factor is the creation of a critical mass, also considering that the required investment in IT for implementing a P2P-Platform does not really increase proportionally to the number of participants.

This basic business model would improve if the Market-maker acts also as the P2P-Aggregator using the resources of the prosumers participating in the P2P-Platform to provide services to different agents in the electricity market TSO, DSO, Microgrid Trader,…

This optimized model would have more profits although those must be shared, at least, between the P2P-Aggregator and the prosumers who provide the resources. Besides, depending on the final Market Design for the Demand Response integration, Third-party agents as Suppliers or BRP's should also be compensated (Market Design for Demand Side Response. ENTOSE Policy Paper - November 2015).

This arises another obstacle for the P2P business model: it may bring conflicts between commercial agents due to different interests and objectives.

3.2.2 Availability of funding

A key driver for the sharing economy is the availability of funding sources. Due to the previous problem, the cost of implementing the P2P-Trading may be too high to be profitable to all involved parties taking into account the required investments:

- For customers: equipments/communications, Energy Management Systems, smart appliances, PV/batteries,…
- For the P2P Marketplace: IT platform, advertising,…

Support from both public and private parties has been significant for many sharing economy startups. But in order to build a profitable business model, there is a high risk to relay on subsidies even at the kick-start. A more sensible approach would be to establish a proper funding method to allow traditional customers to become a prosumer making smart appliances more affordable (directly or indirectly through the manufacturers).

3.2.3 Customer trust

The lack of customer's trust is spread to different aspects:

- Trust relations among users (buyers and sellers)
- Trust relations on online technology, especially with the payment system
- Trust relations between users and the Market-maker (concerns for privacy or regulatory matters).

Building consumer trust takes time and a lot of hard work for any organization. Whether a company sells products on a website or simply use it as a marketing tool, that website has to gain prospective customers' trust in order to work for the business. This general problem becomes more complicated when the traded services are "unconventional" like in P2P Trading.

Sharing economy companies are also beginning to understand the importance of the trust among "peers". In April of 2013, Airbnb added identity verification to its platform, adding more transparency and reducing the fear and friction that can occur when strangers do business. In a peer-to-peer marketplace, verifying user identity increases trust, and from there users begins to build their online reputations.

3.2.4 Consumer information/understanding

The European Commission has been addressing the obstacles to consumers, households, businesses and industry, for fully benefitting from the ongoing energy transition. As one of the most important, they include the lack of appropriate information on costs and consumption, or limited transparency in offers, that makes it difficult for consumers (or intermediaries, such as aggregators, acting on their behalf) to assess the market situation and opportunities [28].

Information is certainly an important factor for the customer engagement. Based on a representative survey applied to UK households, Oxera (2005) concludes that lack of information and knowledge represents one major barrier to energy efficiency investment.

But the solution is not simply giving more information to people. Psychological studies show that what matter most is not the amount of information made available, but the way it is communicated.

If this is a reality for simply changing the routines in the energy use of appliances, it is much more significant to engage customers for participating in the P2P-Trading. So, on one hand, customers should have transparent and clear data on their consumptions, on prices, on market rules and, of course, on the terms and conditions of their contracts. Besides, customers should also have access to competitive and transparent market-based offers to freely contract the products or services that suit them the most.

But, on the other hand, an excess of information or whether the traded products are complex, they will be difficult to understand by the potential users. So a balance should be met in the definition of P2P products between transparency, innovation and simplicity.

4 TECHNOLOGICAL ENABLERS AND BARRIERS

There is broad consensus that the transition to a low carbon energy system will have significant impacts on our electricity distribution networks. In particular, the electrification of heat and transport and the growth of intermittent generation will bring new challenges over the coming years. However, it is also widely expected that by introducing more intelligent monitoring and control into these networks and engaging the demand side the cost of meeting these challenges will be reduced, compared with utilising conventional solutions alone.

Market forces and the effect of incentives, will drive the spread and speed of deployment of low carbon technologies across the EU. This is likely to result in an irregular deployment of technologies throughout each country, creating local clustering particularly in the early years of uptake, as a result of both locational suitability and consumer appetite.

For example, the electricity networks of GB are similarly not uniform. A network feeding a dense central business district is fundamentally different from one feeding a more dispersed collection of rural farmsteads, this being due to a combination of factors including load type, load density and the physical construction of the infrastructure. The capacity (or headroom) available on existing networks to accommodate new low carbon technologies therefore differs across the country.

New solutions to address network constraints are coming to fruition. The transition to the so-called ‘smart grid’ is essentially a term to describe the integration of conventional and innovative solutions to accommodate the low carbon challenge, utilising solutions with customers, network equipment and generators. Whilst this presents significant opportunity, the choice of solutions available to a network operator can be expected to increase substantially as the innovation learning curve takes effect. Knowing which solutions to use, when, and on which type of network will be essential to assess investment needs and ensure that electricity networks continue to operate in an efficient manner, are capable of responding to continuing change, and deliver value to consumers.

4.1 Enablers

Smart grid technologies embedded within distribution network enable automated outage notification, fault detection and repair, and routing of current flows around faults to maintain regional service. More importantly, such innovations have enabled the interconnection of increasingly heterogeneous types of devices, owned and operated by increasingly heterogeneous agents, making multi-directional connection and current flow in a physically stable distribution network possible.

Enhanced monitoring and planning: the pace of digital innovation at the distribution level provides easier and cheaper ways to monitor, observe, and automate electricity consumption and production in a decentralized way. Smart metering data and advanced monitoring help DSOs to build a more granular network model of constraints for distribution level planning investment.

Increasing penetration of DER within distribution network: distributed generation and energy storage embedded within distribution network and micro-generation and flexible loads at end customer premises are becoming increasingly economical, placing pressure on the historical regulated distribution utility business model.

Active network management: on HV and EHV levels, DSOs currently are able to use new commercial arrangements, DSO and new tools to monitor and manage network constraints on specific branches of the network, while at LV feeders demand/generation balancing at premises helps to mitigate low voltage feeder contingencies and provide DSR by managing customer's demand using its own micro-generation and storage.

Distribution system balancing: smart grid technologies make it possible for DSOs to centrally balance generation and demand across the whole network through use of new commercial agreements with generators, DSR and storage.

ICT: another change underway enabling the development of P2P energy trading is the revolution in information and communications technology (ICT). ICT has become the enablers of change in the retail sector. It focuses on providing the end customer the ability intelligently to schedule consumption for non-critical loads, to respond to price signals thereby reducing total demand or moving load from one time block to another. Individual consumers have the ability to participate in electric markets for energy and capacity and under specific circumstances to provide ancillary services to the wholesale utility. Outside of the electricity sector, ICT has become a highly competitive platform based business [29]. Companies such as Google, Apple, IBM, and a range of large and small companies have developed and are developing platforms and corresponding based products.

4.2 Barriers

The lack of monitoring and control devices particularly on LV distribution networks at this moment, the potential challenges of local power exchange on distribution level operation, stability and reliability, and the consequential impacts on conventional DSO network reinforcement/investment decision making model, all these factors are preventing the development and actual adoption of a P2P energy trading business model.

Lack of monitoring, automation and protection devices on LV distribution network: due to the large scale of LV network, it is neither economical nor practical to monitor and control numerous transformers and feeders on this voltage level. For example, currently there are more than 230,000 HV/LV substations, 580,000 transformers and 376,000 km overhead lines and underground cables on the LV level alone in the UK. This lack of visibility hamstrings the capability of system control and contingency handling within regional areas, thus presenting a key potential barrier to achieving local energy trading on distribution networks.

Network operating issues, i.e. voltage and frequency instability, security of supply, increased fault levels, and potential harmonic currents, due to unpredictable power exchange in-between local consumers and prosumers.

Demand forecasting for differing energy products, system dynamics and uncertainty under the new P2P trading mechanism: this requires the distribution network operator to establish an understanding of the behaviour and flexibility of various DERs both temporally and spatially. For example, with the increasingly higher penetration of various DERs, quantification of uncertainties associated with intermittent distributed generations such as wind and PV output forecasting is essential for optimal management of the power system. However, these uncertainties can only be appropriately quantified and represented in the form of probabilistic rather than deterministic.

Conventional distribution network planning and investment strategy: the distribution networks have been designed to passively take power from higher voltage levels and distribute to end customers at lower voltage levels. Hence, the current DSO network planning and investment strategy was conceived with neither low carbon technologies nor local prosumer behaviours in mind. Under such conventional investment principle, DSOs unsurprisingly prefer to address the challenges of increased demand by heavily investing in asset reinforcement, inevitably leading to over investment and low utilization of the network. This presents a barrier on the development of a local peer to peer trading mechanism as it requires an accurate understanding of the characteristics of differing local technologies, transactions between generations and demands, and more importantly a fundamental change of mind on future distribution network planning.

5 SOCIAL AND CONSUMER ENABLERS AND BARRIERS

The electric utility industry is undergoing a paradigm shift. Traditionally, it is a business with the sole responsibility of delivering power to consumers, and now it is transforming into a dynamic mode of operation through the deployment of smart meter and other smart energy applications. There are numerous companies with a variety of technologies to capture the opportunity in smart grids. A fundamental question regarding these efforts is, "How motivated are consumers to manage their electricity consumption?" If they are uninterested, then there may not be opportunities for many of the services and applications being introduced into the market. On the other hand, if they are interested in cutting energy costs, we need to determine what motivates them and whether they are willing to pay money to achieve their goals [30].

Furthermore, Aspinwall in [40] suggests that prosumerism offers unique advantages for consumers and utilities alike. Taking net metering as an example, utilities are adopting the policy of net metering. When a household's microgeneration equipment generates more energy than the home requires, or when the consumers are away during the day, the excess energy is directed into the electrical grid and runs the meter backward. At the end of the billing period, the consumer pays only for the net energy amount of energy consumed from the grid. The consumer can be paid by the utility if they produce more than they consume during a billing period.

According to Chang et al. [31], with respect to the potential to address carbon and climate issues, the smart grid is regarded as a foundational technology that will enable the integration of renewable, yet variable sources of power such as solar and wind while facilitating the large-scale adoption of electric vehicles (EVs). Yet the smart grid is still largely unknown or poorly understood by most of the public. This is unfortunate because leading proponents are convinced that of all the grid's stakeholders, consumers are critical to the smart grid's success [31].

Under this circumstance, utilities have begun placing their smart grid vision on consumers by installing tens of millions of smart meters that empower utility customers with real-time usage and pricing data. However, as Chang et al. [31] argued it is the consumers who will drive the market for new products such as EVs, new services such as Demand Response (DR) and smart appliances that take advantage of the smart grid's new capabilities.

Thus, with the aim of engaging consumers with smart grids, Broman [32] stressed that utility companies, system integrators, and local governments have been ramping up their research efforts to find out what consumers know and how they feel about the smart grid recognizing that a successful overhaul of the grid will depend on an ongoing dialog with the public. National governments and other actors thus have for years tried with different information campaigns and other initiatives aiming to get consumers to adopt sustainable energy technologies and change their behaviours related to electricity use [32]. However, as the statistics and a majority of research reveal, private consumers are reluctant to adopt these technologies (e.g., photovoltaics, solar heating, heat pumps and private wind turbines) and change when it comes to energy use [41].

Technologies are to some consumers perceived as complex, difficult to understand and use. Furthermore, sustainable energy technologies are often most beneficial to the society, whereas the private rewards from adoption is usually not realised in time and place [42]. This could mean that consumers might have difficulties understanding the benefits of the smart grid and technology adoption [43].

Referring to Paetz's research [44], the reluctance towards behaviour change is arguably associated with key characteristics of electricity. Electricity is invisible and use of it is an indirect outcome of other types of activities, such as cooking food, watching TV, using the computer [44]. Since the use of electricity is invisible to the consumers, they often do not relate these behaviours directly to electricity use and the damaging effect it has on the environment [44]. Furthermore, it is common practice for electricity suppliers to bill their customers a while after the actual use of electricity has taken place, for instance, a bi-monthly or quarterly bill. This results in that not many electricity consumers are aware of the cost of their behaviour. Thus, Broman confirms in [45] that social research back this up indicating low levels of public awareness and interest in energy technologies and that energy consumption is taken for granted [46,47].

As a consequence of the current practices in energy industry, consumers may be a little behind the curve right now [32]. Jackson argues in [48] that sustainable consumption and consumer behaviour are key issues to the impact that society has on the environment. A lack of consumer confidence or choice in the new energy systems will result in a failure to capture all of the potential benefits of Smart Meters and Smart Grids. Therefore, the new technologies of the smart grid have to be explored and understood from the consumers' perspective.

Referring to the literature [33, 34], electricity consumption highly depends on the social norms and economic factors. As argued by previous researchers [35], the only aspects of the smart grid that can be truly smart are the people within it [49]. In other words, consumer action is the fundamental driver. Therefore, if we do not observe, understand, and engage consumers at these early stages, smart grid initiatives risk failing to realize their full potential [49]. This is why many argue supporting the ever increasing focus on consumers and their daily routines, while the smart grid ecosystem and community currently still focuses mainly on technological issues and economic incentives [50]. Observing consumers in their social context and engaging and including them at an early stage is fundamental for the future electric system to deliver the expected goals [35].

Thus, the goal of this chapter is to provide an overview of the social and consumer barriers and adoption issues in regards to the concept of P2P energy exchange and transfer. The objectives is to study and evaluate the enablers and barriers/limiting factors resulting from the current or potential future social and behavioural contexts to peer-to-peer energy transfer.

We categorise all barriers related to the social and behavioural aspects of P2P energy exchange adoption in the chapter. Some of the factors or barriers are both relevant to individual or society as a whole. For instance, the consumer's individual awareness versus public awareness; the safety and security issues that can affect a single household as well as public in general.

We will discuss the existing social and consumer issues and barriers relating to peer-to-peer energy transfer first. These are mainly posed as the problems that need to be solved or addressed if smart grid and P2P energy exchange were to be adopted. Then, our research efforts are also focused on looking for the potential enabling factors that could facilitate the adoption as solutions to the social and consumer barriers. All the enabling factors included in the chapter have already been studied, and are identified to be able to potentially help and promote the P2P energy exchange.

5.1 Enablers

In Ghanem et al. 's research [36] on the adoption of active demand (AD) concept within one of the EU FP7 research, the ADDRESS projects, a number aspects of AD emerge from the empirical work that refer to the "contents of expectations" as outlined by Konrad [51]. They find the enrolment of social elements related to the imagined lifestyles of householders, including their routines, daily rhythms and activities, and further suggesting that these factors pertain to electricity markets and new tools and principles for modifying electricity consumption. Ghanem and Mander in [52] suggest that their finding reflect the social factors and expectations manifest in the design of energy efficient service. Thus, study [52] shed light on how to design and promote adoption of new energy concept among consumers and in the society in general, especially in guiding the exploration of the social and consumer enablers to bring the vision of P2P energy exchange forward.

Understanding the values that influence consumer choice is of critical importance to motivate consumers to change behaviour and adopt smart grid concepts, such as P2P energy exchange. Gangale et al.'s study in [35] reveals that the motivational factors commonly used by smart grid projects in Europe are:

- The reduction of and control over electricity bills;
- Environmental concerns, and
- Better comfort such as the technological solutions allowing the optimisation of comfort and more control over own energy use

The review of other literature allowed us to broaden and expand the social and consumer enablers found by Gangale et al. [36]. These further enablers include:

- Enabling consumers the choice of control
- The greater good (environmental, social, and sustainability)
- Network effect
- Social norm and lead user

Figure 6 Categories of social and consumer barriers to P2P energy exchange

5.1.1 Cost Saving Potential

Ablondi's research shows that more than 80% of consumers are very interested in learning about the methods to cut energy spendings [30]. Nearly 75% want to know how they can reduce electricity consumption. In a survey question of most attractive elements of smart grid (including smart grid itself, tax incentives for participating in smart grid program, reducing electricity consumption, cutting energy costs), the highest rated item is cutting energy costs. Thus, Ablondi concluded that there is a high levels of interest in savings programs [30]. Most consumers are very interested in learning about money-saving products and programs from utilities.

In terms of renewable installation, one study showed that 39% of consumers who invested in small wind based their decision on energy savings, 33% based on environmental concerns and 28% to save money on their electricity bill [53].

Aspinwall et al. further confirm that the most significant motivator for generating electricity at home is economic benefit [40]. In their study 30% of the respondents indicated a short payback period was most important, and another 26% indicated that saving money on their monthly electric bill was most important [40]. The third most common factor, indicated by 17% of the respondents as most important, was that the cost of purchasing and installing a photovoltaic solar panel array must be manageable.

Similarly, Dianshu et al.'s research in [37] also reveals that a significant portion of the sample of households surveyed reported a willingness to save electricity or purchase more efficient energy using devices.

Moreover, the enabling factor from peer-to-peer service in general mainly means offering more benefit with less cost, as presented in numerous literature [54,55].

Thus, from these researches it shows that utilities and their partners have numerous opportunities to tap into this demand with new products and services that can reduce the amount of electricity required for the conventional energy use. At the same time, these solutions must be properly designed to meet consumers' needs and budgets [30].

Moreover, an importance element to address is the revenue sharing scheme that is commonly integrated as a revenue model for sharing economy or peer-to-peer transaction. In this way, the consumers and prosumers are given the opportunity to get financial gain when they participate energy efficiency programmes or demand response events when providing flexibility to the network.

5.1.2 Allow consumer to gain control

Research conducted over the past few years proves that some consumers are interested in remote home monitoring and likely to subscribe as these services become available.

A recent research asked consumers to rate their interest in several remote monitoring applications, and remote home monitoring via IP or web cameras scored the highest of the applications listed [30]. Remote monitoring and control of thermostats followed, and remote lighting controls were third in popularity in this Residential Energy Management Survey carried out by [30].

Thus, it shows a clear sign that if consumers were given the right information and guidance plus the right level of engagement and sense of security, they exhibit a positive behaviours towards smart grid technologies. However, the key is to allow consumer the freedom of choice, giving them the sense of control in the process.

5.1.3 The greater good

In this section, we also reviewed and found the benefits to society and the environment that motivated some consumers via multiple studies done previously.

Aspinwall et al. suggest that one big motivator to install micro-generation equipment is environmental stewardship and concern [40]. In other words, people generally agree that it was important to make an effort to ensure that energy is produced from renewable sources.

Thus, feelings of a moral obligation or responsibility towards the environment and a positive contribution to society are important. Referring to [36], numerous researches find that private and societal/environmental benefits separately contribute to the acceptance of smart grids. That is to say individual benefits are not the only driver of technology acceptance. Societal and environmental considerations are unique and significant drivers to the acceptance of technologies that primarily benefit the environment and society at large.

Further research [56] found that promotional communication stressing societal and environmental benefits evokes positive feelings, while communication stressing individual benefits does not. Instead, communication on individual financial benefits may evoke feelings of “greed” which is not how most people desired to be seen. Thus, it is particularly important when the individual benefits are limited and the societal and environmental benefits are substantial, which is the case for smart grid [32].

Moreover, there is also evidence that a great number of consumers appreciate the big picture, such as the idea that smart grid technologies will fundamentally remake and improve the power grid [31].

As enabling factor, collaborative consumption (as one key element of sharing economy or peer-to-peer transaction) is identified to reduces the development of new products and the consumption of raw materials, thus supporting local residents and local economy [54]. In other words, adoption of such concept in energy sector many facilitate the uptake of P2P energy exchange, and the greater good, does not only mean the goodness for environment, but also the goodness for sustainability, society and local community.

5.1.4 Network effect

The social characteristics (facilitated by technology) of P2P technologies give rise to the discovery of network effect as an enabler for customer adoption.

The most widely known economic theory for explaining how decision makers react to other decision makers in forming opinions about a technology (such as ICT technology) is called network effects [57]. Kauffman, et al. in [58] suggest that network effects occur when the value of membership in a network is a function of the number of members on the network. This theory has been used to explain the adoption of technologies [59]. In other words, the more people adopt the technology, the more the value of that technology increases, encouraging additional adoption. This virtuous circle continues, causing rapid adoption and leading to markets wherein a single firm promptly emerges as the dominant player [60].

Song studied network effect's application in P2P service, suggesting that the basic impact of network effect should be that a customer adopts the technology with the larger P2P network [61]. As the number of members in the network increases, the probability of finding the desired value and benefit increases.

It can be also considered that P2P energy exchange is subject to the power of network effect. Furthermore, the more consumers and prosumers participating in the P2P energy network, the more valuable the energy exchange becomes.

5.1.5 Social norm and lead user

Another branch of smart grid studies discovers that social norm may be an important enabler for customer adoption. Mah et al. suggest that in their research, social norms (52.7%) were some of the key motivating factors for people to reduce electricity use and be energy efficient [62].

In the area of P2P service, social norm becomes especially important. Study done in [63] shows that social norm is a clear motivation for customers to participate in a peer-to-peer network to get to know, interact, and connect with local communities in a more meaningful way, because people value and would like to be part of the local community, which is consistent with [54] and [64]'s suggestion on the societal drivers.

Furthermore, lead user studies have also been conducted in understanding how this group of initial customers can be the social enablers for the adoption of smart grid service. According to [65], since the majority of consumers in the market are more hesitant to adopt new smart services than the lead users are, the practical benefits of these services need to be not only established, but also communicated through real-life peer examples. If service developers and marketers wish to enter the mass energy market, they need to make a clear connection between the benefits offered (costs, electricity saving, CO2 reductions) and the particular applications they are offering.

To explain further, lead user theory is based on an assumption that there are users in any market that have needs that the market does not yet meet [66,67] and are ahead of the markets [68]. Finding such people at the early phase of an innovation is important because they are willing to make efforts to bring the desired solutions to the market [69]. Thus, there is a potential in this group of early customers for the development of future products and services in the smart grids [65].

[40] suggests that prosumers, on the other hand, may be well suited to be lead users. The reasons are two folds. First, consumers need to learn about prosumerism, for instance from media or people they know. Consumers need to be familiar with the concept of contributing electricity to the grid in order to save money on their electric bill. However, before turning into prosumers, most of them know little about their options in the marketplace and the incentive programs that are available to them [40].

Second, prosumers are very active in energy efficient behaviours. As Aspinwall et al. described in [40], prosumers actually learned by word of mouth and by researching on the internet actively. They spent a lot of time consulting websites for information, and consistently learned from the websites of renewable generation and installation. Prosumers are likely to have a complete and correct understanding of the market, thus, as lead user, they may have the ability to teach and influence other consumers.

5.2 Barriers

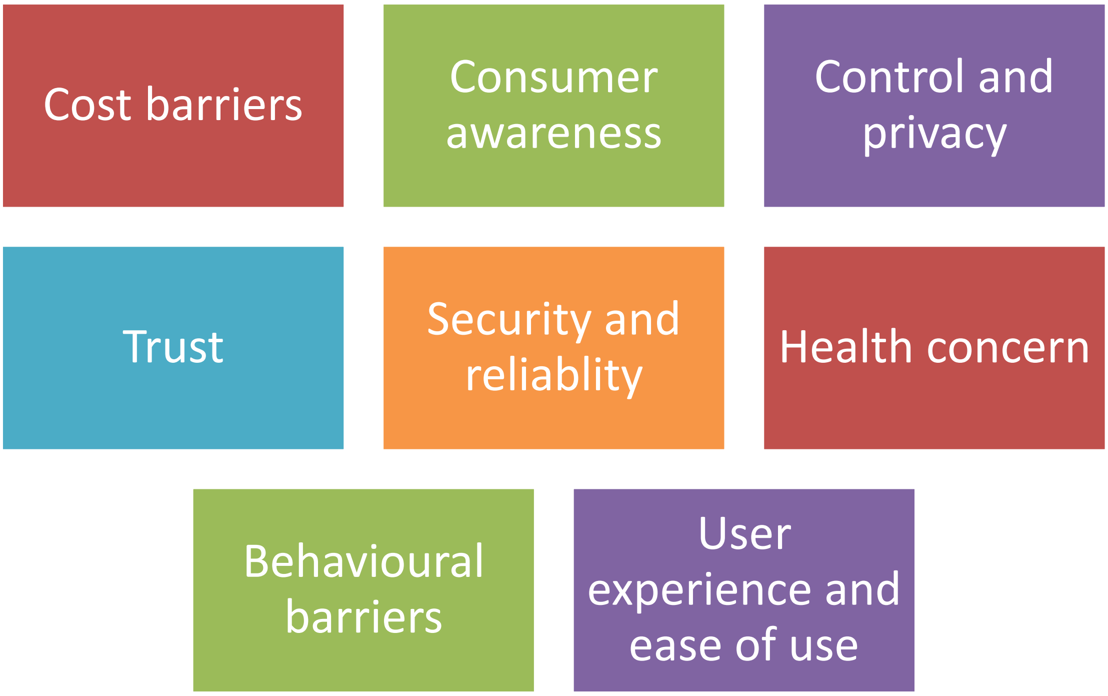


Figure 7 Categories of social and consumer barriers to P2P energy exchange

To find the root cause of the social and consumer barriers, we reviewed an extensive collection of literature, and examined broader transitions in new socio-technical systems. When confronted with reluctance of accepting a new energy infrastructure in UK, [70] stresses that while broad ideas of future energy systems might be acceptable, specific plans can be met with very different outcomes.

5.2.1 Cost barriers

As identified in numerous studies [41,45,71], the cost barrier is a major concern of the consumers regarding the uptake of smart grid technology and smart energy services. In Ablondi's study [30] on energy efficient appliance adoption, some consumers are willing to pay a premium for a flat-screen TV that uses 20-40% less electricity than other models, with the amount rising as savings increase. However, not everyone is willing to pay more, even for assured savings of up to 40%. Reasons for this may vary. For some consumers, electricity costs are low enough not to warrant concern while others do not value energy efficiency [30].

In terms of energy monitoring service, Ablondi finds out that not many consumers already exhibit interest in and a willingness to pay for an energy efficiency service.

Furthermore, Ablondi studied the willingness to pay for smart energy equipment in order to participate in programs that guaranteed 10-30% savings on their monthly electricity bill. The good aspect is that most consumers are willing to pay "something" for the required equipment. The bad news is that amount may not cover the total cost of equipment and installation, according to Ablondi [30]. Hence, developing viable business models will require innovation on the part of both utilities and their vendors. The explanation is that smart technologies often require an up-front investment, which is compared with the calculated private returns of the investment and a payback period which is often perceived as long [41,45,71].

Overall, Ablondi suggests that consumers are unlikely to replace existing appliances with smart appliances until existing appliances fail or become too expensive to maintain. Although certain segments of consumers are willing to pay a premium for smart appliances, the amounts are only less than 9% of the total cost of the appliance. As such, the small premium that consumers are willing to pay for smart appliances is unlikely to convince appliance manufacturers to develop such appliances without accompanying utility or tax incentives.

Regarding, renewable installation and micro-generation (such as home wind turbine and roof-top solar panel), Aspinwall et al. show that the finances of the investment were by far the most significant motivating factor [40]; prosumers were motivated by the idea of saving money in the long term, and deterred by the upfront costs of an installation. The larger upfront cost required is a significant deterrent for both wind turbine and roof-top solar panel. According to their survey, 34% of survey respondents felt that solar panels were too costly to purchase and install, and another 17%

felt that the savings on electricity would be too small, and would not be enough to justify the cost. This is particularly true for smaller households who do not benefit as much as larger prosumers, and do not find it as appealing [40].

In addition, the potential running cost and maintenance expenses for consumers and prosumers to make a choice on the different types of micro-generation and smart services and application could be another concerns to whether adopting P2P energy exchange as well as smart grid in general.

From these researches, it is evident that in the case of smart grid technologies, society at large, including the environment is the primary beneficiary. The benefits for individuals are smaller in terms of savings on the electricity bill, receiving feedback on electricity consumption, and becoming energy efficient [72,73]. For instance, Dianshu et al.'s study in [37] shows that one-third of respondents indicated they did not remember or care about their electricity bills at all, and efforts to promote energy efficiency are mitigated by the high initial price of energy efficient equipment.

From a systemic perspective, a consumerism culture, affordability (such as upfront costs) of more durable products, difficulties in defining appropriate levels of sufficiency, and concerns about the effects of slower growth can also be barriers [74].

Since the current research project is to study the concept of P2P energy exchange, the literature review also covers the potential barriers related to P2P and sharing economy service uptake in general. According to [63], concerns of receiving bad quality products and services and that the value from collaborative consumption (as a major element of sharing economy) is not worth the effort to participate in peer-to-peer type of exchange. [75] also provides evidence that collaborative consumption in certain situations is perceived as lack of economic benefits (such as lack of cost savings), which prevents consumers from participating in such type of exchange.

5.2.2 Consumer awareness

Consumer attitudes about the benefits of smart grid technologies are still in a formative stage. Most consumers are not aware of the term, much less the capabilities smart grid technologies will be bringing in the next few years [30].

[76] analysed a number global and regional studies, and identified the overall patterns in consumer's awareness in smart grid related technologies. For example, a global survey in 2011 found that more than 60% of respondents did not know how to describe a smart meter [77]. Similarly, another 2011 survey in the United States found that 46% of respondents had never heard of the term "smart meter". The same survey found even less understanding of the term "smart grid": 51% had never heard of the term, and an additional 21% did not know much about it [78]. Canadian

survey work also show similarity with these broader global trends, only 27% of respondents in a survey claimed even a basic understanding of “smart grids”.

[40] suggests that when searching for detailed information, consumers tended to reference information provided by equipment retailers and installers. These sources are biased, and this is reflected in consumer interactions with them.

Knowledge of the government incentive programs for contributing energy to the grid is low among consumers. In [40]’s survey, only 16% of the respondents were aware of the policy solar or small wind electricity generation about the policy of net metering.

Furthermore, Aspinwall et al. argue in [40] that there are some existing sources of independent information, but they were not utilized by any of the prosumers they interviewed. However, this can be difficult as there are very few reports to tell consumers and prosumers what is good and what is bad in micro generation. Although [40]’s research indicated that some regulatory organizations have made some efforts in creating the related information package, these resources are not easily accessible to the average consumer and do not cover the entire market.

In Dianshu et al.’s research in [37], roughly half of the respondents reported that they have never thought about conserving electricity or energy efficiency before, and 10 percent of respondents stated that they knew how to save electricity but decide not to.

[73]’s study on smart meter suggest that there is tremendous misconception from the consumers regarding smart meter and grid technology. For example, consumers would consider the purpose of the smart meters is designed to control resident’s electricity use either by direct load control of their home appliances such as air conditioning or shutting down their entire electricity supply. [62] also presents the similar results, suggesting that one of the three factors that consumers not to take action to reduce electricity use is lack of information.

In general, given that people’s understanding of the traditional power system is modest at best, a new means of service provision (such as smart grids) can be confounding to many, as Rowlands put [76].

5.2.3 Control and privacy

The fear of losing control and privacy is another major social/consumer barrier that often appear in smart grid technology research.

In a report about benefits derived from the Smart Grid, prepared for the United States Government, it is concluded that “the direct financial benefits to consumers are not compelling, particularly when compared to the risks" [72]. Here they are pointing at the drawbacks related to the use of smart grid technologies. One often mentioned barrier is the risk of violation of consumers' privacy. Utilities and distribution system operators will receive more accurate information about consumers' electricity consumption patterns resulting from the installation of Smart Grid technology. However, this data might reveal personal behaviour and habits and whether the consumer is at home or not [79].

Many consumers balk at allowing utilities to control their appliances. Some consumers would allow utilities to control systems in their home, but many are not willing to relinquish control even if they can override utility commands [30].

Chang et al. in [31] identified that some critics of consumers are already using the term "Big Brother" to describe smart metering programs because they allow utilities to remotely monitor customer usage and remotely cut off service.

Furthermore, the privacy issue has been raised by many consumer advocates [80] and the International Energy Agency [81] as one of the most significant concerns in the deployment of the smart grid. The smart meter conceptually will allow both the consumer and utility to see electrical load fluctuations at a discrete level. In essence, the smart grid will have the ability to track and capture detailed electricity usage in each home. Over a period of several months, the utility would have enough information to develop a very specific profile of the consumer, identifying personal habits such as cleaning, cooking, sleeping, or absence from the home. In addition, it is not clear who will own this information, the consumer or the utility, and who will have ultimate rights over it. It would be very valuable in the hands of marketing firms or criminals as [82] indicated.

Another aspect of the privacy barrier is that privacy concerns also lead to the question of who owns, protects, and develops appropriate use policy on the vast amount of detailed consumer energy usage data that will come into existence [83]. Advocacy groups believe it will be critical that data protection and ownership be resolved before consumers become large scale supporters of the smart grid [84]. Especially as more utilities become private, this information may come to be seen as a revenue-generating asset which can be sold. Such a violation of privacy would severely damage today's consumer/utility relationship [83].

5.2.4 Trust-related barrier

Building trust among consumers is mission-critical to overcome consumer resistance to new energy solutions and service. Gangale et al. suggest in [36] that trust is a pre-requisite if utilities and governments were to get consumers' cooperation and goodwill in the process of introducing smart grid to the society. As addressed by [76], when people know little a technology (such as smart grid technologies), acceptance might largely depend on trust in the actors responsible for the technology (utilities, regulators, technology and service providers). Trust in actors that are responsible for the technology generally increases acceptance and adoption [84].

However, studies carried out in the USA and UK [85] have highlighted that consumers do not have much confidence and trust in their electricity providers. For example, a consumer conditions survey in the UK, which ranks how different markets are perceived by consumers to be performing in terms of their transparency and in generating consumer confidence listed the electricity and gas markets as the most poorly rated markets [36].

Trust may also related the trust in energy efficiency standard and labels. [37] stresses that consumer’s trust to utility may be another key barrier in related to social and consumer barrier to P2P energy exchange as well as smart grid in general. Their study highlights some serious concerns with the energy efficiency labelling and product identification program. Only 35 percent of their responses believed that the energy efficiency labels accurately described how the products would perform, and 25 percent indicated they did not care about the label at all when selecting products. The explanation is that the consumers believe that there are systematic errors among both manufacturers (for example, they lie to the government) and the government (for instance, they mismanage the program and are incompetent) in the supervision of the labelling process.

Furthermore, the energy efficiency measurements and certification is currently developed by regulatory or public organizations. In reality, taking Finland as an example, the energy efficiency certification is based on a pre-set formula to rate and determine the energy efficiency level of a building. This type of formula may favour certain types of energy use over the other. In this case, the consumers might be mis-led by the so called “standard”, which gives consumers little possibility to make their choice, because the trust is enforced by government or regulatory organizations.

One of the reasons that there is significant mistrust between consumers and utilities may also arise from unfair distribution of costs, benefits and risks between consumers and utilities. For instance, Maryland Public Utilities Commission rejected initial smart meter plan on a number of consumer related issues including the risk burden for consumers, because the plan would potentially guarantee electricity utilities double-digit profits [86].

A further aspect of trust, as identified by Dedrick and Zheng in [38] is about utility company’s fear of losing consumer and prosumer’s trust might be another issue in the adoption of smart energy technologies and services. As they suggested, the most important barriers to adoption are the lack of a national energy policy and utilities’ cautiousness in introducing new technologies that could be disruptive to their existing customer relationships. As a regulated industry, utilities are more motivated by external incentives than internal innovativeness [38].

Looking at P2P energy trading in general, Satama's framework in [39] shows that online trading platform also affects trust, which in turn affects consumer actions that lead to positive or negative results for the adoption. Consumers also learn from their buying experiences and transactions, from word-of-mouth communication from other consumers and from their real or virtual social networks. Consequently trust is a mediating factor that influences consumer buying behavior [87]. In this case, higher levels of trust thus lead to higher perceived usefulness and thereafter indirectly to a higher intention to use P2P service in the context of P2P energy exchange. However, lack of interpersonal trust (prosumer and consumer in the case of P2P energy exchange), lack of trust toward technology, lack of trust toward the service provider all hold barriers to consumer adoption [54].

In terms of trust issue related to sharing economy and P2P exchange, [64] suggests several challenges associated with the collaborative economy concept, stemming from perceived disruption of existing regulation, lack of trust between P2P users, lack of reputation and standard could be the problems that need to be resolved. [88] suggests trust as the most cited barrier to collaborative consumption, which includes the basic mistrust among strangers and concerns for privacy. As suggested [54], collaborative consumption implies trusting strangers to a varying degree.

Furthermore, [89] argues that the mediation of ICT brings forward the new complexities to trust relations in the context of collaborative consumption. The central role of ICT in mediating peer-to-peer exchange implies "trust through technology", which results in interpersonal system trust that is built and shaped by ICT. Indeed, in the context of collaborative exchange, trust through technology plays a significant role in consumer adoption [90]. Therefore, as a barrier of peer-to-peer exchange, lack of trust can be rooted from trust relations among users, such as interpersonal trust between buyers and sellers; trust relations between users and technology, such as trust with the payment systems; and trust relations between users and the service provider [63].

As identified for the P2P SmarTest project, the concept of sharing economy's long term value still requires for further investigation. Such perspective would be an additional concern to the consumers and prosumers whether to adopt and embrace the new paradigm brings forward by P2P energy exchange.

5.2.5 Security and reliability

A representative factor with respect to technology acceptance is perceived risk. There are important issues that hinder the acceptance of smart grid technologies such as cyber security threats in a smart grid and the performance reliability of smart meters. The analysis of the smart grid acceptance factors should include the consideration of those risk factors [91].

According to [91], perceived cyber Insecurity is the key risk that smart grid consumers experience. Consumers' concerns about power consumption data leakage grow all over the world, acting as a barrier to the deployment of smart grids.

The functional/economic risk is also represented by concerns about the accuracy and reliability of the smart meter functions. Alleged inaccuracies of smart meter and other smart grid technologies can also be problematic, such as the ‘‘Bakersfield effect’’: smart meters blamed for dramatic increase in electricity bills [92].

However, it is interesting to note that following a large amount of consumer complaints blaming smart meter for electric shocks, Fyfe’s research in [93] found that only one of the reported cases was linked to incorrect smart meter installation while 3500 others were due to faults in existing wiring. Nonetheless, no matter a true claim or a mis-conception, the concerns about the reliability issue still presents a key barrier in the mind of general public.

5.2.6 Health concern

According to [45] and [82], another key concern raised by consumer groups is the safety impact of the wireless signals transmitted by the smart meter to communicate with the equipment, since transmission of wireless information produces non-thermal radiofrequency radiation [94]. This was the subject of much debate in the general public

Smart grid initiatives primarily require the development of a communications infrastructure or network parallel to the power grid [95]. Many of these parallel networks have employed wireless communications from the home to the pole through a RF technology. There are several RF technologies under consideration, from wi-fi and Z-Wave to ZigBee, while ZigBee is emerging as the predominant choice [96]. The utilities have chosen this technology over a physical infrastructure as it is low cost, quick to deploy, and can be secured, however, significant public education is still required to overcome the concern on health related issues [97].

5.2.7 Behavioural barriers

[34] emphasizes that: "Once end-users have been provided with smart grid products and services, they may have to change their behaviour in order to utilize the system in ways that are favourable for both end user and electric power system". [98] argues that there is dependency between behaviours and infrastructure. Therefore, the restructure of energy sector may impact the electricity consumers’ behaviour, and majority of the sustainable energy technologies require consumer behavioural changes, because of consumers might form negative attitudes and resist adopting them [45].

One of the behavioural barrier is related to information seeking. [40]'s study shows that consumers and prosumers stated that research on home electricity generation can be tedious and difficult. They further suggested that independent information, provided by an organization not tied to the sale or manufacture of equipment, would have simplified the process for them. Referring to [45], these are situations where consumers are unable or unwilling to cope with and obtain all available information about different choices and use short-cut decision rules (known as heuristics) instead, to ease the decision making process.

In these situations, if the consumer following a "low-effort" path when making a decision (also known as behavioural system 1, which operates when judgments are made rapidly [99]. These automatic judgments can sometimes make consumers to choose differently than they would if they had carefully considered the matter [100]. Because smart grid technologies are new and unknown to private consumers, it is likely that they might perceive the technologies as complex and therefore be uncertain about the consequences of adoption. Often when people are uncertain they try to avoid choosing, which often leads to doing noting instead [101].

Moreover, another stream of behavioural study suggest that consumers often behave on impulses in their everyday life. Such impulses may sometimes make them procrastinate [102], for instance, delaying an intended course of action, in spite of being aware of negative outcomes of doing so [103].

When consumers are given a free choice of whether or not to adopt smart grid technologies, they may hesitate to adopt due to their inclination to procrastinate [102]. It is usually assumed that consumers adopt a complex new technology, through a high-effort decision-making process. However, due to consumers' inclination to procrastinate, they may never get around to seriously reason about the advantages and benefits for adopting the technology. [99]'s dual process model of cognitive functioning is helpful for understanding this fundamental asymmetry in decision-making about innovation adoption as confirmed by [45]. For example, loss of comfort in terms of too low indoor temperature and not enough hot shower water are identified as some of major behavioural barriers attribute to the reluctance of adopting smart grid technology in [45]'s study.

5.2.8 User experience and ease of use

Regarding the ICT aspect of P2P energy exchange platform, as it is envisioned to be enabled by next generation ICT technologies, consumers' adoption of these new concepts and technologies can be influenced by the characteristics of technology. The user experience and ease of use facilitated by technology become an increasingly important issue. For example, in the context of online commerce, ease of use, complexity, and trialability of the technology system are considered important adoption factors that allow multiple users to interact, collaborate, and transact with each other using an online platform [104].

Conversely, consumers will not participate in P2P energy exchange if they find the technology systems too complex, or if the consumers have poor user experience when they start to learn about the technology and the concepts behind. In other words, lack of technology efficacy deters consumers' participation and engagement and, in this research context, it could be a social/consumer barrier to P2P energy exchange.

[31] stresses that all new technologies naturally face barriers to adoption. Without a better understanding of the benefits, many people may be afraid of how the smart grid will affect their lives. This fear could lead to efforts to hinder the vital aspects of the smart grid. Even if public reaction is not hostile, individuals may be indifferent if they are uninformed regarding the smart grid. This is not an ideal situation either because the promise of the modern grid lies in its ability to be a platform for something greater.

One solution suggested by [30] is the segmentation of consumers in order to target those with both an interest and willingness to pay for smart energy solutions. In this case, it is imperative to understand consumer attitudes and demands in different segments and how they will impact the return on investment for their offerings, which will determine where a new solution, offering or business model can be successful.

The smart grid will succeed if it can capture the public imagination, for example, if consumers can be shown how a "web of electricity" will improve the electricity system, save them money, help the environment, and potentially create brand new industries, they will be likely to participate and help shape the future direction of the smart grid [31].

However, as [45] stressed, because smart grid technology is new, it is likely that consumers will perceive risks, for instance regarding to installation problems, technology breakdown, and that they will have reservations towards adoption [73]. Furthermore, only small financial benefits are expected as outcome for the private electricity consumers [106], while the benefit for the society as a whole is larger, with the penetration of more renewables in the grid [72]. Thus, tremendous efforts are still required to help consumers and prosumers "cross the chasm".

Historically, energy consumers have just been passive consumers using electricity whenever they need. Going forward, full and effective engagement, rich and unbiased information on smart grid, renewable, and governmental incentives should be made clear and easy to access by the general public. More work should be also done to research and evaluate appropriate incentive programs and how consumers will react to changes. For instance, there are multiple well-ground theories could guide the development of technologies, solutions and business models for P2P smart grid, for instance, the diffusion of innovation theory, the technology acceptance model and norm activation model, just to name a few.

Certainly, this will require a concerted effort by all stakeholders and the energy ecosystem to ensure that consumers are educated and motivated. As [40] stateded, only with a well-informed and engaged public, the smart grid will be able to live up to its potential.

6 CONCLUSIONS

In this report, the key regulatory, business, technological and social enablers, limiting factors/barriers, and challenges of P2P energy trading have been investigated. Some of the key findings are summarized here:

- **Regulatory**: It is considered that tax credit for households on installation work costs, and tax credit for small scale production are crucial enablers for the development of P2P energy market and corresponding business models. Also, particularly in the circumstance of Finland, the lowering investment barriers for households, which are already available for some forms of micro-production and governmental policies requiring standardized smart home/house technologies in all new buildings might become future enabling factors. In terms of barriers and limiting factors, uncertainties are the main issue: transparency of regulation, legislation and rules regarding government supports, differences between areas, reliability of technical solutions and savings projections, and data security and privacy.
- **Commercial**: Major business obstacles and drivers to the development of P2P business models are to a large degree related with the regulatory and technical factors. In other words, for P2P trading, the inherent hurdles to unlock the flexibility of the demand or the well-studied barriers for local energy must be studied. Other barriers include: weak value proposition, the relatively high cost of implementation, lack of customer trust, and lack of consumer information and understanding.
- **Technological**: The transition to a low carbon energy system have brought a series of smart grid technologies for the LV distribution system. From this perspective, the enablers include the increasingly higher penetration of PVs, heat pumps, and EVs, enhanced monitoring and planning on distribution levels, active network management on HV and EHV levels, and also the possibility of distribution system balancing. Main barriers in this domain include: the lack of monitoring and control devices particularly on LV distribution networks at this moment, network operating issues caused by DERs, such as voltage and frequency instability, security of supply, increased fault current levels and even more difficult demand forecasting.
- **Social**: Understanding the values that influence consumer choices is of critical importance to motivate consumers to change behaviour and adopt P2P concepts. Key enablers include: the reduction of and control over electricity bills, environmental concerns, better comfort such as the technological solutions allowing the optimisation of comfort and more control over own energy use. However, mishandling of a number of elements might lead to consumer’s reluctance of accepting new energy innovations: cost barriers, consumer awareness, control and privacy, trust, security and reliability, health concern, behavioural barriers, user experience and ease of use.

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