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LOCAL ENERGY COMMUNITY ARCHETYPES IN EUROPE

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ABSTRACT

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New means are needed to reduce emissions, such as local energy communities. With the development of technology and falling prices, the opportunity has arisen to set up various energy communities. This Master's thesis studies the most common archetypes of local energy communities in Europe through desk research and targeted structured interviews. Identified archetypes were categorized based on the key services they provide, and named: collective renewable energy source self-consumption, renewable energy source supply, peer-to-peer sharing, electric mobility, flexibility, and energy management. This thesis will identify energy strategies, and technologies these different archetypes have. In addition, this work seeks to clarify, through interviews, the challenges, and opportunities these archetypes face and their future development plans. Finally, the thesis clarifies the key drivers and motivators behind their actions.

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Päästöjen vähentämiseksi tarvitaan uusia keinoja, kuten paikallisia energiayhteisöjä. Teknologian kehityksen ja hintojen putoamisen myötä, on syntynyt mahdollisuuksia perustaa erilaisia energia yhteisöjä. Tämä diplomityö pyrkii löytämään tyypillisimmät paikallisten energiayhteisöjen arkkityypit Euroopassa kirjallisuustutkimuksen ja kohdennettujen jäsenneltyjen haastattelujen avulla. Löydetyt arkkityypit on luokiteltu tarjoamiensa avainpalvelujen perusteella ja nimetty seuraavasti: kollektiivinen uusiutuvien energialähteiden itsekulutus, uusiutuvilla energialähteillä tuotetun sähkön myynti, vertaisjakaminen, sähköinen liikkuminen, jousto sekä energianhallinta. Tämä työ identifioi minkälaisia energiastrategioita ja teknologioita nämä arkkityypit omaavat. Lisäksi tämä työ pyrkii selventämään haastattelujen avulla, minkälaisia haasteita ja mahdollisuuksia arkkityypeillä on sekä minkälaisia tulevaisuuden suunnitelmia niillä on. Diplomityössä selvennetään myös toiminnan taustalla olevat avaintekijät ja motivaattorit.

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I would like to thank Samuli Honkapuro and Gonçalo Mendes for providing this interesting topic and helping me contact suitable energy communities for interview. Also, I would like to thank those representatives of the energy communities who agreed to take part in the interview. Special thanks go to my family and friends.

TABLE OF CONTENTS

LIST OF ABBREVATIONS

CEC	Citizen Energy Community
DSO	Distribution System Operator
EC	European Commission
EDF	Électricité de France
EEA	European Environment Agency
EU	European Union
GHG	Greenhouse gas
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
JRC	Joint Research Centre
LCOE	Levelized Cost of Electricity
LEC	Local Energy Community
Ofgem	Office of Gas and Electricity Markets
P2P	Peer-to-peer
PPA	Power purchase agreement
PV	Photovoltaic
REC	Renewable Energy Community
RES	Renewable Energy Source
SaaS	Software as a Service
SEDC	Smart Energy Demand Coalition
TSO	Transmission system operator
USD	United States dollar

1. INTRODUCTION

The transformation of the energy sector towards an emission-free system has introduced new types of actors, such as local energy communities. The emergence of local energy communities is driven by climatic change, price drops and increased availability of renewable energy technologies, and the reduction of legal barriers. Local energy communities are energy-related activities run by local members. These activities can refer, for example, to electric mobility or the production and consumption of renewable energy.

This Master's Thesis studies the archetypes of LECs (local energy communities) in Europe. The thesis adopts the method of desk research for determining these archetypes, as it compiles and utilizes written sources of different kinds. Additionally, targeted structured interviews were conducted to gain knowledge and better understanding of real-life cases. This research identifies technologies, energy strategies LEC archetypes have. In addition, the thesis seeks to clarify the challenges faced by archetypes as well as to clarify their key motivations and drivers. The Master's Thesis answering to the following questions:

- What are Local Energy Communities?
- What kind LEC archetypes are most prevalent in Europe?
- What are key drivers and motivators for identified archetypes?
- What kind of challenges different archetypes face?

The planet's limited resources and accelerating climate change are key challenges that have led to the need for a societal energy transition driven by decarbonization. As a result, the future energy must be produced and distributed in a clean and energy efficient manner. Therefore, there is need to take advantage of new energy technologies and develop ways to reduce GHG emissions and the losses from energy production and distribution. Local energy communities are part of the solution to improve energy efficiency and reduce greenhouse gas emissions.

Climate change is currently considered to be one of the greatest threats to humanity (United Nations 2021a). To fight this threat, many inter-governmental agreements, regulations and directives have been made in order to reduce GHG (greenhouse gas) emissions during coming years. One of the best known and most comprehensive agreements is the Paris Climate Agreement, which covers almost all countries in the world, at the time of writing 191 Parties out of 197 Parties to the Convention (United Nations, 2021b). For example, the Member States of the EU (European Union) have ratified the Paris Climate Agreement (EC, 2020a). The aim of the Paris Agreement is to limit global warming to well below two degrees Celsius when compared to pre-industrial temperature levels. The agreement states that, curbing global warming to 1.5 degrees Celsius would significantly reduce the effects of climate change and the associated risks. Achieving this would require significant changes in, for example, housing, industry, transport and energy production and distribution. The Paris Agreement supports the involvement of non-party stakeholders in reducing emissions. Non-party stakeholders include cities, the private sector, civil society, financial institutions, and other subnational authorities. The agreement takes into account the opportunities for local communities to use technology, information, and practices in an energy-efficient and climate-friendly way. (United Nations, 2016)

Based on the Paris Agreement, the EU has decided to reduce emissions by 40% compared to 1990 levels. In addition, the EU aims to achieve at least 32.5% improvement in energy efficiency and 32% share for renewable energy sources in 2030 (EC, 2020b). At the time of writing, it is planned that the GHG reduction target would be increased to 55% when compared to 1990 emission levels. The European Commission (EC) will present a proposal by June 2021, and in 2023 the EU Member States will change their national energy and climate strategies to meet the strict goals of the proposal. A stricter target is needed because in 2050 the EU aims to be emission neutral (EC, 2020c). These stricter targets are part of the so-called European Green Deal (European Parliament 2019). The key principles of the European Green Deal are energy efficiency, renewable energy sources, fully integrated EU wide energy market, affordable and secure energy production and delivery

(EC, 2019). The EC wants to empower consumers, increase regional cooperation, promote innovative technologies and interconnect energy systems (EC, 2019). This strongly suggests that local energy communities have an important role to play in achieving emission neutrality by 2050.

As mentioned earlier, the energy sector must strive to reduce GHG emissions. EU-28 (current EU members states and United Kingdom) GHG emissions come from energy supply, transportation, and industry as seen in Figure 1.1.

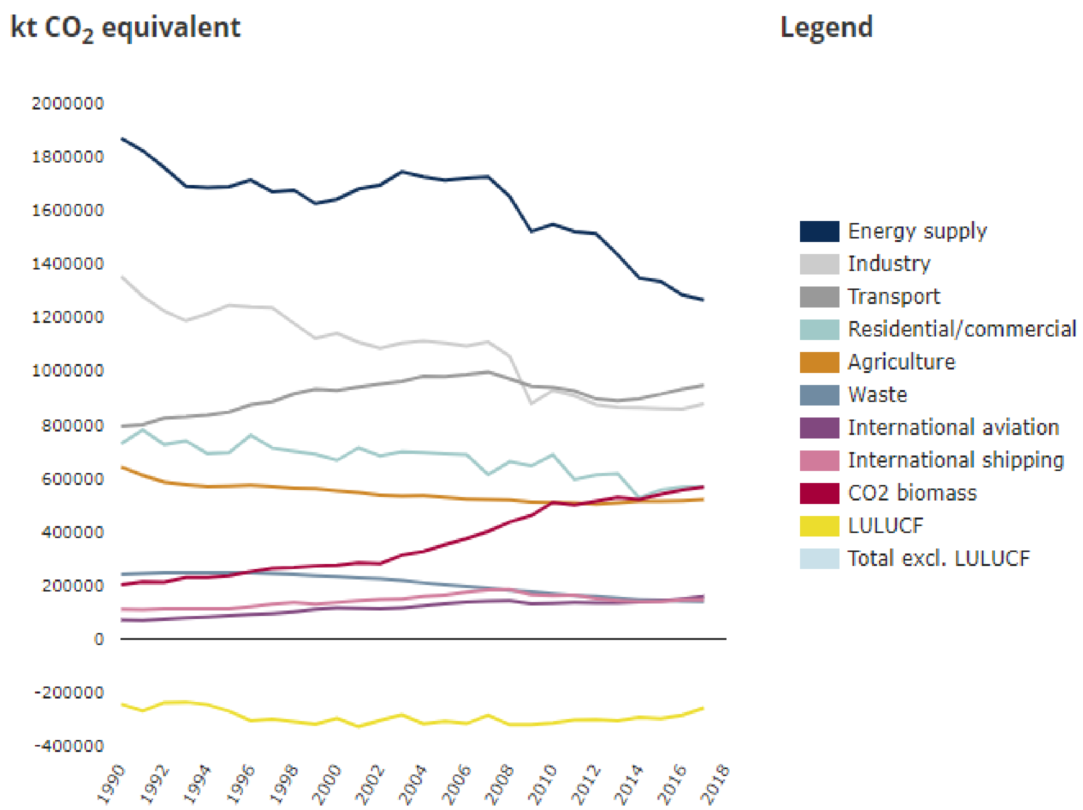

Figure 1.1 Greenhouse gas emissions by aggregated sector in EU-28 countries from year 1990 to 2017. (EEA, 2019)

EEA's (European Environmental Agency) report shows that, while GHG emissions from the transport are still rising, GHG emissions from the energy supply and industrial sectors are declining having decreased by about 32 percent from 1990 to 2017. The reduction in GHG emissions in the energy sector is due to the EU's action in relation to the targets it has set based on the Paris Climate Agreement. Biomass-based emissions are on the rise.

Biomass can be considered as an emission-free energy source if its use is carried out in a sustainable way, for example by replacing felled trees with new ones. On the other hand, emissions from residential/commercial as well as waste are declining slowly. In other sectors, there is no noticeable changes in one way or another. (EEA, 2019)

The reduction in emissions from energy supply is due to improved energy efficiency and increasing uptake of renewable energy sources. The competitiveness of fossil fuels has weakened due to higher taxation and emission trading, which in turn has made c renewable energy sources more competitive. In addition, other efforts are being made to support renewable energy sources, for example through tariffs and tax concessions. The development of renewable energy technologies and the consequent lowering of prices have made them more viable for energy production. This is noticeable, for example, from case of solar and onshore wind power as seen in figure 1.2.

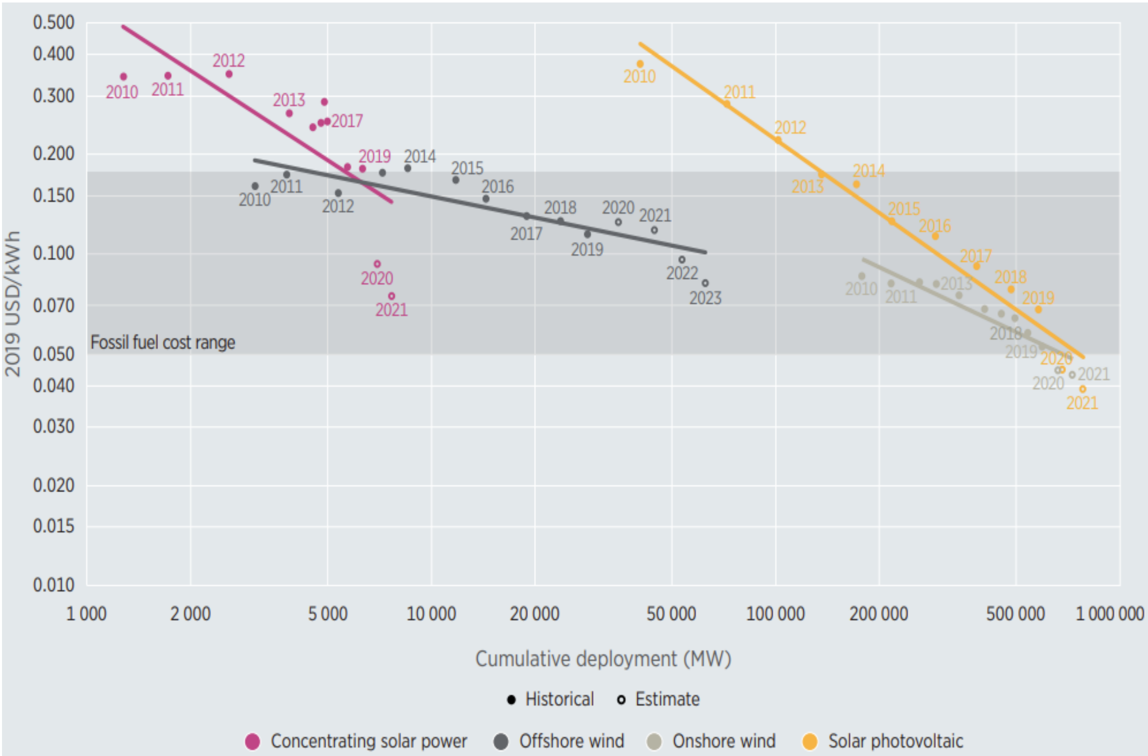

Figure 1.2 Learning curves for the global weighted average LCOE (Levelized Cost of Electricity) for utility-scale projects in years 2010-2021. (IRENA, 2019)

Solar photovoltaic and onshore wind power have reached the lowest point of fossil fuel cost range. Somewhere between years 2020-2021 LCOE (Levelized Cost of Electricity) of these power sources will reach 0.045 USD/kWh (United States dollar) which would be lower than fossil fuel cost range. Behind this development are the reasons that were mentioned earlier, such as taxation and technological development. However, it is important to understand that taxation and legislation can vary significantly between the European countries. Concentrating solar power has just reached the fossil fuel cost range while offshore wind is around middle of the cost range. It is expected that LCOE for concentrating solar power will drop from 0.175 USD/kWh to around 0.075 USD/kWh in 2021. The fall in prices has a positive effect on the interest of local energy communities, as in some cases the implementation of these projects becomes viable. (IRENA, 2019)

As installation cost of renewables falls, interest in them increases. This is reflected in a significant increase in renewable energy production (IEA, 2020). In the EU in renewable energy capacity has almost doubled in ten years as seen in figure 1.3. (IRENA, 2020).

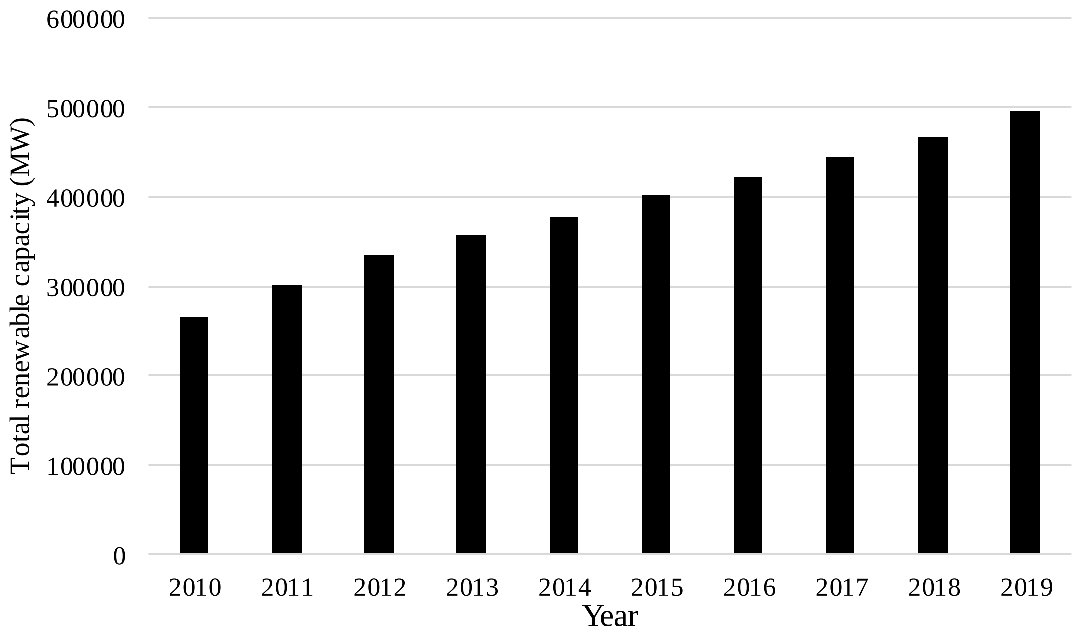

Figure 1.3 Total renewable capacity (MW) in EU (28) countries in 2010-2019 (IRENA, 2020)

Installation capacity has steadily increased from 2010 to 2019. Capacity has roughly doubled from 265 GW to 497 GW during that time. In heat production, fossil fuels are replaced by biomass and biogas. Biomass and biogas can be processed even in small plants and raw materials are relatively easily available. For example, biogas and biomass can be processed from livestock manure. In addition, biomass raw materials are available from wood industry surplus products. Electricity production in the future will rely on wind power, biomass, hydropower, nuclear power and, in part, solar panels.

Relying only on wind and solar power, which are intermittent output resources can cause problems with stability of the electricity grid. In order to maintain the balance between consumption and production, electricity storage scan be used in the way that the reserved energy can be used to compensate for renewable energy generation fluctuations. Like solar power and wind power, prices of the battery systems are falling. Prices of battery storages are expected to decrease considerably according to research conducted by Eero Vartiainen and others as seen in figure 1.4. (Vartiainen et al., 2019).

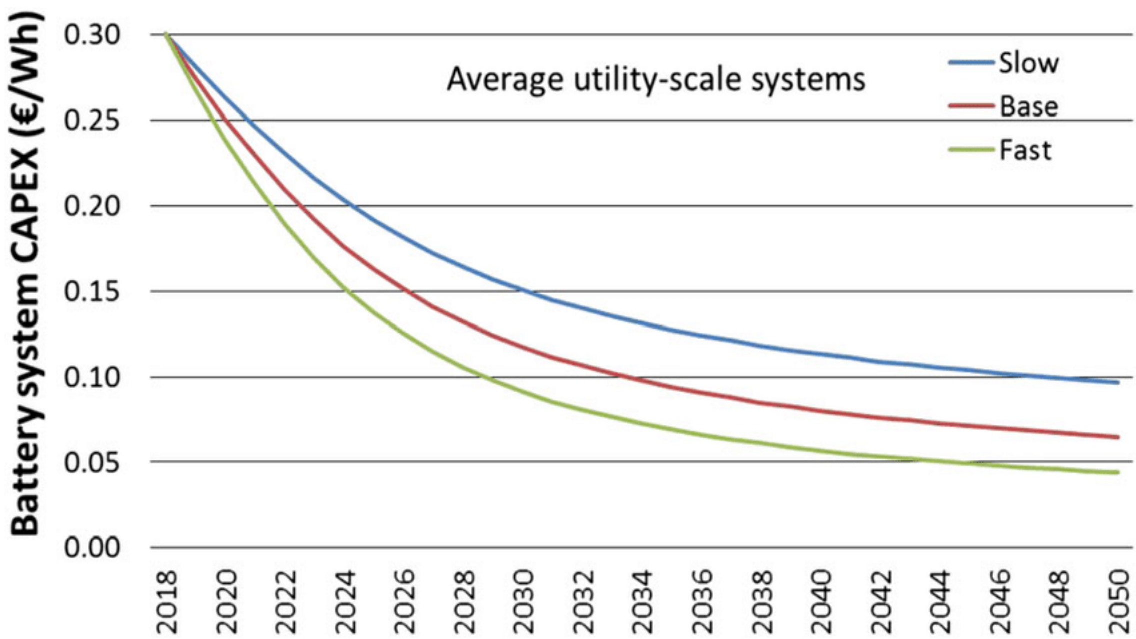

Figure 1.4. Li-ion battery system capital expenditure price development projection for the years 2018-2050 for slow, base, and fast scenarios, prices are in 2019 real money without value added tax. (Vartiainen et al., 2019)

From Figure 1.4. it will be seen that battery prices will fall sharply as we move towards 2030. The reason for the slowdown may be that battery development becomes more challenging, making it harder to find savings targets. After that, the price decline will slow down. Cheap battery system creates opportunities for new innovations that can help effectively manage renewable energy sources and cut consumption peaks.

The transport sector has begun to shift from traditional internal combustion cars to electric, hybrid and gas-fueled vehicles. ICCTs (International Council on Clean Transportation) report suggests that several car manufacturers have announced that they will reduce manufacturing cars using internal combustion engines and start making more climate friendly hybrid and electric cars (ICCT, 2020). The electrification of transportation is just beginning which is why there are also problems. For example, the operational range of electric cars is significantly worse than that of internal combustion engines. In cold conditions, the operational range of electric cars is further shortened because energy is needed for heating the car cabin. Due to the high energy efficiency of the electric cars, there is not enough waste heat, which could be used for heating of the cabin. Also, fast charging stations are still offered in small numbers, which makes it a less desirable option. New innovations can be used to solve some of the problems associated with the electrification of transportation. Local energy communities might offer new ways to add recharging stations and electric cars to the transportation sector thus contributing to ameliorate these problems.

The rapid development of technology also brings challenges for decision makers. New technologies bring new policy innovations. In some cases, legislation cannot keep pace with technological development. Specifically, the rigidity of legislation also affects the viability of local energy communities.

2. LOCAL ENERGY COMMUNITIES

Concerns about climate change have increased people’s awareness of how fossil fuels and overconsumption impact negatively our climate and natural resources. It has increased people's interest in energy efficiency, reducing emissions, and producing their own energy. This has originated citizen interest in establishing communities that do new types of collective energy actions. For example, the growth in memberships and foundation of new energy communities in Europe could be driven by the increase in competitiveness of solar energy installations.

Expressed in colloquial language, local energy communities are energy related activities run by collective entities. Typically, local energy communities are open and run democratically, which means that each member has one vote. The goal of the local energy communities is not to make a profit, as is traditionally part of business culture, but to create widespread value for its members. Value in this case can mean clean and cheaper energy, jobs or more investments linked to energy and sustainability.

Local Energy Community was defined in the proposal for recast Electricity Directive (EU) 2019/944, part of the EU’s Clean Energy Package. This naming, however, was changed to CEC (Citizen Energy Community) in the final version of the directive. Renewable Energy Directive (EU) 2018/2001, which is also part of the Clean Energy Package, introduced other very similar definition: Renewable Energy Community (REC). REC and CEC serve as the official definition of LEC. The biggest difference between definitions of the CECs and the RECs is related to energy sources. There are also other smaller differences, which are opened later in this thesis. Recast Electricity Directive (EU) 2019/944 Article 2 defines CEC as legal entity that:

(a) is based on voluntary and open participation and is effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises;

(b) has for its primary purpose to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates rather than to generate financial profits; and

(c) may engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders;

The Directive (EU) 2019/944 does not limit energy sources to only RES (Renewable energy sources). So, for the CECs, it is also possible to use fossil fuels like oil or natural gas. However, in the case of RECs, this is not possible because, as the name suggests, it focuses only on RES. Recast Renewable Energy Directive (EU) 2018/2001 Article 2 defines REC as legal entity that:

(a) which, in accordance with the applicable national law, is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned and developed by that legal entity;

(b) the shareholders or members of which are natural persons, SMEs or local authorities, including municipalities;

(c) the primary purpose of which is to provide environmental, economic or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits;

Both have open and voluntary participation. Compared to the definition of CEC, the definition of REC is more limiting. REC can be described as subtype of CEC (REScoop 2020). RECs stricter requirements relate to the energy sources used, the proximity of the projects and the governance. definition of the REC requires that it is controlled in proximity of the project or projects. This condition is not found in the CECs definition. Directive (EU) 2018/2001 does not take a position what proximity means in this case, so the decision on this matter is left to the Members States (EU, 2018). Definition of REC doesn't allow forming virtual energy communities. In other hand, definition of CEC doesn't have problem like this. Unlike the RECs definition, the CECs definition makes no mention of the autonomy which in this case means democratic governance that makes all members equal. It effectively prevents the purchase of votes with funds. REC allows involvement of medium-sized enterprises while CEC does not.

It is possible to satisfy conditions for both CEC and REC. For example, community that uses renewable energy sources could achieve requirements for both energy community types, because it would satisfy energy source requirements for CEC and REC. Needless to say that other conditions must also be met. In practice, an REC is also a CEC. However, opposite may not be true in all cases. As mentioned earlier, definitions of the REC require energy related activities to be within proximity, which might not be true some cases.

Local energy communities may consist of one or more energy-related activities. Activities of local energy communities may include, but are not limited to, the provision of energy management services, the generation, distribution, sale and consumption of energy, as well as the sharing/lending of electric cars and the maintenance of charging points. As seen in Figure 2.1 the recent survey by JRC (Joint Research Centre) reveals that generation is the most popular activity with 20 communities according to 24 case studies. (JRC, 2020)

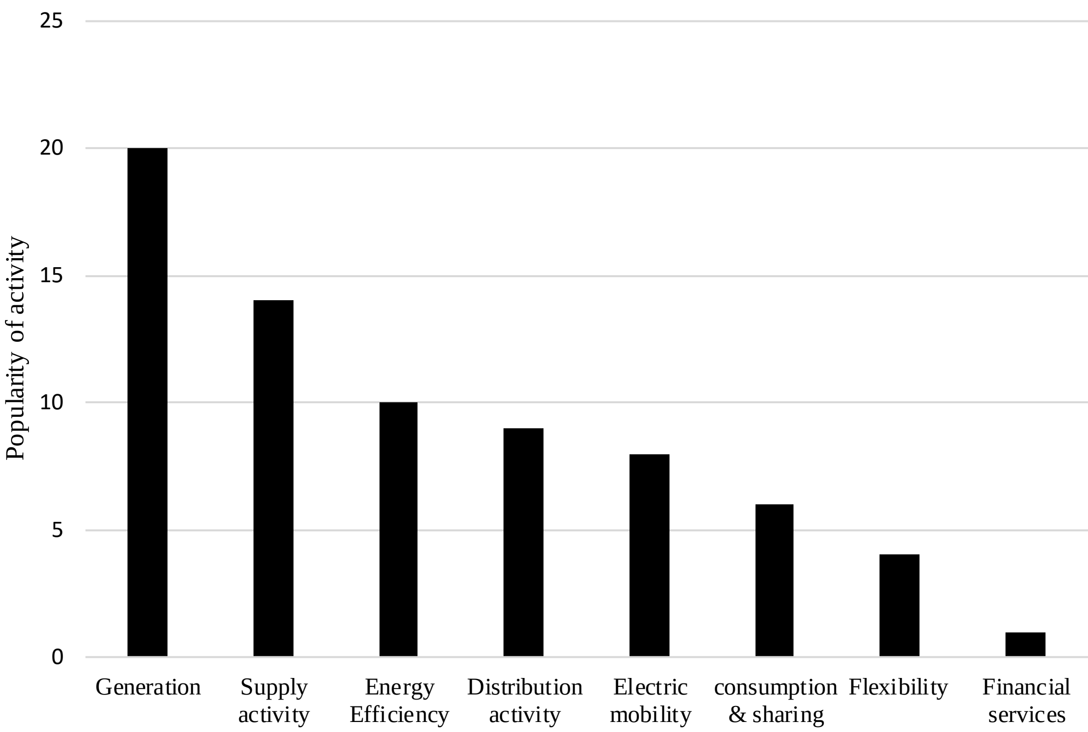

Figure 2.1 Identified activities of the local energy communities in 24 case studies made by Joint Research Centre (JRC, 2020)

Generation, supply, and energy efficiency are most popular activities according to JRC. Generation and supply are in close to all cases renewable. Flexibility and financial services are least popular activities. Although only six cases of electro-mobility were observed in case studies, it is on the rise. "*Additional services in the field of electro-mobility are becoming increasingly popular.*" according to JRC. The potential for electrification of transportation is reflected in increased interest in these projects.

The activity portfolio of some local energy communities can cover almost all the activities mentioned earlier. For example, Żywiecki Klaster Energii produces, distributes, and sells electricity and heat. It also balances energy demand, plans, and helps to reduce emissions, electrico-mobility and improves energy efficiency. Żywiecki Klaster Energii includes over 40 affiliated entities, 14 municipalities, 150 000 residents and 1000 km^2 of operating area. Żywiecki Klaster Energii aims to make Zywiec energy independent and reduce emissions with renewable technologies and energy efficiency (Żywiecki Klaster Energii, 2021). Typically, the produced energy for local energy communities comes from renewable energy sources such as biomass, hydropower, solar panels, and/or wind power. As mentioned earlier, concerns about climate change and declining costs of renewable production methods have had a positive impact on demand for renewable energy sources.

2.1 A look at the legislative differences between LECs in European countries

The aim of the directives is to bring the laws of the EU member states so that they do not create unfair situations and facilitate cooperation between the countries. Yet the laws and its enactment differ between European countries. From the point of view of this work, local energy communities may bring different opportunities to different EU member states and also in other European countries. On the other hand, the United Kingdom is free to develop its laws, enabling it to enforce laws that are important to energy communities more quickly. Restrictive legislation can slow or, in the worst case, prevent the emergence of local energy communities.

It is important to understand how a directive is transposed in national legislation. It is given only by Council of the EU or in cooperation with European Parliament to all EU members or members that it is addressed. The directive is binding so, those countries that are addressed by it must achieve the set goal or goals within specified timetable which is typically two years. The Directive leaves room for how the defined objective or objectives are achieved. It is up to the Member State how it will pursue the objective or objectives set by directive. The directive can therefore be seen as a legislative guide. It is possible that the country's legislation meets the objectives of the directive, in which case there is no need to change the national law. However, typically some changes need to be made to the legislation to match set goals. EC assists member states with implementation. It organizes meetings with experts, guidance documents and implementation plans. National authorities must inform EC about measures that they to achieve objective of the directive. EC monitors that the directive is implemented into the national legislation correctly and it is done within given deadline (EC, 2020d). If member state fails to meet these conditions, EC may start infringement procedure. According to the EC, the procedure involves the following steps (EC, 2020e):

1. The Commission sends a letter of formal notice requesting further information to the country concerned, which must send a detailed reply within a specified period, usually 2 months.

2. If the Commission concludes that the country is failing to fulfil its obligations under EU law, it may send a reasoned opinion: a formal request to comply with EU law. It explains why the Commission considers that the country is breaching EU law. It also requests that the country inform the Commission of the measures taken, within a specified period, usually 2 months.

3. If the country still doesn't comply, the Commission may decide to refer the matter to the Court of Justice. Most cases are settled before being referred to the court.

4. If an EU country fails to communicate measures that implement the provisions of a directive in time, the Commission may ask the court to impose penalties.

5. If the court finds that a country has breached EU law, the national authorities must take action to comply with the Court judgment.

After step five, if member state still does not take action, case will be taken back to the Court of Justice (EC, 2020e).

Although the EC monitors the implementation of directives, achieving the objectives in different ways can in some cases lead to significant differences in national legislations. In addition, it is possible to comply with the directive more strictly than specified, which contributes to increasing differences between countries. For example, privileges and rights of the energy communities differ in context of the Clean Energy Package. On December 22, 2020 the Finnish Government approved amendment that adds provisions for the local energy community to the regulation. Amendment enables compensation calculation, which allows sharing of produced and stored electricity to members of LECs when it is done within same property or group of properties by using DSOs (distribution system operator) metering equipment. Amendment entered into force on January 1, 2021 and it fulfills requirements that were given by Clean Energy Package related to LECs (Työ- ja elinkeinoministeriö, 2020). France and Luxemburg do not allow LECs to participate in distribution while Netherlands allows it by derogation. Some key rights and privileges are compared in table 2.1.1 (Bridge, 2020).

Table 2.1.1 Transposed laws regarding local energy communities in Portugal, France, Slovenia, Netherlands, Germany, and Luxemburg (Bridge, 2020)

	Portugal	France	Slovenia	Netherlands	Germany	Luxemburg
Production	Allowed	Allowed	Allowed	Allowed	Allowed	Allowed
Distribution	Not Specified, but possible	Not Allowed	Not Allowed	Allowed, pilot projects	Not Specified, but possible	Not Allowed
Supply	Allowed	Allowed	Not Specified	Allowed	Allowed, Not Specified	Allowed, Not Specified
Sharing	Allowed	Allowed	Allowed	Allowed	Allowed, Not Specified	Allowed
Storage	Allowed	Allowed	Allowed,	Allowed, Not Specified	Allowed, Not Specified	Allowed, household level
Sales	Allowed	Allowed	Not Allowed, without supply license	Allowed	Allowed, Not Specified	Allowed
Collective Self-consumption	Allowed	Allowed, building and block level	Allowed, building and block level	Allowed, building level & postal code area	Allowed, building and block level	Allowed, building level

As seen in table 2.1.1 in table, most differences are related to distribution. Collective self-consumption has some minor differences related to cases where it allowed. However, even small differences and lack of specification can lead to unfair situations. For example, preventing participation in distribution may limit the energy community's ability to operate efficiently, or in the worst case, preventing some of them from emerging at all. This can also manifest itself as the concentration of the LECs in specific countries or only as the emergence of certain types of LECs because, legislation is favorable to them. In addition, in some cases, EU member states may even have too much room for leeway in terms of legislation, which can lead to significant differences between countries.

The differences are not just focused on the legislation related to the local energy communities. Differences can be found in the whole energy sector in the roles and responsibilities of the DSOs and the TSOs (transmission system operator). In addition, there are various country-specific restrictions and responsibilities related to the markets. It would be important for energy efficiency and local energy communities that demand response is possible in all European countries. However, the truth is different, as in Portugal, and Estonia, for example, it would be difficult or in some cases impossible for energy communities to participate in demand response due to lack of legislation or it is not accepted resource in electricity markets. For example, according to SEDCs (Smart Energy Demand Coalition) report aggregators in Portugal cannot participate in demand response because concept does not exist in regulation (SEDC, 2017).

3. ARCHETYPES

Local energy communities are relatively new in Europe, technological developments and new innovations are diversifying and leading to increased interest in local energy communities. This is reflected in the emergence of new pilot projects, which in turn means the emergence of potentially new types of energy communities. There are other significant reforms in the energy sector, such as at legislative level, so it will be interesting to see how different energy communities will influence the development of the energy sector in the future. Technological advancement also brings new opportunities for local energy communities, so it will be interesting to see how different energy communities will influence the future development of the energy sector.

As earlier mentioned, the LECs are diverse and can vary greatly. As seen earlier in Figure 2.1, energy communities can focus on different energy-related activities such as, energy production and consumption, energy efficiency, or even electric-transportation. Based on the most commonly found the activities, six different archetypes were identified, which are focusing on following activities: self-consumption, RES supply, peer-to-peer (P2P) sharing, electric mobility, flexibility, and energy management. The first three focus on energy production and use as described by names of each archetype. Electric mobility focuses on charging stations and sharing/lending of electric. The Flexibility archetype is oriented towards providing flexibility to electricity markets through demand response and peak shaving. Energy management optimizes consumption, for example, by taking advantage of smart tariffs. Consumption, which may mean heating or an electric car, is controlled in a way that minimizes costs to community members. For members of energy management energy community, this means a lower electricity bill.

At least one practical example has been selected and interviewed for almost all archetypes. Flexibility-focused energy community could not be interviewed, because of its rarity. Reasons behind rarity are related, for example, the legal situation of demand response. The interviewees and the interview method are listed in the table 3.1.

Table 3.1. Interviewed communities and interview platforms.

Archetype	Self-Consumption	Supply	Peer-to-Peer	Electric Mobility	Energy Management
Community name	Finsolar	Coopérnico	Project CommUNITY	Som Mobilitat	Lumenaza
Location	Finland	Portugal	United Kingdom	Spain	Germany
Interview platforms	Microsoft Teams	Zoom	Email	Email	Email

Most of the interviews were conducted by email. The reason for this is that those interviewees wanted to think and hone their answers. Other interviews were conducted through video calls on Microsoft Teams or Zoom. A total of seven questions were asked to each community representative in the interview, five of which were general, meaning that the same question was asked of each participant. The remaining two questions were community specific. The standard questions are in appendix I and specific questions are in appendix II. Questions that were intended for flexibility archetype are in end of appendix II.

For each archetype, the aim is to identify what technologies and energy strategies they use and what kind challenges they might face. Legislation affects the possibilities for setting up energy communities. In the case of archetypes, with interviews the aim is to determine whether the legislation poses problems for energy communities. Other constraints may be lack of knowledge, or the establishment of an energy community is too costly. The work also evaluates key drivers and motivators behind their actions, possible future plans, and tips for setting up similar energy communities.

There are several reasons why local energy communities are formed or why people want to participate in one. For example, concerns about climate change and increasing competitiveness of renewable energy sources were mentioned earlier in this thesis. Other motives are financial, sustainability, self-sufficiency, energy efficiency, supply and sharing RES and secure energy supply. The financial motives relate to the potential savings that can be achieved through the LEC. Financial savings can be result from lower electricity bills or in case of electric mobility as lower travel costs. The importance of Social and environmental sustainability is due to concerns climate. People who see this as important motivator want to increase energy efficiency and the use of renewable energy sources. Self-sufficiency is valuable, especially for people living in energy-poor areas such as islands. Another reason for valuing self-sufficiency is that people want to control things themselves. Support for energy efficiency is based on the desire to use natural resources as efficiently as possible. Some also see it as a tool in the fight against climate change. Supply and sharing of renewable energy, as the name implies, intended to provide renewable energy for sale or distribution to members. Secure energy supply is important in areas with a lot of power outages due to storms. Future chapters on archetypes will look closer look at what kind of motivations and drivers different energy community archetypes have.

Drivers can also indicate in some scale what kind of local energy communities might gain more popularity than others. Renewable energy was one of the most common drivers for energy communities. It might indicate that more communities might lean to energy generation and self-consumption-oriented action. In the other hand energy efficiency might steer to more energy management service like operation.

3.1 Collective RES self-consumption-focused LECs

General idea behind this archetype is simple, so it is also quite easy to implement in practice. This local energy community archetype is based on the idea that, self-produced energy is also self-consumed by its members. In case of this archetype, the energy production is done by using renewable sources. Depending on the size, members and location of the local energy community, solar panels, wind power, hydropower and biomass are typically used as energy sources. In a city-like environment, solar panels are usually the energy source because space is typically limited. Residents of a block of flats can form a energy community, in which case the energy produced by solar panels is used among the member residents. This type of self-consumption energy community was chosen for interview and as example. The interviewee was Professor Samuli Honkapuro, who was involved in a Finnish pilot project Finsolar studying the use of a solar panels for self-consumption in apartment buildings. More remote areas have more space and opportunities to use other energy sources, such as wind and in some cases hydropower. Also, biomass raw materials such as wood and manure are also better available in more remote areas. Biomass can also be used for heat production or even combined heat and power.

This style of energy community typically arises from a desire to produce and use clean energy, improve energy efficiency, and increase self-sufficiency. According to Professor Honkapuro, in the case of an apartment building pilot project Finsolar, the consumption of green energy is one of the main motivators and drivers. In some cases, self-sufficiency-oriented communities could also aim to reduce dependence on the grid. The aim is also to benefit financially. Self-generation and consumption reduce need for electricity from the grid which in turn means smaller electricity bill. The other import factor that can lead to birth of the self-consumption local energy community is climate change. As mentioned earlier, climate change is perceived as threat, so people want to fight against it (United Nations 2021a). For this archetype, self-produced renewable energy is intended to reduce and in rare cases to fully offset electricity from the main grid. The reason for this is that electricity generated to the grid is usually not completely renewable and emission-free. Knowing the origin of the energy that is consumed can be important to some people.

Since generated energy is going to be self-consumed by energy community, the energy source must be close to the point of consumption, which is in this case the local energy community. This means that self-consumption archetype fulfills proximity requirement for REC. Expansion in this archetype is also going to be somewhat limited, because the generations need to be in close range. In addition, because this archetype uses renewable energy sources for its activities, it can be classified as REC. The archetype also meets the requirements of the CEC.

Self-consumption can be useful in the case of apartment buildings. It is possible to form local energy community with members of the apartment building. The Easiest way to make this kind of energy community is installing solar panels to rooftop of the apartment building. Generated energy can be used to supply, for example, apartment building lights, elevators, and ventilation. Surplus energy can be shared and used by members of the self-consumption energy community. A pilot project like this, Finsolar, was conducted in Finland (Auvinen et al. 2020). The mobile application could be used to monitor production, allowing consumption to be timed when electricity generation from solar panel is high. However, in case of Finsolar project, there was not dedicated mobile app for monitoring. Solar panel on rooftop reduces electricity consumption related costs in an apartment building and, in some respects, also the consumption related costs for energy community members. Example of apartment building self-consumption energy community is in Figure 3.1.1 (Auvinen et al., 2020).

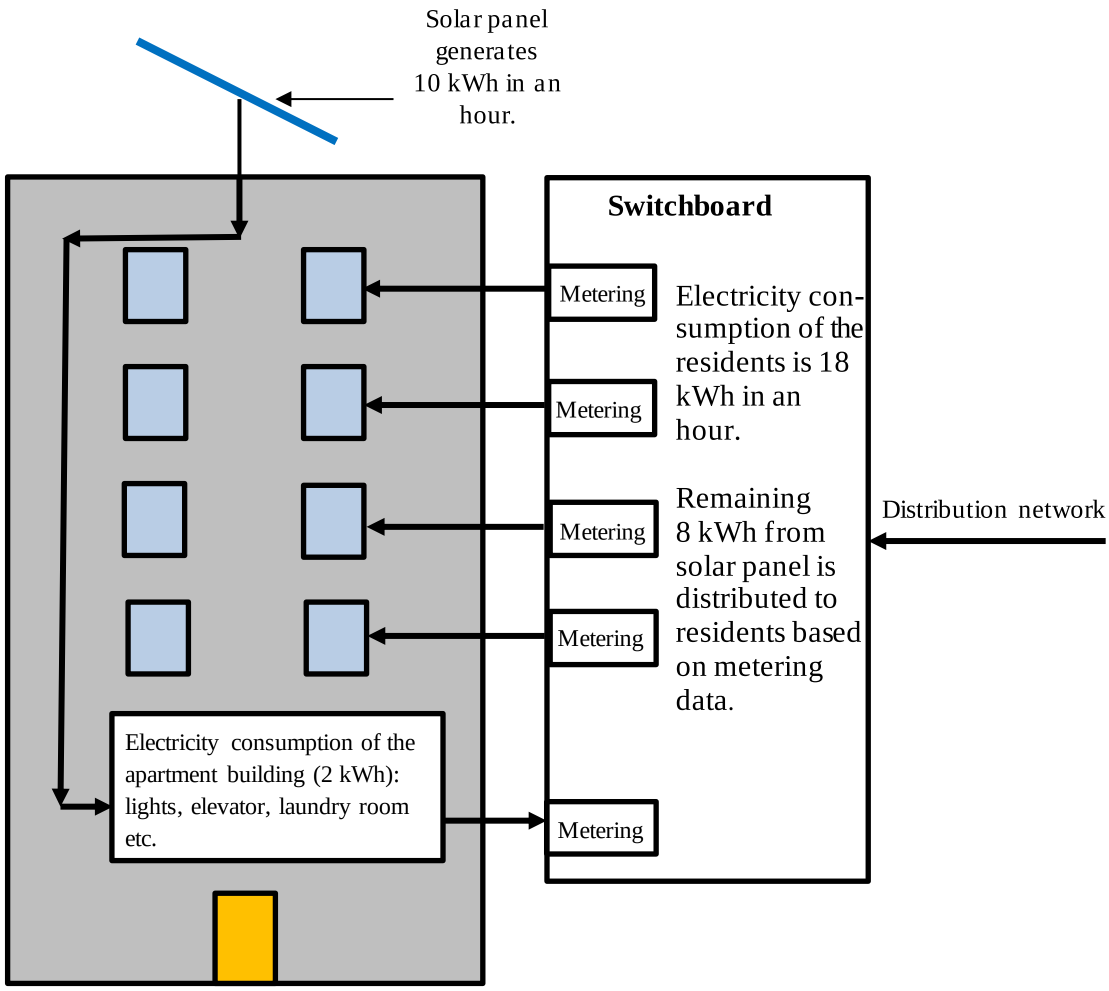

Figure 3.1.1 Apartment building self-consumption energy community studied in the Finsolar project (modified from Auvinen et al., 2020).

In this example, the total consumption of the system is 20 kWh in an hour from which Residents consume 18 kWh in an hour and the apartment building itself consumes 2 kWh in an hour. Solar panels generate 10 kWh in hour from which apartment building consumes 2 kWh during an hour for lights, elevator, laundry room etc. Rest of the 8 kWh is shared between resident members based on metering data. Members of the apartment building energy community can use that energy to power fridge, television, mobile phone charger, dish washer etc. Electricity consumption from distribution network is halved in this case. As vehicles transition to electric alternatives, it is also possible to use the energy produced by solar panels to charge an electric car. The solar panel should be sized in the way that all generated electricity can be consumed by energy community without supplying it to distribution network (Auvinen et al., 2020). In this case, the dimensioning of the solar panel is affected by the installation conditions and the consumption habits of the apartment building and its occupants (Motiva, 2020). The need to use energy sources that cause emissions is reduced, which in turn helps country to achieve its emission reduction targets. The impact of several small projects can be significant on a large scale.

The biggest challenges in the apartment building energy communities are related to legal problems, according to Professor Honkapuro. For example, during the pilot project, which was done during 2019, compensation calculation was not legally possible (Auvinen et al., 2020). Basically, compensation calculation enables excess generated electricity to be shared with community members of the apartment building. Finland enabled compensation calculation in January 2021, as part of energy community related legislation (Työ- ja elinkeinoministeriö, 2020). However, as stated earlier in chapter 2.1., there are differences in the legislation of European countries. There are differences in electricity and housing legislation, so the chances of setting up a community like this vary from country to country. In other words, depending on the country's legislation, the establishing of such energy community may not be viable or in worst case not even possible. The Finsolar project mentioned the possibility of so-called sub-metering, but it is difficult to implement because it requires the unanimous approval of all residents. Therefore, it was not tested during the Finsolar project (Auvinen et al., 2020). So, in practice it would be possible form self-consumption oriented local energy community by using sub-metering, but it is very difficult to achieve.

As Honkapuro mentioned in interview, there should not be major challenges from technical and financial standpoint. From a technical point of view, such a solution is not complicated. In the case of the pilot project in Haapalahti, the acquisition and installation costs of a 5 kWp solar system were approximately 10000 euros (Auvinen 2018). When the amount is divided into several shares, for example in 20 shares, the price would be 500 euros per shareholder. The amount to be paid depends on the size of the solar panel system and the number of participants. However, the price of the share can be problematic in some cases. Not everyone may have extra money available. For example, the state could provide small subsidies for such energy projects.

The feedback and experiences from the project have been positive. Honkapuro told during the interview that during the FinSolar project there has not been any problems. Residents do not notice the existence of the system anywhere other than the reduced electricity bill.

In the interview Honkapuro stated that during coming years self-consumption energy communities could improve their energy community with energy storages. Excess electricity generated by solar panels could be stored in the energy storage for later use. This kind of solution might be beneficial if spot price for electricity is used. When spot price is high, generated and stored could be used to offset electricity from distribution network, which can mean considerable savings.

Storage could also be used for peak shaving in small scale. However, this kind of action is not priority for self-consumption community. Concept of peak shaving will be discussed later in this thesis at flexibility archetype as it is one of the ways provide flexibility.
The sizing of solar panels and battery storage must be considered in such a way that the electricity from the solar panels can be stored and used as economically and efficiently as possible. The solar panel and battery must be dimensioned in way that all electricity can be used by self-consumption energy community, therefore it does not need to be sold. For battery storage, a cost analysis should be performed to assess whether it is economically viable to buy and install the storage system.

Small neighborhood would be able to form a local energy community focused on collective self-consumption. Like in apartment building case, the correct sizing of the energy source is important, because all generated electricity has to be consumed by community or possibly stored to battery for later use. Depending on the location of the community, the energy source could be biomass, wind power, hydropower or the aforementioned solar electricity. However, setting up a community like this has its own challenges, such as legal, financial, and technical challenges. Setting up wind turbine or hydropower plant can be expensive. Setting up system like that would probably mean that some consultation might be needed.

The example above can be taken a little further. In some rare cases there is no feasible way to connect to the main grid like, for example in islands. A good example of an energy community like this is in the Isle of Eigg. Energy is produced and distributed by community owned Eigg Electric, which uses solar panels, wind power and hydropower to feed electricity to all residents of the island. The most impressive thing is that the Eigg Electric manages to provide 24-hour power to the Isle of Eigg. Community has one 100 kW and two 5 kW hydro generators, which nets approximately 110 kW. Eigg Electric has also four small wind turbines and one solar panel array. At optimal conditions four wind turbines produce around 24 kW and solar panel array 50 kWp. Theoretical maximum generation for whole system would be 184 kW. Almost of the production depends on cloudy and windy it is which means that real generation is somewhere between 110 kW and 184 kW. To make sure that there is enough electricity to everyone, there are consumption limitations. Houses have 5 kW and businesses 10 kW maximum limit for power consumption. For backup, there are battery banks which can provide electricity to Isle of Eigg up to 24 hours. Battery banks are used in situations where generation is low and charged when there is excess electricity. Charging of the batteries is handled by smart inverters. If capacity falls below 50 %, inverters signal generators to start and charge the batteries. When the batteries reach 90 % inverters will disconnect generators and turn them off. Maximum power that can flow in or out from batteries is 60 kW. For last resort, the Eigg Electric also have two 80 kW diesel generators which can be switched into the system automatically if needed. (Isle of Eigg, 2021)

With smart grid like solution this kind of energy community could operate even more efficiently. Smart metering and encouraging residents to participate in demand response and also invest on their own solar panels and battery storages could be beneficial. It would be possible to increase maximum power consumption limit for short periods in homes and businesses. Solution like this could work in other very isolated places as well. Locations where hydropower is not available, it could be possible to use biomass instead. As earlier mentioned, other benefit of using biomass as energy source that it can also be used for heat production, which in turn might reduce need for electricity generation. For example, air-source heat pumps might not be ideal heating solution for cold climates because, efficiency will decrease as difference between outdoor and desired indoor temperature increases.

3.2 RES supply-focused LECs

This archetype uses similar energy production types as the self-consumption archetype. Main difference between these two archetypes is the way energy is handled. Instead of self-consuming, generated renewable energy is sold to supplier and feed to distribution grid.

Similar to self-consumption archetype, renewable energy is important for this archetype. Financial motives and social & environmental sustainability might also be important for this kind of community. Financial motives are related to income from supply activity. These claims are supported by an interview with Coopérnico, which revealed that the main motivators and drivers are related to the environment and green energy. The motivation is therefore ethical and financial. The gathered funds are used to expand supply activity, that is, for new energy generation equipment. This will lead into positive expansion and investment cycle, which enables growth for this archetype. As noted in the introduction, the competitiveness of solar panels has improved to the point that it is starting to be a cheaper option than fossil fuels as energy source. Solar panels are well suited for the purpose of this archetype and are therefore also used in such activities.

Popularity of fossil fuels is decreasing while green energy is becoming more and more important for end user. Availability of the green energy depends on country. In some cases, there might not be enough green energy for everyone that wants it which is why RES supply-focused LECs try to offer alternative solution to this problem. With the advancement of technology, lower prices have a positive effect on the interest in such communities.

Coopérnico is one of the largest energy communities in Europe that falls under this archetype. It is the first Portuguese energy community. Coopérnico was formed by 16 citizens concerned about sustainability. At the time of writing, it has 2123 members and 1672 contracts. According Coopérnico's website, their goal is to sell electricity at competitive prices while using RES for electricity generation. They want to involve more citizens and companies in their renewable energy projects in such way that it benefits environment and society. Sustainability and other green values are becoming more important aspect to many people as concerns about Earths warming and resources rise as time passes (Business Insider, 2020). This may be one of the reasons why Coopérnico has so many members. (Coopérnico, 2021a)

Becoming member of Coopérnico requires that individuals must be over eighteen years old and a legal person, who agrees and is committed to the goals of the energy community. In order to join and participate in the activities of the community, an individual must buy three equity shares of the energy community and make a written request, email or fill a form via website to inform about your interest in participating in energy community. Value of one share is 20 euros, so minimum joining fee is 60 euros. After payment and admittance by the Director of the Coopérnico, the member can start participating in decision making, which is done democratically, gain access to educational information and ability to invest in renewable energy projects. Educational information makes it easier to understand advantages and risks related to the energy projects. This educational information can encourage members of the supply-oriented energy community to make investments that will make it easier to fund new projects. Members have who make investments can get financial benefits from these projects. Coopérnico has made an illustrative picture of how it runs its energy community in figure 3.2.1. (Coopérnico, 2021b)

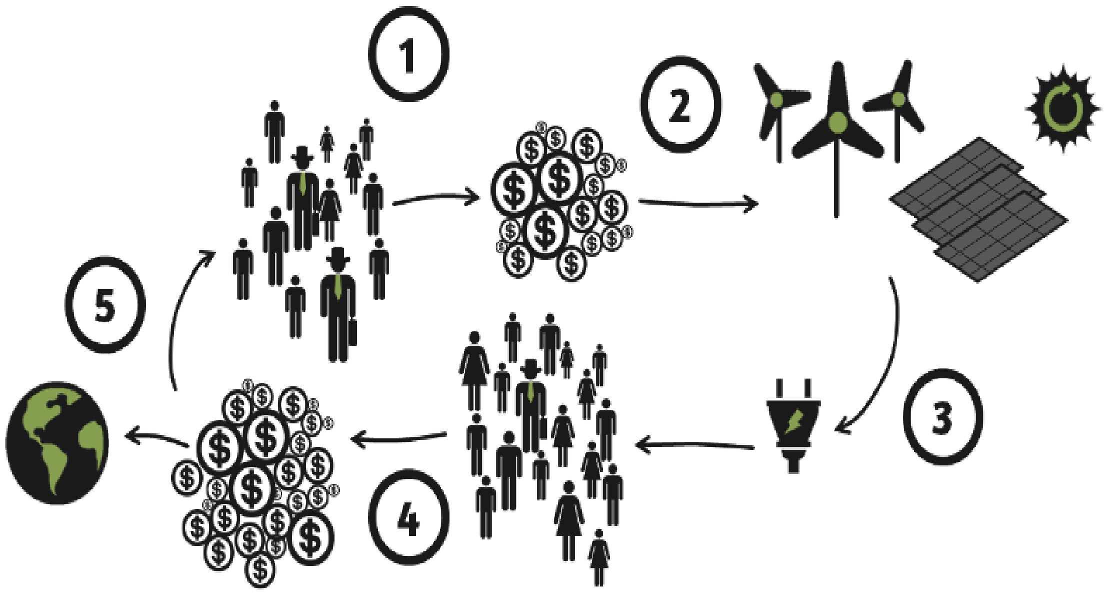

Figure 3.2.1 Cycle of Coopérnico 's renewable energy projects (Coopérnico, 2021c)

The first step shows new and existing members who decide democratically on the next renewable energy projects. Once the decision is made, money from the shares will be used to carry out the renewable energy project as implied on step two. Members can make investments in renewable energy projects that make it possible to reap financial returns. Projects also have positive social and environmental impact. To invest in projects, investment must be at least 250 euros. The goal is that annual return for investment would 3% (Coopérnico, 2021d). In step three, generated renewable electricity from these energy projects is supplied to local businesses, residents, schools or other end users. After that comes step four where consumers pay for their electricity consumption. Some of the money is distributed between investors, society and the environment. Rest of the money goes back to new projects. (Coopérnico, 2021c)

The Coopérnico has several different size renewable energy projects across Portugal. For example, projects can be found in Lisbon and Faro. So far, renewable energy projects are mainly focused on solar photovoltaic (PV) panels (Coopérnico, 2021e). Risks related to these projects are small, because Portugal has good conditions for solar PV, solar exposure is high and consistent. The most favorable solar conditions for an energy community like Coopérnico can be found in southern Europe. In more northern Europe conditions are not as good as in Portugal (EC, 2021). However, this does not mean that solar PV could not be viable option for electricity generation in norther Europe. Annually generated amount of energy from solar PV will be lower. Still, solar PV panels are valuable option for supply activity. Prices of the solar panels will continue to decrease making it more economically viable option in northern regions of Europe. There are other options for solar PV as well. It could be possible that renewable energy projects could include small hydropower plants and wind turbines. However, there might be difficulties to find suitable places for these projects which is why solar PV is preferred option for Coopérnico's RES projects. Forests hinder power output potential of wind turbines. That is why wind turbines need to be large enough to take advantage of wind in forestry areas. Larger size means higher investment costs which might be too high for energy communities. Hydropower requires rivers or big stream to generate electricity. The main problem with hydropower is that many good spots are either already used or protected which is why it might be hard to find suitable place for it. Coopérnico has wide variety of different projects like solar car park, schools, and residential buildings. Coopérnico prioritizes local partners in their energy projects because they want to create more jobs and promote sustainability. Coopérnico has made public list of their projects in their website. Some of the successful projects are shown in figure 3.2.2. (Coopérnico, 2021e)

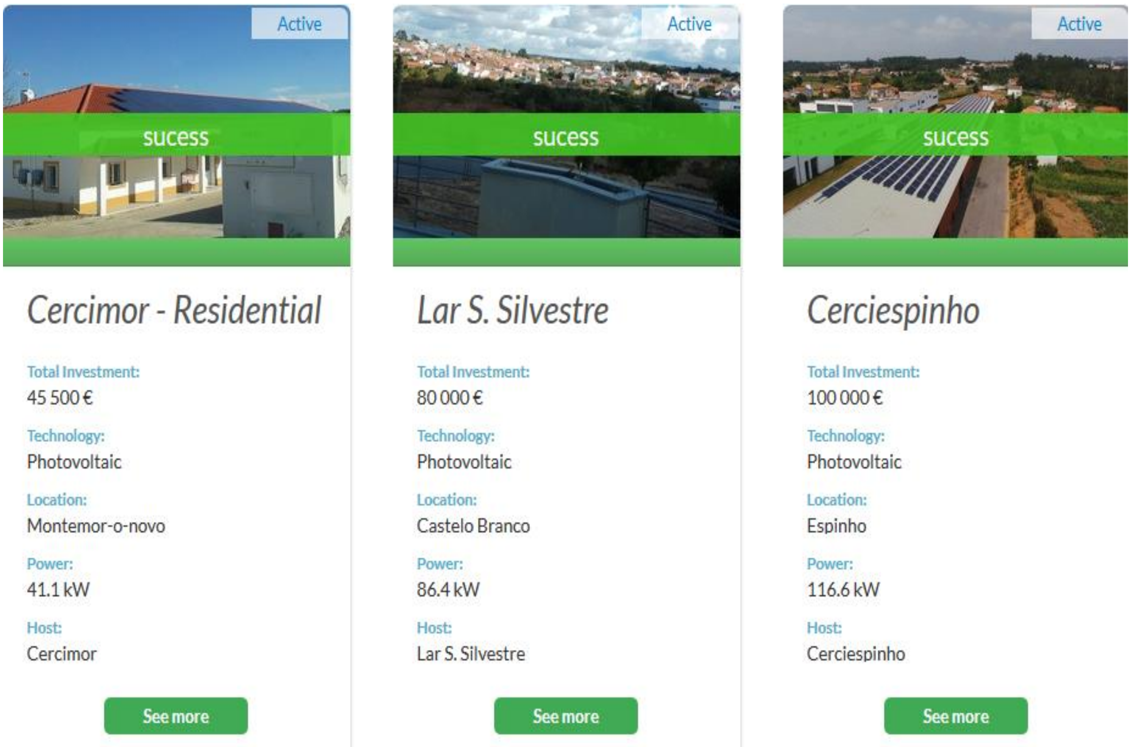

Figure 3.2.2 Some of Coopérnico's previous projects shown in their website. (Coopérnico, 2021e)

The projects in figure 3.2.2 are middle sized when compared to other Coopérnico's projects. There are many smaller and bigger projects than these three in figure. Showing projects on a website can be a good advertisement and it can attract more people to participate and join in community. It is easy for the average person to understand what it is all about when they see a project page. So far, since 2013, Coopérnico has managed to make 16 energy projects. Smallest renewable energy project is Biovilla with 9500 € total investment and 7.1 kWp power from PV panels. It is one of the first projects done by Coopérnico which explains the small size. In the other hand, the largest and most expensive renewable energy project is Adega de Palmela with total investment of almost 220 000 €. It was connected to grid on January 22, 2020. Power of the solar PV panels is 271.5 kWp which equals in these conditions 400 MWh of energy annually. That amount of energy would be enough for 150 families. According to Coopérnico, this project saves CO_2 emission annually 255 tons. Coopérnico shows that there are a lot of growth potential in this archetype. Growth potential like this, can be encouraging and motivating for forming new supply-oriented communities. (Coopérnico, 2021e)

Interview with Coopérnico revealed that biggest challenges are related to legal side. Portugal had few years ago feed-in-tariff change which, according to interview, impacted Coopérnico negatively. There are no financial or technical challenges. According to Coopérnico if there were any technical difficulties, they could be solved. They do not have financial problems related to new projects, because they get funded quickly. However, interview revealed that there might be financial issues on member level because of diverse backgrounds.

The Coopérnico's model is a good foundation for establishing and running a local energy community based on supply activity. It opens multiple ways to participate in interesting renewable energy related projects. Also, ability to make investment and gain some investment returns makes it more appealing to many people. It also does well its most important role, which is to increase availability of renewable energy. With many energy projects it has significant impact on sustainability. Coopérnico serves as a good example for others interested in supplying and selling clean electricity. Although in Portugal the conditions for solar panels are better than in most of Europe, the emergence of such communities is not an impossibility. The reduction in the price of solar panels will improve the viability for setting up similar energy community in northern regions of the Europe such as Sweden, Finland, and Norway. However, during winter it is required to clean solar panels from snow even tough amount sunlight is limited.

To citizens that are interested in forming a supply-focused energy community, Coopérnico gave one tip. To start a community, you must make your concept known to neighbors and other people in your social circle. People might be suspicious about you/your idea, which is why you need to clearly explain your intentions. Explain to them why your idea is good and why should they participate too.

Coopérnico does not have special tool for feedback collection. However, it gets feedback from local leaders. Feedback can be considered positive as it gives new ideas to Coopérnico. Feedback is pushing Coopérnico to make new investments.

In theory it would be possible to make similar community to self-consumption apartment building example but instead of self-consumption, generated electricity would be supplied to distribution network. However, self-consumption might be better in this case because money paid for generated small production is small compared to savings that can be made with self-consumption. This is, of course, dependent of the regulatory context in each country.

An energy community like this does not offer significant flexibility capacity. Because the community is focused on generating green electricity, it has no electrical loads. In addition, the reduction of generation from renewable energy sources can be challenging. The generation of solar panels can be limited by turning them away from the sun or by placing barriers between them and the sun. However, in many cases this is not possible. Another factor is that there might be reluctance to waste "free energy", which may discourage the supply-oriented energy community from reducing production in cases where it would be possible.

3.3 Peer-to-peer sharing-focused LECs

Peer-to-peer (P2P) electricity trading is a new and innovative way of giving ordinary citizens the ability to share their generated surplus energy and with that reap economic benefits, while contributing to maximizing renewable energy utilization. Typically, surplus electricity is generated using by solar panels. A P2P community meets the requirements of CEC and REC if it is located close to production and is renewable.

P2P-based local energy communities are in the pilot phase and are scarce in Europe. The reasons why P2P local energy communities are rare will be covered later. One of these projects can be found in the Brixton, United Kingdom. EDF (Électricité de France) Energy has named it the "CommUNITY" Project, which aims to improve the ability of small communities to benefit from clean energy at a low cost. "*Residents of a block of flats in Brixton are pioneering a community energy trading project led by EDF Energy that will enable them to trade solar energy with each other*" (EDF Energy 2019). Another P2P project worth mentioning can be found in Eemnes, the Netherlands. The Eemnes project is investigating the use of P2P in a neighborhood consisting multiple houses (Renaissance 2021). The EDF Energy project community was selected for a more detailed review and interview.

The main idea of a P2P-based energy community is that local community members can sell and buy electricity directly with each other. So called prosumer members, who are at the same time consumers and producers, can sell generated surplus electricity to other consumer member. It is also possible to take advantage of battery storages, in which case it is possible to store electricity for a later time and try to sell it at a better price later. Optionally generated electricity can be self-consumed if selling price does not meet expectations. On the other hand, the consumer does not have to buy electricity from prosumer if the price is too high. Figure shows simplistic interaction between prosumer and consumer members. 3.3.1. (EDF Energy, 2018)

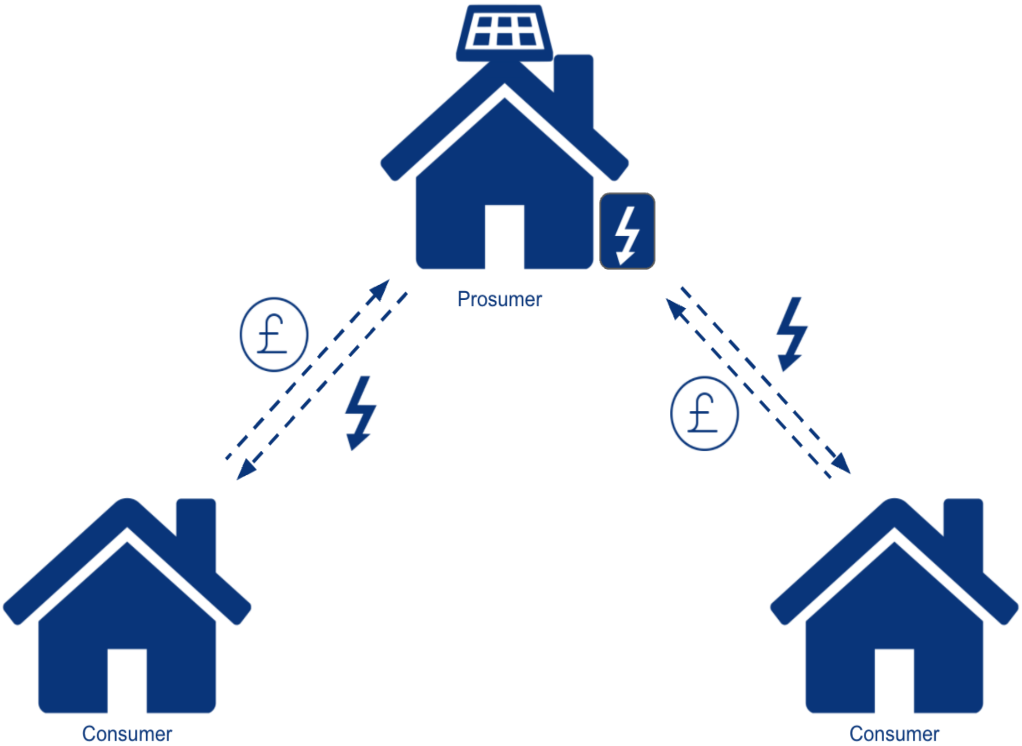

Figure 3.3.1. Trading interaction with prosumer and consumer members. (EDF Energy, 2018)

This arrangement is beneficial to both members because seller gets benefits financially from excess electricity and buyer gets cheaper electricity than normally. P2P community can be thought as advanced combination of supply and self-consumption energy communities. Other benefits come from consumption of green energy which means typically less emissions. Like in case of self-consumption community, P2P can benefit DSOs as well trough reducing need to make investment in distribution network.

According to EDF energy three, conditions must be met to avoid problems with P2P trading: transparency, auditability and trust. Transparency means that all data should be visible and available to everyone. Auditability requires that data cannot be changed, and it can be verified by anyone. Trust means that transactions need to happen as name suggests peer-to-peer without involvement of third parties. Blockchain technology that is also used in bitcoins is suitable solution as it fulfills these three goals. (EDF energy, 2018)

According to EDF Energy, P2P trading process with blockchain could happen in following way:

"1) Microgenerator creates excess electricity, beyond their needs,

2) Electricity is exported to the grid and recorded by a smart meter before being written into a blockchain,

3) The exported electricity would be represented as a token (e.g. 1 token = 1 kWh),

4) Tokens could be listed on an open market for anyone to purchase,

5) Consumers would see a list of sales along with their generation type and location."

(EDF Energy, 2018)

In the case of the P2P energy community, trading would only be open to community members instead of being open market to anyone as fourth paragraph suggests. Joining the P2P energy community would take place in the same way as in the case of Coopérnico. The party interested in the P2P community pays the agreed amount and puts in an application to join. Once the application for membership is approved, the member will have access to the P2P platform and can participate in influencing community-related decisions. EDF energy gave information capabilities of P2P trading app. Trading is done by using an app that allows participants to perform following actions: set trading preferences, view energy consumption, view energy consumption allocation (from grid, from sun, sold, received) and savings. Compared to self-consumption archetype P2P solution offers more freedom for each member. However, it is important to remember P2P solution sets requirements for the accuracy of smart meters to prevent errors in the balance sheet.

The Brixton community is partly reminiscent of Finsolar's self-consumption community because the apartment building uses rooftop solar panels for electricity generation. Unlike the Finsolar self-consumption project, Brixton also uses battery storage to store excess energy. Residents own a share of the solar panel that produces electricity. Residents can sell their own share of the production of electricity using P2P technology, store it to the battery storage or use it themselves. Brixton's P2P project can be seen to some extent as a more advanced form of Finsolar's self-consumption project. However, it is important to remember that for this archetype, self-consumption is not collective unlike in the self-consumption archetype.

Interview with EDF Energy revealed that key motivators and drivers for P2P activity are access to locally produced renewable energy to people living in block of flats and enabling self-consumption at building level. Availability of local renewable energy seems to be import similarly to self-consumption archetype.

According to EDF Energy, there can be legal challenges related to P2P activity. There might be difficulties if self-consumption related mechanism for people living in apartment buildings is not implemented to law. So basically, this archetype has similar regulatory challenges as self-consumption archetype. Additionally, P2P activity itself can be problematic. Regulations limit citizens ability to buy and sell electricity to other consumers. EDF Energy was able to work outside of the regulatory framework because project was part of Ofgem's (Office of Gas and Electricity Markets) "innovation link" (EDF Energy, 2019). The Eemnes project was also able to start with an exemption (Renaissance, 2021). From this can be drawn some sort of conclusion that P2P activities involve major legal challenges. This contributes to explaining why P2P-based energy communities are rare.

To set up similar community EDF Energy recommends contacting local energy groups who have experience in setting up community energy schemes. The reason for this can be assumed to be that the P2P solution is significantly more complex than the collective self-consumption community. Second advice is to find an electricity supplier who is willing to support you.

EDF Energy has finished the trial in Brixton. They are starting and setting up process for decommissioning. Right now, they don't have feedback available as they are collecting and analyzing it. From the point of view of this thesis, it is unfortunate. However, it is likely that EDF Energy will later publish the results related to the project "commUNITY", which will also make it clear what kind of reception the P2P solution received from participants.

Economic benefits in case of P2P energy community come from price difference between the wholesale energy market price and price of the PPA (Power purchase agreement) for the solar panel. EDF Energy told in the interview that financial benefit is not large, and it gets even smaller after additional costs like social levies. In UK, it is possible to gain additional savings if system is administered by smaller electricity supplier, because small supplier does not pay social levies. Interview also revealed that in the UK there is no dedicated policy for self-consumption and community energy, which means that there are no incentives or deductions. Regulatory context defines what kind of additional fees P2P-oriented energy communities might face in different European countries.

When it comes to flexibility, P2P has similar opportunities to participate in flexibility as a self-consumption community. In the case of Brixton, batteries were used, so the stored energy can be used to cut consumption spikes. Every member of the community is free to choose whether or not to participate in, for example, demand response. The amount of compensation available for flexibility affects how attractive the option is.

3.4 Electric mobility-focused LECs

Demand and supply of electric transportation have grown significantly in the last ten years. Cars powered by internal combustion engines are being phased out and are being switched to hybrid and electric cars. As electric cars become more widespread and evolving, various innovations begin to emerge around them, such as various car loan and ride services. In most places, the car is still necessary transportation method for everyday life.

Electric cars are also very expensive, so not everyone can afford to buy them. Also, Electric cars are still such a new and thing that it is hard to find used or cheap. The lack of charging points can also in some cases negatively affect attractiveness of the electric cars. This archetype tries to address some of the problems mentioned above.

Electric mobility-focused LECs offer electric car loaning services, recharging and in some cases ridesharing services for its members. This archetype seeks to reduce emissions by replacing traditional polluting cars with an electronic alternative. Electric mobility LECs offers more sustainable alternative compared to combustion engines because, electric vehicles can be recharged with renewable electricity. Also, electric vehicles have significantly higher energy efficiency. Conventional combustion engines can convert approximately 12-30% of the energy from gasoline to power at the wheels. Electric vehicles can convert 77% of the energy from grid to power at the wheels (U.S. Department of Energy, 2021). However, the energy efficiency of electric vehicles is reduced in some scale by their large and heavy batteries. Moving "extra" weight wastes energy, so advances in battery technology, such as improved energy density, will reduce the size and weight of batteries, which in turn will reduce energy consumption.

There are several energy communities in Europe that focus on electric mobility. Most electric mobility energy communities focus on Western, Central and Southern Europe. Good examples of electric mobility communities are Som Mobilitat in Spain, Partago in Belgium, and CoöperatieAuto in the Netherlands (REScoop, 2021). In the case of this archetype, the activities of Som Mobilitat are explored, through an interview and information available in their website.

Som Mobilitat's operates in Spain Catalonian area and offers services that focus on electric car sharing. It is Spain’s first energy community to offer electric carsharing. Shared cars can be owned by Som Mobilitat community or members, which in this case means individuals, public institutions and enterprises that are members of the electric mobility community. Additionally, Som Mobilat aims to widen its activity portfolio to electric bike-sharing and to ridesharing (Som Mobilitat, 2021a). Som Mobilitat also aims to position electric vehicles close to public transportation so that it promotes intramodality. Typically, community members use the electric cars for typical activities like work trips, vacations, moving home etc.

The interview with Som Mobilitat revealed that the key drivers and motivators for Som Mobilitat's activities are social & environmental sustainability, energy efficiency, consumption of green energy and sustainable infrastructure. The development of sustainable infrastructure is related to the construction of new electric car charging stations. The motivations reflect well the previously mentioned benefits of electric cars, such as better energy efficiency and the ability to use renewable electricity as an energy source which reduces emissions from the transportation sector. Motivators and key factors like this serve as a good foundation for electric mobility-focused energy communities.

To become member of Som Mobilat, the first step is to fill form on their website and pay 10 euros to buy one share of the community. No monthly fees are required to become a member. Individuals, companies, foundations, associations, etc. can become members of the Som Mobilitat. According to Som Mobilat, it takes 24 to 48 hours for registration to become effective. If for some reason member decides to leave community, paid 10 euros are returned. Leaving member must inform Som Mobilitat by email or letter in one month advance and not earlier than two months before their registration to community. Members have ability to access services provided by Som Mobilitat, which in this case means access to electric car sharing service. Also, like Coopérnico, Som Mobilitat offers for its members an access to make investments, participate in decision making, gain economic and social information of the community. Som Mobilitat says that there is no significant risk of being a member because the member does not have any patrimonial or legal responsibility, which means that joining fee of 10 euros is the biggest loss that member can face if community goes bankrupt. If member has made additional investments to community, losses are bigger.

The members of Som Mobilitat have access to Electric cars that can be rented for hours or days through use of an exclusive mobile app. The app shows location, availability, and battery status of the electric cars. It is also possible to see availability with limited information through website as seen in figure 3.4.1.

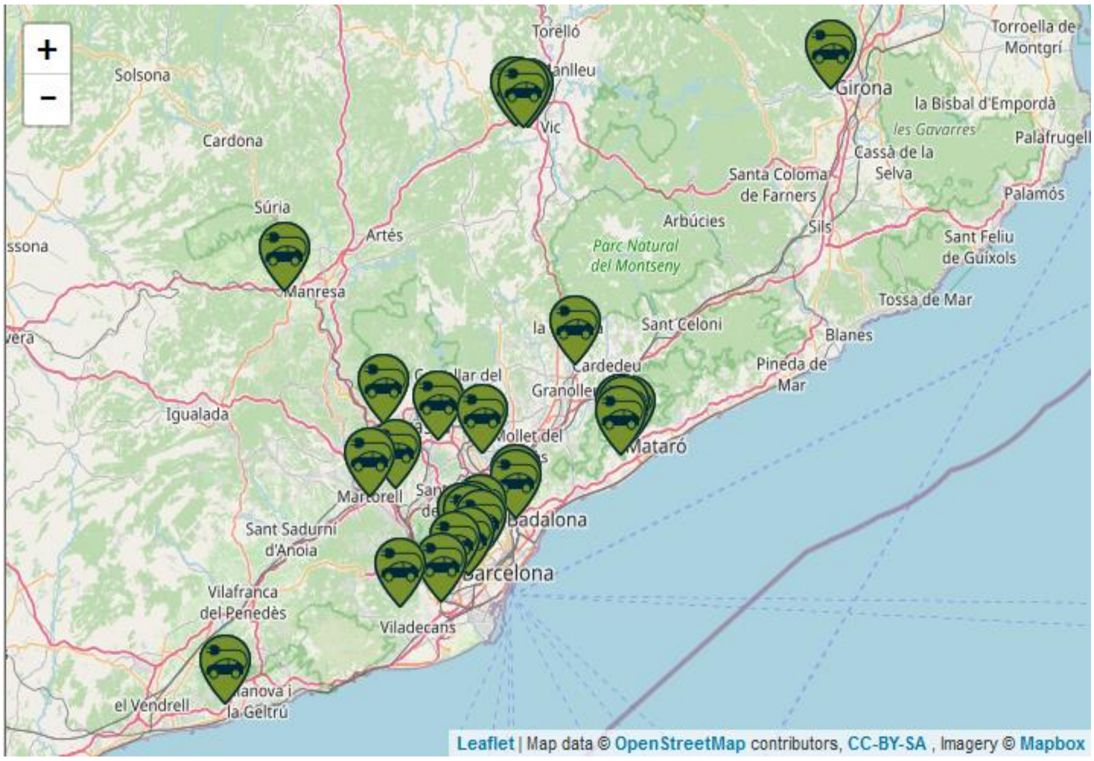

Figure 3.4.1 Car parks where shared electric vehicles are available (Som Mobilitat, 2021c)

At the moment, most of the electric cars are located near the Barcelona area. The interview revealed that Som Mobilitat seeks to support public transport, cycling and walking. Therefore, the aim is to place electric cars close to public transport. In web version, by clicking green electric car icon, the user gets information of how many cars are available in given location. The renting cost depends on location, chosen car, length of car loan and membership. For the first three months member gets a welcome rate which reduces prices by 20 %. (Som Mobilitat, 2021d)

The interview revealed that Som Mobilitat collects information on customer satisfaction. At end of all car reservation's members can optionally answer questionnaire which gathers information about user experience. Som Mobilitat questionnaire includes opinions about reservation process, experience using their car and how clean the car was when they rented it. The interview did not reveal what kind of feedback the community has received about its service and electric cars.

The interview revealed that electric mobility-focused energy community can face technical and financial challenges. Som Mobilitat did not mention in their interview if there had been any major legal difficulties. However, they mention that they have faced all possible challenges and limitations along the way, so that implicates that there might have been some legal difficulties as well. Technical difficulties came from need to develop an app and a control center for electric cars. Also, there are some limitations with charging stations. According to Som Mobilitat charging station infrastructure is still in developing in Spain. Without proper charging stations infrastructure, it is not possible to make electric mobility-based energy community more widespread. The lack of charging points can limit the use of electric cars as a means of transport, for example for long distances. For electric mobility-oriented energy community this is a bad thing. The main problem with charging station infrastructure in the Europe is that they are deployed unevenly between different countries. This leads to inequalities related opportunities between European countries in what concerns establishment of this type of energy communities. Report of the European Court of Auditors shows that availability of public charging stations is limited in Eastern Europe as seen in figure 3.4.2. (European Court of Auditors, 2021).

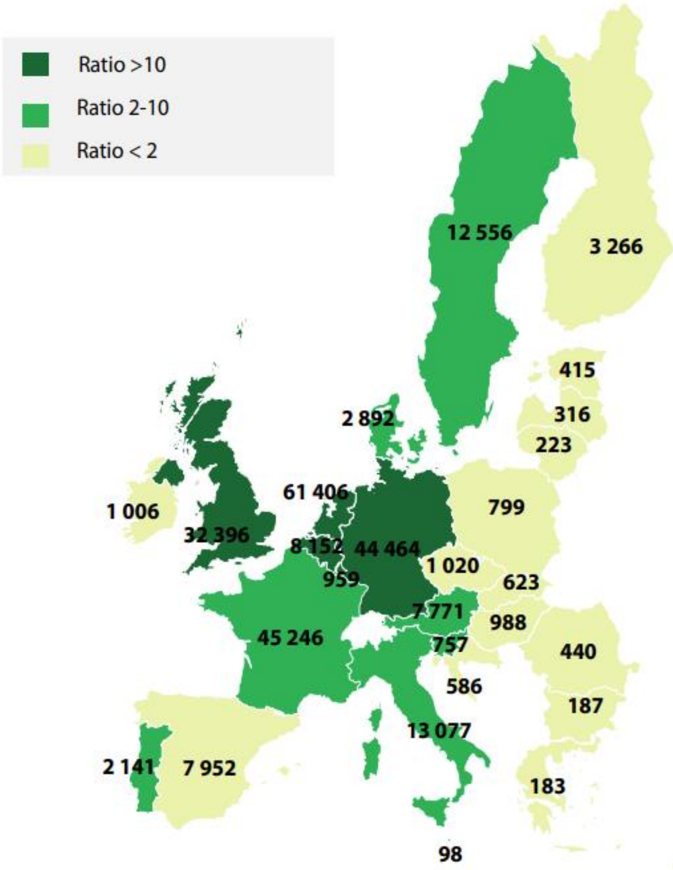

Figure 3.4.2. Number of public charging stations and ratio of charging points to 100 km^2 land area in European in countries (European Court of Auditors, 2021)

Germany, United Kingdom, Belgium, Netherlands, and Luxemburg have more favorable conditions for electric mobility-focused energy communities compared to other European countries if amount and density of the charging stations is only limiting factor. The figure does not show how the charging points are distributed within the countries, but probably a significant part is located near the cities.

Financial problems that Som Mobilitat has faced are related to expenses of developing technological tools to create electric car-sharing platform and acquiring the electric cars. Developing this working platform can be expensive and time consuming. The solution for platform was to work with a cooperative that provides a car-sharing platform. This cooperative has an electric car sharing platform that is used by multiple electric mobility-focused energy communities. The platform works with most car models, can be seamlessly integrated into charging stations, it shows reservation calendar and battery charging status. From management point of view, The Mobility Factory offers tools to monitor energy and usage statistics, as well as charging information and fleet information (The Mobility Factory, 2021). The solution offered by The Mobility Factory can be helpful for new communities as it includes all necessary tools to manage electric mobility-based energy communities.

The interview revealed that electric cars are difficult to obtain because they are expensive. Some form of subsidies could be in place to enable communities to better fund charging stations and electric cars. Electric cars have some similar maintenance costs as regular cars, such as tires, brakes and shock absorbers. Combustion engine requires that oil and filters are changed within time frame specified by manufacturer. Electric cars do not need oil changes, which can bring savings in maintenance costs compared to combustion engine cars. However, batteries of the electric cars are expensive. They must be replaced when a certain number of years or kilometers specified by the manufacturer have been reached (EDF Energy, 2021). The representative of Som Mobilitat had no information available on how high the maintenance costs of electric cars are in their case and how large fraction of overall costs it is.

For those interested in forming electric mobility energy community or participating one, Som Mobilat gives a few tips. According to Som Mobilitat approximately 93% of the time cars are not being used. During that time somebody else could loan your electric car that you do not need. Som Mobilat also encourages to change your own mobility model and take advantage of public transportation. When car is really needed, one can get it from community. Presumably, the goal is to make sure that there are enough cars for those who need them and that own habits can reduce the need for driving.

Energy communities like this could also provide demand response and peak shaving in markets where this would be regulated. Charging electric cars can cause large consumption spikes, reason why in some cases it could be beneficial to reduce or disable charging of some cars at time of peak loads. The DSO would benefit from this in the sense that electricity consumption peaks would be reduced, which in some cases could move need to make investments to later time. Also, it could help balancing consumption locally. The need for flexibility is increasing as renewable energy sources increase. Electric cars have large batters that could be used in peak shaving, which is discussed later in chapter 3.5. Participating in demand response or/and peak shaving can lead to compensation for electric mobility-based energy community. However, it is important that electric cars are available when needed. In some cases, the battery charge could be too low for driving. That is why it is important to ensure that peak shaving doesn't consume all energy from batteries, so that electric cars are available when needed.

3.5 Flexibility market-focused LECs

The flexibility-oriented community strives to use renewable energy sources and battery storages as a flexible asset, which it can offer to electricity markets. When flexibility is needed electricity markets can buy it from community. Flexibility generates revenue to energy community because flexibility should be compensated. However, such energy communities are rare because in some cases there are legal barriers preventing compensation.

Need for energy communities like this is increasing because popularity of heat pumps and electric cars is increasing. For DSOs and TSOs (Transmission system operator) this means spiky peak loads. Some cases DSOs or TSOs must reinforce the network so that it continues to work in future as amount electrical appliances is increasing. At the same time peak times are shifting which lead in same cases fluctuations between demand and supply (Swissgrid, 2021). In addition, for multiple renewable energy sources, production is affected by external factors such cloudiness for solar panels and wind for wind power. Increasing peak loads and uneven production of renewable energy sources increase the challenges related to maintaining a balance between consumption and production. This increases the need for the flexibility that this energy community archetype seeks to provide. There can be many motivations and drivers for setting up a flexible energy community. A clear motivator for this kind of community are energy efficiency and sustainability. Other drivers suitable for the archetype are self-sufficiency and investment in sustainable infrastructure. Additionally, there are financial motives, as there should be compensation for participating in flexibility.

As part of the STORY project (STORY, 2021a), studies regarding flexibility capabilities of small neighborhoods were carried out in the small town of Oud-Heverlee in Belgium. One of the objectives of the STORY project was to demonstrate how neighborhood could operate as flexible energy community by taking advantage of thermal and electrical storages, solar PV panels and load shifting. In this case study a microgrid was created at the end of the distribution line enabling the participation of 13 houses in the flexible energy community. (STORY, 2021b).

This archetype can provide flexibility in a number of ways. It can contribute to demand response by turning off unneeded electrical devices such as lights. Load shifting to a time when consumption is low, for example during the night. Load shifting allows loads to be shifted to a better time when consumption of the community is low, for example during night. Suitable targets for load shifting are, for example, electric cars and heat pumps. A third important way to provide flexibility is to use battery storages for peak shaving. Figure 3.5.1 shows how peak power consumption can be shaved by using battery storages.

Figure 3.5.1. Typical example of peak shaving by using battery storages (Karmiris & Tengnér, 2013)

During peak power consumption, energy from the battery storage can be used to reduce consumption seen by distribution network and DSO. Peak power consumption would fall to load after shaving which is indicated by red line. During recharging period, generated energy by solar PV panels could be used for recharging. So, in this case, during recharging period, power consumption would not follow the redline but instead it would follow the blue line. If electricity generation is low, the missing electricity can be taken from the distribution network. This would mean that during charging, the actual power consumption would be in the range between the red and blue lines. This can reduce or move investment needs for DSO which in turn can reduce transmission fees for energy community.

The presence of storage and renewable energy sources means that the flexible energy community also increases access to locally produced energy, with less load on distribution networks. In some cases, it means smaller investments in distribution network. Basically, flexibility-focused archetypes and DSOs have a win-win situation. There are also efficiency benefits because less electricity is needed to transfer through distribution network which mean less distribution losses. Locally produced electricity has a shorter distance to the consumer compared to large, centralized generation facilities.

Without interview it is difficult to assess possible challenges that this archetype might face. However, as mentioned in chapter 2.1., demand response is not possible in all European countries. Demand response is not enshrined in law or is prohibited. Thus, in some European countries situations may arise where it is impossible to set up an flexibility-focused energy community because the compensation mechanism are not in place. This is also the reason why this archetype is rare. Report by European Smart Grids Task Force identified that price signals may not be clear in case of demand response. Report also mentions that compensation from flexibility might not be big enough compared to effort and risks related to setting up flexibility-oriented community. There is lack of clear information regarding what opportunities are available and what kind of benefits there are (European Smart Grids Task Force, 2019).

There are some technical difficulties. For example, in order to effectively control flexible sets, several sensors and gauges are needed to monitor, variables such as temperature and voltage. In addition, an intelligent algorithm is needed to handle load control. The system may seem too complex to the average person, which is why it may reduce the interest in setting up a flexibility-focused energy community.

3.6 Energy management service-focused LECs

In many households, the use and consumption of electricity does not take advantage of smart management. By using different tariffs, the consumer could get significant savings with the help of smart energy management. An energy management service provider community aims to solve this problem by implementing smart monitoring and the adjustment capabilities to buildings and/or the group of buildings. The mission of this community is to perform the management in such manner that members can save energy and energy related costs. With monitoring tools, members can more actively try to control their energy consumption and possible production. Consumption When the amount of energy from production is large, consumption can be timed to the same moment. Energy management also enables better capabilities to participate in demand response and in some cases in peaks shaving if battery storages are utilized. This could bring even more financial motivations.

Lumenaza is a Germany based company that provides Software as a Service (SaaS) solution, that enables multiple energy management related capabilities (Lumenaza, 2021). Although Lumenaza is a company, a similar solution could be provided by energy management- focused local energy communities. Lumenaza has many solutions and innovations that could be applied to energy communities, which is why it was chosen for interview and example.

The advantage of the Lumenaza SaaS solution is that it can be installed in almost any location. This allows members of the energy community to be in various locations. Therefore, Lumenaza's SaaS based solution could be used to form virtual energy communities. Definition of CEC doesn't specify how close members. However, as discussed in chapter 2. REC requires community to be within close proximity. Therefore, virtual energy management-focused energy community wouldn't meet requirements to be called REC. Lumenaza's SaaS solution can be installed

Lumenaza's main motivators are to enable community models. According to interview with Lumenaza, environmental values, green energy with expectations of return of interest are drivers and motivators that have been identified in their community models. Other motivating aspects were social and economic benefits to the local regions.

Lumenaza's main challenges come from the legal aspects. According to Lumenaza it is hard to build business when there are heavy regulatory constraints and when the cost structure is still based on old, centralized energy system models. Lumenaza has noticed that EU directives have had a positive impact in some European countries, due to the reduction of some of the regulatory constraints applicable to local energy communities.

Lumenaza's SaaS solution which is also referred sometimes as "utility-in-a-box", offers tools to remove energy management-related barriers and to enable customers to take advantage of more advanced monitoring capabilities. Energy management and monitoring should be straightforward, as complex solutions can reduce interest in smart tariffs and efficient energy handling. Solution prevents problems associated with inexperience and lack of knowledge related to energy management. For example, it can schedule the charging of an electric car or the heating of a house automatically in a way that minimizes electricity consumption related costs with smart tariffs.

Lumenaza's tip for forming energy community is that citizens should take multi-vector approach. In layman's terms it means mix of electric mobility, renewable energy sources to for example maximize the potential of collective self-consumption energy community. Lumenaza encourages to find partners that who would balance benefits among community and stakeholders.

Lumenaza's solution could also work as a base for flexibility, and with little modifications with P2P-oriented communities. Lumenaza's solution has many different functions that it could be suitable for the load and battery storage control in flexibility case. It would also enable means to participate in demand response and peak shaving market opportunities. The monitoring capability enables a more efficient pairing of consumption and generation.

As a service platform Lumenaza wants to connect producers and consumer of green energy. Access to the electricity market also includes flexible billing with significantly reduced cost-to-serve and time-to-market. According to Lumenaza their company maximizes value from renewable assets, enabling propositions based on electricity from clean origin, individual and collective self-consumption models, time and type of use tariffs, as well as innovative customer-centered offerings. Their SaaS supports the aggregation of renewable assets in a virtual power plant, enabling the exploitation of flexibility services.

4. CONCLUSIONS

The threat of climate change has increased interest in developing new environmentally friendly ways to produce and use energy in many applications, such as electric mobility. It has encouraged policy makers to enter into agreements and targets to reduce emissions. Based on these targets and agreements, efforts have been made to change the legislation so that new environmentally friendly innovations can emerge in Europe. In this thesis, innovations refer to different types of local energy communities.

With the development of technology, things can be produced more efficient manner. As production costs decrease, so does the final price. For example, as noted in the introduction, prices for solar panels and battery storages will continue to fall. This is a positive thing for local energy communities as they become more viable to establish. More people can establish or participate in new different types of energy communities. Solar panels, battery packs and electric cars seem to be key technologies for energy communities.

The thesis identified six different archetypes of energy communities, which were: collective self-consumption, RES supply, peer-to-peer sharing, Electric mobility, flexibility and energy management. The self-consumption energy community seeks to use all the generated energy collectively by itself while the supply energy community seeks to sell energy to others. The purpose of the P2P energy community is to enable the direct sale of electricity from one member to another. The Electric mobility archetype, as its name implies, seeks to increase electric mobility by lending electric vehicles to its members. Flexibility archetype provides flexibility to the electricity market through demand response and peak shaving utilizing batteries, efficient load management and solar panels. The energy management archetype manages the energy production and consumption of its members in a way that maximizes savings.

Green values are important drivers and motivators for identified archetypes. Generation and consumption of the green energy seems to be one of the main driving factors. Other important factor is financial motives. Energy communities enable new investments in green projects which further improves availability of green energy. Som Mobilat had sustainability and energy efficiency as its motivators.

Legal and/or regulatory barriers proved to be the most common challenge for energy communities. This is linked to the fact that legislation has not kept in pace with the innovations brought by energy communities. Additionally, there are legislative differences between European countries which might also cause issues in some cases. Demand response is not allowed in all European countries which means that flexibility-oriented energy communities are impossible in those cases. For P2P energy communities the main limiting factor was related to the fact that sharing activity was impossible without an exception permit. Although the sample size is small, it is likely that similar problems can be encountered in other European countries. At a general level, regulatory challenges diminish over time as positive feedback from various energy community experiments and projects puts pressure on policy makers to break down these barriers.

To sum up the tips for setting up a LEC, it is worthwhile to try new things, persuade others to join and participate. Also, if necessary, seek help from someone with experience in setting up energy community schemes. Some people may not be aware of all the opportunities that technological advances have brought. For example, leveraging P2P in electricity trading or providing flexibility electricity markets can be unfamiliar concepts to the average person. This may lead to the favor of simpler archetypes.

At the general level, local energy communities try to improve their activities in coming years. Som Mobilitat is seeking to expand its operations to electric scooters and electric bicycles. In case self-consumption, battery storages will bring more flexibility to the energy community. Also, electric cars can act as flexible assets and they also work as loads which might enable energy community to install slightly larger solar panel. In P2P case, future improvements could be related to mobile app that used is for electricity sharing between members.

Only Som Mobilitat had a tool for feedback collection. In other cases, feedback had been received, for example, in meetings and by e-mail. In those cases where feedback had been received, it had been encouraging and positive in tone. Systematic feedback collection would be beneficial for the energy community as it makes it easier to identify areas that need improvements. The feedback collection system would allow members of energy communities to report problems they have encountered, so that they can be addressed as quickly as possible.

Flexibility archetype is well suited for demand response and peak shaving when compared to other archetypes as it designed around offering flexibility to electricity markets. Electric mobility and energy management archetypes are also good options for providing flexibility. For example, charging electric cars causes spiky loads. Charging can be temporally disabled in situations where there are many other spiky loads. However, it is important to make sure that electric cars have enough charged energy to be used when needed. In addition, compensation for demand response or peak shaving should be large enough to make partial or flexibility to be valid option for energy community.

There are differences in the technological complexity of archetypes. For example, a community that focuses on self-consumption can face less technical difficulties than P2P-focused energy community. Both have renewable assets that can be used for self-consumption. However, P2P energy community needs an app for electricity trading between members. That is why P2P energy community could be seen as advanced self-consumption energy community. In P2P energy community members need participate in selling and buying of the electricity in order to gain additional financial benefits.

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APPENDIX I. STANDARD INTERVIEW QUESTIONS

Standard question 1.	What are key motivators and drivers for your collective action? (Examples: Consumption of green energy, Supply & sharing of green energy, Energy efficiency, Self-sufficiency, Financial motives, Sustainable infrastructure, Secure energy supply, Social & environmental sustainability)
Standard question 2.	What kind of challenges and limitations have you faced along the way? (Technical, Legal, Financial)
Standard question 3.	Based on your experience, what advice would you give to citizens willing to engage in similar collective action?
Standard question 4.	How will you develop your community over the next ten years and what kind of impacts it has on operation?
Standard question 5.	Do you have a platform for collecting feedback from participants/ members and what kind of feedback have you received?

APPENDIX II. SPECIC INTERVIEW QUESTIONS

Self-consumption 1.	What opportunities does the monitoring of self-production offers to individuals? What are, in your view and in relation to this case, the advantages of using mobile apps?
Self-consumption 2.	Can you elaborate on the rationale behind and on actual figures behind payback time improvements for solar installations in this case?
Supply 1.	Can you offer insights on your process for selection of renewable energy projects and your respective imposed requirements?
Supply 2.	What are typical sizes and what is the implementation cost range for the renewable energy projects that incorporate your cooperative?
P2P 1.	Can you elaborate on the workings of the P2P app used in the community and on its features and/or advantages?
P2P 2.	Would you be able to specify and/or elaborate on any economic benefits for this community from adoption of the P2P solution?
Electric Mobility 1.	Can you describe and/or summarize the use cases for shared electric mobility that you have developed in your community?
Electric Mobility 2.	Can you describe, both qualitatively and quantitatively, if possible, the nature and volume of annual costs involved in maintaining your mobility community activities? What is the share of these costs in the whole universe of costs that you bear annually?

Energy Management 1.	What kind of energy management features does the “utility-in-a-box” offer and how customizable it is? What services does it enable? What elements are current and future in the platform?
Energy Management 2.	What is the key target customer for your solution, and why?
Flexibility 1.	How does the community perform management of its flexible assets?
Flexibility 2.	How is the market participation of flexibility compensated? Do you consider this compensation to be appropriate?