Energy Communities in Positive Energy Districts - Case Kera

19/04/2022

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 864242
Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

About SPARCS

Sustainable energy Positive & zero cARbon CommunitieS demonstrates and validates technically and socioeconomically viable and replicable, innovative solutions for rolling out smart, integrated positive energy systems for the transition to a citizen centred zero carbon & resource efficient economy. SPARCS facilitates the participation of buildings to the energy market enabling new services and a virtual power plant concept, creating VirtualPositiveEnergy communities as energy democratic playground (positive energy districts can exchange energy with energy entities located outside the district). Seven cities will demonstrate 100+ actions turning buildings, blocks, and districts into energy prosumers. Impacts span economic growth, improved quality of life, and environmental benefits towards the EC policy framework for climate and energy, the SET plan and UN Sustainable Development goals. SPARCS co-creation brings together citizens, companies, research organizations, city planning and decision making entities, transforming cities to carbon-free inclusive communities. Lighthouse cities Espoo (FI) and Leipzig (DE) implement large demonstrations. Fellow cities Reykjavik (IS), Maia (PT), Lviv (UA), Kifissia (EL) and Kladno (CZ) prepare replication with hands-on feasibility studies. SPARCS identifies bankable actions to accelerate market uptake, pioneers innovative, exploitable governance and business models boosting the transformation processes, joint procurement procedures and citizen engaging mechanisms in an overarching city planning instrument toward the bold City Vision 2050. SPARCS engages 30 partners from 8 EU Member States (FI, DE, PT, CY, EL, BE, CZ, IT) and 2 non-EU countries (UA, IS), representing key stakeholders within the value chain of urban challenges and smart, sustainable cities bringing together three distinct but also overlapping knowledge areas: (i) City Energy Systems, (ii) ICT and Interoperability, (iii) Business Innovation and Market Knowledge.

Partners

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1. INTRODUCTION

Energy communities are a social concept focusing on local energy production and distribution, that have gained traction recently due to the move towards more sustainable energy systems. The aim of energy communities is to expand the acceptance of renewable energy by enhancing citizen engagement and social cohesion. In addition, energy communities aim to increase the role that citizens have in the energy transition via expanded funding options.

Energy Communities are defined in two EU directives, the Internal Energy Market Directive and the second Renewable Energy Directive. These definitions cover Citizens' Energy Communities (CECs) and Renewable Energy Communities (RECs), respectively. The definitions overlap, but there are differences in geographical extent and eligibility of non-renewable energy sources. Together these definitions provide a legal framework to support Positive Energy Districts (PEDs), where citizens can collaborate in producing and distributing energy. Self-consumption increases the financial viability of distributed energy generation and thus improves the opportunities to maximise on-site renewable energy. Thus, energy communities are also a key research area within the Sustainable Energy Positive and Zero-Carbon Communities (SPARCS) project and other ongoing Espoo sustainable development projects. In addition, several other projects have done research on energy communities and provided guides on how to implement these communities based on national and international (e.g. EU-wide) regulation. This paper will provide examples of these for further analysis.

Energy communities are already established in many European countries, but power sector regulation often restricts the options that normal consumers have. This is often due to the fact that regulation on energy does not change as fast as the surrounding research and business activities do. This issue can be seen in Finnish regulation as well. For example, LEMENE, a research project that implemented an energy community within the city of Lempäälä in Finland, ran into problems with the Finnish Energy Authority while applying for a closed electricity distribution network permit after completion of the energy solution. As a result, the highly innovative solution has not been able to operate fully since it's inception due to regulatory difficulties. However, regulation constantly changes, and recent regulatory amendments have already eased the formation of energy communities supplying locally produced electricity, leading to more potential for community-based concepts in Finland.

In the power sector, local utilities have the exclusive right to distribute electricity, and have the mandate to collect electricity tax in addition to their own distribution tariff. Selling excess electricity from rooftop solar systems directly to neighbouring plots is only allowed via a single connected power line between two actors. However, as the construction of the Kera area will continue for decades to come, the energy community landscape and related legislation can change throughout the construction process. This means that to provide insight on the opportunities that energy communities can provide in Kera, this report needs to investigate both the current situation and the future as the legislation is possibly altered to fit new types of energy communities that are already taking shape in other nations across the globe.

Energy communities can also consist of users producing and distributing other energy such as heating, biogas, or synthetic fuels in addition to or instead of power. In Finland,

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different kinds of local heating systems are already widespread. Typically, this comprises a central heating station fuelled with biomass from nearby forest owners, and heat is distributed to the members of the cooperative. A business focusing on this kind of activity is known as a “Lämpöyrittäjä”, or a heating entrepreneur. [1] In 2019, Finland had approximately 300 heating entrepreneurs operating 612 heating facilities. The produced heat is most often purchased by the local municipality, thus allowing the municipality to support local business. [2] As regulation within these fields allows for more local competition, key questions arise on competing solutions, and the infrastructure needed. This report aims to provide a short analysis on the heating and fuels -sectors as well.

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2. Relevance to SPARCS

The deliverable D3.1 specifies a set of topics to be discussed to meet the Action E10-1 under Intervention E10 - Solutions for Positive Energy Blocks. One of these topics is the identification of opportunities offered by energy communities. The detailed plan of the aforementioned action can be seen in Figure 1 below.

Energy community legislation was not explicitly mentioned in the Grant Agreement, as this development is fairly recent. However, their impact on PEDs is significant, and a study of this topic is well placed in SPARCS.

Action E10-1	City Planning for Positive Energy Blocks. Exploring the possibilities to utilize the continuously updated Espoo 3D City model as a support and tool in the development and planning of the new Kera area.
Detailed plan	• Communicate with city architects and zoning personnel to understand and document the role of the 3D city model in Kera planning. • Map technical, economic and regulatory barriers in piloting innovative PED solutions. • Identify opportunities offered by energy community legislation and new cost-efficient renewable energy generation and distribution technologies • Assess new business models for generation, aggregation, storage and distribution. • Explore the benefits of using 3D city model in pursuing new opportunities and implementing PED solutions • Draft process to mainstream 3D city model support in PED development in Espoo.
Targeted outcome	Mainstreamed process to routinely integrate PED considerations in the early stages of city planning will reduce costs and improve the effectiveness of energy efficiency and distributed energy generation measures in new area development.
Roles and responsibilities	ESP: Main responsibility VTT: Support in identifying technologies relevant to PED development leveraging experiences from similar Lighthouse projects Siemens, Adven, PlugIt, Kone, stakeholders: Propose private sector solutions and new business models for public private partnerships in PEDs
Schedule	M18: 3D model in city architecture and zoning process documented M21: Barriers, opportunities and business models assessed M28: Assessment of 3D model feasibility in PED implementation finalized
KPIs	Qualitative assessment (Likert scale) of city planning tool Prospective On-site Energy Ratio and Annual Mismatch Ratio in Kera Prospective impact on energy expenditure for residents (€/year)
Financial scheme	This action does not require infrastructure investment. The city is actively engaged in projects to support renewable energy, circular economy and low-carbon mobility solutions, with specific budgets allocated to local pilots.

Figure 1: Excerpt from deliverable D3.1 indicating the Action E10-1 breakdown. This report bolded in yellow.

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3. EXISTING REGULATION ON ENERGY COMMUNITIES

The Internal energy market directive [3] IEMD defines Citizens' Energy Communities (CECs):

> *"A legal entity that:*
>
> *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;*
>
> *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*
>
> *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;"*

Similarly, the REDII directive [4] defines Renewable Energy communities (RECs):

> *"A legal entity:*
>
> *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;*
>
> *the shareholders or members of which are natural persons, SMEs or local authorities, including municipalities;*
>
> *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."*

These definitions are partly overlapping, as described in Table 1 on the next page. The national legislation implemented by different EU member states may introduce specific definitions that encompass both REC and CEC requirements. However, definitions should not be too strict to allow citizens to benefit from the entire spectrum of activities, and to avoid differences between member states that might complicate the roll-out of EU-wide regulatory measures and financing options and discourage peer learning.

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Table 1: Differences between Citizen Energy Communities (CECs) and Renewable Energy Communities (RECs) [3] [4]

Feature	CEC	REC
Eligible Participants	Local or non-local residents, municipal actors and	Local residents, municipal actors and MSMEs
Demographic governance	Less restrictive	More restrictive
Geographic limitation	May include virtual communities	Only within geographic boundaries
Non-commercial purpose	Same: environmental, economic or social benefits	Same: environmental, economic or social benefits
Voluntary membership	Same: Open and voluntary membership	Same: Open and voluntary membership
Effective Control	Local or non-local micro- and small enterprises	Local micro-, small and medium sized enterprises
Technology focus	Electricity, renewable or non-renewable	Any renewable energy (heat, electricity, fuels)

These recent directives by the European Union require all member states to implement measures regarding energy communities and self-generating customers. Finland has begun meeting this requirement by amending local regulation. The amended Government decree on the determination of electricity supply and metering defines local energy communities, active customer groups, and a new service model for electricity net-metering. The new legislation entered into force in January 2021 and changes will be implemented by January 2023. By 2023, Fingrid will establish a national datahub to collect metering data from all Finnish power customers and allocate self-produced solar electricity directly to residents, according to limitations set by the amended decree.

The new legislation allows:

1. to form local energy communities (definition of an energy community was added to the legislation)
2. end-customers to form an active customer group (definition of an active customer group was added to the legislation)
3. energy communities and active customer groups to operate a local energy production plant (e.g. solar plant) and share the electricity between members via a new net-metering service model.

The new legislation allows housing associations and their residents to benefit from local small-scale energy production under the same principles and rules as private small-scale energy producers. Before the new legislation entered into force, there was only little motivation for housing associations to invest in renewable energy, especially within the highly regulated electricity generation sector. Small-scale electricity producers were obliged to pay a distribution fee as well as taxes for the produced electricity and housing associations and multi-apartment buildings could only benefit from using the self-produced electricity for covering the general building's electricity bill (e.g. for elevators and lighting). Since January 2021, it has been possible to share rooftop solar power directly to the residents living in the building. While solar energy did not appeal as an interesting investment opportunity for housing associations before, it has now become a

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viable option. As illustrated in 2, solar systems were relatively small and expensive compared to their size, since based on the old legislation any produced electricity should be consumed within the premises. Enabling residents to consume the electricity increases the size of the solar system up to three times and at the same time reduces the pay-back time of the system. [5]

Figure 2: Usage of local small-scale energy in housing associations before and after the legislation changes [6]

The new net-metering service model will allow for hourly-based net-metering, meaning that locally summed production and consumption is metered, calculated and aggregated to determine the sum of electricity bought or sold between the consumption site and the grid within the hour. The net-metering service model is based on the information provided by already existing smart meters, meaning that there is no need to install new smart meters within the housing association. The electricity production is shared between the shareholders computationally based on the data received from the installed smart meters. The hourly-based net-metering service will be available in most of the municipalities in Finland already before 2023 (see left-hand side of Figure 3).

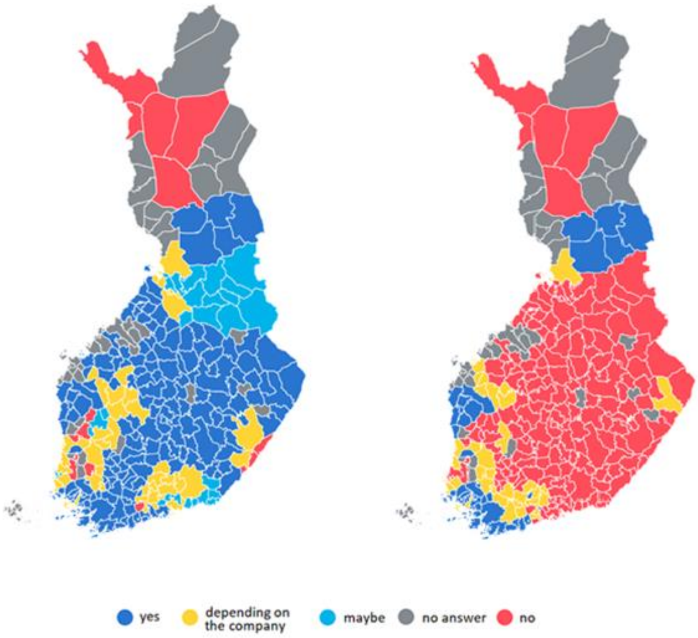

Figure 3: Hourly-based net-metering for customers before 1.1.2023 (left hand side) and current implementation status of net-metering of phases (right hand side) [5]

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At the moment, the majority of installed electricity meters do not net-meter between phases (see illustration on the right-hand side of Figure 3). Without phase metering, each phase of the electricity grid will be measured separately, and this may result in situations where electricity is bought as well as sold at the same time (an imbalance of phases results in tax and distribution tariff paid for self-consumed energy). Especially when appliances are not connected to all three phases, but instead e.g. only to one phase.

By May 2023, Finland as well as all other Nordic countries will change the imbalance settlement period from one hour to 15 minutes [7]. In addition to power sector regulation, energy communities can possibly face other regulatory requirements depending on the type of energy production, transport, storage and use. Possible regulatory requirements include the following, divided by type [1]:

Bio-CHP or Bio heating plants:

If the plant capacity exceeds 50 MW, it will fall under tighter EU industrial emissions directive requirements, thus falling under governmental jurisdiction for the admission of environmental permits.

The plant might fall under the Chemical safety act, if flammable substances are stored on premises.

The plant might require an Air Navigation Obstacle Permit from Traficom, depending on the height of the smokestack, and the siting of the power plant.

If the plant capacity exceeds 20 MW, an GHG emission permit is required to release emissions to the atmosphere.

The size of the plant often requires careful considerations in city-level zoning, especially if the energy community is within an urban area.

Biogas:

If capacity exceeds 20 MW, it will fall under tighter EU industrial emissions directive requirements, thus falling under governmental jurisdiction for the admission of environmental permits. In addition, if a plant with a lower capacity than 20 MW produces over 3000 tons of fuel per annum, a national permit is required.

If the operator of the plant personally handles logistics of raw materials, their operations will fall under the Finnish Waste Act. Thus, the company is required to join the Finnish waste management registry.

If the plant handles waste streams of animal origin, such as biowaste from restaurants, approval from the Finnish Food Authority is required.

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Handling and storage of gas falls under the Chemical safety act, thus requiring a permit from the Finnish Safety and Chemicals Agency.

If the plant capacity exceeds 20 MW, an GHG emission permit is required to release emissions to the atmosphere.

If produced biogas is fed to the national gas grid, acceptance from the network operator is required.

Geothermal heating and heat pumps:

Heat pumps installed to the outer walls of buildings might need an action permit from the city, depending on the area. A geothermal heat pump universally requires an action permit. The geothermal heat pump also requires a permit under the Finnish Water Act, if it is situated within a groundwater area.

Other possible permits can be required depending on location and size of the well. However, this is highly situationally specific.

3.1 Types of Possible Energy Communities Under Current Regulation

Elenia, a Finnish Distribution System Operator (DSO), together with VTT Technical Research Centre of Finland, has provided a guidebook on the possible energy communities under current Finnish regulation. these energy communities focus on the electricity sector, as Elenia is not an actor within the heating sector. The handbook notes three different options [8]:

On-property energy community

Energy community between properties

Decentralized energy community

An on-property energy community is an entity, where locally produced renewable energy is divided between participants within a single property. This can include sites such as a housing association, a shopping center, or a university campus. In this case, the produced energy can directly benefit the local actors, and reduce energy costs by substituting purchased energy. The whole community is connected to the grid via a single contact point, and all electricity bought from the grid will include normal grid service and energy charges including taxes. Energy consumed on site will not include these additional payments.

Energy communities between properties include communities where locally situated energy production is directly connected to a local consumption site, which is directly connected to the grid via a single contact point. This type of energy community cannot be connected to multiple consumption sites, as this will be against current regulation. This

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exemption was prepared for situations where local energy production is not possible on-site but can be possible on a nearby location with easy access to consumption. Charges on consumed energy follow the rules set within the previous type of energy community.

Within a decentralized energy community, the consumption and production can be situated within differing geographical locations, and production and possible storage resources can be jointly owned by multiple actors. In this case, all production and storage must be grid-connected, and transfer must be made through the current power grid. In this case, only the energy charges will be lowered, as grid service charges and tax will be paid as normal due to the grid transfer. This type of energy community can use new and innovative business models, such as reserve market participation, crowdfunding of investments and rental of production resources for additional value.

Other energy production options mentioned in section 3, such as Bio-CHP or bio heating plants, Biogas plants or geothermal heat pumps are possible for local solutions under current regulation, if permits are handled according to regulatory requirements. However, depending on the site and scale of the plant, or the nature of the operator, these permission requirements might have an adverse effect on the potential of the energy community. This might lead to a situation where an otherwise viable plant is not constructed due to long and costly permission procedures.

4. LITERATURE AND RESEARCH ON ENERGY COMMUNITIES

This section will look into the current literature and research encompassing energy communities and provides information on projects and publications that can add value to the SPARCS development actions.

4.1 Governmental projects and reports

The Finnish Ministry for Economic Affairs and Employment has published the report 'Study on electricity self-production, energy communities and energy projects related permit procedures' [1], which analyzes the Finnish context for Energy Communities, covering both the power and heat sectors. The report looks into the barriers affecting the development of energy communities, and their potential in Finland. In addition, the report specifies the different permit procedures regarding renewable energy divided by type and provides recommendations for future action.

The report provides an estimation on the potential of local energy communities, meaning energy communities situated within a single apartment complex, in Finland. For this estimation, a 14 kW PV plant was deemed potential for apartment complexes, and a 2.8 kW PV plant was deemed potential for terraced housing. In total, this would lead to 983 GWh of renewable energy per annum, if all 61 745 apartment complexes and 81 981 terraced houses within Finland implement solar generation. This would mean 1.5 % of total current Finnish power generation capacity [9]. According to the report, this would lead to a 103 ktCO_2 reduction in emissions per annum. With a mean emission allowance price of 54.18 €/tCO_2 in 2021 [10], this would mean 5.58 million euros of avoided emissions. The report notes that this local energy community has the most potential within the current Finnish landscape.

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In addition to the report on electricity self-production, the Ministry has also published the report "A Flexible and Customer-driven Electricity System" from the Smart Grid Working Group [11]. Within its main proposals, the working group has noted that the load control of the power grid should gradually be changed towards a market-based system, and that the additional use of load control and flexibility should be enabled via next generation smart meters and flexible electricity distribution fees. The working group also provided a proposal for the enablement of energy communities, which was used as a basis for the amended governmental decree explained in section 3 [12].

4.2 RESCoop transposition guidance

The RESCoop organisation has published a transposition guidance document [13], portraying the provisions of CECs and RECs and giving detailed information on how different aspects have already been implemented or can be implemented in national legislation. The document also gives an overview of the differences between the two legal entities, as summarised in Table 1 in the previous section. The transposition guidance document provides the most value as a comprehensive guide to the EU legislational tools, and their possible use nationally.

4.3 ERA-Net

The ERA-Net Smart Energy Systems is a research network and platform featuring the European Task Force on Energy Communities, which in April 2020 organized a workshop with Mission Innovation Austria. The workshop [14] brought together academics and pilot projects, who were invited to arrange more collaboration on this topic. Key takeaways were presented in a visual format in Figure 4.

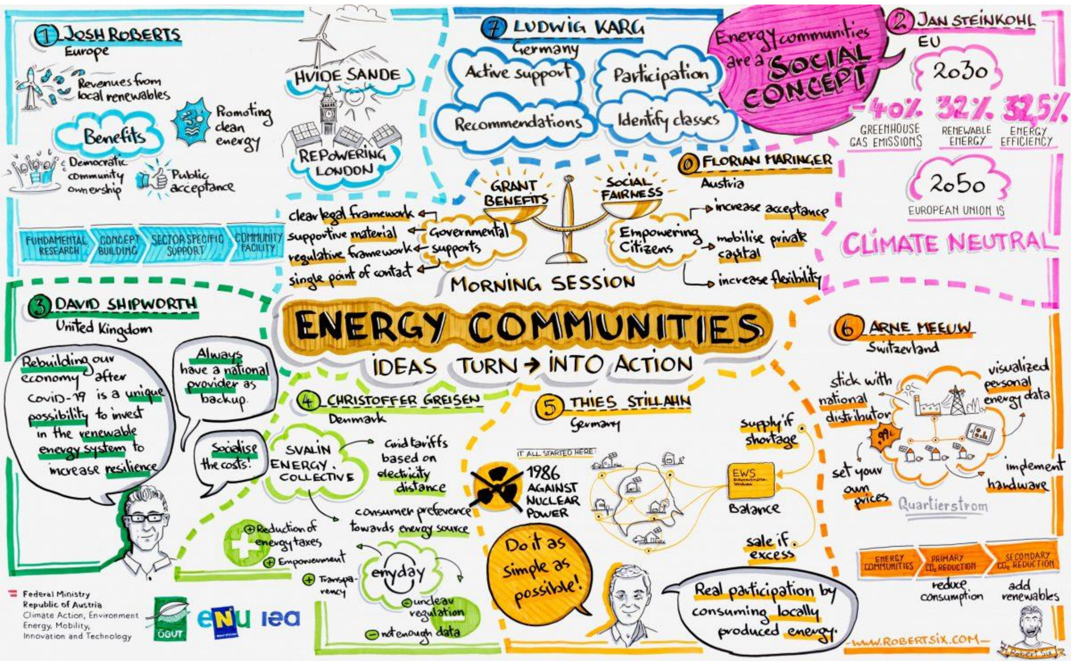

Figure 4: Key takeaways of the online workshop on 23.4.2020 [14]

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Another useful output of the platform is a categorization of Energy Communities, prepared in conjunction with the H2020 Bridge Project. The definitions also include Positive Energy Districts (PEDs) as a specific form of Energy Community [15].

Classes of Energy Communities

No	Name	LEC Taskforce
class 1	Collective generation and trading of electricity	all types of territorial or commercial groupings of generators – whether active on the market or under feed-in mechanisms (often called Virtual Power Plants)
class 2	Generation-Consumption Communities	certified sourcing of electricity in a closed group of generators and consumers - not necessarily in proximity but including local or regional energy markets
class 3	Collective residential & industrial self-consumption	generation, storage and consumption in residential cases with multiple dwellings; includes Tenant-Power (Mieterstrom) - models
class 4	Energy positive districts	districts with residential and business entities operating their energy supply systems under their own regime
class 5	Energy islands	real islands or parts of the distribution system that can be operated standalone (e.g. cellular system as in SINTEG, holonic model as in PolyEnergyNet)
class 6	Municipal utilities	existing organizations for energy production, supply and grid operation under citizens' control – directly (e.g. cooperative) or indirectly (e.g. controlled by local government)
class 7	Financial aggregation and investment	a "community" of investors joins to scale the amount of or manage the investment in generation systems (without further involvement in organisation etc.)
class 8	Cooperative Financing of Energy Efficiency	citizens jointly investing in efficiency means of SMEs and municipalities, possibly in their own region (e.g. contracting / ESCO, crowd-funding
class 9	Collective service providers	all types of commercial groupings of energy services (e.g. grouping of EV charging stations, aggregation of demand side management services)
Class 10	Digital supply and demand response systems	all types of digitally controlled energy systems (e.g. implemented with blockchain), these days possibly operated as a sandbox-model

Flavours of Energy Communities

Figure 5: Proposed categorization of Energy Communities [15]

4.4 RENCOP

The Co2mmunity project, funded by the EU Regional Development Fund, has prepared a Finnish manual [16] for implementing energy communities. The project has assessed the enabling environment for energy communities in countries of the Baltic Sea region, as measured by contextual factors and regulation. The results are presented in a 2-dimensional graph indicating Denmark, Germany and Sweden as most promising for Energy Community development.

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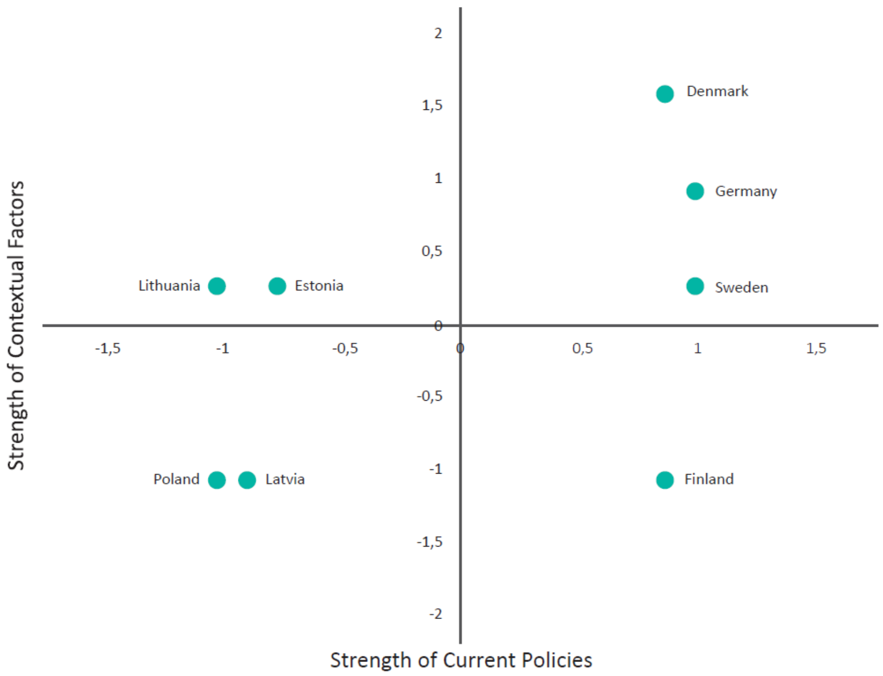

Figure 6: Baltic Sea Region countries' readiness for Energy Community development [16]

The manual notes that heating communities are more promising within Finland, as they may utilize local heat sources while being subject to less regulation. In addition, district heating networks are not prominent in sparsely inhabited areas, leading to more business cases for on-site heat production when compared to the power sector. The publication describes the stepping stones of constructing an energy community, and explains a tool used in the Co2mmunity-project to promote community energy, the renewable energy cooperative partnership (RENCOP). The tool consists of different elements for preparation, design and maintenance phase. Two different approaches are available, Community-driven and Expert-driven, as depicted in Figure 7.

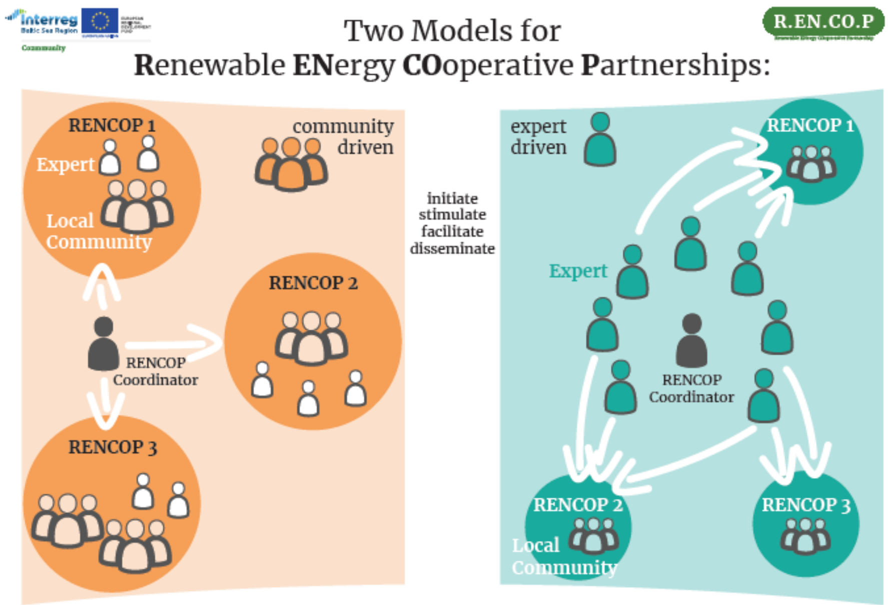

Figure 7: Community and Expert driven models for Energy Communities in RENCOP [16]

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The guidebook also provides the barriers and drivers for energy communities within Finland, thus providing a thorough explanation on how the local political, economical and social climate affects energy community implementation. The barriers and drivers are as presented below [16]:

"Economical

Barrier and driver: Low electricity prices.

Barrier and driver: Relatively high distribution prices (when compared to price of consumed electricity) combined with low trust on distribution companies.

Barrier and driver: The technological advancement of renewables.

Barrier and driver: Available funding for investment.

Political

Barrier: Current regulation on electricity metering and distribution.

Driver: Large-scale distribution operators have shown interest in providing services for local electricity production.

Barrier: The needed reporting to ensure regulatory compliance.

Driver: The Finnish goal of eliminating coal use by 2029.

Social

Barrier: A historical reliance on large-scale energy production facilities.

Driver: The sense of community that energy communities bring has already been a tradition especially in rural areas.

Driver: High interest in technological advancement.

Cultural

Finland has a tradition of large-scale co-operatives in several fields, such as food sales (SOK), banking (OP-group) and forestry (Metsä Group)."

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4.5 Smart Cities Information System (SCIS)

The SCIS has released a solution booklet on energy communities [17], linked to their other booklet releases encompassing several themes within the energy sector. This booklet looks into the activities within an energy community, societal viewpoints, business models and regulation. In addition, the booklet provides a visual representation of smart energy barriers and solutions, made by TH!NK E for the City-Zen project. This visualization is presented below.

Figure 8: A visual representation of smart energy barriers and solutions [17]

From the Espoo point of view, the societal aspects explained within the solution booklet are of special interest. SCIS notes that energy communities can provide increased social cohesion and trust in local representatives. Thus, energy communities can aid in enhancing the social dimension of sustainable development, while providing clean and affordable energy to local citizens and the larger energy system. This social cohesion can aid the dialogue between specialists, local authorities, and the public by giving new solutions for a more democratic decision-making process.

However, the booklet also notes the need of prior social cohesion between energy community participants to ensure the performance of the community. The booklet also explains the importance of local heroes and new employment opportunities especially within the rural areas which have experienced notable population loss caused by urbanization.

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5. Relevant Case Studies

This section provides information on three energy community case examples, the LEMENE project in Finland, the Brooklyn microgrid project in the USA, and the Drake Landing solar community in Canada.

5.1 LEMENE Project

The LEMENE project is one of 11 key energy projects in 2017 that have been granted an investment aid from the Ministry of Economic Affairs and Employment. The project was implemented by Lempäälän Energia in the Marjamäki industrial area, which is located along one of Finland's busiest highways connecting Helsinki to Vaasa via Tampere and Lempäälä. The project features the use of renewable energy sources, alternative electrical energy production methods and other latest technologies. The main sources for energy are solar power and gases (e.g. biogas). Additionally, a centralized energy storage system is used to mitigate fluctuations in the system. An overview of the LEMENE energy system is shown in Figure 9. It features 4 MW of solar power, storage batteries, six gas engines with a total capacity of 8,1 MW, two fuel cells with 130kW total power, and a 9 km long 20 kV distribution network. The system design allows the grid to operate as a part of the public grid network or, on demand, as an independent off grid entity, while considering local fluctuations in demand.

Figure 9: Overview of the Lemene energy community system [18]

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Since, in 2017, the law did not recognize energy communities as a legal entity within the power sector, and because only the local grid owner would be allowed to construct a new electricity grid network in the Marjamäki area (which is not profitable to do), it was decided to apply for a permit to operate a closed distribution network. In February 2020 however, the power regulator Energiavirasto declined the request. [19] The application was rejected because the system did not meet the special conditions set for the electricity network permit for a closed distribution network in section 11 of the Electricity Market Act. This permit, only given to four closed distribution networks within Finland so far, is usually given to industrial areas with clearly defined borders, and no customers apart from the owner of the grid itself. The requirements for a closed grid include the following [20]:

> *"Network operation is exercised within a low- or high-voltage distribution network situated in a geographically limited industrial or business area, or within an area where other joint activities are provided."*
>
> *"In addition, at least one of the following conditions must be met:"*
>
> > *"The users of said network form a unified structure due to specific technological or security-related reasons."*
> >
> > *"The network distributes electricity primarily to the network owner, holder, or a third party owned by these actors."*

While evaluating the LEMENE project, the power regulator decided that the need for a closed distribution network for the reason of security of supply did not fulfil the conditions set by the law, since the already existing local distribution network could offer the services needed. This decision means that residents within the energy community cannot connect to the electrical grid of the community directly. Since power transfer over property borders is still not possible even after the latest amendment of Finnish regulation, it is uncertain how the LEMENE energy community will be able to work. Currently, energy production at the Marjamäki site is already up and running, and electricity is fed into the national grid and district heating sold to the Lempäälä area.

5.2 Brooklyn Microgrid

The Brooklyn Microgrid (BMG) established a microgrid energy market within three distribution grid networks in Brooklyn, New York. The idea of this local energy market between residents was presented after hurricane Sandy, to reduce grid issues caused by severe weather effects in the largely outdated and overstretched Brooklyn distribution network. In addition, the BMG project provides a P2P marketplace where residents can trade generated energy with each other locally. The project implemented two components, a virtual energy market platform using private blockchain solutions, and a physical microgrid to work alongside the existing grid as a back-up island grid. It must be noted that the microgrid only applies to a single housing block within the project, and mostly the traditional grid infrastructure is still used. The microgrid is only used to decouple from the physical grid in power outages or other emergency situations. [21]

Figure 10: Solar rooftop panels in Brooklyn [22]

The virtual energy market provides a solution for transferring data between prosumers and consumers within a P2P marketplace. This is done by utilizing the blockchain technology mentioned before, combined with smart meters installed within the participants homes. The marketplace itself utilizes smart contracts, while orders are made according to information collected on the smart devices. The topology of the BMG project can be seen in figure 11 below. [21]

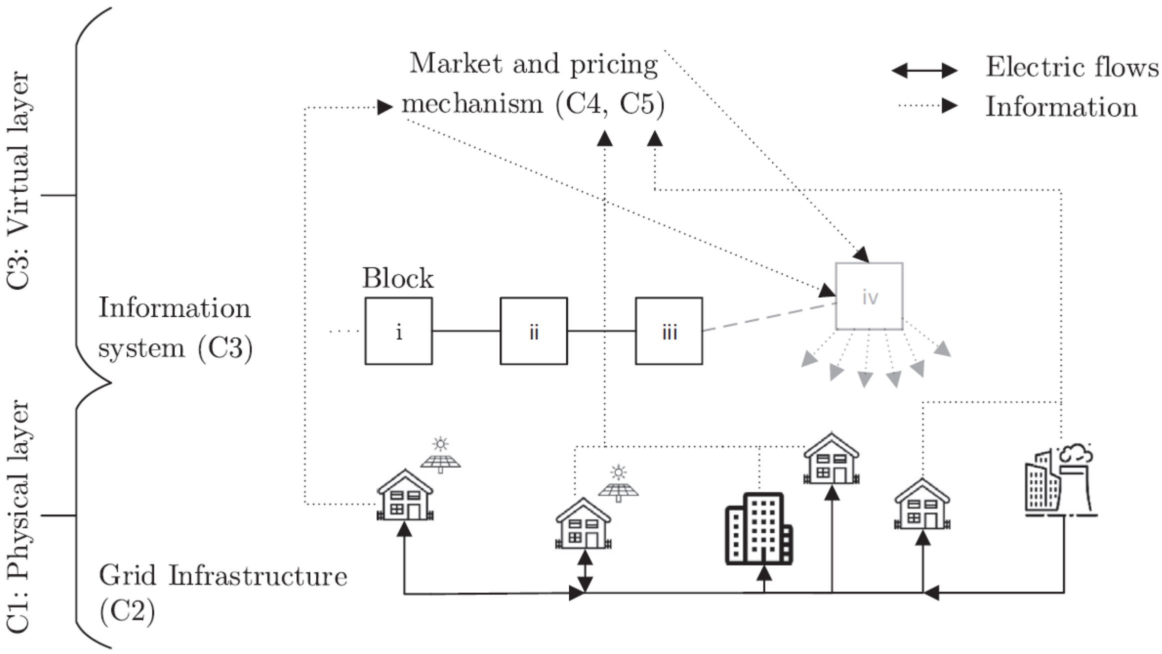

Figure 11: Topology of the BMG project [21]

The BMG project aimed to provide several benefits to local communities. It provides means for prosumers to sell their surplus electricity locally, while providing job opportunities for local companies providing the construction and operation of the renewable generation and P2P trading devices. These two aspects aid in keeping profits from the surplus electricity trade within the local community. This, in turn, provides social benefits for the community for local support in constructing additional microgrid projects. [21]

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5.3 Drake Landing Solar Community

The Drake Landing Solar Community (DLSC) project located in the Okotoks residential area in Alberta, Canada features distributed solar thermal collectors, combined with Short Term Thermal Storage (STTS) tanks and a shallow Borehole Thermal Energy Storage (BTES) field [23]. The boreholes are used for seasonal heat storage, as energy is stored within the field during the warm summer months and extracted during the cold winter months for space heating. The efficiency of the field has been observed to be between 35% and 54% after an initial settling period [24]. This settling period lasted a total of three years as the field was charged to full temperatures. Afterwards, the fields have managed to store enough heat for almost the full winter season [23].

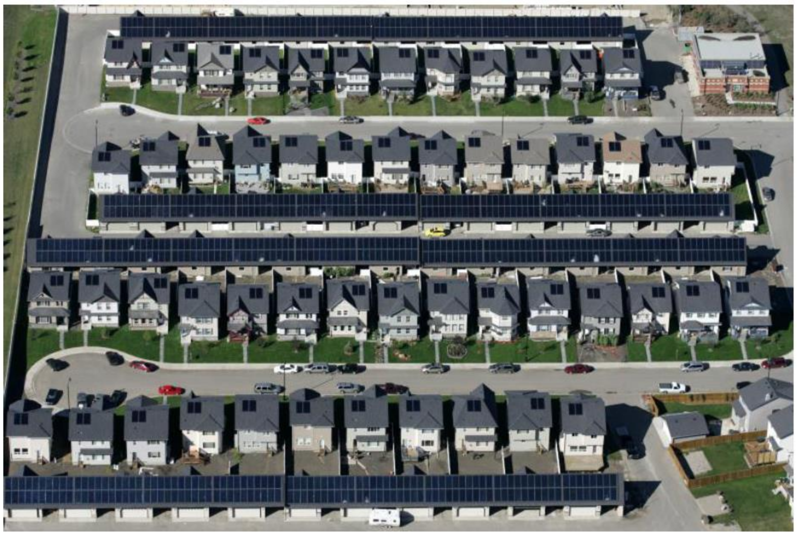

Figure 12: Satellite picture of DLSC [24]

The STTS tanks act as buffer and connector between the district heating system, the solar collectors and the borehole field. A control system directs the flow of energy between the three different energy systems. The STTS tanks are needed because the solar collectors produce heat at a faster pace compared to how fast the borehole field stores energy. Not having a buffer tank would lead to an efficiency loss as the fluid heading to the collector loop would stay at a too high temperature.

The community is composed of 52 single family homes with solar plate collectors fitted on garage roofs, a central storage facility and a mid-temperature heating network. The self-sufficiency of space heating exceeds 90% and reached 100% in the 2015-2016 heating season [23]. If the solar thermal system combined with seasonal storage cannot temporarily meet the heating demand, the community must be heated with natural gas using a back-up boiler. Electricity supply is not addressed in the project. An overview of the project system can be seen in figure 13.

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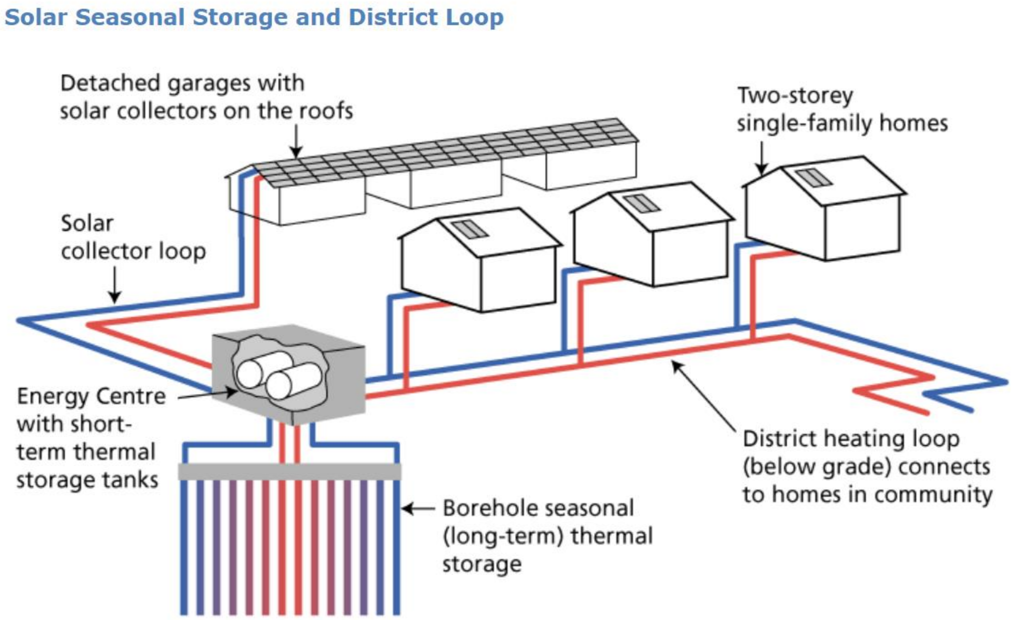

Figure 13: The DLSC storage and district heating loop [23]

The DLSC project provides a heavily researched testbed for solar heating solutions for a more renewable community, as it has been researched thoroughly since its inception. This includes several reports on the operation of the system during different milestones, such as five [24] and ten [25] years after initiation. It also provides a concept for replication within Canada and in Europe as well, as it proves the applicability of the included technologies in geographical areas where solar radiation is absent during the winter months. However, considerations need to be made for economical feasibility of the system when compared to other heating systems when scaled up from this pilot.

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6. THE KERA CONTEXT

This section provides an overview of the Kera district and demonstration area and explains the possibilities of energy communities for the district. The potential of energy communities is explained from the viewpoint of three different energy sectors, heating, electricity, and fuels. The fuels-section includes biogas and synthetic fuels produced via P2X technologies.

6.1 The site

The SPARCS demonstration site of Kera currently houses industrial buildings due to be demolished and replaced by residential and mixed-use buildings for about 14.000 residents. The current property owners include blue chip companies like Linde Gas, S-Group and Nokia, with significant involvement in renewable energy generation and ICT. A large portion of the current building stock, such as the old S-Group logistics center and the Linde Gas plot, has been under disrepair due to lack of use and will be demolished. The largest plot, owned by S-Group, is located on the south side of the railway, and it is expected that these properties will be sold. Nokia owns properties on the north side, close to the Nokia Headquarters area north of Kera. The company still has an incentive of involvement in Kera, as it could serve as housing for staff, and a showcase of smart city infrastructure like 5G smart poles.

Some of these properties have been in temporary use for local actors, leading to a unique local feel for the area. Actors such as breweries, billiard halls, gyms, tennis halls, and small-scale firms focusing on circular solutions have situated themselves within the old logistics hall, decorated by murals commissioned by the Kera collective. Plans on keeping the local feel as a part of the design and work process of the area are ongoing, even as the demolition of the logistics hall has begun.

The site will undergo a city planning process, new zoning, purchase by real estate developers and will subsequently emerge as a modern and vibrant district with excellent train connections to other Espoo districts and neighboring Kauniainen, Helsinki and Kirkkonummi. The city council has set a target for Kera to serve as a front runner on sustainability, smart ICT solutions and circular economy, and there are several co-creation projects to engage stakeholders in this development.

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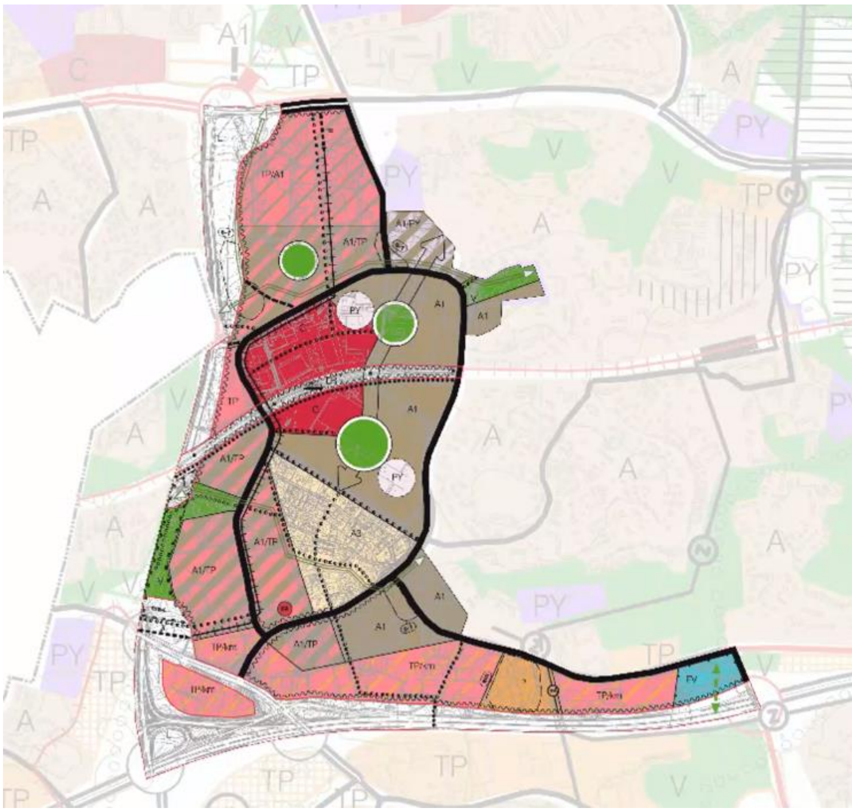

Figure 14: Zoning of Kera

6.2 Heating

Energy Community considerations in Kera could easily include distributed heat generation and prosumer models, as there is no law restricting heat transactions even across property borders. However, heating grid infrastructure requires enormous upfront investment, and an informed decision on the capacity and temperature levels. As there are no residents yet, there is no mechanism of raising the required investment for a heating grid in advance, and a decision on the scale of investment would be based on rough estimates on local interest.

If the heating grid is designed to operate at currently prevailing third-generation district heating temperature ranges of 50-120 °C, any low-temperature waste heat is difficult to recycle. Fourth-generation district heating systems use lower temperatures, down to 30-50 °C, enabling a variety of waste heat sources. Lower temperature levels also improve the potential of available technologies for thermal energy storage and demand-side management.

The district heating infrastructure in Kera will be developed by Fortum Power and Heat. Their proposed solution for Kera is an air-source heat pump serving a water-based distribution system at about 70°C. The power demand for the heat pump and circulation pump is procured from renewable sources, making the heating system emission-free. While the temperature is lower than traditional district heat, it is still sufficient to provide domestic hot water without heat pumps. However, most waste heat sources like data centers, chiller units, exhaust air heat exchangers and wastewater are unable to provide heat at the required temperature. Fortum has published a tariff table for purchasing excess heat from customers, with price depending on outside temperature and

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distinguishing between heat injected into the hot or cold loop of the network. This enables two-directional heat transfer, but the economic returns for prosumer customers could be insufficient to cover connection fees and any heat pumps needed to prime the waste heat to required temperature levels. The economic interest for the provided solution will be determined as the property developers enter the area and the construction phase begins.

In short, the local district-based heating solution provides more potential for local energy communities to form within the heating sector compared to a more traditional solution, if the tariffs provided by the local utility are deemed sufficient to connect to the district heating grid. In addition, the local utility has shown interest in connecting waste heat sources to the local system, thus affirming the possibility of local energy communities. As the heating sector is non-regulated, all properties within the area can freely choose their means of production. However, as a dense urban area, the optimization of the whole district and its connection to the Espoo district heating grid is important and should not be overlooked.

6.3 Electricity

In its current form, the Kera district is a deprived industrial and logistical site with relatively large plot sizes. Particularly the former Inex Partners logistical complex, owned by S-Group, is located on a large plot, easily encompassing several prospective residential buildings, shops and perhaps even a school or kindergarten. As such, it thus could provide the ground for a Positive Energy District with a local microgrid for sharing any self-generated electricity.

However, it is likely that the city zoning process will lead to smaller plot sizes, leaving only a small number of buildings to collectively produce and share electricity. Smaller scale increases the risk of grid feed-in, which reduces the financial attractiveness of self-generation.

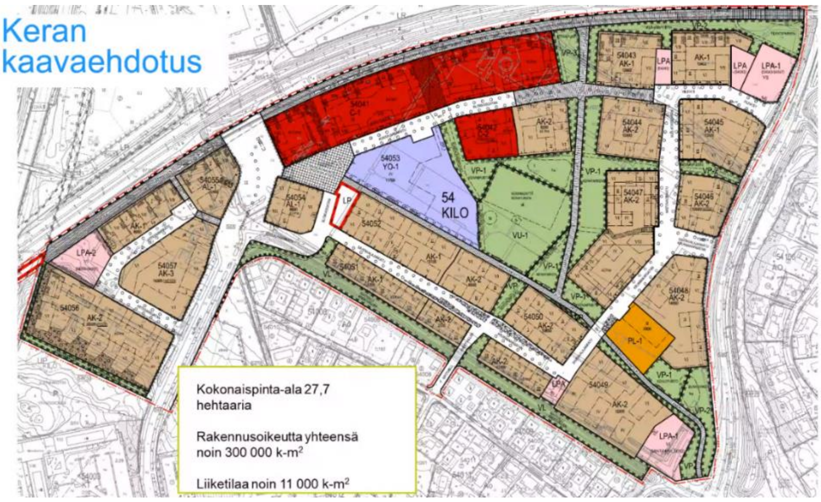

Figure 15: The proposed zoning of the south side of Kera

The proposed zoning of the south side of the railway includes medium and high-rise buildings. Higher density improves the feasibility of energy community synergies, as distribution distances remain low. However, solar energy availability is dependent on geographical area, and high population density reduces the chances of onsite energy ratio exceeding one.

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Under current legislation, Citizens Energy Communities are unable to share electricity over property borders, and therefore the site would need to host a number of smaller communities, each within one plot. This reduces the opportunity to avoid curtailment with prosumer transactions. In particular, residents with an electric vehicle parked on a neighboring plot will be unable to charge their vehicles with residential solar energy. This is problematic due to the possible plans of arranging local parking via central parking garages, thus leading to a situation where electricity for vehicles is either derived from the grid or produced on the garage roof or façade. However, possible future regulation changes can lead to more opportunities for energy communities within the district, as it is planned and constructed for decades to come. In addition, a decentralized energy community as explained in section 3.1 can be a possibility for co-invested electricity generation. However, the potential of this solution can be deemed low compared to in-property communities due to the extra charges required as electricity is transferred through the power grid.

6.4 Fuels

With the emerging Power-2-X technologies and possibly producing biogas from municipal biowaste and biomass from landscaping, it is possible for residents and local companies to manufacture liquid or gaseous fuels and share such products within the community. The 'non-biological fuels' are already featured in Finnish traffic fuel blending mandate proposal, implying fuels derived from electrochemical processes. Such fuels could comprise hydrogen, synthetic methane, ammonium or any higher order hydrocarbons. While any fuels used in road transport are subject to excise tax and therefore strongly regulated, there is no certainty of what regulatory measures are taken on self-consumed prosumer models for fuels.

The most intuitive benefit of fuel-based energy communities lies in energy storage, as distributed renewable energy sources like solar and small wind units are weather-dependent and inherently intermittent. In addition to vehicle use, biogas and liquid biofuels can be readily consumed in micro-CHP units or cooking. This improves the energy security particularly in Finland, where the seasonal mismatch of solar energy and heat demand is obvious.

However, biogas and other fuels require careful consideration in zoning, especially within urban areas. Issues caused by the smell of biogas operations are important to note to prevent long and costly appeal processes from local citizens. In addition, the permission process for biogas plants can be long and involve several different authorities, which has been deemed overly cumbersome especially for small-scale operators [1]. Lastly, the production of biogas will most probably use local biowaste as a resource. Thus, the potential of the plant will depend on other competing solutions, such as the centralized compost and biogas production site within the Ämmässuo ecological industry center owned by the Helsinki Region Environmental Services HSY, and on the recycling level, as all non-recycled biowaste is converted to energy within the incineration plant in Vantaa. For other fuels such as hydrogen, EU-level regulation will develop during 2022 [26]. Thus, national legislation is still waiting for EU-level guidance in several issues, which might curtail investments. More information on hydrogen regulation will be received at a later date.

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7. CONCLUSION

Within Finland, the development of Energy Communities is an ongoing activity. In Finnish legislation, the amended decree on the determination of electricity supply and metering will enable housing associations and multi-storey buildings to distribute rooftop solar power to residents to offset purchased grid electricity. In addition, electricity can be transferred via properties if a direct cable is constructed between them, or if they both link themselves to the local distribution grid. However, there is no current possibility for energy communities that extend beyond property borders on a larger scale microgrid. Without such law, the Kera site would be unable to form one energy community with full peer-to-peer transaction privileges between prosumers. As the local utility is entitled to distribution tariffs for all power sales across property borders going through the grid, self-consumption will not encompass the entire district until the legislation is expanded.

Energy communities can also form around biogas, P2X or heating. Biogas and P2X solutions could be utilized for storage in a local energy community to combat the intermittency of renewable production. Heating, as a sector, has low regulatory confinements for local production, but high infrastructural requirements combined with competition against the local district heating provider might lead to low energy community potential.

While excellent synergies exist between the legislative provisions of Energy Communities and academic efforts to develop Positive Energy Communities, the municipal process of combining these two concepts and pursue the concrete development of citizen-centered, locally administered, and low carbon communities is very complicated. New residential development projects must provide a solid framework for city planning, real estate developers, equipment suppliers and service providers to operate for decades to come. Current solutions like third generation district heating and one-directional power grids are well established and understood by stakeholders.

The Espoo SPARCS sites include two commercial sites, Lippulaiva and Sello. Both are privately owned and professionally managed to provide an attractive setting for tenant retailers and visiting customers. The owner has the privilege of assessing all available options, studying their respective benefits, and selecting the most feasible solution based on their proprietary strategies. The locality, scale and type of these demonstration areas provide potential for local energy solutions, while the type of ownership provides means for easy investment and increases interest from constructors.

A new residential district, however, must be developed based on the expected preferences of future residents with differing requirements and wishes. The heating utility must invest in piping infrastructure, electric utility must install cabling, switching stations and transformers. The city must build roads, parks, schools and kindergartens, and hope that the new district attracts private sector services, retail and jobs. The financial reward for these upfront investments arrives with the first residents, often years or even a decade later. Technical solutions might prove to be outdated, and private sector participation in providing jobs and services may fail to reach expectations for various reasons: competition by other new built districts, economic recession or real estate prices. There is a significant risk of stranded assets, for example if potential district heating customers decide to invest in ground-source heat pumps instead.

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The scale of the Kera development area, combined with the long timeframe between planning, construction and operation, can require long-standing actors with prior knowledge of similar district-sized projects. However, energy communities can provide new solutions for fast-paced local investments that work together with the infrastructure constructed by local utilities. In this case, Kera can become an interesting testbed to research the cohesion between property-based, district-based, city-wide, and national energy solutions. Heating can be produced via the local air-to-water heat pump utilizing renewable electricity produced elsewhere in Finland, while local excess heat is fed into the district heating grid for additional local value. Simultaneously, locally produced electricity can be sold to the power grid constructed by the local DSO or stored for future use by utilizing the constantly developing storage technologies. All of this will depend on local innovation and collaboration between the city, the private entities and the future citizens of Kera, which has already been shown to be immensely effective.

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