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Stakeholders' Interests in Developing an Energy Ecosystem for the Superblock—Case Hiedanranta

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Abstract: Policy objectives aimed toward zero-energy buildings call for the utilization of building-integrated renewable energy and distributed energy resources (DER). To enhance the utilization of DER, previous literature proposed the concept of an integrated community energy system (ICES). This research suggested using superblocks (units of multiple urban blocks) to define geographical limits, social contexts, and possibly common administrations for ICESs along with other living- and sustainability-related activities in an urban context. Through interviews with key stakeholders and an analysis, this research investigates the applicability of the superblock-ICES as a way of reaching the low-carbon objectives in the Hiedanranta brownfield development project in the city of Tampere, Finland. This research confirms that the driving forces of community-based solutions are economic benefits, technical development, and objectives of sustainability, and reveals or confirms that social acceptability, missing planning practices, economic risk, and missing or hindering legislation are the main issues or barriers of superblock-ICESs. For a wider adoption of superblock-ICESs, this research suggests cross-disciplinary piloting, together with developing planning practices and simulation tools. In Finland, legislative reforms are needed to remove the barriers and clarify issues related to security, reliability, customer protection, and public interest in governing a locally and collectively owned energy system.

Keywords: distributed energy resources; integrated community energy system; superblock; urban planning; sustainability

1. Introduction

In 2010, buildings consumed 32% of the total global energy consumption and caused 19% of energy-related greenhouse gas emissions [1]. Due to the long lifespan of buildings and cities, energy systems call for urgent consideration to avoid a harmful lock-in situation, with yielding technologies preventing technological transition to resilient cities, thereby mitigating climate change. By 2050, 68% of the world's population is projected to live in cities [2]. This rapid urbanization calls for carbon-neutral heating, cooling, and electricity systems in cities, and solutions for these needs are constantly emerging on the market. For example, building-integrated photovoltaics (PV) have become a potential solution to compensate for building life-cycle emissions, as the cost of PV panels has dramatically decreased over recent decades [3]. Technological advances and their cost-efficiency benefits open up new opportunities for production, savings, and storage of distributed energy resources (DER). The increasing share of local PV production brings new balancing and congestion challenges which call for investments in energy storage and peak-shaving technologies [4].

In addition to the technical factors, administrative and legislative issues also need to be considered when attempting to establish climate neutrality. Because of the seasonal availability, pushing forward the installation of solar panels calls for solutions to overcome the problem of supply and demand. This is why many countries opened the electrical grid to producer consumers ("prosumers"), but this is rarely attractive because of the self-consumption-promoting feed-in tariff [5,6]. Another proposed solution to engage prosumers in energy production is bidirectional district heating, where the thermodynamics of the network remain as open questions [7]. However, precedents exist showing that large apartment buildings or new housing developments can establish profitable business models to share energy, while the last meters of the grid can be privately owned, so most of the grid fees and taxes do not apply [8]. Transmission charges and taxes make it difficult to share energy facilities and excess energy through the public grid and increase consumers' interest in grid defection, which are not favorable developments from the perspective of the whole system [4].

1.1. Integrated Community Energy System for a Solution to Local-Level Energy Sharing

An emerging paradigm in the field of distributed energy (DE) is the concept of an integrated community energy system (ICES) that provides a solution to match supply and demand on a neighborhood level. This is a concept that simultaneously engages local communities in the energy system and organizes the integration of DER. Koirala et al. [4] defined an ICES as a locally and collectively organized energy system that combines the concept of sustainable energy communities, community energy systems (CES), community microgrids, and peer-to-peer energy, stating that the main purpose of an ICES is to fulfill the energy requirements of local communities through better synergy among various energy carriers.

ICESs provide benefits for both society and citizens through the better reliability and security associated with an increase in the flexibility of local and larger energy systems [4,9]. ICESs also cut public investments in power lines, increase the energy consciousness of citizens, increase the penetration of renewables and reduce the system peaks that a higher share of renewable energy may cause. Moreover, social benefits are also possible, such as the enhancement of local employment, community development and social cohesion [9]. The main benefit for the customer is saving on energy bills by increasing self-consumption through matching supply and demand at the local level. ICESs also enable the participation of consumers in the energy system, provide higher bargaining power, bring less risk to investments in DER, and reduce dependencies on imported fuels [10]. Politics, at least in Europe, recognize most of these benefits, with guidelines being laid for local energy communities in the Directive regarding common rules for the internal electricity market [11].

1.2. Integrated Community Energy System from a Technical Perspective

The term "integrated" in ICES refers to the technical ability to capture attributes of any possible virtual and location-specific energy system integration options and apply them to a community-level energy system. Mendes et al. [9] considered the ICES as an approach to supply energy on demand to a local community with high-efficiency co-generation or tri-generation and renewable energy technologies coupled with innovative energy storage solutions, as well as electric vehicles and demand-side management measures.

From a technical perspective, they also interpret ICESs simply as combinations of community microgrids and integrated energy systems (IES). In this system, a community microgrid is a local scale power grid that enables locally controlled clusters of DER to reduce transaction costs due to fewer intermediary parties when supplying local resources to local demand. As the concept of the IES is included in that of the ICES, the latter provides additional benefits through deeper synergy compared to community microgrids [9]. A single facility for an IES is called an energy hub, which manages energy flow through the conversion and optimal management of multiple energy carriers [12,13].

Despite its location-specific nature, an ICES can also apply concepts that are flexible in terms of location, such as a system for load management called a virtual power plant (VPP) [14]. The next evolutionary step of the VPP is the concept of a prosumer community groups (PCG) [15], which refers to a virtually interconnected network of prosumers who utilize smart management systems to pursue a mutual goal and jointly compete in the energy market. Basically, what makes an ICES different from other state-of-the-art technologies of DER is its objective to employ all possible flexible and location-specific technologies to provide the highest possible degree of integration and value to the community [4].

One key enabler for ICESs is the recent development of information technology. Multiple researchers have proposed, investigated, and developed easy-to-use evaluation methods to enable an optimally planned solution for the installation of an ICES [9]. Another issue is the development of an automated steering system for optimal day-ahead scheduling that enables cost-efficient operation and achieves all the benefits of ICESs [16–18]. This kind of system could increase the economic attractiveness of the community-based solutions for DER.

1.3. Integrated Energy System as a Local Community

In addition to technical systems, local community is a fundamental component of ICESs [4]. Therefore, Huang et al. [19] defined CES through three fundamental elements, namely, the energy system, the geographical area, and governance. These three aspects link together, as community is a social unit (a group of people) which has something in common, such as the energy system and geographical area. Koirala et al. [4] argued that the key enabler for local engagement and self-consumption inside a community is local ownership, for which the literature provides multiple ownership models, such as co-operatives, development trusts, co-ownerships, and community charities [20]. A specific community-owned technical component that enables self-management and self-consumption is the microgrid [21]. To achieve all the benefits, the planning of locally and collectively owned energy systems should coordinate with local land use planning by using the area of the local community as a basic land use unit [19].

The literature does not provide a clear answer to the issue of area as, from a technological point of view, ICESs may be established on various spatial scales, ranging from individual buildings to neighborhoods or entire cities [4,13]. Respectively, cases vary from hundreds of kilowatts to megawatts [22], and from dozens of households [10] to several square kilometers with diverse land use [19]. Larger areas incorporating diverse functions provide a higher degree of self-consumption in microgrids because different functions have different consumption profiles [21]. On the other hand, a growing scale of implementation implies the involvement of more actor groups and creates new challenges for management, which is why the final solutions must be defined through transparent communication with local stakeholders [13].

1.4. Background and Interpretations of Superblocks

One option to coordinate ICES planning with land use planning is the concept of the superblock, something that researchers in the city of Barcelona suggested will turn into planning units for microgrids [21]. The origin of the superblock concept dates back to 1929 in the USA, where Florence Stein and Henry Wright were inspired by Clarence Perry's idea of a neighborhood unit where surrounding arterial streets defined the walkable area of multiple traditional blocks [23]. The earliest definitions of superblocks link to the American garden city movement and its implementation, such as the residential area of Radburn, NJ by Henry Wright and Clarence Stein in 1929. Early ideas regarding superblocks focused on mobility and organizing public space.

Despite the earlier criticism of cul-de-sacs and gated communities [24], recent superblock concepts linked to sustainable urbanism and sustainable mobility [25,26]. Mehaffy et al. [27] considered that negative experiences in previous neighborhood units were related to overly large super grids, leading to an imbalance of pedestrian and vehicular mobility, thus proposing a 400 m super grid as a starting point for an improved neighborhood unit model. Moreover, building volume affects the character of superblocks, as it varies from American single-family houses to the typical urban density of a European city center, and further to Asian mega-housing [28]. Different experiences indicate that the sustainability and quality of superblock applications may be more dependent on other aspects than the principle of using an area of multiple blocks as a development platform.

The city of Barcelona co-created design guidelines for the city's regeneration, also describing the characteristics of superblocks [29]. In Barcelona, a superblock is defined as an urban area that is smaller than a neighborhood but larger than traditional urban blocks, and they use the concept as a principle for the areal division of an integrative platform for various concepts of urban sustainability [21]. While Clarence and Stein suggested the original superblock concept to extend the city in a suburban context, the superblock concept in Barcelona was implemented in an urban core, giving a different starting point for urban activity. Concerning road networks, the Barcelona superblock concept differed from original implementations in the application of a 400 m super grid and the replacement of dead-end streets in the original superblock concept with one-way streets without dead-ends.

1.5. Superblock as a Platform to Organize ICES in the Case of Hiedanranta

The Barcelona-style superblock concept, as a platform for ICESs and other solutions of sustainable urbanism, also attracted interest in the Hiedanranta development program in Tampere, Finland. The Hiedanranta redevelopment project is a 25-hectare brownfield development project on a former pulp mill site approximately 5 km from the Tampere city center. As the city is growing, with a new tramline expected to soon pass through the area, the goal is to have 25,000 inhabitants and 10,000 jobs in the new district. The objectives of the project are to make the area a pioneer in circular economy practices and sustainable urbanism, including a high degree of self-sufficiency in energy [30,31].

The purpose of this research is to investigate the key stakeholders' interests in and expectations of sustainable and cost-effective ways of saving, producing, and storing energy in the neighborhood defined as a combined concept of a superblock-ICES. The paper draws from the case study of the Hiedanranta brownfield development in Tampere, which aimed to investigate an approach to and the critical aspects of launching the development of a new city district based on energy efficiency and the principles of a circular economy, such as tapping the surplus energy of one activity in an urban block for users needing energy or storing it for future use. The features of this approach are discussed from the stakeholders' perspective to analyze its potential to support the technological transition of cities to circular economy-based models.

1.6. The Rationale

The rationale of this paper is to look at the drivers of and barriers to the stakeholders' interests and point of view in a city development project aiming to create a new carbon-negative city district. A similar approach was previously used in the energy sector to analyze success factors [32]. This kind of approach provides additional information on the possibilities of applying the combined concept of ICESs and superblocks in the case of Hiedanranta and contributes to the scientific discussion regarding the drivers and barriers for the concepts in general. The drivers and barriers were investigated on a general level in reviews provided by Mendes et al. [9] and Koirala [4]. Closer analyses regarding the barriers and drivers for the sub-concepts of ICESs, such as microgrids [33–35], grid storage systems [8], and energy hubs [13], are also available.

Based on the investigation of stakeholders' interests in the case study on Hiedanranta, this paper aims to provide prescriptive advice to promote the formation of an ICES as part of the superblock development. A stakeholder is defined as any group or individual who affect or is affected by the achievement of the objectives of the organization [36]. The interests, in turn, are the key issues that the stakeholders consider to affect them in one way or another, without a fixed position or solution [37]. From the stakeholders' perspective, diverse interests can be conceived to hinder or promote the formation and content of an ICES. It must be noted that the stakeholders may have contradictory views on the content, potentially exposing conflict. Implementing any ICES calls the alignment of interests regarding the organization of ICES ecosystems. Efficient negotiations, governance, and management are likely to improve the building of technical ecosystems. Technical advancements, on the other hand, affect the interests of the stakeholders in the ecosystem when new solutions become feasible and profitable, gradually changing the technological landscape [38].

1.7. Research Question

The transition to decentralized energy requires radical changes managed through long-term strategies at all levels of the energy market, as well as collaborative efforts from all actors with shared interests in low-carbon objectives [39]. Based on earlier investigations of researchers such as Koirala et al. [4], the presumption of this paper is that the implementation of an ICES calls for rethinking the whole process of urban planning and development and the involvement of infrastructure and construction companies. Although von Wirth et al. [13] suggested using geographical information systems to quantify the potential for the local acceptance of DESs with respect to technical, spatial, and social aspects, this is not applicable here because the case area does not contain any inhabitants and the city owns the land. In a socio-ecological system framework for ICESs by Acosta et al. [40], the research was grounded in the early design phase, where the discussion moved from the initial phase to soft variables. In negotiation terms, this phase addresses the mapping of interests without premature commitment to the potential solutions [41].

The research question in this paper is: "Is there a way to enable transition toward integrated community energy systems as a solution for carbon-negative city districts?" The idea is to predict whether the preconditions are favorable for the successful implementation of the concept by asking about its acceptability from different key stakeholders' perspectives, potentially indicating a future conflict that may hinder implementation. In the search for potential solutions to mitigate conflicting interests, detailed barriers and drivers are investigated and categorized in depth.

2. Materials and Methods

2.1. The Interviews

The implementation of the ICES should ensure the engagement of all stakeholders based on, for example, the principles of urban design management [42]. However, the overall sphere of stakeholders (Section 1.6) is larger than just the initial stakeholders. The latter may be considered as parties launching the development of an ICES, which made up the group of interest in our study. Von Wirth [13], on the other hand, showed that conducting semi-structured interviews with local stakeholders was an effective method of investigating the acceptability of technology at the neighborhood level. This method is especially useful for topics that are not well structured, as it lets the interviewees present their own understanding of the subject area.

A total of eight interviewees were chosen to represent the initial stakeholders in the planning of Hiedanranta. Grouped according to the six interviews, of which two are group interviews of two persons, the selection was as follows:

1. An architect at the City of Tampere, in a key role in the urban planning of the area;
2. An infrastructure planner at the Sitowise consulting company, responsible for the general plan of the municipal infrastructure;
3. The Chief Executive of Tampereen Sähkölaitos Oy, the municipal power company;
4. The Chief Executive and Planning Manager of Tampereen Sähköverkko Oy, the municipal grid operator;
5. A facility development director at the City of Tampere;
6. Two directors from the construction company called YIT.

The selection of the interviewees, keeping in mind the research question of Section 1.7, was based on the following aspects: (a) The City of Tampere has a primary role in the planning of the area. Since the superblock concept was adopted only after the competition phase, the planning architects are responsible for the overall implementation of the concept. They advised us to also include the facility development director, in order to clarify organizational issues. (b) Planning for street and area infrastructure is auxiliary but essential to the superblock concept. We chose the initial stakeholders from that point of view; the infrastructure planning company Sitowise and the key energy providers.

The electricity company supplies energy but also maintains the heating network. The grid operator was included as well. (c) Finally, construction companies have a decisive role in the realization of the block structure.

As the idea of the study was to ask each interviewee about the acceptability of the Hiedanranta ICES concept, it was essential to consider what they knew about the subject. Each interviewee was an expert in her/his own field and represented one stakeholder. Most were not familiar with the concepts of ICESs and superblocks. However, two of them had participated in an earlier workshop on the subject area 4–5 months earlier. The purpose of the workshop was to get feedback on the system proposed to Hiedanranta and to see how participants linked the technological problem of the energy system with other design problems and the superblock concept. The participants of the workshop were professionals and researchers.

In order to provide the same level of understanding to every interviewee, each interview started with a presentation about the superblock-ICES and its various aspects, including technical structure, energy economy, administration, community, urban structure, and urban planning. This material is summarized in Section 2.2. The theme areas of the subsequent discussion were more general. They were chosen to help the participants browse through various aspects of the ICES and the superblock from each interviewee's own standpoint and their knowledge about their own organization. This, in turn, allowed novel aspects to emerge during the interviews, including various drivers and barriers that were important in the study. Accordingly, the following listed themes were not simply questions but directed the discussion to ensure that the essential aspects were covered:

- **Potential and risks of ICESs and superblocks**
  Are the concepts of ICESs and superblocks familiar to you, and what kind of thoughts arise from the ideas? What are the expected problems or advantages? What kind of transition will the concept cause in current regimes? What are the issues that need closer research and development?
- **Commitment and cooperation**
  What are the most important stakeholders in the implementation of superblock-ICESs? Do the stakeholders have the ability to cooperate? Are there any barriers to cooperation between public and private stakeholders?
- **The stakeholder's own organization**
  Have the concepts of ICESs and superblock been discussed in your organization? What kind of role could your organization have in the implementation of an ICES superblock? Is the organization capable of implementing it? Will the implementation be problematic for your organization or are changes required?

The interviews took place between 17 October 2018 and 9 November 2018. Each of them started with a slideshow presentation which provided basic information and examples of ICESs and superblocks. A few structural alternatives for the Hiedanranta system were also included. By using these examples, the interviewees were given some basic ideas about what an ICES could be and what kind of projects had already been developed elsewhere. Another reason for this presentations was that some interviewees had already participated in the preceding workshop while others had not. The same set of slides, narrated by the same person, was used in every interview. During this phase, the interviewees could present any remarks or questions and raise issues for further discussion. This helped to deepen the interviewees' understanding and to yield more relevant responses in the interviews. The remaining part of the interviews was guided so that it covered the three main areas of potential and risks, cooperation and commitment, and the stakeholder's own organization. The length of the sessions varied between 63 and 85 min. The discussions were recorded and then transcribed on a basic level (clean verbatim). These transcriptions were then used for further analysis, as described in Section 3.

2.2. Background Material for the Interview

2.2.1. Technology and the Energy Economy

An ICES is a locally and collectively organized energy system with objectives to economically fulfill the energy requirements of local communities, to make local inhabitants commit to the energy system, and to organize the integration of DER [4]. Following the definition of Mendes et al. [9], the technical system of the ICES is split into two categories where the collectively owned energy supply infrastructure consists of energy networks and automation systems necessary to enable energy supply and trade, and supplementary components consist of diverse technologies for the local production, conversion, and storing of energy.

To avoid grid defection, which scientists have found to be an uneconomic solution, energy supply systems are designed as two-level hierarchical systems [4]. In the hierarchical system, the upper level consists of district heating and power networks that make up the regional system, and the lower level consists of the local heat and power networks that enable self-production inside the ICES (Figures 1 and 2). The ICES connects to the main district heat and power grids through a common point of coupling (CPC), enabling the system to rely on imported district heat and grid power [35]. Main electric grid connections enable benefits through operating as a VPP and as part of a PCG. Because bi-directional district heat is still under development, interviewees received information regarding different options for heat management. Multiple options were suggested, such as combined supply and feed-in substations [43], a low-temperature network with ring topology [44], a distributed solar thermal system with centralized storage [45], and a semi-decentralized system utilizing heat pumps and PV [46]. In addition to energy networks, ICESs include automation systems that utilize data from various sources and enable day-ahead scheduling, smart metering, flexible demand, VPPs, and PCGs [4].

Figure 1. Energy communities formulate a regional system with a district heating system. Thick lines represent district heating, thin lines represent the local network of the integrated community energy system (ICES), and grey fields represent superblocks.

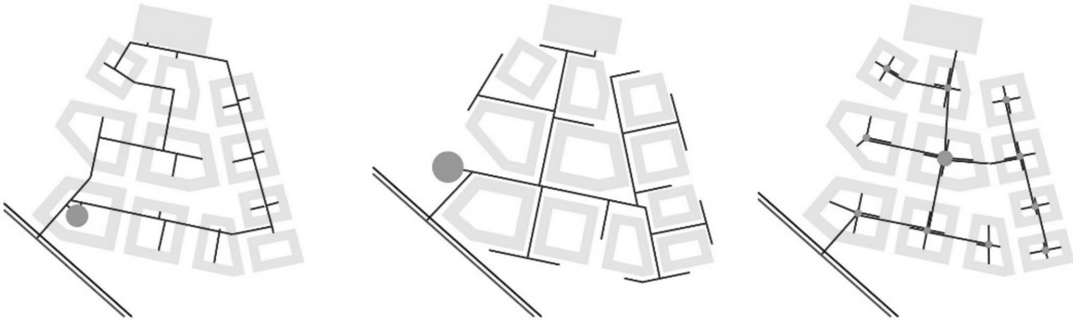

Figure 2. Zoom-in to different topological options for the local heating network of the superblock-ICES. Round objects represent thermal energy storage systems, grey fields are buildings, and lines represent local networks connected to the district heat.

Proper energy networks enable a broad variety of centralized or decentralized supplementary components for storing, producing, converting, and managing chemical, thermal, and electrical energy. Examples of decentralized production include building-integrated PV panels, hot tanks, and heat pumps. [4] Due to the seasonal mismatch of supply and demand in solar energy, the system requires centralized components, such as combined heat and power (CHP), industrial heat pumps, and large-scale energy storage systems. In centralized energy storage systems, such as seasonal thermal energy storages and grid batteries, the value propositions are an improved rate of self-consumption, compensation from reserve capacity, and peak-shaving, thereby enabling a lower output rate in main grid connections [8]. Centralized components are integrated following the idea of energy hub [12]. Placing the energy hub near the CPC enables energy trading through regional grids [35].

2.2.2. Administration and Community

Because researchers suggested establishing appropriate governing institutions for the design, planning, implementation, and operation of ICESs [4], a company to take on the responsibility for the ICES should be founded before any construction on the area. The key features of ICESs are local ownership and self-management, which is why real estate owners and housing companies in the area purchase shares of the company. City governmental bodies and residents' associations are also able to be owners and are entitled to vote to strengthen the local involvement of stakeholders. To overcome the challenges originating from the varying skills and motivations of members [4] and problems surrounding trust-building [13], the main duty of the ICES company is to organize a democratic model for self-ownership and self-governance of the collectively owned assets. Therefore, the company takes responsibility for the long-term development of the system and oversees the benefits of the owners and users in choosing designers, contractors, and caretakers from the market. The city may have an active role in finding a founder for the ICES company to obtain financing and to procure the construction of the energy supply infrastructure and, optionally, some of the supplementary components in the energy system.

The economic model and charging policy should also be aligned with the main goal of providing affordable and sustainable energy for the local community [4]. The revenues of ICESs come from energy sales and network services provided for the community [4], and additionally from compensations for reserve capacity [8]. While supplying energy for customers, the ICES company needs to define transparent tariff-setting policies aligned with the European Union (EU) directive on energy markets and take care regarding liabilities related to health, safety, reliability, and tax collection [35].

2.2.3. Urban Structure, Planning, and Superblock

To achieve all of the benefits from ICESs, researchers suggested coordinating energy system planning with land use, traffic, and infrastructure planning [19]. A tool to integrate the management of sustainable urban development is the concept of the superblock, which covers an area limited to busier roads and contains multiple traditional urban blocks and public space or parkland [21]. A contemporary superblock is also a platform for the promotion of urban green and active urban spaces, sustainable transportation, self-sufficiency, social cohesion, and integrated governance [47]. To achieve success in the implementation of the superblock concept, the urban planners also need to find a way to get local stakeholders engaged in the establishment and operation of ICESs [19].

One basic problem in planning is the definition of an operational area for the superblock. Because diversity in production and consumption improves the rate of self-consumption in an ICES [10,21], a large enough area of mixed-use urban structures is the suggested objective of land use in a superblock. Larger areas help to achieve critical mass for the services of the superblock and increase the chances of finding motivated and capable members on the board of the company. On the other hand, it is beneficial to keep the area limited to avoid challenges in the building of trust, acceptability, and agility, caused by the increasing number of stakeholders involved [13]. From the perspective of urban life quality, the desirable side dimension for a superblock is less than 400 m [27] which, with urban population density, would contain over 4000 inhabitants.

3. Results

3.1. Summary of the Interviews

Each interviewee had her/his own role in the fields of urban planning, energy, or construction and, for some of them, in the planning process of Hiedanranta. This was reflected in the discussion. The main points were summarized and are described as follows.

- Interview 1

The interviewee was broadly interested in town planning issues, including the application of superblocks, their properties and internal structure, the relation between the ICES and the superblock, urban scale, and urban identity. Another important topic was planning cooperation regarding the schedule, phases of construction, coordination and long-term adaptability. Land ownership, legislation, various steering methods, pilot projects, and research needs were also mentioned. The planning task as a whole was demanding because of many details, like energy infrastructure, traffic, the circular economy, and the economy, so the path from general plans to detailed realization seemed challenging.

- Interview 2

This interview focused on the general planning of infrastructure, including the structure of municipal networks, fitting together different networks, expanding the system, and the phases of construction. The relationship between centralized and distributed systems was discussed as well. The application of superblocks was expected to lead to changes in infrastructure. In this situation, the economy, commitments, land ownerships, and legal issues would become important.

- Interview 3

The main topics were district heating and electric power. Comparisons between municipalities, system alternatives, their feasibility and economy, reserve capacity, cost structure, market issues, the criteria for investment decisions, and energy trade were the central issues. Artificial intelligence and smart technology could facilitate new systems and services. Legislation, economic incentives, tariffs, consumer rights, and commitments were also discussed.

- Interview 4

This interview focused on electrical networks and their operations. Many issues were technological, such as energy optimization, power management, quality control, measurements, safety regulations, reserve capacity, and reliability. The interviewees welcomed the potential of intelligent technology. They were interested in the business potential of energy communities, but also mentioned the current legal restrictions for network operators.

- Interview 5

Ownership, administration, rights, commitments, and the rules that regulate cooperation were the central topics. Also, the long construction phase, phases of expansion, and problems of the initial establishment of ICESs were discussed. As superblocks are relatively large, specific attention must be paid to plot division, distribution of possessions, commons, easements, and alienation conditions. Economic incentives and profitability are important. The new possibility for 3D property formation could facilitate, for example, the founding of underground energy storage systems.

- Interview 6

This interview addressed the issues of building projects, construction, and the practical applications of ICESs, for example, regarding energy connections, reserve spaces, ownerships, cost-efficiency, financing, investments, partnerships, and life-cycle approaches. Economic predictability and stability, trustworthiness, and keeping promises to consumers were important issues as well.

3.2. Analysis

After the data collection phase (the interviews), our analysis followed the principles of qualitative research, including data reduction, data display, and conclusion drawing, as presented, for example, by Miles and Huberman [48]. In the reduction phase, the transcriptions were read, and important passages were annotated. Next, the speakers' clear expressions were extracted from the text material and arranged into categories, with the number at this stage being 42. Examples of the titles included "boundaries of the superblocks", "power management", "responsibilities within energy communities", and "planning schedule". In order to ensure backward compatibility, the categories were encoded in such a manner that every observation could be traced back to the original transcribed material. Hence, it was possible to check the speech context of each observation. At this stage, it was already relatively easy to group these categories into four more general classes, namely "Energy system", "Community", "Superblock", and "Building up". However, this grouping was not adopted, as such, but was elaborated further.

In the final phase, the contents were discussed and table (matrix) of the data was created (Table 1). The construction of this table was conceptually the most important step and served the task of displaying the data in a systematic way. This task was based on theoretical interpretations; in the first two columns, it was based on the theoretical view of drivers and barriers, as explained in Section 1.6. The third column was called "questions and issues", which included observations that could not be directly classified as drivers or barriers. Second, the entries in the table were "condensed" observations based on each category. Third, the entries in each column were divided into three upper classes: "Technology and the energy economy", "Administration and other community-related aspects", and "Superblock, urban structure, and urban planning", which corresponded to our initial views of the parts of the ICES.

In Table 1, the third column in particular, which includes questions and issues as well as some of the drivers and barriers, may indicate a more complex subfield or problem area not adequately covered in the interviews. Legislation, for example, is a complex system related to many issues external to ICESs. Some other issues may be inherently engineering problems that cannot be resolved without theoretical or experimental approaches. Other issues are related to land use policies and thereby to legislation and politics, like those regarding land ownership and urban planning processes.

Table 1. The classification of comments of the interviewees.

Drivers	Barriers	Questions and Issues
Technology and the Energy Economy		
D1.1 Among the electrical network operators, ICESs have already been discussed/considered. D1.2 The ICES may simplify municipal infrastructure and make its construction more economical. D1.3 Intelligent electrical power management and local storage may decrease the need for reserve power. D1.4 The 3D system of the environmental division of real estate facilitates new (underground) solutions, e.g., for thermal storage. D1.5 Through a community microgrid, ICESs avoid duties and energy transfer fees regarding self-consumed electricity. D1.6 District heating topology following the principles of ICESs and superblocks does not require additional investment, and extra costs compared to conventional topology are minimal. D1.7 Electricity companies are interested in ICESs as a business opportunity.	B1.1 Cost efficiency of district heating and medium voltage electric grid may suffer if used less due to ICESs. As a consequence, they would be economically more challenging to integrate with municipal networks. B1.2 Renewable energy sources may increase the potential of grid instability and peak loads. B1.3 Expensive, underperforming, or non-existent technology for ICESs in neighborhood-scale biogas production and bi-directional district heat. B1.4 Responsibility for electric grid security and quality could bring extra costs for ICESs.	Q1.1 ICESs should be connected to a medium-voltage electric grid. Q1.2 Does this lead to less integrated grids overall? Q1.3 How should the infrastructure of an ICES be designed and dimensioned at the beginning? Q1.4 What are the development bodies for ICES-related technical issues? What is the role of network operators with regard to current legislation? Q1.5 Demand response, different types, different purposes (year cycle, diurnal cycles, spot price optimization, and external energy-need optimization. Q1.6 Adaptability, life-cycle approach, and maintainability. Q1.7 The energy economy of superblock-ICESs calls for comprehensive simulation and analysis, as residential costs need to be predicted.
Drivers	**Barriers**	**Questions and issues**
Administration and Community		
D2.1 Collective use of solar panels is possible in a property even today if electricity is included in the rent or maintenance charge. D2.2 Building contractors already have experience of collective investment and operation of infrastructure among new housing companies through a case of a pneumatic waste collection system. D2.3 Planning officials in Hiedanranta encourage constructors to use integrated approaches. D2.4 Residents desire community-based solutions on new housing areas.	B2.1 Unclear rights and responsibilities between an ICES and individual consumers in current legislation, e.g., regarding customer choice and the electric market act. B2.2 Due to legislation, local energy systems cannot exceed plot boundaries. B2.3 The municipal planning organization does not share responsibilities optimally in the development process. B2.4 Current legislation does not allow power generation business for electrical grid operators. B2.5 ICESs create new responsible parties which increase license bureaucracy.	Q2.1 Issues with regard to ownership and administration as key factors for an ICES, e.g., company form, governing body, rules, etc. Q2.2 Differences in development processes and incentives between city-owned and privately-owned land. Q2.3 On what terms and economic principles can individual consumers be charged fairly? Q2.4 Legislation with regard to possible partners, alliances, etc. Q2.5 Preliminary investments in distributed energy systems call for financing.

Table 1. *Cont.*

Drivers	Barriers	Questions and Issues
Urban Structure, Planning and Superblock		
D3.1 Tampere city has adopted the idea of the superblock as a planning concept and has a positive attitude toward related solutions.	B3.1 No established models exist for ICESs, they have to be created. The general plan is just a starting point. B3.2 Current planning system does not necessarily support the planning process of an ICES. B3.3 Housing costs should not rise because of the superblock-ICES. B3.4 Development of advanced systems calls for public funding and investors with risk-taking capacity.	Q3.1 The interviewees did not give a clear opinion about whether the ICES and the superblock correspond with each other. Q3.2 What are the key methods for the administration and ownership, responsibilities, and rights with regard to land use, easements, distribution of possessions, etc.? Q3.3 What are the tools for the planning and management of cities to facilitate superblock-ICESs? Q3.4 Because of the long timespan of urban construction, the superblock-ICES needs to be planned as a system that expands in phases.

3.2.1. Drivers and Barriers for ICESs in the Current Scientific Literature

Some notions on drivers and barriers for the ICES or its background concepts are presented in the recent literature. Koirala et al. [4] classified issues of ICESs into socio-economic, institutional, technical, and environmental categories. Respectively, drivers for microgrids relate to the economy, reliability, and the environment [35]. Koirala et al. [4] expected environmental policies and awareness to be the major driving forces behind the surge in the implementation of ICESs as a presumably more efficient and reliable alternative to the centralized power supply system. From the perspective of society, the main benefits of ICESs include the increasing penetration of renewables, better reliability, security, flexibility peak-shaving, lower public investments, an increase in citizens' energy consciousness, enhancement of local employment, community development, and social cohesion [4], [9]. From a consumer's perspective, energy autonomy, increasing environmental concern, and renewed attention on universal energy access are the main drivers for the surge in the progress of local energy communities. Moreover, ICESs bring energy bill savings, cut the risk of investments in DER, enable participation, and provide higher bargaining power in energy markets. [4]

The recent literature classified barriers in ICES cases [4], microgrids [33,34], grid storage systems [8], and energy hubs [13]. The barriers in these sources fell into classes of technical, regulatory, financial, and market or stakeholders. Von Wirth et al. [13] noted that energy hubs suffered from problems that are common for early niche innovations, relating to not only to technical optimization and losses of energy conversion, but also to a lack of financial backing needed for market acceptance and the political and structural barriers set by regulations. High upfront costs compared to existing national grid alternatives combined with the risk aversion of banks in the granting of loans for communities may cause barriers for required investments to establish the system and make members' entry and exiting inflexible [4]. In fact, market and community acceptance coincide, which is why institutional conditions that are favorable for innovation cannot be established without sociopolitical acceptance [49].

One of the biggest barriers to ICESs are institutions that favor centralized energy systems, which lead to a lack of active engagement from local communities and cause existing regulatory barriers [4]. To avoid the erosion of revenue, a distribution system operator (DSO) may hinder microgrid projects using monopoly rights on its service territory that current regulations allow. Liabilities related to tax collection, transparent tariff setting, health, safety, and the security of supply might cause unreasonably heavy bureaucracy and costs for small communities. Some of these liabilities are still undefined and explicit legal definitions on microgrids are still missing [35]. For example, to avoid resubsidies in the local trading and sharing of electricity storage, tariff setting methodology must be rethought [8].

Moreover, EU law does not allow the network operator to produce energy and give customers the right to leave the energy community at any time, which poses a risk for investments in local production [50]. Furthermore, environmental impact assessment may cause a barrier for CHP installation in the urban context [35].

The main barrier to incorporating local and community actors in the emerging energy governance structures and policy delivery mechanisms is the lack of understanding of how they work in the field and how best to support and develop effective local energy governance. There are good examples of collectively owned energy systems, but they often rely on the intellectual capacity of members and enthusiastic leaders, making the formation of the systems coincidental [4]. As the construction and operation of ICESs call for even more expertise, there is a need to find convenient roles for private businesses, such as consultants and contractors in the system. In addition to technological skills and capabilities, a lack of trust among the various actors creates barriers toward the establishment of the system, where a growing number of stakeholders, may cause additional challenges due to a larger area [13]. Koirala et al. [4] claimed that appropriate governing institutions could be established to overcome the barriers and challenges in the design, planning, implementation, and operation of ICESs.

3.2.2. Drivers and Barriers According to the Interviews

It is now possible to analyze the drivers and barriers recognized in our interviews by using the knowledge found in the literature. As discussed in Section 3.2.1., authors had classified drivers, barriers, and issues of ICESs and their sectors into categories, including socio-economic, institutional, technical, and environmental [4]; the economy, reliability, and the environment [35]; and technical, regulatory, financial, and market or stakeholders [8,33–35]. As a synthesis of available classifications, the following analysis discusses entries in Table 1 from the perspective of social acceptance, institutions, economic risk, and regulations. In the analysis, the topic of economic risk involves financial and socio-economic issues, and the issues related to stakeholders and technology are discussed under the subject of social acceptance, following the approach of Maarten Wolsink [49].

Current energy sector stakeholders look at ICESs from the perspective of threats and opportunities. The interviewees and the previous literature recognized that one of the main drivers of ICESs is the economic benefit for consumers by avoiding intermediate parties in local electricity transfer via microgrids (D1.5) [9]. While an ICES improves the attractiveness of building-integrated PVs through a community microgrid, it also advances the potential of peak-load problems (B1.2), but simultaneously provides a peak-shaving solution through flexible demand and energy storage (D1.3, Q1.5) [14,15]. Another threat in an ICES is the acceleration of grid defection via DER self-consumption, which, according to both the interviews and previous literature, is expected to weaken the financial basis of the energy transfer infrastructure (B1.1, B1.2, and Q1.2) [4]. Simultaneously, ICESs also provide economic gains for CHP companies by cutting investments to public energy infrastructure without significantly increasing overall network costs (D1.6, D1.2) [4]. Therefore, local CHP companies were particularly interested in ICESs as a business opportunity regarding the transitioning energy markets (D1.7). Also, building contractors assumed that they could find new business in superblocks-ICES establishment because they already had experience in organizing collective procurement for real estate in new neighborhoods (D2.2). Based on these comments, it seemed that due to technical development, stakeholders accepted the proposed concept of superblock-ICESs. According to Wirth et al. [13], providing final proof on public acceptance would require a survey.

The interviews provided new findings on the issues related to urban planning institutions regarding the implementation of the concept of superblock-ICESs. Due to the objectives of sustainability, planning officials in Hiedanranta, as well as in Barcelona, were active in encouraging stakeholders to adopt the integrative approach (D2.3, D3.1) [51]. In Hiedanranta, this was because the results of co-designing workshops showed that residents desired community-based solutions (D2.4). Despite the good intentions toward superblock-ICESs, practices for implementation are missing in Tampere, which is why the distribution of responsibilities among officials was unclear and the planning process and the almost completed land use plan did not support the establishment of the scheme (B3.1, B3.2, and B2.3). A critical issue for the successful establishment of the superblock-ICES was also stakeholder commitment, thereby calling for universal or separate models on private and municipality-owned land (Q2.2). Regarding the optimal operational area for superblock-ICESs, the interviewees were not able give an estimation (Q3.1), but they advised designing the infrastructure so that it would be easily expandable, maintainable, and adaptable for modular improvements (Q1.6). Because the urban structure is expected to expand over multiple decades, a master plan should enable the expansion of the energy transfer infrastructure so that it is able to function from day one in full scale (Q1.3, Q3.4). Expanding the local grids along with urban structure and providing the main network near the first blocks would support the phasing of the system and modern digital tools would help in the planning of the infrastructure, such as simulation in evaluation and dimensioning (Q1.7) [9] and 3D-modeling techniques regarding the management of land use permissions for underground installations (Q3.2, D1.4).

It was noted in the previous literature that banks' risk aversion may become a barrier for the ICES, especially for niche technologies that may be expensive or underperforming (B1.3) [4,13]. The interviewees in this research also underlined the importance of controlling and predicting energy costs from the perspective of consumer protection when selling a new apartment (B3.3); simulation and planning tools could help with this (Q1.7) [9]. The risks may not only be technological, as the interviewees assumed that an EU directive allowing local inhabitants to leave the ICES any time would pose a financial risk for power-generation investment (B2.1). The interviews also confirmed the previous notion by Valta et al. [35] describing that ICESs face costs from electric grid security-related bureaucracy if they have to procure a medium-voltage connection (B2.5, B1.4, and Q1.1). To overcome economic and financial barriers, the interviewees (B3.4) and Koirala et al. [4] noted that emerging technologies that are expensive in the development phase and energy investments with high upfront costs require public funding or investors with risk-taking capacity.

In addition to economic issues, the current European and Finnish electricity market legislations need to be reformed to clarify the role of ICESs and remove barriers for development. The interviewees noted that specific tariff-setting methodology in ICESs is required (Q2.3), which was discussed in the interviews and also in the previous literature in cases of microgrids [35] and locally shared electric storage systems [8]. It also came up in the interviews that microgrids need new legislation to define the role of the system operator (Q1.4), while Valta et al. [35] concluded that, under existing regulations, the DSO would be a potential operator of microgrids on its own territory. However, regulations that do not allow power generation business for DSOs disable the establishing of ICESs, which is not only the operator of the local grid but also produces and stores energy. (B2.4) [11]. One barrier in Finnish legislation that limits ICES growth potential is the regulation that prevents microgrids from crossing plot boundaries (B2.2) [35], but it was also noted that ICESs are free to operate inside a housing company on one property if electricity is included in the rent or maintenance charge (D2.1). This is why the interviewees discussed the legal issues in establishing a superblock-ICES on one larger plot divided by contracts among owners, which differs from the conventional division into several plots for individual housing companies. As the boundary conditions for ICESs under the current legislation are far from optimal, it is necessary to recognize the unique role of local communities in the electricity market act.

Institutional barriers and questions indicated any "future conflict that may hinder implementation", as expressed in our research question but, as Wirth et al. [13] suggested, they also simply indicated the early niche innovation status of the proposed system. Therefore, the interviews could not clearly answer the research question. Still, the analysis of the interviews provided or confirmed three main drivers and four main issues or barriers that may advance or hinder the development of superblock-ICESs. The drivers were (1) economic benefits, (2) technical development, and (3) objectives of sustainability, and the barriers or issues were (1) missing practices in planning institutions, (2) missing or hindering legislation, (3) social acceptance, and (4) economic risk. The need for simultaneous changes in multiple sectors extending from local planning to the level of EU regulation underlines the complexity of the subject. Technological development could resolve some of the detailed problems, but many questions and issues regarding the legislation and institutions indicate a need for systemic change.

4. Discussion

In the case of Hiedanranta, missing planning practices created a barrier for the implementation of superblocks and ICESs. Despite the objective of a low-carbon circular economy and the positive attitude toward superblocks and smart energy systems in the Hiedanranta development program, urban planners could not form an opinion regarding how the visions should affect the general plan. Also, the district heating planner seemed to be unaware of the planning principles of superblocks and ICESs, which is why the current district heating plan follows traditional principles. This may have led to an infrastructure plan that failed to utilize the potential for a cheaper and simpler district heating network, rather creating inefficient design with overlapping networks. In any case, it is advisable to implement network topology that follows the principles of superblock-ICES, as this does not bring significant extra costs and still allows for the usage of the grid in the traditional manner. Now that the project is already underway, it is high time to start a highly interactive design process between the program level visionaries and implementing planners. To enable smoother implementation of pilot projects, the vision work providing concrete guidelines for design and planning should be a separate phase and scheduled clearly before the design and planning process of the area. The results of this work showed that continuous research to develop neighborhood level planning practices is needed.

Missing and hindering legislation caused the greatest barriers for ICESs to become widespread. The main barrier was regulation in the electricity market act, which caused economic risk originating from the emphasis on customer's choice and denied microgrid extension over lot boundaries. Some of the regulations relating to quality, security, and consumer protection could be unreasonable for local communities but might not cause actual barriers for ICESs. There seems to be a call for additional legislation to notice the potential role of local communities in the energy system while striving for security and whole system benefits without harming the residents. The institutional basis for the legislation could be in a specific company form for locally and collectively owned energy systems that would have the freedom to produce, store, optimize, and distribute electricity on a limited voltage level. An interesting comparison in Finland is the institution of limited liability housing companies ('asunto-osakeyhtiö'), which is a common form of private housing ownership. Such companies are under legislation dating back to 1926. Each share of the limited liability housing company provides the right of possession to the apartment or other part of the building or real estate. The company is responsible for the upkeep of its possessions. Similar legislation could clarify the position of the shareholders of ICESs. Technical, legal, and institutional issues related to the legislation of the new company call for additional multidisciplinary research.

The establishment of new legislation for local energy communities calls for public acceptability, something that scientific proof regarding the risks and benefits of ICESs for national-scale systems could provide. The current Finnish district heating and CHP markets demonstrate that the unpredictable consequences of technical development challenge the current actors. One of the biggest concerns in the sector is that when the capacity of building-integrated PVs and heat pumps improve the degree of self-sufficiency, under-utilization of the district heating system could be caused, making it unprofitable as an investment and leading to grid defection anyway. A solution that could rationalize grid integration is a bi-directional junction, where collective investments through ICESs in industrial-scale heat pumps to increase the temperature of low-grade excess heat could offer efficiency improvements and economic benefits. ICESs could also help to retain the district heating system through cutting network investments because they are only able to cover the main network if the local heating network covers multiple urban blocks, following the concept of the superblock. Ultimately, ICES solutions may contribute to the transition of the conventional district heating systems to a network of local systems, including multiple distributed heat sources, such as geothermal wells supported by the off-site and on-site production of electricity. The optimal solution is still unknown, which is why there is a call for a large enough environmental–economic whole-system simulation on ICESs to verify the benefits of the promotion of local systems in legislation.

5. Conclusions

This paper analyzes stakeholders' interest in and perceptions of ICESs in an urban context and especially as part of a certain planning concept, the superblock, which defines a shared area as a collective development platform in multiple urban issues. In the combined concept of superblock-ICESs, this paper identifies three aspects: (1) The technical system with its own logic in relation to energy economy and regional systems, (2) the community with collective decision-making, which is a fundamental component of any collectively owned asset, and (3) the urban structure that defines the social and physical boundary conditions for the ICES-system.

In previous literature, multiple researchers considered the ICES as a potential concept to provide systemic benefits for energy infrastructure along with promoting the production of DER, but found barriers related to current technology, regulations, financing, and stakeholders. In turn, scientific discussions on the acceptability of superblocks are limited to a couple of papers, despite the broad global effects of superblocks on contemporary urban planning. By asking different key stakeholders in Tampere about the acceptability of the concepts of superblocks and ICESs, this paper investigated and categorized the barriers and drivers with the aim of predicting whether the preconditions were favorable for their successful implementation.

One of the key results of this paper was to present, based on the current body of literature, a combined concept of superblock-ICESs, where the ICESs shared the same geographical limits, social context and possibly common administration with other activities related to living and sustainability in an urban context. The results showed that city planners had a positive attitude toward community-based solutions and that Tampere wanted to seek tools for guiding and encouraging such activities in new areas. Due to the long timespan of urban construction, the plan was noted to be required to enable the superblock-ICES to grow along with urban structure and function from day one. The idea of superblocks was new for multiple interviewees, in particular from the energy point of view, which is why they were unable to give strict opinions about the details, such as scale, possible synergy between different functions, and how to organize the planning systems if a superblock-ICES is desired. The results showed that continuous research to develop neighborhood-level planning practices is needed.

Building contractors were familiar with the establishment of collectively owned infrastructure in new housing areas, including preliminary investments and planning in phases, but if the superblock-ICES raised housing costs, it would be challenging to engage developers in the project. As the contractors cannot carry the whole risk in the development of advanced systems, there is a need for public funding and venture capitalists. Clear technical barriers to ICESs raise doubts regarding the energy economic efficiency of superblock-ICESs and some of their technologies, which is why research and development, as well as simulation, pilot projects, and living labs are needed to reveal the advantages and disadvantages of different options. Better control regarding the technology risks would help local communities achieve financing for upfront costs in an ICES.

Establishing ICESs is already possible in real estate and housing companies if the cost of electricity is included in rents or maintenance charges, but there are doubts on whether it could be acceptable practice to share energy costs. Enabling ICESs, including energy trading inside a community of multiple buildings, calls for a relaxation of the Electricity Market Act on a local level, as currently it tries to guarantee unlimited individual freedom on national markets and does not allow the expansion of microgrids over plot borders. In general, the interviewees reminded us that an ICES should be interpreted as an industrial-scale operator with security and consumer protection-related responsibilities. Legislation that clarifies ICESs' issues related to security, reliability, customer protection, and public interest would enable the concept to become widespread. The institutional basis for the legislation could be in a company form for locally and collectively owned energy systems that have the freedom to produce, store, optimize, and distribute electricity on a limited voltage level.

Public acceptability of the local energy communities would provide preconditions for new legislation. Due to its potential to enhance the implementation of DER and the creation of new local business opportunities, the interviewees of this research saw the ICES as acceptable, but getting any proof on public opinion would require carrying out a survey. From the perspective of a district heating company, the consequences of the ICES are unclear, as it would improve the economy by cutting network investment costs but would simultaneously increase the amount of energy consumed by customers themselves, thereby hindering its demand. Also, there is a risk that ICESs would lead to grid defection anyway. Scientific proof around the risks and benefits of the ICES in relation to public interest would help to justify enabling the legislation.

This research confirmed that the driving forces toward community-based solutions are economic benefits, technological development, and objectives of sustainability, and revealed or confirmed that the main issues or barriers that may hinder the development of superblock-ICESs include social acceptability, missing planning practices, economic risk, and missing or hindering legislation. Considering the interests of stakeholders on ICES-superblock implementation, future research should focus on technical analysis and simulation based on real-life design, development of planning practices, in-depth investigations into administrative models in the context of local jurisdiction, and, lastly, the social dimension and citizen engagement regarding implementation, which all impact the feasibility of the administrative model.

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