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A Socio-Technical Approach for Energy Management in Heritage Buildings: Case of Kopli 93, Tallinn

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"Old ideas can sometimes use new buildings.
New ideas must use old buildings."

Jane Jacobs

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Abbreviations

AI	Artificial Intelligence
ANT	Actor Network Theory
CO_2	Carbon Dioxide
DR	Demand Response
DSF	Demand Side Flexibility
DSM	Demand Side Management
EMS	Energy Management Systems
EU	European Union
ICOMOS	International Council on Monuments and Sites
ICT	Information and Communication Technology
IoT	Internet of Things
LEM	Local Energy Markets
M&V	Measurement and Verification
ML	Machine Learning
PMV	Predicted Mean Vote
RES	Renewable Energy Sources
UNESCO	United Nations Educational, Scientific and Cultural Organization

Abstract

Urban planners today are rethinking how cities can grow sustainably while caring for both people and the environment. This research investigates how sustainable energy management in heritage buildings can contribute to urban development while preserving cultural resilience. Since physical interventions are often restricted in heritage structures, this study explores the potential of energy communities as a workaround to address energy challenges in such contexts. These communities can enhance their capacity for efficient and non-invasive energy management when combined with digital tools. Applying Actor-Network Theory and Commons Theory, the research explored the significance of socio-technical networks in collective and shared resource management of energy. The qualitative method approach comprising of expert interviews and ethnographic fieldwork, is based on the case study of Kopli 93, Tallinn in Estonia, which currently lacks sustainable energy initiatives. The findings reveal that the bottom-up approach and the cultural sentiments among the citizens to preserve the heritage building and gain energy democracy offer a strong potential for establishing energy communities at Kopli 93. Further, the non-invasive tools, like smart sensors or off-site solar parks and behaviour-driven demand-side flexibility, offer a balance between sustainability and preservation.

1. Sustainable Energy Transition of Heritage Buildings

Today the urban planners and dwellers increasingly seek a sustainable and resourceful ecosystem that supports both people and nature (Foster, 2020). Within this context, the urban cultural heritage buildings serve as public or common goods, that preserve the cultural identity for the future (Hosagrahar et al., 2016; Misirlisoy & Günçe, 2016). Beyond a mere building, the heritage carries the potential towards contributing to social and economic development in and around the area (Guzmán et al., 2017). Their underutilization causes urban decay, accumulation of hazards, and rise of criminal activities, thus, diminishing their cultural and architectural values (Bezerra De Sousa & Henriques Da Fonseca, 2022; Jiang et al., 2023; Spelman, 1993). To drive sustainable urban planning, the 'adaptive reuse' (Foster, 2020) and 'retrofitting' (Sedláková et al., 2020) of the heritage buildings offer a unique opportunity to mitigate these negative impacts. The process of redeveloping and repurposing buildings to preserve cultural heritage from deterioration, by following existing standards and requirements, is known as '*Adaptive Reuse*' (Plevoets & Van Cleempoel, 2011). Adaptive reuse is an innovative concept, which fosters reusability of the buildings into 11 headings as: residential, industrial, commercial, religious, military, agricultural, governmental, cultural, educational, health and office buildings (Misirlisoy & Günçe, 2016). Depending on the physical characteristics of the building, such as location, physical dimension and condition, construction material and techniques, the most appropriate new use is decided. Retrofitting of the heritage buildings also give rise to the idea of circularity as this avoids energy-intensive new construction, imparting air-borne particles from demolition, reducing waste, raw-materials consumption and long-distance transportation.

Effective repurposing of spaces with efficient energy transitions can enhance the functionality of abandoned heritage spaces. Numerous studies have been dedicated to reduce the exhaustion of fossil fuels and adopt Renewable Energy Sources (RES) (Thebault et al., 2020). Beyond reducing environmental impact, RES also fosters greater energy awareness and encourages individuals and communities to take responsibility for sustainable practices (Baiani et al., 2023). In the context of urban development, energy optimisation contributes not only to environmental goals but also to urban resilience. Lucchi et al., 2023 emphasizes that the stakeholder engagement contributes to the social and cultural regenerative design at the urban level. This collaborative and participatory energy transition can be seen as part of a broader shift towards an ecosystem of "Urban Commons" (Feinberg et al., 2021). Urban Commons represent the sharing of urban elements or city infrastructures. It creates a sense of shared responsibility alongside, the benefits or losses are also shared by the individual as well as the group-level participants. By integrating the perspective of urban commons, it highlights that heritage buildings are not just fixed assets, but are living social entities that are maintained and redefined through collective use, care, and engagement by communities. In the dimension of energy, this further gives rise to the concept of energy communities. Energy communities are not merely technical solutions or governance models, but potential drivers for the commons. Hence, energy becomes a shared resource, and the heritage building remains embedded within local social and cultural networks. The case of Kopli 93 reflects this intersection: its adaptive reuse is not about turning it into a purely commercial asset, but about exploring how collective energy practices can support its identity as a cultural common.

To address the above, a bottom-up approach has been gaining pace for energy analysis and planning (Klinge Jacobsen, 1998). Among the various energy transition initiatives, the emergence of energy communities is transforming the local energy system (Barabino et al., 2023; Koirala et al., 2016). Energy communities are a group of citizens or local stakeholders who come together to produce, manage and share energy collectively. Based on the principles of cooperation, local ownership and democratic governance, energy communities not only create decentralisation of energy production, but also intend to foster the idea of social cohesion, equal access to energy and environmental stewardship. These systems not only address the challenge of supplying electricity to remote areas, but also respond to growing energy demand, promote regional self-sufficiency, and contribute to sustainability goals (De São José et al., 2021).

Recent developments in digital technologies have created numerous pathways for these communities to operate in an efficient and inclusive manner. Technological innovations like smart meters, sensors, building automation systems and data-driven platforms are now able to monitor, optimise and coordinate the energy usage, through real-time data. With the effective implementation of these tools, a nuanced energy management strategy has been developed, named Demand Side Flexibility (DSF). DSF is the ability of users to adjust their energy consumption patterns in response to grid and pricing signals (high or low), and environmental conditions (Jäntti et al., 2022). By shifting energy use to off-peak hours or using energy that was generated from RES, like on a sunny morning, DSF can help stabilise local energy systems and reduce overall emissions.

This paper focuses on the case study of a heritage building from Tallinn, Estonia, named Kopli 93. Through further exploration this research intends to explore the potential of forming energy communities at Kopli 93 and the ways of leveraging modern digital technologies by such communities that can enable a sustainable and flexible energy management in the heritage buildings. At the intersection of these issues lies the concept of

DSF, where the users can shift or reduce energy consumption in response to external signals such as price or grid demand. Through the qualitative methods of expert interviews and thematic analysis, and ethnographic fieldwork, this research highlights how digital tools like smart meters, sensors, and energy management platforms can empower communities to adopt DSF practices, even in settings with strict physical constraints. The paper aims to uncover not only the technical possibilities but also the social and institutional conditions needed to support such transitions.

1.1 Problemetisation and Research Gap

Repurposing of heritage buildings presents a complex challenge of delicately balancing historical preservation with modern sustainable demands (Mehanna & Mehanna, 2019). The fragile nature of original building materials poses a risk, as any structural alteration has the potential to compromise the cultural integrity or aesthetic of the original version. These buildings were formerly the kinds of factories, castles, harbours or ports. Till today they retain the legacy energy equipments and are not suitable to support the contemporary energy-efficient systems. Hence, the architecture, construction materials and electrical infrastructure are often not compatible with the modern standards of energy transition (Jiang et al., 2023). Efforts to retrofit these structures are hindered by regulatory restrictions and technical limitations on deploying renewable energy and digital technologies for automation and monitoring (Dauda & Ajayi, 2022). Such constraints are required to be addressed by innovative solutions, interdisciplinary collaborations and a suitable framework to harmonize and proceed towards a sustainable energy transition.

(Barnes et al., 2022), claim that integrating digital technologies with the energy communities have distinct capacity to develop demand-side solutions and flexibility. To keep pace with the recent transformations, the energy sector itself is undergoing significant change. Driven by technological innovation, the climate crisis, and the urgent need to transition away from fossil fuels, the sector is experiencing a fundamental shift in both how energy is produced and how energy systems are organised. This shift is marked by a move toward decentralisation, where large, centralised systems are increasingly replaced by smaller, distributed generation units. Among the most notable developments is the rise of small-scale and community-based renewable energy systems. Perhaps just as importantly, they foster greater public awareness and engagement, empowering individuals and communities to take a more active role in shaping their energy futures.

The unique context of such spaces often involves diverse stakeholders—owners, employees, customers, and conservation authorities—each with differing priorities and perceptions of energy use. Electricity today is considered a social necessity (De São José et al., 2021).

A basic requirement for repurposing heritage buildings is to enable access to reliable electricity, which is essential for ensuring comfort, powering appliances, and supporting the everyday functions. Further, it aligns with the principles of resource efficiency, waste reduction, and the extension of building lifespans (Foster, 2020). Without proper planning and action, these structures deteriorate or get demolished. Both of these scenarios contribute to material waste and carbon emissions. Their adaptive reuse supports sustainability by maximising the value of existing infrastructure. Operationalising the abandoned buildings, based on different utilities, like commercial, cultural, hospitality, or educational purposes, not only ensure continuous economic activity but also fosters community engagement. This strategy develops them into viable hubs for energy communities.

While current research on sustainable energy transitions emphasises technological solutions, it often overlooks the complex interplay between diverse stakeholders, technologies, and institutional frameworks that shape the ecosystem of local energy initiatives. Further, the influence of historical and cultural significance on stakeholders' attitude and decision-making regarding heritage buildings remain underexplored. The lack of a clear and integrated framework that bridges the smart technologies and community-driven approach, limits the heritage buildings' potential for adaptive repurposing into commercial spaces. As a result, they end up abandoned, underutilised and a burden for the urban development initiatives, as in the case of Kopli 93. Kopli 93 does not enrol in sustainable energy practices, and hence does not involve any energy communities. Deeper exploration and research is essential to pay equal importance to both technological as well as social representative factors to maintain circularity.

1.2 Research Goal

The case of Kopli 93 provides a valuable opportunity to examine the intersection of cultural heritage, digital innovation, and community participation, as they do not have any form of sustainable energy management strategies in place. This also implies that no energy communities have been formed to introduce RES into reimagining the building. This research offers new insights into the basic requirements and motivations of forming an energy community. This will highlight the ways that will meaningfully contribute to the energy transition through technological innovation, coupling with cultural and architectural heritage. It deepens our understanding of how the varied range of human and non-human actors come together to overcome the constraints of protected buildings and contribute to sustainable urban futures. At the same time, it discovers the broader social and institutional value of participation through community-led efforts, inclusive governance, local ownership, sharing energy, and capacity building for renewable energy solutions. Some challenges are also highlighted, especially related to legal, financial barriers and digital literacy, which can hinder the process of implementing the solutions. Hence, the research offers theoretical and practical insights from scholars, practitioners, and engineers for energy transition that are sensitive to historical contexts and driven by community engagement.

1.3 Research Questions

1. What is the potential for building an energy community to support the sustainable reuse of the heritage site at Kopli 93?
   1.1. How can energy communities integrate digital technologies for better energy management in heritage buildings?

Building on the research questions outlined above, the structure of this paper is organised as follows. The next chapter presents a review of the existing scientific literature that forms the foundation of this study. Chapter 3 outlines the theoretical framework guiding the research, followed by a detailed explanation of the methodology in Chapter 4. Chapter 5 introduces the case study of Kopli 93 in Tallinn, providing background on its history, the state-of-the-art in community engagement and the innovation projects for reviving the site. The findings are presented in Chapter 6, structured around the two research questions and analysed through the lens of the theoretical framework. The paper concludes with a discussion of key insights in Chapter 7, followed by the conclusions and suggestions for further research in Chapter 8.

2. Literature Review

The following section provides a comprehensive overview of the existing literature that forms the foundation of this research. Beyond offering a thorough research background, this chapter serves as the basis of developing the theoretical framework, data collection and analysis. The literature review was conducted through iterative exploratory stages. This ensured the inclusion of all the relevant themes through structured and dynamic assessment of the existing relevant literature. Furthermore, the review also highlights the identified gaps, challenges and opportunities among the multifaceted thematic areas. With proper synthesis, the reader can understand the relevance and urgency to explore innovative approaches towards inclusive urban sustainability.

Applying a thematic approach, this section is structured around the interrelation of key themes and concepts relevant to the study. By organising the literature in this way, the review ensures a comprehensive and coherent exploration of diverse yet interconnected aspects of sustainable urban development. This research integrates multiple perspectives on sustainable urban planning, energy management, smart technologies, community engagement, and demand response, recognising their collective role in shaping resilient and efficient urban ecosystems. Such themes are examined to highlight how socio-technical capabilities can be leveraged to foster innovation, sustainability, and inclusivity in urban environments. By synthesizing insights from these domains, the review establishes a strong theoretical foundation for analyzing how integrated urban systems can drive sustainable transformation.

As this research developed, the literature was continuously updated and refined to reflect into the key themes. The chapter is organised accordingly, to ensure a logical storytelling from broad foundational concepts to narrowed and focused discussions. Followed by the introduction to energy management for adaptive reuse of heritage buildings, the literature review sheds light on the emerging digital technologies. This section delves deeper into the implementation of various smart technologies like Artificial Intelligence (AI), Machine Learning (ML), Internet of Things (IoT), and smart grids in the energy sector. The second part of this chapter focuses on the role of energy communities, hence the social aspect of this research. Lastly, it presents an outline of the approach to cumulatively implement the mentioned themes into the concept of demand-side flexibility. Hence, providing a socio-technical approach to address the research objectives that builds upon the existing literature.

2.1 Energy Management for Adaptive Reusability in Buildings

With the rapid growth in urbanisation, the demand for energy in urban areas is constantly rising. Especially, the buildings for commercial and industrial use are major consumers of energy (Alijoyo, 2024). The buildings consume significant amounts of raw materials and energy. This accounts for more than 40% of global energy consumption and 36% carbon dioxide emissions leading to almost one-third of global greenhouse gas emissions (UNEP, 2009; Vujkov et al., 2020). Further, research shows that over 75% of the buildings are energy-inefficient (European Commission, 2024). Adaptive reuse offers a pathway to bypass the wasteful process of demolition and reconstruction for heritage conservation to address sustainability goals. There is an increasing need for sustainable energy practices in the buildings. Douglas, 2006, broadly defines adaptive reusability as an intervention within a building to change its capacity, function or performance to reuse or upgrade a building with a new purpose. This process extends the lifespan of buildings, reduces demolition waste, and promotes the reuse of embodied energy systems, simultaneously delivering significant environmental, social, and economic benefits (Ulu & Durmuş Arsan, 2020; Yung & Chan, 2012). Enabling energy systems is at the core of reviving any building (De São José et al., 2021). Utilising energy from renewable energy systems such as solar panels and wind turbines can significantly reduce their carbon footprint and enhance energy efficiency in the heritage buildings.

Hence, the European Union (EU) has established new regulations for public buildings to increase energy efficiency (Vujkov et al., 2020). As part of such regulations, the EU member states are targeted to achieve at least 32% of total energy production by the RES (Directive-EU, 2018). Currently, the RES plays an important role in sustainable energy production in public buildings, as compared to conventional power plants.

The focus on the reusability of the embodied energy systems within the heritage buildings is essential in addressing the social, economic and environmental needs (Lidelöw et al., 2019). Additional to the three aforementioned needs, researchers have added a fourth component which is political-institutional (Chan & Yung, 2004; O'Connor, 2006; Shen et al., 2011). Further, (Yazdani Mehr & Wilkinson, 2018), points at understanding the existing energy system and design as the energy interventions might slightly damage the heritage value of the building. ICOMOS (International Council on Monuments and Sites) advocates for adaptive reuse to conserve heritage while enhancing building functionality. The Climate The Climate Transparency Report, 2020 emphasises the need to halve global building emissions by 2030 and achieve an 80-85% reduction by 2050. The adaptive reuse of heritage buildings contributes significantly to this goal, indicating 29% of CO2 emissions reduction by 2030 (Gregório & Seixas, 2017). Summarising the previous research findings, enhancing energy efficiency in historic buildings preserves resources and aligns with sustainable development objectives, integrating environmental, social, economic and political dimensions.

2.2 Smart Technologies in Energy Sector

Introduction of smart technologies has led to digital transformation in the energy sector. These technologies aim to improve efficiency in energy consumption patterns. Küfeoğlu et al., 2019 defines digitalisation of the energy sector as 'the creation and use of computerised information and processing of the vast amounts of data which is generated at all stages of the energy supply chain' (p.1). While Kuzmin et al., 2024 specifies the rapid integration of the Information and Communication Technologies (ICTs) in the buildings for energy transition. The digital technologies are the integral part for developing smart grids, which are powered by RES (Saqib et al., 2023). The combination of the data generated, smart technologies and the digital infrastructure creates a bidirectional communication to improve the demand-supply efficiency. The deployment of smart energy infrastructure offers flexibility in the energy demand response. Researchers have particularly emphasized on Smart Grids, IoT devices, AI, Machine Learning (ML), advanced energy management platforms and data analytics, to monitor and optimize the energy use of the heritage buildings (Bayindir et al., 2016; Kuzmin et al., 2024; Luo et al., 2024; Murshed et al., 2021; Raza & Khosravi, 2015). Building on this foundation, smart energy management has the potential to optimize energy production, distribution, consumption. Such practices will enhance efficiency, cost-effectiveness and sustainability (Pandiyan et al., 2023).

Building Energy Management Systems (BEMS) effectively manage and monitor the energy use in buildings. Equipping the heritage buildings with smart meters, sensors, IoT devices and smart thermostats can transform it into a smart building. The installation of the smart devices are simple and does not cause any significant wear-and-tear of the existing features (Mehanna & Mehanna, 2019). According to Agostinelli, 2024, digitalization:

1. Bridges the scales of built environment: Data flows seamlessly from individual components to building-level information and urban planning;
2. Collaboration among stakeholders: Enhances interoperability and cooperation among designer, construction teams, end-users, optimising building and community management;
3. Trust and transparency: Data-driven analytics improve decision-making and create transparency in the building and urban ecosystems.

The smart devices generate energy related data from the buildings, which they integrate and analyse, uncovering their consumption, production or storage patterns. The data is also gathered from various sensors, weather forecasts and occupancy schedules to optimise energy performance. With the help of these patterns, the flexibility in the energy utilisation can be identified, fostering the idea of demand side flexibility (Reis et al., 2020), which has been further elaborated towards the end of this Chapter. For example, scheduling the EV charging or doing laundry during not-so peak hours, or storing excess energy in the batteries or selling it to the central power grid or energy communities. This also introduces the possibility of incentivizing the energy produced locally, making them the 'prosumers' (Sawyer, 2022). The community prosumers are the members who collectively generate and store energy and establish Power Purchase Agreements (PPA) with energy suppliers. The surplus energy is sold, and additional power are distributed within the community borders, creating Local Energy Markets (LEM) (F.G. Reis et al., 2021; Koch & Christ, 2018). This not only enhances operational efficiency but also reduces environmental impact by balancing the grid load.

Digital technologies are increasingly recognised as key enablers in the transition to more local and collaborative energy systems. IEA, 2017 highlights how tools like smart meters, IoT devices, and AI-based platforms help optimise energy flows, support demand-side flexibility, and engage users in more responsive ways. However, these technologies do not operate in isolation. They are embedded within socio-technical systems, where human behaviours, institutional settings, and cultural values shape how they are adopted and used. This interrelation among the network of actors (human and non-human) has served as the framework for this study and is discussed in the later chapter. Strzelecki et al., 2024 emphasise that smart home technologies are most effective when they are accessible and socially meaningful, helping individuals and communities shift their energy behaviours over time. In the sections below, the interrelations between digital tools and energy communities highlight the socio-technical strategy to support sustainable energy management in built spaces.

2.2.1 Artificial Intelligence

Artificial Intelligence has significantly transformed energy management in buildings through advanced optimisation, predictive analytics, and integration with emerging technologies. AI algorithms enable dynamic control of Heating, Ventilation, and Air Conditioning (HVAC) and lighting optimisation to reduce reliance on the power grid. These adjustments are made based on occupancy pattern, and the integration of renewable energy sources (Nicol & Humphreys, 2002; Shaikh et al., 2014). A key subset of AI is machine learning, which learn patterns from historical data and use real-time inputs (Haq et al., 2022), such as weather conditions and occupancy levels to predict and adjust energy needs. Such processes enhance these capabilities to optimize energy usage while maintaining a continuous occupant comfort.

The modern smart buildings rely on Fanger's Predicted Mean Vote (PMV), which defines an occupant's desired thermal comfort zone with the range of -3 (cold) to +3 (warm), with 0 being the comfort point (Ahsan et al., 2024; Asakawa & Takagi, 1994). To analyse thermal comfort, there are two types of models: (1) stationary models (2) adaptive models. Fanger's model is based on stationary models, which states that the human body balances its thermal comfort depending on the surrounding environment of the building. Parameters such as (1) air velocity, (2) radiant temperature, (3) air temperature, (4) relative humidity, (5) clothing insulation, and (6) metabolic rate are crucial to calculate the PMV Index (Lala & Hagishima, 2022). However, the adaptive models emphasise on the occupant's capability to alter the indoor environment conditions, such as opening or closing the windows for ventilation (Mosallaei et al., 2023; Yao et al., 2022). Drawing from the concept, AI has created a convincing model for optimizing building load usage and predictive controlling in energy management. Researchers have further drawn commonalities between thermal comfort and energy management as depicted in Table 1. In both cases, considering the parameters like outdoor/indoor air temperature, humidity and Carbon Dioxide (CO_2) levels can be used to train and better develop AI models.

Energy Management Model Parameters	Occupant Comfort Model Parameters
Outside temperature	Outdoor temperature
Supply duct temperature	Room temperature
Outside humidity	Outdoor humidity
Room carbon dioxide	Room carbon dioxide
Room humidity	Room humidity

Table 1. Similar parameters between energy management and thermal comfort. Source: Ahsan et al., 2024

AI deploys predictive analytics to efficiently forecast energy demand by leveraging data from smart devices and advanced algorithms. These insights enable real-time adjustments that optimize the use of renewable energy sources, reduce energy waste, and enhance overall grid performance. By anticipating consumption patterns and aligning them with generation capacity, AI supports a more resilient and sustainable energy infrastructure.

2.2.2 Internet of Things

The term "Internet of Things (IoT)" was first introduced in 1999 (Ashton, 2009), and has been interpreted in numerous ways. Over time, it has been described as a network (Gubbi et al., 2013), a paradigm (Butgereit et al., 2011; Ning & Liu, 2012), a concept (González et al., 2008), an Internet-based application (Huang & Li, 2010), and even as a global network infrastructure (Oriwoh & Conrad, 2015; Vermesan & Friess, 2022). In the current literature, IoT has been defined as the group of infrastructures, and/or sensors interconnecting various devices that generate data, and allow their management and data mining (Dorsemaine et al., 2015). In terms of application, IoT is changing how buildings manage energy by making it possible to monitor and control systems like HVAC, lighting, and appliances in real time. With sensors and connected devices, IoT enables automatic adjustments based on actual usage and conditions, helping reduce energy waste and improve efficiency. This kind of smart energy management is especially valuable as buildings aim to become more sustainable and responsive to occupant needs.

One powerful feature of IoT is its ability to support predictive analytics. By combining data from sensors with machine learning (a subset of AI), IoT systems can develop patterns and environmental conditions, like weather and occupancy, to forecast energy needs (Shah et al., 2019). This allows buildings to adjust heating, cooling, and lighting in advance, saving energy while maintaining comfort. Some systems even use renewable energy sources, like solar or wind, to power the sensors, making the setup more sustainable and reducing the need for wired infrastructure.

However, despite the growing potential of IoT, its current deployment in buildings remains limited (Poyyamozhi et al., 2024). While many buildings are equipped with basic temperature regulation systems, only a sub-group have fully integrated HVAC systems. Within this sub-group, an even smaller percentage incorporates smart sensors, and fewer still integrate these sensors into comprehensive IoT ecosystems. This gap is particularly pronounced in non-residential buildings, such as public institutions, government facilities, and service buildings, many of which are housed in historic or monumental structures that lack modern HVAC infrastructure altogether. These physical and structural constraints make large-scale retrofitting costly and technically challenging, highlighting the need for minimally invasive, flexible, and cost-effective solutions—an area where IoT technologies excel.

Among the many technical advantages of IoT in this context, three features stand out (Cano-Suñén et al., 2023). First, the cost of IoT deployment is minimal when compared to the economic burden of full-scale building retrofits. Second, modern wireless IoT technologies offer high functionality with a low number of sensors, and many operate independently for years, even when powered by photovoltaic batteries, without requiring wired power or communication infrastructure. This allows sensors to be easily mounted on surfaces such as walls, windows, or ceilings with negligible impact on the building's structure or heritage value. Third, IoT ecosystems are mature and once installed, typically demand very little maintenance while delivering reliable, real-time performance data that accurately reflect the operational state of the building.

IoT also facilitates demand response capabilities, allowing buildings to engage in grid-interactive operations. Through two-way communication with the power grid (Mandic-Lukic et al., 2016), smart buildings can adjust their energy consumption during peak demand periods, participate in utility-driven load shedding programs, and even return excess power generated from on-site renewables back to the grid. This not only improves the stability and resilience of energy infrastructure but also offers financial incentives to building operators (Rojek et al., 2025).

Integrating IoT into energy management offers major benefits in reducing carbon emissions and reliance on fossil fuels. It can reduce energy use by up to 30% through automation and smart control, and lower operational costs by up to 20% with predictive maintenance (Poyyamozhi et al., 2024; Ravichandra et al., 2024). However, there are challenges. High upfront costs, concerns about data security and privacy, as IoT systems collect large amounts of sensitive data, can discourage adoption (Gupta & Quamara, 2020). Finally, connecting different IoT devices and systems can be technically complex, especially in older buildings (Arun et al., 2024).

Figure 1 below illustrates how the systems and network infrastructure (Future Internet) and the IoT form the backbone of an interconnected digital ecosystem that supports various smart domains (Vermesan et al., 2011). By enabling seamless communication between devices and systems, these technologies drive innovation across areas such as energy, health, buildings, cities, transport, and daily living. The image highlights the integrated nature of these smart systems, emphasizing how digital connectivity enhances efficiency, sustainability, and quality of life in a rapidly evolving technological landscape.

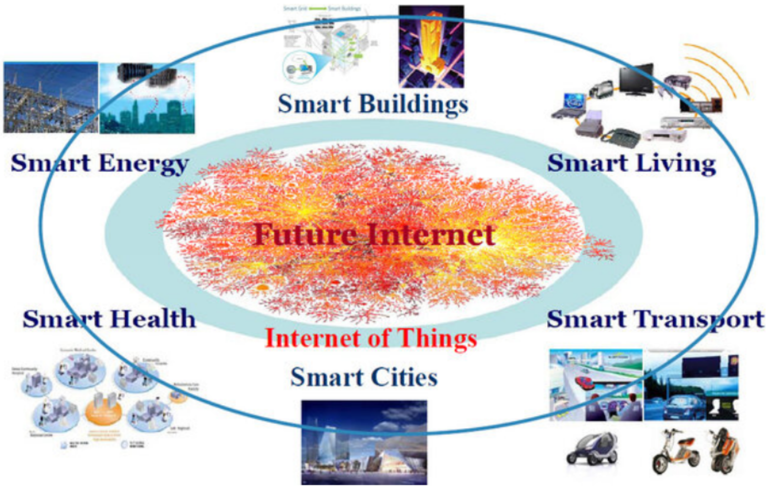

Figure 1. Visual representation of IoT, Source:Vermesan et al., 2011

2.2.3 Smart Grids

Smart grids represent a transformative evolution in energy management systems, particularly within building infrastructures. It includes a network of advanced technologies such as AI, IoT, and renewable energy systems, ensuring efficient and reliable energy delivery and management (Gungor et al., 2011; Kim et al., 2019). It uses ICT and real-time data to employ advanced algorithms. Smart grids enable two-way information flow, thus facilitating demand-side management, optimising energy consumption, and integrating renewable resources effectively (Kim & Lim, 2018; Olatunde et al., 2020). Information is sent from the central utility to the smart devices of the consumers about the load and price signal. In return, the data generated from the smart devices are also sent to the utility to capture consumption patterns.

With the integration of renewable energy systems such as photovoltaic solar panels, wind turbines in the smart grid systems, the buildings can reduce reliance on conventional energy sources. The Energy Management Systems (EMS), incorporate smart grids to deal with unexpected changes-like unpredictable energy demand, fluctuating electricity prices, and sudden grid load. Accurate modelling of the devices ensure robustness of the EMS, as they effectively deal with the uncertainties. Maintaining the convenience and comfort of consumers by optimizing the overall energy consumption is also a significant characteristic of the EMS.

The reliance over RES, however, can cause a significant mismatch between the demand and supply of the energy, making the operation asynchronous (Märzinger & Österreicher, 2020). To address such a challenge, smart solutions are the key. Strategies like demand-response

(DR) strategy and energy storage systems are gaining pace. The traditional grid systems, with centralized energy market, is making a shift towards decentralized and smart grid systems. These systems incorporate RES, through coordinated DR to amplify the benefits.

When multiple buildings are aggregated for cooperative energy management, they can collectively shift loads, share energy systems, and significantly improve energy efficiency. Research on microgrids with the integration of the renewable systems, confirm the importance of demand response techniques to maintain system stability and optimise performance (Hakimi et al., 2020). Building on this foundation, decentralised storage and peer-to-peer (P2P) energy trading are gaining recognition as powerful tools for deepening community participation. Moreover, peer-to-peer (P2P) energy trading allows energy consumers and prosumers (those who both consume and produce energy) to store and exchange surplus energy directly. This reduces reliance on large-scale utility grids and encourages wider adoption of renewables (Zhang et al., 2018).

These emerging models of decentralised energy exchange not only empower users but also raise important questions about fairness, access, and system design. As communities actively begin to share energy and infrastructure, issues of equity and benefit distribution become more noticeable. For instance, fair distribution of economic benefits, between the central heat plants and consumers remains challenging. There may occur several hidden costs or benefits for the central energy suppliers in contrast to the consumers. Comparative studies show that no single energy-sharing model can be universally applied. Each must be tailored to its specific technical, spatial, and social context. This underscores the need for mathematical and systems-based optimisation approaches to guide the design of inclusive and sustainable future energy systems.

2.3 Role of Energy Communities

With the evolving trends of decarbonisation, digitalisation and decentraisation, often referred as the 'three Ds- the energy sector is undergoing significant transformation (Di Silvestre et al., 2018; P. Hansen et al., 2022). The UNESCO (United Nations Educational, Scientific, and Cultural Organization) Recommendation on Historic Urban Landscape promotes "conservation through transformation," emphasizing the involvement of local communities in managing urban changes (Arfa et al., 2022). The urgency to shift towards low-carbon and renewable based systems, the importance of people-centred systems is growing, adding a fourth 'D': democratisation. Hence, the role of energy communities comes to play a role in this development.

Energy Communities (ECs) are a relatively new concept, that was introduced in the EU Clean Energy Package (CEP) (European Commission, 2020). The European Commission defines ECs as a legal entity, where the members or shareholders of the community actively participate at any stage of the supply chain in the energy building process, mostly due to environmental or social reasons (European Parliament, 2022; Kupiec, 2018; Lode et al., 2022).

The transition to ECs has been studied from differing perspectives and varying emphases. Wolsink studied the social acceptance of the smart grid as common-pool resource. While (Walker & Devine-Wright, 2008) explored trust and sense of community in renewable initiatives, and (Wirth, 2014) shed light on the institutional conditions necessary for the development of such initiatives. Brummer, 2018 and Berka and Dreyfus, 2021 offer comparative reviews, uncovering common factors that help or hinder the development of energy communities (ECs) across different times and places.

Energy Communities was conceptualised by the combination of two separate ideas: community energy and local energy (P. Hansen et al., 2022). Community energy focuses on active citizen involvement, with open and inclusive processes aimed at benefiting the local community (Devine-Wright, 2019; Walker & Devine-Wright, 2008). Such energy initiatives have a long history in Europe and have expanded especially in Germany, the Netherlands and the UK in the past decade (Bauwens et al., 2016; Oteman et al., 2014; Seyfang et al., 2013; Wierling et al., 2018). The national policies of these countries have a major role in their growth, as they actively support the emergence, implementation and committed volunteers towards renewable energy (Hewitt et al., 2019; Nolden, 2013).

According to EU legislation, there are two types of energy communities: Renewable Energy Communities (RECs) and Citizen Energy Communities (CECs) (Biresselioglu et al., 2021; P. Hansen et al., 2022). While the two communities are related, yet they differ in their ways of operation and purpose. RECs and CECs have a similar governance model based on open and voluntary participation from the citizens, local governments and start-ups. Additionally, both emphasizes on creating socially and ecologically sustainable benefits rather than focusing on financial profits (Caramizaru & Uihlein, 2020). However, there are also key differences. RECs are bound to specific location, while CECs are not limited by geography. Further, RECs are limited to the usage of only renewable energy and related technologies, CECs can use any energy and technology, exclusive for the electricity sector (Biresselioglu et al., 2021; Caramizaru & Uihlein, 2020).

From the literature, it can be summarised that energy communities are reshaping how energy systems function by blending social, technological, environmental, and economic goals. Despite differences in structure and scope-such as that between RECs and CECs-they share a commitment to citizen involvement and local empowerment for achieving a more just and sustainable energy future. With the advancement of smart grid technologies, these communities are no longer passive consumers but active participants in a two-way communication with the grid, as described below.

1. Grid to Communities: During peak hours, the grid can signal energy communities that the load is too high, and prices will rise accordingly due to increased energy demand. This situation places immense pressure on central grids and contributes to greater greenhouse gas emissions (D'Ettorre et al., 2022). In response to such load or price signals, energy communities are incentivised to adopt flexible consumption patterns, like shifting or reducing usage during high-demand periods, or to rely more heavily on locally generated renewable energy. This not only alleviates grid stress but also promotes a more sustainable and decentralised energy system.

2. Communities to Grid: The communities, in turn, can also sell their surplus energy, generated from renewable sources such as solar or wind, back to the grid. This fosters a sense of empowerment, autonomy, and responsible energy usage among local stakeholders (Smart Energy Europe Report, 2024). By becoming active participants in the energy market rather than passive consumers, communities take ownership of their energy future. This collaborative, bidirectional approach not only helps stabilise grid loads and prevent power outages but also significantly reduces greenhouse gas emissions. At the same time, it cultivates a deeper sense of purpose and engagement within energy communities, reinforcing their role as vital contributors to a more resilient and sustainable energy ecosystem.

Moving beyond the governance and participatory dimensions of energy communities, recent academic work has increasingly focused on their role in addressing issues of energy poverty and energy democracy (Wahlund & Palm, 2022). By enabling local participation, energy communities align closely with the goals of energy democracy, which emphasises fairness, inclusion, and a bottom-up approach in the energy transition. Given its significance toward decentralisation and equal access to energy, this concept is further explored in the subsequent sections.

2.3.1 Energy Poverty and Energy Democracy

Energy poverty can be defined as inadequate access to basic energy services that provide warmth, cooling and lighting with a decent standard of living and thermal comfort, disturbing the physical and mental health (EPAH, 2021; P. Hansen et al., 2022). The report on energy poverty from the European Commission 2022, recognises three underlying causes of this deprivation: a high proportion of household expenditure spent on energy, low income, and low energy performance of buildings and appliances. The numbers of those at risk have risen considerably after the COVID-19 pandemic and the Russian invasion of Ukraine, to around 125 million people unable to afford indoor thermal comfort (European Parliament, 2022).

Kanellou et al., 2023 claim that empowering citizens to be part of the energy transition can ensure a just and inclusive transition. Bottom-up, citizen-led solutions promote energy democracy, which is essntial to tackle energy poverty. Often, the technologies, policies, and plans remain abstract for the citizens, creating difficulty for many to perceive and understand their role in the process. Through collective energy action, new pathways can be determined to produce or access energy- renewable energy sources - enabling the citizens to understand their role in the energy transition. For example, they can shift their dependency from the traditional retailers to community or self-generated renewable energy systems, as a source for electricity. The collective energy actions involve citizens as prosumers and/or communities through active participation in energy systems. They promote community leadership with social and environmental sustainability by driving innovation and gaining public support. Such steps introduce the concept of energy democracy, allowing them to redefine their role in the energy market.

The idea of energy democracy emerged from social movements and civil society groups (Berthod et al., 2023). They recognised the shift from fossil fuels to renewable sources, as an opportunity to revise the means of control over energy production and distribution (Strachan et al., 2015). It was also viewed to bring about economic and socio-political transformation in the energy sector (Burke & Stephens, 2017). Energy democracy allows the active involvement of new actors, such as prosumers, people who both use and produce their energy, energy cooperatives, social enterprises etc. Becker and Naumann, 2017; Szulecki, 2018, points to some essential feactures of energy democracy: (1) decentralisation of energy systems, (2) engagement of citizens in the decision-making process, (3) collective (public and cooperative) ownership, (4) sharing economic benefits associated with energy activity, and (5) self-determination and alternatives to extractivism processes. Researchers like Hess, 2018; Teron and Ekoh, 2018 further mention that energy democracy aims at fixing unfair energy policies by improving access to energy for the marginalised communities. With growing interest in reclaiming public control over energy systems, the stakeholders aim to shift from a centralised and authoritative approach to a transparent and fair energy system, ensuring sustainability (Angel, 2016, 2017; Blanchet, 2015).

However, the more they aim for accountability and participation, the higher are the levels of challenges they face (Berthod et al., 2023). This is due to the completely different approach from the uniform or centralised government or business-models. Instead the projects dealing with energy democracy, bring on board a varied range of actors and organisations, increasing the complexity levels (Bauwens & Devine-Wright, 2018; Heldeweg & Saintier, 2020; Rogers et al., 2008).

In summary, energy democracy offers a way to make energy systems more fair, inclusive, and locally controlled. Energy democracy operates on the principles of collective ownership, equitable resource management, and treating energy as a shared commodity, which aligns with the framework of commons theory and has been described further in the next chapter. While it brings opportunities for social and environmental change, it also comes with challenges due to its complex, collaborative nature. Its success depends on strong community participation and supportive political and legal systems.

2.4 Demand Side Flexibility

With increasing attention from the fields of both industry and research, optimising energy management through the lens of the demand side of the energy systems has gained pace. Demand side management (DSM) offers innovative measures to reduce grid load and maintain the energy systems by addressing the consumption patterns (Palensky & Dietrich, 2011). This shifts the classical unidirectional, top-down operation of traditional electric grids to a bottom-up approach among the energy community. DSM encourages distributed energy generation, which facilitates the consumption of locally generated energy, supporting the central grid load.

The Demand Response strategy is an energy management tool that focuses on the demand or user-side of the electricity system, rather than the supply or electricity generation side of the system (Aljabery et al., 2021). Its primary objective is to modify and optimise the energy consumption patterns of the consumers, that offers a flexible and cost-effective approach to manage and reduce central-grid load. By encouraging users to shift, reduce, or control their energy demand, especially during peak hours, causing high price periods, demand response contributes to grid stability. Moreover, it allows consumers to actively participate in energy markets, either by reducing their electricity costs or earning incentives or profits for their responsiveness and flexibility. Palensky and Dietrich, 2011, categorises DSM into the following based on customer processes:

- Energy Efficiency (EE): Permanent changes to inefficient devices or equipment, deliver immediate and sustainable energy savings, contributing to reduced emissions.

- Time of Use (TOU): TOU tariffs incentivise the customers to adjust their energy consumption pattern by imposing high rates during the peak-hours (e.g. 5:00-7:00 PM). By shifting the usage to off-peak hours, DSM enhances reliability, reduce costs, and lower the emissions.
- Demand Response (DR): Enables rapid adjustments to energy consumption in response to the signals from Distribution or Transmission System Operators (DSO/TSO). Signals such as price updates, load-shedding/shifting, commands to address the grid load emergencies, and can be anticipated in advance.
- Spinning Reserve (SR): SR represents the additional energy generation capacity from the power systems. By increasing the energy production from the generators, the system's stability during peak-hours or emergencies can be addressed.

Further, Aljabery et al., 2021 pointed to the classification of demand response as presented in the Figure 2 below:

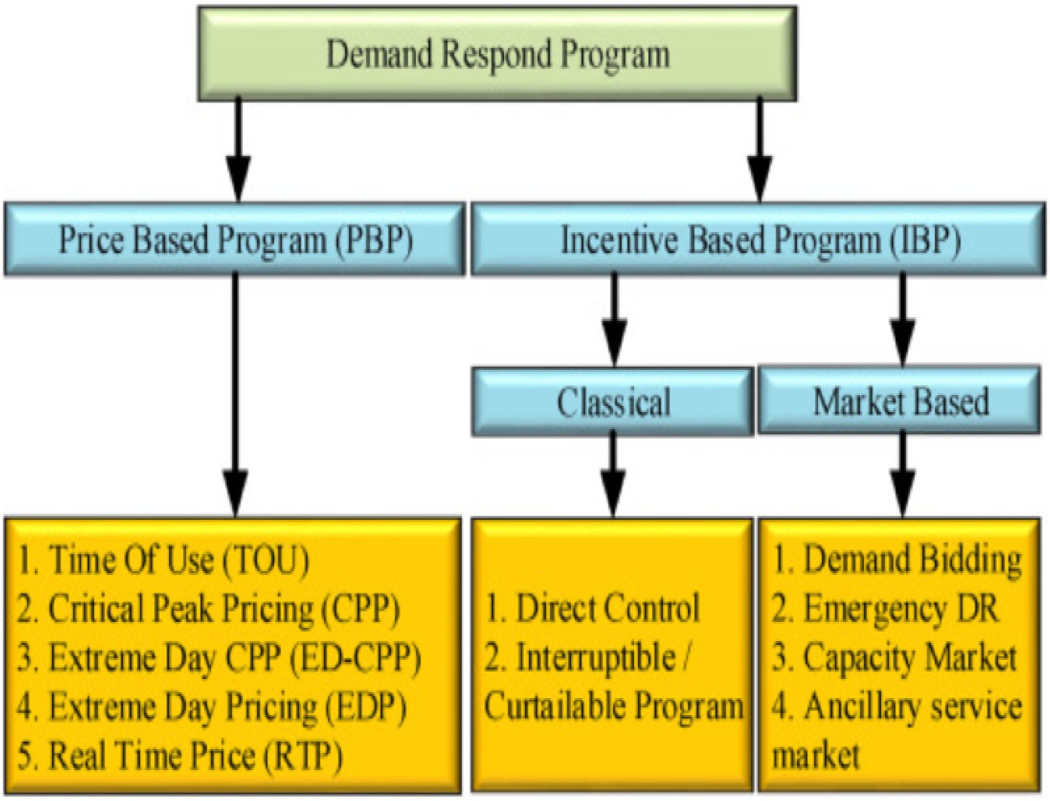

Figure 2. Classification of Demand Response Program. Source: Aljabery et al., 2021.

Primarily, the programs can be divided into two main types: (1) Incentive-Based Programs (IBP) and (2) Price Based Program (PBP). Under IBP, consumers are financially rewarded for adjusting or cutting their electricity usage in response to specific requests or agreements from the utility. This form of DR typically involves a contractual agreement between the consumer, what are typically large commercial or industrial users and the utility, grid operator (Asadinejad & Tomsovic, 2017). Usually, when the central grid is under stress, high price signals or in case of an emergency, participants are notified and asked to curtail or shift their electricity use. In return, they receive monetary rewards or bill credits. These are two kinds:

1. **Classical:** The utility or grid operator can either manually or automatically control or reduce the consumer's electrical load during the times of peak demand or system stress. In return, customers get bill credits, rebates or discounts on their electricity bill. This does not involve real-time pricing (Aljabery et al., 2021).
2. **Market-Based:** The customers voluntarily adjust their consumption amount based on the market signals or price incentives (Aljabery et al., 2021). The consumers are paid based on how much they reduce or shift their usage. This allows them to respond to real-time price changes and participate in energy market prices or agreements. Table 2 summarises the four types of market-based programs.

Table 2. Market-Based Demand Response Programs

Program	**Description**	**Trigger event**	**Best suited for**
Demand Bidding	Consumers offer to reduce their consumption, if the energy price crosses a certain limit- also set by the consumer. If the price goes higher than the pre-decided limit, the consumers maintain the promise and are paid by the utility.	High market price	Large consumers with load flexibility
Emergency DR	Consumers reduce usage during emergencies like storms or grid threats and are incentivized for their curtailment	Emergency events (e.g., heatwaves, disasters)	Industrial or commercial consumers
Capacity Market	The electric company pays the consumer in advance, based on his/her promise to reduce their load, during peak times or emergencies.	Future critical events	Consumers with predictable flexibility
Ancillary Services Market	During the excessive need, the consumers curtail the extra load in their consumption by acting as backup energy sources.	Real-time or sudden grid needs	Consumers who can react quickly and reliably

While PBP, refers to a strategy in energy management where consumer adjust their electricity usage in response dynamic price signals. Instead of fixed tariffs, electricity prices fluctuate based on supply and demand conditions (Qdr, 2006; Severin et al., 2002). This pattern encourages the consumers to reduce or shift their consumption during high-price periods to save cost and help balance the grid. The price-based demand response uses various patterns of time varying electricity prices, as enlisted in Table 3.

Table 3. Price-Based Demand Response Programs

Program	**Description**	**Trigger**	**User Strategy**
Time of Use (TOU)	Different fixed prices for different times of day (e.g., peak, off-peak).	Scheduled (daily/seasonal)	Shift usage to off-peak periods
Critical Peak Pricing (CPP)	Very high prices during a few critical hours per year.	Short-term, announced ahead	Reduce usage on notified peak days
Extreme Day CPP (ED-CPP)	Much higher prices on extreme peak hours of critical days; flat rate otherwise.	Event-based (short notice)	Drastically cut use during extreme hours
Extreme Day Pricing (EDP)	High price applied all day during a critical event.	Crisis or market strain	Cut usage throughout the entire day
Real Time Pricing (RTP)	Prices vary hourly based on real-time wholesale market rates.	Continuous, real-time	Use automation or tools to track & react to price changes

Demand Response (DR) has proven effective in reducing peak loads and deferring infrastructure upgrades (D'Ettorre et al., 2022; O'Connell et al., 2014). It also promotes active demand-side participation in grid operations, helping manage renewable variability and enhancing system efficiency, reliability, and safety (Vardakas et al., 2014). Recent initiatives have supported dynamic pricing, DR market access, aggregator roles, energy communities, and flexibility use in distribution networks to reduce congestion and boost efficiency (Madsen et al., 2015).

Despite these efforts, DR remains underutilised as a core flexibility tool in power system operations (Willems & Zhou, 2020). Regulatory progress varies across EU Member States, with only a few updating the frameworks to integrate demand-side resources and DERs into electricity markets (Bertoldi et al., 2016). A key barrier is the absence of standardised DR performance measurement. Clear, transparent measurement and verification (M&V) methods enable end-user participation, ensure accurate load assessments, verify compliance, and manage incentives or penalties (Smart Energy Demand Coalition, 2017). Establishing a reference baseline is also critical for evaluating DR contributions.

Summarizing from the literature, integrating adaptive reuse of heritage buildings with the energy communities present a holistic approach to sustainability. The peer-to-peer resources sharing, approaching heritage as cultural identity instead of just a physical structure and leveraging digital tools for energy management, can transform the urban energy landscape. To address this intersection, it is essential to build upon the frameworks that conceptualise shared resources and uncover the socio-technical relationships between various human and non-human actors to co-create the energy transition models in a heritage context.

3. Theoretical Framework

As previously stated, the objective of the research is to contribute to the studies about enabling the energy communities to leverage the digital devices for a sustainable retrofitting of Kolpi 93, a heritage building, in Estonia through demand-side flexibility. The integration of DSF in such buildings presents both technical and social challenges due to their historical constraints and limited adaptability. This research is grounded on two frameworks, the Actor Network Theory (ANT) and the Commons Theory.

Using ANT, the study considers digital technologies, heritage buildings, community participants, and regulatory frameworks as interlinked actants within a socio-technical network. ANT is especially suitable as it facilitates the examination of how human and non-human entities co-shape the dynamics of energy management. This framework allows for tracing the interactions and negotiations for the alignment of diverse interests, such as preservation, energy efficiency, and citizen participation, within the evolving network of sustainability.

Simultaneously, Commons Theory offers a complementary perspective for investigating the participatory governance and collective action inherent in energy communities. It frames these communities as self-organized entities that manage shared energy resources through established rules, trust-building, and iterative cooperation. By focusing on the outcomes and values stemming from participation, this theory aligns with the objective to evaluate the potential and significance of establishing energy communities that contribute to the renewable energy transition.

Together, ANT and Commons Theory provide a robust analytical foundation to holistically answer the following research questions:.

1. What is the potential for building an energy community to support the sustainable reuse of the heritage site at Kopli 93?
   1.1. How can energy communities integrate digital technologies for better energy management in heritage buildings?

3.1 Actor-Network Theory

Actor-Network Theory (ANT): ANT provides a comprehensive framework to analyse the dynamics of the socio-technical networks. It includes both human and non-human actants that possess agency i.e. stimulate changes within the network (Sayes, 2014). In the context of energy transition human factors include property owners, municipal authorities or consumers, while the non-human actants are smart technologies, policies, renewable energy sites or technical infrastructure (Barnes et al., 2022). (Van Der Waal et al., 2018) defines that ANT not only maps the interaction among the actors, but also explains how they define and assign roles to themselves or to the new participants into these roles. Van Der Waal et al., 2018 mentions that (Callon, 1984), identifies the process of establishing the entire socio-technical network into four phases:

1. Problematization: The energy communities identify and define a critical problem. They are required to convince their desired stakeholders that the problem can only be addressed by their collaboration with the energy initiative.

2. Interessement: After problem identification, the actors are now locked into their proposed roles. The actants define and redefine their interests. This ensures alignment and weaken competing influences and encourage cooperation within the network.

3. Enrolment: A successful interessement leads to enrolment where the roles of the actants are interconnected into a cohesive functional network.

4. Mobilisation: The phase that makes all the previously static entities mobile and active within a network. Mobilisation may require some actants to detach, if required, leading to necessary changes and displacements within the network (Callon, 1984).

Hence, ANT emphasises the roles and interplay between social and technical components within energy communities to influence socio-technical innovation.

3.1.1 Interrelation between Institution, Technology and Actors

Institution and Actor: Institutions, referred to as formal and informal rules, norms, and belief systems, play a crucial role in coordinating but not determining the activities of actors in society. According to (Van Summeren et al., 2021), there are three types of institutions:

- Regulative: formal rules like laws and punishments.
- Cognitive: shared ways of thinking or understanding the world (like common beliefs, worldviews).
- Normative: ideas about what is "good" or "proper" behaviour (like values and moral expectations).

Such a set of rules and values not only constrains the actors of their actions but also helps them to guide and coordinate complex tasks. However, actors are not passive followers. They actively interpret, challenge, and recreate institutions through their everyday practices. This dynamic interaction explains the 'paradox of embedded agency' (Van Summeren et al., 2021), where actors are both shaped by and capable of reshaping the institutional structures they inhabit.

Institution and Technology: Technology is not merely a tool, but is part of a broader socio-technical system comprising machines and the social skills and norms necessary for their operation. New technologies have the potential to disrupt established systems or norms by incorporating new and better practices (Van Summeren et al., 2021). While, it can also stabilise the existing ones upon which certain technologies are already or being built.

Technology and Actors: Technology influences society in several ways. As per studies, first, technology designers install their vision on the users, describing (not determining) the ways of how they can be used (Akrich, 1992; M. Hansen & Hauge, 2017). Secondly, the technology itself can shape the usability actions through its physical characteristics, like energy grids situated in isolated areas, limiting their accessibility to the people. Thirdly, new technologies create new ways of everyday practices, like bicycles enable the practice of cycling (Watson, 2012).

ANT reveals that technology does not evolve on its own. Rather, technical designs are results of collective agency and collaboration among various social groups. It is embedded into society by the actors, giving them a meaningful purpose by integrating into user practices and routines (Grin et al., 2010; MacKenzie & Wajcman, 1985).

The interplay between institutions, technologies, and actors, form the core dynamic in sustainability transitions. The Figure 3 summarises that institutions guide and constrain actions, technology both enables and restricts practices, and actors have the agency to innovate, adapt, and challenge existing systems. Understanding the transitions, therefore, requires analysing these interconnected relationships, focusing not only on structural constraints but also on opportunities for agency and transformation.

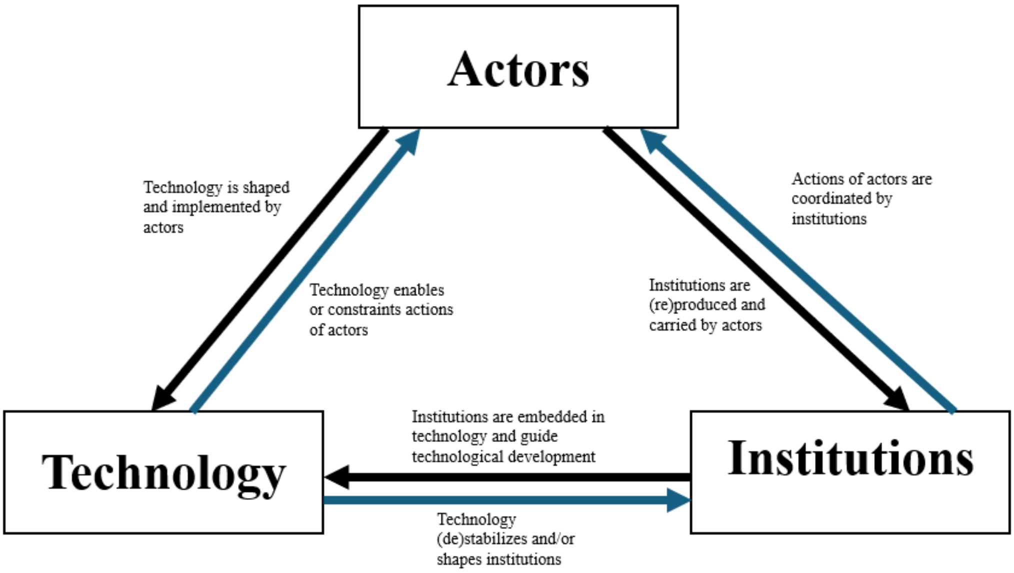

Figure 3. ANT-Interrelation. Source: Van Summeren et al., 2021.

3.2 The Commons Theory

In this research, commons theory offers a conceptual lens to understand how energy communities can play a transformative role in the adaptive reuse of heritage buildings. Rather than viewing the buildings as mere structures, this framework redefines it as a socially shared resource, by collective participation and mutual responsibility. Scholars such as (Frischmann, 2012; Melville et al., 2017; Rose, 1986) argue that infrastructures should be treated as commons due to the societal benefits of universal access to energy systems, alongside the negative environmental impacts from greenhouse gas emissions and the authoritative tendencies of energy infrastructure. Hence, energy is not only a commodity to consumed, but also a shared necessity that must be governed responsibly and democratically.

The Commons Theory challenges the 'tragedy of the commons' (Hardin, 1968) narrative which claims that shared resources are inevitably overused and depleted (Kostakis et al., 2018). Therefore, the theory mentions that communities can self-organise to manage and use the natural resources sustainably and fairly. Rather than relying on a profit-driven approach, commons theory offers a bottom-up, community-centred model that moves away from financial growth. It emphasises cooperation, shared responsibility, and the importance of social and ecological well-being over economic expansion (Benkler, 2006; Kostakis et al., 2018; Ostrom, 1990). A key strength of this framework is its multi-level, citizen-centric approach, where all stakeholders have a voice in how resources are governed (Kerschner, 2010). For the energy sector, it highlights how communities can sustainably manage common goods, such as shared energy infrastructure or locally generated renewable electricity, through self-organised institutions, trust, and participatory decision-making.

Commons Theory provides a useful framework for examining the social and institutional outcomes that emerge from participation in energy communities. Collective governance and shared responsibility can lead to valuable outcomes such as increased energy awareness, stronger community ties, and a greater sense of ownership over local energy systems. These participatory values support long-term engagement with renewable energy initiatives and promote fair access to their benefits. Importantly, commons theory also reveals how energy communities can function as resilient and adaptive systems (Bauwens et al., 2024). The resilient and adaptive systems are characterised by the decentralised and flexible models, in contrast to the top-down ones. They lead to the growth of dynamic networks of people, technologies and practices that continuously evolve. In a commons-based energy system, resilience emerges from the community's capacity to self-manage resources. Through demand-side flexibility or traditional collective memories, effective adaptation of local solutions contributes to human agency. Rather than focusing solely on the modern technical aspects of energy transition, this approach emphasizes on innovative capacity building and supports sustainable practices. In doing so, the theory offers important insights into the broader role of participatory energy governance in advancing renewable energy solutions.

Further, energy community members are no longer only the consumers of the energy, but active participants in the production of energy. This gives rise to the concept of "prosumers" (Ritzer, 2010; Skjølsvold et al., 2015). This dual role of the energy communities strengthens the commons theory adaptability in the context of this research, as the energy consumers are equally involved in its generation, sharing and regulation among the peers (Mitchell, 2014). In heritage buildings like Kopli 93, this horizontal approach of behaviour flexibility and energy sharing contributes to the collective care.

In the context of this research, Actor-Network Theory (ANT) and Commons Theory together serve three key purposes. First, they ensure that the integration of digital technologies in energy communities represent a valuable intersection of technological potential, with experts in the field and social innovation. This highlights the socio-technical aspect and participatory governance for this research. Second, these frameworks provide a schematic structure for data collection and analysis. ANT helps trace the interactions between human and non-human actors such as technologies, community members, and heritage constraints. Thirdly, the Commons Theory guides the exploration of participatory processes and collective outcomes to generate social value and contribute to renewable energy solutions.

4. Methodology

This chapter presents the methodological framework upon which the research is based. An exploratory qualitative method with single-case study is centred on the Kopli 93 Makerspace in Tallinn, Estonia. The case-study approach has been chosen due to the need for examining a contemporary and complex phenomenon, with the intersection of heritage buildings, energy communities, their adoption of digital technologies and sustainable energy management, within the real-life context. Case studies, as outlined by (Yin, 1992), are particularly effective when the boundaries between phenomenon and context are not clearly defined. Although Kopli 93 does not currently operate as a formal energy community, it presents a valuable site for investigating the potential conditions, practices, and values that could underpin the emergence of such community-led energy initiatives. The makerspace occupies a heritage building and is shaped by a strong ethos of collective organisation, experimentation, and sustainability, the characteristics that align closely with the principles behind energy communities. Rather than selecting a fully established energy community, this study focuses on a site that reflects a more exploratory or transitional phase. This allows for the investigation of how digital technologies, participatory practices, and spatial constraints intersect in a real-world context that is actively shaping and is being shaped by, broader energy transitions.

Kopli 93 offers a unique environment for such a study. To capture the complexity of these dynamics, this research applies qualitative methods comprising of both expert interviews and ethnographic fieldwork. The semi-structured interviews are used to explore the personal experiences, beliefs, and perceptions of individuals involved with or connected to the site (Bazen et al., 2021). By asking open-ended questions, these interviews help reveal a broad range of perspectives in the participants' own words, in relations to energy technology, and community engagement. Ethnography involves the observation and documentation of the participatory activities of various groups of people in different settings. This method supports a dynamic understanding of how values, routines, and informal practices are formed and expressed in certain contexts (Cowdell, 2019). Together, these methods offer a holistic approach, in capturing the social dynamics and valuable insights towards the potential and challenges of community-led energy transitions.

The qualitative focus of this methodology is intended to offer depth in the study rather that generalisation to other contexts. The goal is to understand not just what are the activities happening there, but also how and why can be the space made into a sustainable area. As explained in more details later, the thematic analysis in this research is mainly guided by qualitative data and draws on key themes identified through the theoretical framework. At the same time, the analysis remains open to new, emerging themes that arise directly from the data, allowing for an exploratory, bottom-up approach. The intersection among people, technologies and institutions require an interdependency to unfold the potential, possibilities and challenges of the space. By combining interviews with ethnographic observation, the study looks at both the obvious and the subtle aspects of communities. The combinational qualitative method of expert interviews and ethnographic fieldwork supports a flexible and hybrid analysis, enabling both the application and critical reflection on the findings of the research.

Engaging with energy communities in casual or open-ended discussions will allow exploring the community or member behaviours about energy consumption patterns and perceptions, through ethnographic methods in Kopli 93. The site was chosen, as it lacks a strategic blueprint of implementing smart energy management processes in the heritage context. This has enabled the capture of real-time interactions and social dynamics. To analyse the collected data, the different and recurring themes will be identified, followed by systematically analysing the same. Various findings about the roles and relationships from different actors and the associated non-human actants would create a clear mapping. The identification of behavioural patterns within energy communities in advancing the sustainable energy goals will emphasise on the community's unspoken behaviour and their needs to enhance the energy flexibility practices.

In addition to the software tool like NVIVO 15, discussed later in this chapter, two AI-based tools were also used during the research process. The first was QuillBot, which helped rephrase sentences to improve clarity and readability. The second was ChatGPT, a language model based on the GPT-4 architecture. It was used to get an initial sense of the qualitative data and to help organise sections of text. These tools were only used to support the writing process and not for generating original research content. Additionally, the thesis has been written on Overleaf software, using LaTex language.

Taking such considerations, the following sections explain the methodology used in this study. The expert interviews method is presented first, following the order in which they were applied. After that, the approach to preparing and carrying out the ethnographic fieldwork is described. The chapter ends with a discussion on the limitations of the chosen methods.

4.1 Expert Interviews

The data collection method started with semi-structured expert interviews, primarily serving two purposes of the research. First, these interviews provided essential insights into each of the research questions. Specifically, they were used to collect data about the requirements and their experiences with establishing and working with energy communities. This perspective addresses the first research question. For the sub-research question, further exploration was done on the significance of smart technologies' adoption by energy communities to bring innovation and sustainability in the energy sector. The research received significant attention and active participation from the actors of various backgrounds. Hence, as planned, the data collection process was comparatively smoother, receiving responses from almost everyone who was contacted.

In addition, the interviews aimed to explore challenges and barriers specific to integrating digital technologies for demand-side flexibility in buildings, particularly in the framework and regulations of energy communities. This directly addressed the overarching question by identifying the potential technical, regulatory, legal or social limitations. While the interviews also offered early insights into the participatory aspects of energy communities and their expertise in renewable energy solutions, the subsequent ethnography fieldwork at Kolpi 93, enhanced the emotional awareness, serving as a basis for their voluntary and not-for-profit attitude.

The expert interviews also delved into the participatory dynamics within energy communities about the collective practices, motivations, and values underpinning community-led renewable energy initiatives. This directly informed the sub-research question by highlighting how participation within these communities contributes to or challenges the development of renewable energy solutions. Beyond addressing the research questions directly, the interviews also played a methodological role in shaping the subsequent ethnographic fieldwork. The qualitative insights obtained, helped in refining the focus of participant observation and on-site exploration during the ethnography. This ensured that the observatory approach was aligned with the practicalities of community participation, their motivation towards sustainability practices and ability to operate basic digital technologies like mobile applications within Kopli 93. This iterative, exploratory design is well-suited to emerging research areas of socio-technical approach for energy management.

4.1.1 Selection of interviewees

As previously mentioned, the interviews were conducted with individuals recognised as experts within the scope of this research. Van Der Waal et al., 2018 in their research has included the key stakeholders or experts to probe deeper into the topic of energy efficiency with local communities using digital technologies and their demand response. According to (Kaiser, 2021), an expert is characterised by their outstanding skills and knowledge, their professional role to implement this knowledge and/or their societal position. For the purposes of his study, an individual was considered an expert if they met at least one of the following mentioned criteria. Such criteria have enabled them to provide informed perspectives on the relevance of this research topic from an interdisciplinary lens.

The first criterion was related to their knowledge and involvement in the energy sector from a socio-technical perspective. To elaborate, the interviewees should have been involved in the projects of energy management, where energy communities are at the core of the system.

A second qualification focused on their experience with smart and digital technologies for sustainable energy management. This also focused on their insights about the technological innovation and social equity in availing and accessing these emerging technologies.

Third aspect was to gather insights from the architects, who would share their knowledge about the possibilities and necessities of repurposing heritage buildings. This also delved deeper on the opportunities and challenges of installing renewable energy devices into the heritage buildings.

Given that Kopli 93 has not yet, developed in the sustainable energy management systems, experts from outside Estonia were also considered. This highlighted the factors they took into account to build sustainable and smart buildings with he help of energy communities. In particular, scholars and practitioners from Greece and Finland were significant contributors, due to their pioneering role in acknowledging energy communities and the development of smart grids and renewable systems, respectively.

Through these consultations, it was assumed that such experts would have developed a rich understanding of the energy management systems for smart buildings. These experts are viewed not merely as sources of information but actors, within a broader socio-technical network. Their knowledge, roles and experiences involve dealing with people, technologies, policies and institutions in their everyday lives. Such insights align very closely with the ANT and Commons Theory framework, that is decided for this research. These frameworks will support the findings through expert interviews and directly relate to the main and sub-research questions. It further helped in developing a subsequent ethnographic fieldwork focus and relevance. By including a diverse set of actors, the study acknowledges the distributed agency in shaping energy transitions and highlights the importance of understanding how power, knowledge, and technology circulate through these heterogeneous networks.

Target group: Architects or urban planners, project managers in sustainable energy projects, electrical engineers and academicians working on energy transition and/or renewable energy sector. They provided the insights about approaches and practical knowledge about energy efficient designs and infrastructure, technical perspectives, theoretical and research-based insights on energy transition, followed by energy management platforms and regulatory policies for incorporating certain technologies in the heritage buildings.

Experts were identified using three strategies. First, an in-depth online search aligning with the afore mentioned qualifications. Second, a referral or snowballing approach, where initial contacts were asked to recommend other relevant experts within their professional networks. Third, the strategy involved direct referrals from my academic supervisor, who, based on his experience and networks, suggested individuals likely to provide valuable insights aligned with the scope of the research. Initial contact with potential participants was established via email. Each message included a brief and clear explanation of the research context, its objectives, and its specific relevance of the expert's specific skill. Practical details regarding the format, estimated duration, and mode of the interview (e.g. in-person, or online meeting) were also provided, along with information about data privacy, voluntary participation, and ethical handling of responses. Recipients were invited to contribute their expertise through participation in a semi-structured interview.

4.1.2 Interview Preparation

The interview format was carefully structured and formatted. A semi-structured interview approach was chosen to maintain a balance across the conversations with the flexibility to explore themes unique to each expert's background. This format allowed me to follow a general structure with the flexibility of adapting to the interviewee's background. The open-ended questions enabled a more natural flow of conversation and allowed unexpected but relevant topics to emerge during the discussion (Harvey-Jordan & Long, 2001). Interviews lasted about an hour on average, which provided enough time to cover all key topics along with follow-up questions.

The expert interviews served two purposes: to gather insights for the research questions and to help guide the ethnographic fieldwork. Based on this, an interview guide was developed following the semi-structured interview design process suggested by (Kallio et al., 2016). The questions were closely linked to my main question and sub-question. The guide was further aligned with the theoretical framework, case-specific insights, and relevant literature discussed earlier in the thesis. As this is an exploratory study, the interview guide was refined slightly as the interviews progressed. The questionnaire was also designed as per the interviewees' background to maintain relevance.

The final guide was organised into five parts: a brief introduction to set the context and explain the purpose of the interview, followed by four thematic sections. The first section focused on their experiences and knowledge about the energy communities, and how they assess the outcomes from the communities. The second explored the various stakeholders and target groups that are involved in the energy transition projects for heritage buildings. As the topic is very niche, the questions were often restructured as per the context of residential buildings when required. The third explored how digital technologies and regulations are currently being used or could be used in heritage buildings for DSF. The fourth section addressed the perceived behaviours and attitudes of the energy communities towards adapting or opposing the idea of renewable energy systems. This was related to equity, access, and security about digital tools and flexibility measures. Finally, the last part invited participants to reflect on possible solutions, best practices, or policy suggestions. The interview concluded with a short wrap-up and space for additional thoughts.

Upon completion of the preparation of the interview guide, it was shared with my supervisor to receive feedback on the same. The guide was further updated on the basis of the minor feedback, keeping the core structure and content intact. None of the participants had requested for the questionnaire beforehand. Hence the conversation and insights shared were completely impromptu and organic. Once they agreed to take part, interviews were arranged based on their availability and preferred mode of communication.

4.1.3 Conduct of the Interviews

Out of 7, 6 interviews were held online using Microsoft Teams, and one was an offline discussion. Each session began with a short introduction, followed by the interviewer briefly describing about the research. Further, the interviewee's permission was obtained to record and transcribe the conversation for research purposes. After that, the experts were asked to introduce themselves, with their background and expertise, followed by moving to the main interview topics.

As the interviews progressed, the experts were asked about the significance of energy communities and various tangible and intangible factors associated. The significance of smart technologies was also discussed in the sustainable energy sector. Such insights directly addressed the main research questions. They reflected on how leveraging digital technologies by the energy communities impact the energy management of buildings. The discussions also addressed the challenges of implementing efficient energy systems in heritage buildings and how DSF could be supported in heritage buildings. Although, no experts had the combined experience of implementing smart devices into heritage buildings, they were asked for suggestions about the ways or processes if they ever had to work on one.

When issues about the regulations or technology accessibility to the energy communities came up, the experts were requested to elaborate them, helping to understand the challenges. Potential solutions and expectations, involving government initiatives or support schemes, were also discussed. Depending on the expert's background and the flow of the conversation, different parts of the interview received more emphasis.

Before wrapping up, participants were given time to share any final thoughts or raise questions. This often led to valuable insights or suggestions for further research. Experts were also invited to recommend additional contacts for interviews, supporting the snowball sampling method (Noy, 2008).

Hence, a total of 7 interviews were conducted between 18th of March and 5th of May 2025. All the interviews have been conducted in English. As planned beforehand, the interviews were conducted well within the timeframe of one-hour, except the third interview, which got extended until one-and-a-half hours due to some delay caused by connectivity issues from the interviewee's side. Table 4 provides an anonymised overview of the interviews, including the experts' professional background, dates they were conducted on, duration in minutes and language of the interview. As reflected in the expert selection, all the intended qualifications were met, ensuring a balanced mix of theoretical and practical perspectives. This included insights from both academia and professionals across the public and private sectors, allowing for a well-rounded understanding of the research topic and supporting the triangulation of findings.

Table 4. Overview of Interview Participants

ID	Professional Background	Date	Duration	Language
I01	Co-founder of a renewable energy service providing company in Greece, working and managing projects related with energy cooperatives.	18/03/2025	60	English
I02	An architect and researcher at Cambridge University. A co-founder of Spatialist Studio in Tallinn focused on collaboration with public authorities, universities, and local NGOs to produce high-quality public spaces and buildings.	28/03/2025	45	English
I03	A Solutions Engineer at an organisation working on Digital Twin platforms for heating and cooling grids, focused on decarbonising European heating.	28/03/2025	80	English
I04	A CEO at the IT services firm in Tallinn, working on intelligent solutions and automation of buildings. Leads strategy creation and setting up proper management systems and performance management of energy systems in buildings.	02/04/2025	21	English
I05	Researcher with a focus on energy and agricultural communities in Greece. Also serves as the head of the energy community Board involved in the pilot projects.	03/04/2025	51	English
I06	Employee at an European level organisation that is a federation of energy communities working on capacity building and advocacy to policymakers and promoting democratisation of energy transition	28/04/2025	25	English

I07	Researcher in electrical engineering from Finland, studying about distributed energy systems and smart-grids for sustainable energy management for residential and commercial buildings.	02/05/2025	25	English

4.1.4 Thematic Analysis of Interviews

The online conducted interviews were recorded in Microsoft Teams, which has an automatic feature of transcribing the meeting when it is chosen to start. The offline discussion was recorded through hand-written notes. After the interviews were completed, the transcription and the videos were downloaded. All the 7 transcripts were then imported into NVIVO 15, a software tool used for qualitative data analysis. NVIVO 15 helped with organising, coding and reviewing the content from the transcripts. Due to the real-time transcription during the online interviews, the transcripts contained numerous mistakes. Each mistake was manually corrected, by listening to each recording. This implies that the interview transcriptions followed the denaturalism approach, which removed stutters, pauses, noises, unclear accents etc. (Oliver et al., 2005). All the interviews were conducted in English. It was taken care that the corrections did not change the underlying intention and meaning of the insights which the experts shared.

To analyse the interview scripts, thematic analysis was used as it offers a flexible and accessible approach to working with qualitative data. It was chosen because of it ability to provide a rich, nuanced understanding of experts' perspectives and capture the complexity of the topic (Braun & Clarke, 2006). The method is particularly helpful for identifying and interpreting recurring patterns, known as themes, within the dataset or the uploaded scripts. In this study (Braun & Clarke, 2006) six-phase framework for thematic analysis was followed. The phases are (1) familiarising with the data, (2) generating initial code, (3) searching for themes, (4) reviewing themes, (5) Defining and naming themes, and (6) producing the report. This detailed process allowed extraction of meaningful insights from the a large amount of data to answer to the research questions. Themes were also identified based on theoretical frameworks as suggested in the third chapter.

Once the initial coding was complete, the related codes were clustered into potential themes. The initial design and ideas of how these codes and themes connect began to take shape. In the next step, these themes were reviewed to ensure they accurately reflected the data from the script. During this process one new code was formed, as it went unconsidered and three previous codes were removed, as they were misinterpreted. The review phase concluded once it became clear that no further major adjustments were necessary.

In the next stage, the key themes and their corresponding codes were clearly defined based on the two central research questions. The final structure of the thematic analysis reflected six main themes: Heritage Context and Adaptive Reuse, Governance and Participation in Energy Communities, Role of Actors in Energy Transition, Leveraging Digital Technologies for Energy Transition, Sharing and Managing Energy Through the Grid, and Barriers to Digital Integration. Each theme was grounded in the empirical insights from the interviews and ethnographic engagement, while also drawing selectively from relevant theories and literature. For instance, the interplay between human and non-human actors was especially useful in identifying how digital tools, heritage regulations, and institutional frameworks interact with communities and individuals, focusing on the framework of ANT. Meanwhile, the commons perspective highlighted heritage sites not as a fixed asset but as a living, and shared resource. This process laid the groundwork for the final analysis and findings of the study.

4.2 Ethnography Fieldwork in Kopli 93, Tallinn

Ethnographic fieldwork was chosen as a core methodological approach in this research to gain an in-depth, grounded understanding of how local volunteers come together without the agenda of financial gain. They put forward their experiences and knowledge within the everyday practices of sustainable communities activities, especially in the sensitive and context-specific case of heritage buildings. Ethnography enables close observation of lived realities, power dynamics, and socio-technical negotiations in their natural settings. It is especially valuable for exploring under-researched and complex intersections such as those involving heritage preservation, community participation, and the potential of the emerging energy technologies.

Ethnography offers a holistic and immersive approach to studying cultural systems, with fieldwork being its fundamental method. Two days of on-site visits for this research project, revealed the communities' engagement in daily life across different times of day and week. This extended engagement allowed me to observe not only spatial and cultural practices but also how these dynamics shifted with different groups of people.

In this study, ethnography is understood as a way to deeply explore the lived experiences and social interactions of individuals within their natural environment, without any expectations of return. Through observation, participation and interaction, it was aimed to understand how people act towards the betterment of their surrounding and sustainability.

Observational research is not a single, uniform method, but rather a broad set of approaches that require thoughtful decisions at each step, which have been described in the following sections. The deeper immersions with the communities showed not only what activities they are performing but also the reason and meaning behind their actions. The most suitable type of observational strategy was chosen based on the study. The steps included participating with the locals in their activities, along with observing their actions from a distance, and some informal conversations took place with relevant participants. Hence, ethnography was not only about seeing the people in action but also engaging and interpreting their intentional, reflective and responsive behaviour in the setting.

4.2.1 Research Setting

One of the interviewees, who is also an architect and researcher, is working very closely on the repurposing of Kopli 93. During our interview, we discussed community engagement, the significance of adaptive reuse in heritage contexts, and the broader sustainability goals tied to such projects. On expressing my interest in conducting ethnographic fieldwork, I was warmly invited to a "Teeme Ära" (Let's Do It) volunteering party at Kopli 93 on the 3rd of May, 2025. This annual event is part of a wider civic initiative in Estonia that emphasises grassroots participation and collective action. The day began with local community members arriving at the site, some carrying tools, others simply eager to contribute. As people organised into small groups, there was a noticeable atmosphere of mutual support and informal leadership, which immediately indicated a strong sense of collective ownership over the space.

As the activities unfolded, I gradually became an active participant and observer in the process. Community members of various ages brought tools, shared tasks, and exchanged stories about the neighbourhood and their personal connections to the space. Some were long-time residents of the area, while others were newer participants drawn by the cooperative spirit of the project. This collaborative environment allowed me to observe how community ties were expressed and strengthened through shared labour and informal interactions. The space of Kopli 93, still partially abandoned, seemed to come alive not only by physical restoration but by social and cultural incorporations, where decisions about the building's future were discussed on-site, over coffee breaks and during joint tasks. These lived moments formed the core of my ethnographic observations, giving insight into how spatial, social, and cultural dynamics intersect in community-led energy transition projects involving heritage sites.

Through this event, the ethnographic setting expanded beyond the physical building to include the social networks, values, and motivations of those involved. As I continued my visit to another gathering, involving informal meetings and casual drop-ins, the community members engaged in planning or simply spent time together in the shared space. I documented not only what was said but also what was done, such as how decisions were made, who took the initiatives, how tools were shared, and how conflicts were resolved or quietly negotiated. These immersive experiences allowed me to trace how ideas of commons, collective care, and participatory governance were enacted in everyday actions. In this way, the repurposing of Kopli 93 became more than a restoration project, it stood as a living example of how heritage, sustainability, and social equity can be negotiated through community-driven practices grounded in mutual respect and shared responsibility.

4.2.2 Ethnography and Commons

This ethnographic approach aligns closely with Commons Theory, which is used as a framework for this research. This emphasises that shared resources are managed collectively by a community through norms, cooperation, and mutual responsibility. In traditional commons-communities, rules are defined for usage, distribution, and care. In the context of this study, as energy transition, these shared resources evolve beyond the ecological or material aspect. The built environment, energy infrastructures, and even localised knowledge systems become forms of the commons by managing and serving collectively. In heritage contexts like Kopli 93, the building itself transforms into living-commons, where preservation, sustainability, and adaptation rely on a network of social relations and collaborative care.

Ethnography enabled a strong understanding of how such commons operate in practice. Observing and participating in communal activities, such as renovation work, volunteer days, and informal decision-making processes, sheds light on how community members can negotiate roles, responsibilities, and values, around shared energy futures. It helped identify not just material or policy barriers to energy transition but the intangible social processes, like trust-building, knowledge sharing, and conflict resolution, that shape or hinder collective action. It became clear that social infrastructure is as critical as technical systems in enabling a just and sustainable transition.

By focusing on shared socio-technical practices, particularly in a heritage setting, this research illuminated how notions of power, equity, agency, and belonging are experienced on the ground. These lived experiences are often invisible to top-down analyses that prioritise efficiency or scalability over inclusivity and justice. In this way, ethnography does not just describe community dynamics, it reveals the conditions under which the commons can thrive.

Kopli 93, while not yet a formal energy community, holds the potential to become one. The building already functions as a social commons through events, collaborative decision-making, and shared stewardship. Drawing on the commons theory, it provides a conceptual blueprint for structuring an energy community that is both democratic and resilient. By embedding energy infrastructures like shared solar panels or energy monitoring tools into the participatory and value-driven ethos, the community can evolve into an energy community too. Such an approach could enable fair access, encourage sustainable practices, and foster a sense of ownership and care, extending the building's purpose beyond preservation to regeneration.

4.2.3 Ethnography as Method

In this research, ethnography emerged as a method of studying the current processes involved at repurposing Kopli 93. Through observing, participating and understanding the community dynamics, the site unfolded various potential and strong foundations to support the formation of future energy communities. It is well suited to the practice of the commons, as it allows for the study of cooperative structures, informal governance, and shared resources within community life. Rather than imposing predefined rules or hypothesis, ethnography invites an inductive, flexible perspective that responds to the practical realities of the participants. In this case, the ethnographic approach offered critical insights into how a grassroots energy community might emerge around the shared space of Kopli 93 through participatory and common practices.

The ethnographic fieldwork typically involves three overlapping stages (Whitehead, 2005):

1. **Entry Stage:**
   - Making initial contact through a key informant i.e. an architect-researcher connected to Kopli 93).
   - Participating in the "Teeme Ära" event volunteering day to become familiar with the space and people.
   - Establishing trust and rapport with participants.
   - Remaining aware that I, as a researcher is also being observed, and building respectful, reciprocal relationships is essential.
2. **Immersion Stage:**
   - Involved two visits, with the duration of six hours of observation and participation.
   - Blending into the everyday environment, while maintaining a critical and analytical lens.
   - Engaging in informal conversations, participating in group activities, and observing social dynamics, power structures, and collective actions.
   - Capturing data in diverse forms: detailed fieldnotes, direct quotations, photographs, videos, and informal interviews.
   - Keeping the process semi-structured and flexible, rather than following a rigid script.
3. **Closure and Reflection Stage:**
   - Gradually synthesizing insights and sharing preliminary interpretations with participants and organizers for feedback and validation.
   - Writing reflective notes or capturing the images on one's positionality, emotional responses, and evolving understanding.

- Ensuring that insights stay grounded in the everyday realities of the community, not just in theoretical abstraction.

The process was followed as suggested by Genzuk, 2003, the several key principles that shapes the fieldwork:

- Be descriptively rich: Captured scenes and interactions in clear details to ensure solid and contextualised description.
- Gather multiple perspectives: Spoke to a range of stakeholders, from core volunteers to casual visitors, to understand the diversity of views.
- Triangulate data sources: Used fieldnotes, interviews, photographs, and observed interactions to cross-validate insights.
- Use participants' own words: Quoted them directly and let their perspectives shape the narrative of the commons in formation.
- Select key informants wisely: Engaged with community insiders for deeper insight, while recognising the partiality of any single viewpoint.
- Record continuously: Maintained a continuous habit of note-taking, not just during events but also reflections before and after.
- Separate observation from judgment: Described what is seen and heard before interpreting its significance.
- Adapt to field dynamics: Ethnography is not linear, it developed and deepened, contexts shifted, or newer situations arose.

In the end, this approach helped me to see Kopli 93 not just as a place to observe, but as a living community space, shaped by everyday acts of trust, care, and working together. Even though there is no existence of energy community yet, the spirit of sharing, participation, and collective belonging was already clear. Ethnography made it possible to notice these small but meaningful practices and imagine how they could grow into a more organised energy commons in the future. Figure 4 and Figure 5 illustrates the images of (a) decayed and legacy heating systems of the Kopli 93 building, and (b) the community engagement towards sustainable practices collected by me during the fieldwork.

Figure 4. Decayed walls and legacy heating systems

Figure 5. The community engagement

4.3 Limitations of the Methodologies

The chosen methodology, a combination of expert interviews with ethnographic fieldwork, carries several limitations relevant to the scope and context of this research. A key challenge that lies in the ethnographic method is the limited duration and intensity of the fieldwork. While participation in the 'Teeme Ära' event at Kopli 93 enabled first-hand observation of community practices and socio-spatial interactions, ethnographic research typically benefits from a prolonged duration of engagement. The short two-days field engagement restricted opportunities to witness long-term processes, everyday routines, and evolving power dynamics at the site, making the findings necessarily limited and tentative.

In terms of participant diversity, the data collection from a varied range and a bigger number from the marginalised or less visible members of the community was limited. In ethnography, the volunteering event mostly brought together people who were already active and interested in the project. As a result, it may have missed out on those who are more sceptical, less involved, or feel disconnected from what's happening. This made it harder to understand the full range of community views, especially around how decisions are made informally, where disagreements may lie, or why some people choose not to participate.

Expert interviews were very helpful in understanding broader systems such as actors, institutions, and digital technologies, and getting thoughtful insights about community energy and heritage reuse. However, this method also has some important limitations. Experts, because of their professional roles, often speak from an institutional or strategic point of view. This means their input might not always reflect the everyday experiences of people actually living in these communities. Their perspectives can sometimes focus more on big ideas or ideal plans, and less on the practical challenges or local knowledge of non-experts. The interviewees came from different countries and professional backgrounds. Since several of them were not based in Estonia or lacked deep, ongoing engagement with the specific local context of Kopli 93, there can be a lack in some of the more nuanced, place-based insights, relevant for this research.

Like many qualitative methods, both ethnography and expert interviews rely heavily on interpretation. Even though data were systematically documented through field notes and interview transcripts, the process of analysing and making sense of this material is shaped by the researcher's personal perspective. My background, shaped by my academic training, cultural context, and previous experiences, might have influenced what I paid attention to, how I engaged with participants, and how I interpreted their words and actions. While all formal interactions and interviews were conducted in English, and language was not a barrier in those moments, the fact that I do not speak Estonian may have limited my ability to fully engage with spontaneous or informal conversations happening around me. This likely resulted in missed opportunities for deeper insights, particularly in moments of casual exchange, humour, or culturally specific references that were not translated or explained. Further, the lack of knowledge of the language has also restricted me to approach other experts in the field, who are not comfortable with English. These small, everyday interactions could have been especially valuable in the scope this research and their absence is a notable limitation.

5. The case of Kopli 93

This chapter introduces the case of Kopli 93 by exploring its historical, social, and spatial significance for the context of Tallinn's urban transformation. It begins with a brief overview of Kopli's industrial and architectural legacy, highlighting how the district evolved from a thriving shipbuilding hub to a neglected post-industrial area. The following section focuses on community engagement in Kopli 93, which promotes local resilience through shared knowledge and collective action. Finally, the chapter presents a set of recent grassroots and municipal projects that have played a key role in bringing new life into the area. It demonstrates the feasibility of citizen participation, and experimentation in the repurposing of heritage buildings towards sustainable forms of development.

5.1 Historical Significance

Kopli 93 is located on the Kopli peninsula in Tallinn, an area that once served as the city's industrial hub. In the early 20th century, Kopli was home to major factories for shipbuilding, textiles, and clay production (Volumes, 2022). During Estonia's first period of independence (1920-1939), the area developed into an active workers' district, with not only housing and factories but also essential community buildings, like a hospital, school, church and a cultural centre. Among these, Kopli 93 served as an *Art Deco community centre*, which served as a cultural gathering site for local residents.

However, the building's story changed with the initial Soviet occupation in 1940. The centre was closed only a few years after opening and repurposed several times over the decades into a sailor's club, a school, and a propaganda house (Volumes, 2022). Eventually, it was abandoned and like many historic buildings in post-Soviet cities, left without a clear role in modern urban life. In 1991, after Estonia regained its independence, unlike many neighbourhoods that were privatised, the Kopli area remained municipally owned (Mello, 2024). This implied there was little investment in maintaining the buildings, and many fell into abandonment. Today, buildings like Kopli 93 are a reminder of the past and also present opportunities for thoughtful, sustainable reuse that connects heritage with the needs of today's communities.

5.2 Community Engagement in Kopli 93

Kopli 93 is a community initiative based in Tallinn, Estonia. It is located in a repurposed cultural building in the historically industrial district of Northern Tallinn. Established in 2021 and currently supported by the Tallinn City Municipality, numerous projects seek to strengthen community resilience through hands-on, collaborative activities. Its objective is rooted in both traditional practices and forward-thinking approaches to foster social inclusivity and promote sustainable living. Currently, Kopli 93 has developed a commons-based peer production and cosmolocalism approach (Kruup, 2024), known as a makerspace, a community garden, along with learning about apiary (beekeeping space). These initiatives provide practical resources and serve as platforms for learning, cooperation, and local empowerment. Kopli sets an interesting example in reviving heritage buildings along with the adaptive reusability of the decayed portions. This calls for actively reimagining and restoring them as public shared spaces that serve the community again.

5.3 Community-led Projects and their Potential for Energy Futures

The revival of Kopli 93 was primarily supported by the CENTRINNO project funded by the European Union's Horizon 2020 Research and Innovation Programme. Beginning in October 2019, a local team, comprising of members from Tallinn University of Technology (TalTech) and the Tallinn City Council, began with pilot methods to transform the former cultural site into a vibrant commons-based community hub. Some other small-scale workshops and meetings have also played crucial roles in the self-organisation of the community. A student from Aalto University in Finland, helped participants to jointly map and co-design their core values. In other words, the members broke down their individual principles into smaller components or values to reassemble them into a collective vision for the community. These core values, alongside other innovation-led initiatives, played a key role in reactivating the site as a community-driven platform. The municipality provided access to the site, while the local team focused on creating an inclusive space. Their goal was to reconnect residents with the traditional knowledge and practices, while also introducing modern and sustainable approaches like design thinking, permaculture, and cosmolocalism.

The state-of-the-art highlights numerous innovative solutions to address the decay through commons-based repurposing of the urban heritage. Kopli 93's emphasis on circularity and self-sufficiency uncovers the potential of building a renewable energy project, with the establishment and engagement of energy communities. The heritage sites can become active nodes to build just and decentralised energy futures.

6. Results

The following chapter presents the key findings from the expert interviews conducted for this research, guided by the central and sub-research questions. Drawing on insights from professionals working across energy communities, architects, scholars, electrical engineers and heritage conservationists, the results are organised to first explore the potential for establishing an energy community to support the sustainable reuse of the heritage site at Kopli 93. It then turns to examine how digital technologies, such as smart systems and energy monitoring tools, can be meaningfully integrated into heritage buildings for improved energy management. Finally, the chapter highlights the social and structural challenges that emerge in these contexts, particularly those related to access, participation, and the constraints imposed by heritage protection policies and institutional governance.

6.1 Establishing Energy Communities

The following section directly addresses the first and main research question: *What is the potential for building an energy community to support the sustainable reuse of the heritage site at Kopli 93?* Rich and practical information emerged from the expert interviews and the on-site observation techniques. The conversations with individuals deeply involved in energy cooperatives, digital energy systems and architectural reuse offered first-hand insights. Interviewees like I01, I04 and I05 particularly provided comprehensive answers who have been directly part of energy communities or managed related projects. They provided valuable perspectives, shared stories of grassroots initiatives, navigated policy hurdles and suggested experimenting with new models of participation and energy use.

Alongside these expert views, my ethnographic fieldwork at Kopli 93 added an important dimension to the research. Although the site does not yet have a formal energy community, the people involved there work in ways that reflect the same communal spirit. Their cooperative mindset, shared responsibility for space, and focus on collective benefit reflect the principles of the commons. Spending time with them, listening to their ideas, seeing how they adapt an abandoned space into something meaningful, helped me understand how community values and everyday practices could lay the foundation for more formal energy collaborations in the future.

The following subsections are divided into themes that are elaborated further on the codes or data as analyzed from the interviews and fieldwork.

6.1.1 Heritage Context and Adaptive Reuse

To fully understand the potential for establishing an energy community at Kopli 93, it is essential to first examine the specific conditions that shape the reuse of heritage buildings. Adaptive reuse in such contexts is not solely an architectural or technical matter. It is deeply influenced by layers of regulation, cultural values, and local stewardship practices. Experts consistently emphasised that heritage protection does not always align easily with energy transition goals, showing the spatial and legal constraints that limit interventions. At the same time, they pointed to creative reuse practices and material circularity as entry points for more sustainable approaches. As I03 mentioned, *"the reality is that the actual bit that is protected is not used"*, highlighting how preservation activities can unintentionally hinder innovation and usability. A nuanced understanding of these constraints and opportunities is therefore vital in considering how energy communities might emerge within, and respond to, the realities of heritage space.

Reuse and Circularity

To start with, the interviews highlighted a growing emphasis on circularity as a practical and cultural strategy for rethinking heritage spaces like Kopli 93. Experts pointed to practices such as material reuse, waste mapping, and the design of fully circular construction processes as essential tools for sustainable repurposing. As I02 described, *"they collect a lot of these architectural details from more historic buildings that are being demolished"*, illustrates how salvaged elements can retain cultural value while supporting low-impact building practices. Another noted, *"we need to start reusing [rubbish] better"*, reinforcing the role of local material flows in shaping reuse strategies. In the context of Kopli 93, such circular practices could serve as a foundation for building an energy community that embraces reuse, not just of materials, but of space, knowledge, and governance, making it an ideal sandbox for collaborative and low-impact heritage regeneration.

Underuse and Decay of Heritage Buildings

Further, the experts repeatedly mentioned about was the visible underuse and continuous decay of heritage buildings due to regulatory, financial, and energy-related constraints. These spaces are often too expensive to heat, difficult to upgrade due to preservation rules, and ultimately ignored in everyday use. As I06 mentioned, *"now a lot of those [buildings] are being abandoned and we're looking to explore a framework where they can be producing some energy for local communities"*. This implies that there is a growing need to repurpose the abandoned sites to maximise the sustainable energy production and distribution for the local communities. I05 added that in one project, *"not a lot of energy efficiency interventions have been made... and it's quite costly to keep the building warm,* *especially for people that are quite vulnerable".* This pattern of underuse not only risks the loss of valuable heritage but also represents a missed opportunity to create a secure society and environment. For sites like Kopli 93, this highlights the importance of exploring energy community models that could help bring these spaces back to life, by making them functional, inclusive, and energetically viable once again.

Heritage Protection Constraints

A key challenge that emerged from the interviews was the restrictive nature of heritage protection policies. While these policies are essential for preservation, they often make energy-related upgrades incredibly difficult. Experts spoke of how buildings like those at Kopli 93, which are "grey listed", can neither be equipped with insulation inside nor on the outside. This makes improving energy efficiency nearly impossible. I04 mentions that in one project, *“we’re not actually installing the PV (photovoltaic cells) on the building itself. . . [but] installing it right next to it”*, pointing to workarounds for deploying energy efficient devices. These constraints complicate the integration of sustainable technologies, but they also reinforce the need for creative, community-driven approaches, like energy communities, that can navigate these limitations by focusing on operational strategies, shared infrastructure, and flexible governance models. During the field visit, one of the architects further mentioned that the municipalities have started considering the installation of solar panels at the rooftop of Kopli building, *"as they will not be visible to the regular people, and also serve the purpose of producing energy from a renewable energy source".*

Legal and Regulatory Barriers

Additionally, the complexities of legal and regulatory restrictions were pointed out as a major obstacle against implementing sustainable energy solutions in the heritage context. Ownership structures, national heritage laws and likewise often created uncertainty and delay. I04, I05 reflected on this frustration by explaining that the photovoltaics installation on heritage buildings was *a huge barrier, [the procedures are] not legislated enough.* I01 further adds that even small sustainable energy transition interventions created *"a ton of question marks".* Legal restrictions from co-owners in shared heritage blocks can prevent individuals from participating. These barriers highlight the need for collective, legally supported models like energy communities that can offer shared access and negotiate these restrictions more effectively.

Ownership Challenges

In some cases, even when the will to implement sustainable interventions exists, the legal owner’s lack of engagement or resistance can halt progress entirely. As I05 pointed that one heritage site was rented from a religious institution, *"not too keen to assist with this process".*

This lack of cooperation significantly hinders the process of repurposing a heritage building towards a better cause for society and the environment. Similarly, buildings under state or municipal protection, as in the case of Kopli 93, which is *"under official Estonian protection as a built monument"* (personal communication, 28 March, 2025), often involve layers of administrative oversight that complicate access and decision-making. For an energy community to thrive, strong relationships and clear agreements with public, private, or institutional owners are essential to unlock the building's potential for sustainable reuse.

Financial Dimension of Adaptive Reuse

Finally, interviewees highlighted that the high cost of heating poorly insulated buildings, particularly in colder climates, make them difficult to sustain without significant external support. It was regarded as *"it's just so, so expensive to heat"* and was considered the main barrier preventing the stakeholders from operationalising the abandoned Kopli 93 site. In another case, I05 explained that a solar installation would be *"a huge boon to their costs"* as it could offset the substantial energy demands for both heating and cooling in a vulnerable situation. These financial dimensions encouraged communities by enabling the local members to become prosumers. As prosumers, they can both produce and consume energy, which can ease financial burdens and strengthen local ownership of heritage sustainability efforts. It would provide a more stable, collective model for sharing costs and improving long-term affordability in heritage reuse projects.

6.1.2 Governance and Participation in Energy Communities

To fully grasp the potential of energy communities in the context of heritage reuse, it is essential to understand the governance models that underpin them. Unlike traditional top-down energy systems, energy communities are often structured as cooperatives i.e., locally rooted, people-driven, and fundamentally democratic. Interviewees emphasized that such models not only enable more equitable access to energy but also empower citizens to take an active role in shaping how energy is produced, shared, and used. This participatory design aligns closely with the community-led nature of adaptive reuse projects, where ongoing engagement and shared responsibility are critical. Particularly in a site like Kopli 93, where civic involvement and cooperative values are already embedded, energy communities offer a promising governance structure to support sustainable transformation.

Cooperative approach

A key strength of energy communities highlighted in the interviews, is their democratic and cooperative structure, which not only allows the members to benefit from but also to govern the energy system they participate in. I01 explained, *"it is a cooperative, which means that* *the beneficiaries are also the owners, with families and individuals voting to form boards and guide decision-making"*. This participatory model fosters a strong sense of ownership and agency, especially important in heritage contexts where community involvement is essential for long-term stewardship. I05 and I06 pointed out that people are increasingly motivated by a desire for *"energy independence and control over their resources"*. The ability of members to co-create an ecosystem of sustainable energy systems reinforces the idea that democratic governance extends beyond voting. It is also about collective knowledge-building and shared responsibility for sustainability.

Citizen-Led Initiatives

Further, it was very clear from the conversations that energy communities often emerge solely through the initiative and commitment of engaged citizens rather than institutional actors. I06 described this clearly: *"inspired and enthusiastic individuals, [let's say] a group of seven people that come together with an idea. They have a vision"*. These grassroots efforts are central to forming energy communities, where members not only co-own but also co-drive the mission. Multiple interviewees shared that within their communities, individuals voluntarily take on roles such as *"educating the rest of the members or helping with admin stuff"* (personal communication, 3 April 2025) which creates a space for continuous learning, participation and staying aware. This kind of bottom-up leadership is particularly relevant for a site like Kopli 93, where cooperative values are already present, and local initiative could play a key role in shaping a community-based energy future.

Inclusive Decision-Making

A defining feature of energy communities is their motive on shared ownership and inclusive decision-making, which gives members the direct influence over the direction of projects. The cooperative model ensures that *"the beneficiaries are also the owners"* (personal communication, 18 March 2025) and the decisions, such as forming a Board of Directors are made collectively through voting. This creates a direct link between participation and power. The sense of local ownership fosters confidence, accountability, pride, and long-term commitment, especially when decisions and responsibilities are held by prioritizing the welfare of the community.

Members participate voluntarily, with many contributing through their time and knowledge alongside external experts. This structure allows for a wide range of actors to be included, fostering a sense of trust and transparency. In the context of Kopli 93, where horizontal forms of organisation already exist, this model of inclusive governance could provide a strong foundation for developing a community-led energy initiative grounded in shared responsibility.

Capacity Building

To establish a successful energy community, it is crucial to equip the members with the required knowledge and skills to create an impact for their participation. This can be done internally, through the formation of small task forces, involved in a particular task or by external hiring of experts. The managers of the sites hire, *an engineer, an accountant, a lawyer* (personal communication, 18 March 2025) to fill the gaps in technical, financial and legal aspects. This ensures that the projects or initiatives keep progressing even though the members lack specialized skills. Further, capacity building is not just about technical know-hows, but also enlightening the people about their impact, *"so they become more aware of their impact"* (personal communication, 28 April 2025). Hence, in the sites where collective effort already exists, building technical capacity and enhancing support systems through learning and collaboration can make an energy community both feasible and resilient.

Scalability of Energy Communities

In response to ongoing energy crises and rising prices across Europe, a crucial question arises on the scalability potential for energy communities. Especially after the recent global events like the war in Ukraine, people are increasingly believing in the value of producing their own energy locally. This creates a sense of energy security for the times of crises. I06 mentioned *"It makes a lot of sense from an economic point of view, especially as gas prices remain high"*. The interviewee further explained that the existing communities are helping the new ones get started by offering advice, support with funding, and visibility. This creates a kind of positive chain reaction, *"a virtuous circle tackling energy poverty"*. For a place like Kopli 93, this creates opportunities to start in a small scale and grow over time, especially if they connect with wider networks that can share tools, knowledge, and encouragement along the way.

6.1.3 Role of Actors in Energy Transition

A sustainable energy transition is possible through understanding the interconnected roles of both human and non-human actors. Drawing on principles from Actor-Network Theory, this theme highlights how individuals, institutions, technologies, and even buildings themselves become interconnected in shaping energy futures. Interviewees emphasized that citizens, municipalities, NGOs, and private stakeholders all have unique roles to play in initiating and supporting energy communities. At the same time, non-human elements, such as regulations, infrastructure, and energy technologies, also influence the possibilities and development of sustainable energy management. In this network of interactions, enrolling the relevant stakeholders and technologies becomes a strategic and continuous evolving process, that not just determines the potential of energy communities but also their inclusive, flexible, and resilience in the context of heritage reuse.

Enrolling Stakeholders

Building an energy community relies heavily on the ability to bring together a wide range of stakeholders or (human) actors. This can range from everyday citizens to municipalities, NGOs, building owners, and care organisations. Interviewees consistently highlighted that successful projects often begin with a few dedicated individuals who reach out to others and start mapping local needs and opportunities. As I06, a member of a Greek energy community explained, these initiatives typically *"start with a smaller group of more visionary individuals [and then grow] through an open invitation so more people join in"*. I01 reinforced that process, describing how the communities often form, after calls from local governments or citizen groups asking for help to *"legally form"* (personal communication, 18 March 2025) and launch energy communities. I05 also shared a powerful example of working directly *"in collaboration with an organization that looks after people with heavy forms of psychosis"*. This indicates how energy initiatives can also connect with socially vulnerable groups. This broad, inclusive approach to stakeholder engagement could be essential for building trust, sharing resources, and aligning different actors around a shared vision for sustainable reuse.

Mobilizing Non-Human Actors

In the energy transition, technologies and infrastructures are not just tools but they are active participants that shape how communities engage with energy. Across the interviews, non-human actors like solar panels, water mills, building automation systems, smart meters, and even district heating networks emerged as crucial elements in enabling or constraining energy communities. As one expert described, their work involves not only *"hardware... but also extensive software for configuration and building management"*, showing how physical and digital systems together influence energy flows. Even in small, informal ways like shifting appliance use to daylight hours. I06 and I03 emphasized that people are already adapting to energy-responsible behaviours based on the availability of sun or the limitations of infrastructure. This practice of load shifting by maximizing the renewable energy usage is termed as Demand Side Flexibility (DSF). At the same time, *"the regulations, governance systems and business models"* (personal communication, 28 April, 2025) are some of the areas that need to be developed with clearer frameworks and democratic approaches. For Kopli 93, mobilizing non-human actors through solar and wind infrastructure, smart devices, or digital tools will be key to creating a flexible, smart and efficient energy community.

Mediating Infrastructure

Both physical and digital infrastructures play a crucial role in mediating how energy is generated, stored, and consumed within communities. From HVAC systems and security networks to solar parks and district heating, these non-human systems shape what energy transitions look like on the ground. One expert explained how *"the grid operates as a big battery"* (personal communication, 3 April 2025) allowing solar energy to be shared virtually across locations through decentralized power-generating networks. These networks are also called Virtual Power Plants (VPPs). Experts described technologies like smart load shifting and heat storage as important tools for managing energy in buildings where physical changes are restricted. In heritage contexts, where direct physical interventions are often not allowed, these systems offer a way to improve energy performance. They act as workarounds, helping communities like Kopli 93 reduce energy use or shift it to greener times of day, without needing to alter the building's protected fabric.

Material Participation of Heritage Structures

Heritage buildings can also be considered as active participants in shaping community-based energy solutions. Their materials, design features, and sensitivities to *"humidity or temperature"* (personal communication, 28 March 2025) must be considered when introducing new technologies. As one expert noted, high-level heritage sites with "inbound paintings" (personal communication, 18 March 2025) or delicate features require careful management, as even small environmental shifts can pose risks. While constraints are clear, the physical structure can also enable new forms of use. For instance, I02 suggested that historically Kopli 93 has been adaptively reused *"for so many different things. . . it's easy to justify new uses"* offering flexibility in how the space can evolve. Such as installing sensors, smart thermostats and smart meters can offer innovative energy solutions which can also be adapted by energy communities. This dual role, as both a constraint and an enabler, shows how heritage buildings materially shape the design and logic of energy transitions.

Negotiating Constraints

Working with heritage buildings often means navigating a complex and rigid network of rules, permissions, and expectations. Interviewees described how approvals depend not only on official regulations but also on the attitudes of individual heritage professionals. As one expert put it, *"a lot of those things are really dependent on the local... heritage professionals who will either give you permission or not"*. The mechanised systems, like electronically controlled windows or building-wide automation, can be harder to deploy in protected settings. But negotiation goes beyond technical restrictions. There's also the question of values, whether a heritage space should remain publicly accessible or be repurposed into high-end or luxurious developments. These negotiations highlight the need for energy communities to be flexible and strategic. The communities are required to work within formal rules while also advocating for the reusability vision in a broader sustainable setting.

Reaction of Networked Actors

Further, due to a substantial change in the functionalities and operations of the buildings, energy transition is also shaped by how the people respond to the change. I06 mentioned that *"resistance is inevitable... as we're going to need a [lot] of solar panels and wind turbines"*. People may oppose renewable energy developments for environmental, aesthetic, or political reasons. However, when communities are directly involved in the planning, decision-making, and benefit-sharing, they're more likely to support these projects. This sense of *"procedural justice"* (personal communication, 28 April 2025), where people feel ownership over the process, helps eradicate misinformation and reduce conflict. Kopli 93 is shaped by both heritage protection rules and the everyday needs of the local community. To move forward with an energy community, it's important to involve people early and openly. Creating inclusive, participatory processes will help build trust, gain support, and ensure the project is strong and sustainable.

Cultural Sentiments

The heritage sites carry a deep cultural meaning for the local communities who work, use or simply reside around them over time. Interviewees spoke about how buildings are not just objects to be preserved. They are spaces where traditions, social practices, and collective memories live on. One expert explained that *"the function of the building can't fully be separated from its identity"*, highlighting how preserving public uses, like old saunas or community spaces, is just as important as protecting walls and windows. I02 revisited some cases about attempts to privatise or commercialise these spaces by turning a historical working-class public sauna into a luxury spa, which sparked tensions around authenticity and belonging. Recognising and respecting these cultural sentiments will be crucial in shaping an energy community that feels connected to the past, but also responsive to the present needs of sustainability.

Figure 6 below depicts the thematic analysis of the codes for the main research question, which was retrieved from all the conversations during the data collection method. The findings are presented in a hierarchical map starting with the theme of the research question at the top, which is *Potential for Building an Energy Community*. Followed by the three themes, which are created by aggregating the identified codes relevant to achieving the objectives of this research. The first theme is *Governance and Participation in Energy*

Communities, followed by seven codes, *Democratic Structure, Citizen-Led Initiatives, Inclusive Decision-Making, Capacity Building, Local Ownership, Scalability of Energy Communities and Energy Community Stakeholders*. The second theme is *Heritage context and Adaptive Reuse*, formed from the six codes *Reuse and Circularity, Underuse and Decay of Heritage Buildings, Heritage Protection Constraints, Legal and Regulatory Barriers, Ownership Challenges, Financial Dimension of Adaptive Reuse*. Finally, the third theme is *Role of Actors in Energy Transition*, identified from the seven codes *Enrolling Stakeholders, Mobilising Non-Human Actors, Mediating Infrastructure, Material Participation of Heritage Structures, Negotiating Constraints, Reaction of Networked Actors, Cultural Sentiments*. The fourth level of the hierarchy map shows how often each point was mentioned and which expert brought it up. This helps illustrate which perspectives were most prominent and relevant in answering the research questions.

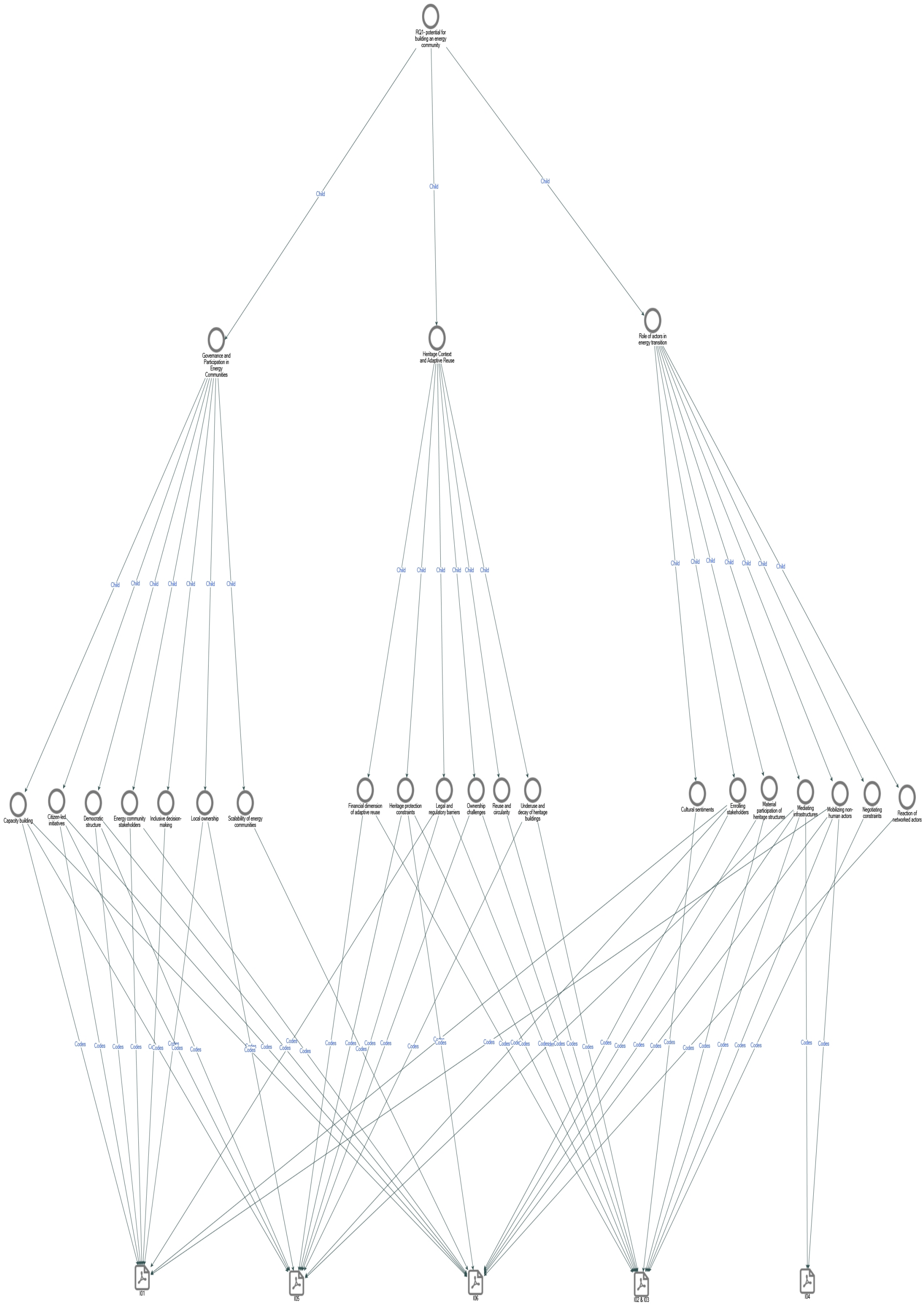

Figure 6. Thematic analysis mapping for main research question from NVIVO 15.

6.2 Leveraging Digital Technologies for Energy Transition

The following subsection addresses the sub-research question: *How can energy communities integrate digital technologies for better energy management in heritage buildings?* Following the preceding section about establishing factors for energy communities, this section will delve deeper to understand how energy communities can integrate digital technologies for better energy management in heritage buildings. The insights are presented from the expert interviews and fieldwork through observation and informal conversation.

Heritage buildings pose unique challenges, like their protection measures, sensitivity to changes, and utilisation by diverse users. At the same time, they are quite energy-intensive and vulnerable to climate and infrastructure risks. Digital technologies offer a bridge to such constraints by enabling smarter, more flexible energy use without the need for major renovations. In other words, digital technologies give energy communities a chance to care for or maintain the heritage buildings in a way that also respects their history. Often, these tools are the silent drivers of sustainable and inclusive energy transition. The findings show that while there is strong technical potential, successful integration depends heavily on social, regulatory, and organisational conditions. Communities play a central role in shaping how these tools are adopted, trusted, and used over time.

6.2.1 Using Smart Technology Without Changing the Building

One of the biggest challenges in improving the energy performance of heritage buildings is that one simply can not touch or interfere with them. Adding insulation, solar panels, or even changing windows might be forbidden because of the preservation laws. But smart technologies offer a way around this. Instead of changing the building itself, they can allow people or energy communities to work with the building. To be specific, like monitoring it, adjusting how energy is being used, and improving comfort behind the scenes. Sensors, smart thermostats, smart meters, smart grids and software systems can track conditions like temperature, energy usage and time and duration for distribution of energy without damaging walls or altering the historic features.

Non-Invasive Energy Tools

As one expert noted, *"You can install sensors... but if you want mechanised systems, like electronically openable windows, that’s harder to justify in heritage contexts"* (personal communication, 28 March 2025). For places like Kopli 93, where the building’s identity and aesthetics are part of its value, these "non-invasive" (personal communication, 2 May 2025) solutions are key to balancing sustainability with cultural care.

Installing smart energy tools offers a practical and considerate way to manage energy efficiently in heritage buildings, where physical changes are tightly regulated. Rather than disrupting the building's structure and features, the emerging technologies *"operate quietly in the background"* (personal communication, 2 May 2025). During the expert interviews and informal conversations in the ethnographic fieldwork, it was consistently highlighted that small-scale sensors, smart meters and digital monitoring systems are among the most feasible and possible interventions as a first step towards sustainable energy management of historic buildings. The conversations also highlighted the significance of balancing both sides of preservation and innovation. I04, being an expert in the smart building technologies, described how their firm supports the building automation by laying in automation tools that manage heating, ventilation and lighting without affecting the inbuilt features. This kind of *"gentle tech"* as it emerged from one of the conversations during fieldwork at Kopli, can allow the energy communities to work with the existing structure rather than forcing change upon it.

Behaviour-Driven Use of Technology

Behavioural shifts, like choosing when to use appliances based on signals like energy prices or grid load can effectively contribute to sustainable energy use. A significant benefit of the smart energy tools is that they can predict and suggest the end-users to change the way they use energy. Leveraging such tools through energy communities can reduce consumption and create reliance over renewable energy sources, without needing costly infrastructure. One expert explained that energy systems can be designed to reduce consumption based on *"presets or time of day"* (personal communication, 2 April 2025). They also mentioned that these savings can happen both inside the building and in response to *"external atmospheric conditions"* (personal communication, 2 April 2025). Load shifting, or moving energy-intensive tasks to off-peak hours when electricity is cheaper or cleaner, was one recurring strategy during the interactions. As I06 mentioned about the basic habits like *"putting on the washing machine only during the day when there's sun"* can help users participate in demand-side flexibility in an accessible way. However, behaviour change isn't only about savings—it's also about trust. People are more likely to accept automation or digital monitoring if they feel they are able to access and control it. In this sense, technologies don't just automate but also invite people to participate. For sites like Kopli 93, where digital interventions must be subtle, empowering residents to shift their habits through clear, user-friendly systems may be one of the most effective paths to energy resilience. However, throughout the data collection procedure, all the experts mentioned that the use of technologies for demand flexibility is still in its infancy. Slowly but steadily, progress is being made, but still, a lot of developments are yet to be made.

6.2.2 Sharing and Managing Energy Through the Grid

For repurposing heritage buildings, the energy community model becomes especially valuable when paired with grid-based solutions. Rather than producing and consuming energy in one place, these buildings can participate in broader networks of energy sharing. Such as benefiting from *"remotely installed solar parks"* (personal communication, 18 March 2025, 3 April 2025), off-site generation, and *"collective self-consumption schemes"* (28 April 2025) that redistribute clean and renewable energy through the grid. Interviews revealed that digital technologies make this kind of virtual sharing possible, allowing members to *"own a portion of a solar park"* (personal communication, 18 March 2025) and receive the benefits through smart metering and cheaper energy bills. The grid itself becomes a kind of bridge, carrying electricity to the designated destinations. But making this system work is not only about infrastructure. It also relies on good coordination, smart planning, and policies that allow communities to legally and digitally connect. For a site like Kopli 93, this model opens the door to energy transformation, even without touching any part of it.

Shared Energy from Other Locations

The off-site energy generation using renewable energy sources was a significant and recurring suggestion that emerged from the interviews. Energy communities are increasingly adopting shared solar parks or regional installations, using digital platforms to allocate that energy virtually to individual buildings. This model allows protected sites to benefit from clean energy without physically installing panels or altering facades. As I07 explained, *"communities install solar parks off-site, and then they allocate the energy virtually"*. Similar experiences and knowledge were also shared by I01, I05 and I06. They also found this approach suitable for heritage buildings for its renewable transition, even when they can not generate locally. While there is some technical loss in transmitting energy over distance, I07 pointed out that *"in modern grids, it's relatively low—maybe around 5–8% from source to socket depending on distance and infrastructure quality"*. More importantly, this model supports a more connected energy system. Resilient systems can be built if they are both socially and technically inclusive and well integrated, not through isolation. Virtual participation through shared energy sources could offer a viable and legally acceptable path to energy efficiency, without having to compromise the building's physical heritage.

Smart Coordination with the Grid

Connecting heritage buildings to a wider energy network requires smart coordination with the grid. As I07 explained, *"The bigger challenge is not [energy transmission] loss, but* *timing"*, since energy is generated in real-time and must either be used, stored, or redirected quickly and efficiently. In such cases, Virtual Power Plants (VPPs) come in as suggested in the interviews. I07 defined VPPs as "*is basically a digital platform that aggregates lots of small energy assets—solar panels, home batteries, EV chargers, heat pumps, even smart appliances. It connects them through software and then controls them like one big power plant. The platform decides when to store, release, or reduce energy use based on market signals or grid needs"*. An analogy was drawn as *"Think of it as a central nervous system. It's constantly checking supply, demand, and prices. For example, if energy prices spike at 6 PM, the VPP might pull from home batteries instead of the grid—or preheat a building earlier in the day. It's all automated.."*. This flexibility not only supports the grid but helps the building access cheaper, cleaner energy without needing major changes to its physical structure.

6.2.3 Making Buildings Comfortable and Efficient

Improving energy efficiency in heritage buildings is not only about cutting down on bills or emissions but also making these spaces more livable. Many older buildings are hard to heat, poorly ventilated, or uncomfortable during extreme weather. During the ethnographic fieldwork at Kopli93, the conditions were very similar, with the rooms being colder than the outside temperature. Also, the area of these spaces were huge, which would certainly require a massive amount of energy to heat. Hence, the energy communities must look for smart, adaptive ways to make the indoor environment comfortable and healthier, due to the restrictions on major structural upgrades. Strategic and efficient use of digital tools like VPPs that *"automate heating systems, or predict climatic conditions of particular zones, and sensors for air quality"* (personal communication, 2 April 2025), can play a very significant role in this case. They would help maintain comfort and health without sacrificing the building's character. As interviewees highlighted, the goal is not just technical efficiency, but also supporting the well-being of the people who live and work in these spaces. For Kopli 93, where cultural and social use are deeply tied to the space, this balance between efficiency and comfort is crucial.

Flexible Energy Use, Without Production

The heritage buildings have the potential of playing an active role in sustainable energy systems by adjusting the *how* and *when* to use electricity. This kind of flexibility, like shifting the heating or lighting to off-peak hours, is becoming a key feature of the public and also several energy communities across Europe, especially in *"Spain, Germany and Netherlands"* (personal communication, 18 March 2025). As one expert, I06, explained, *"It's about flexibility. . . communities are taking on storage or demand response, or* *learning to behaviorally shift their consumption"*. Rather than contributing energy to the grid, heritage buildings can act as “flexible loads,” adjusting their usage in response to grid demand or price changes. Experts further pointed out how *"a VPP might preheat a building earlier in the day or pull from batteries instead of the grid during peak hours"*. This reveals a coordinated approach that mimics the effect of a large power plant by pooling small, flexible actions across multiple sites. Even small adjustments, like dimming lights or shifting HVAC use by an hour, can reduce strain on the grid and lower costs. This approach further enables the use of existing systems more *smartly*. By warming a space by predicting the colder periods of the day or maintaining better air quality through smart ventilation, the visitors experience healthier indoor environments. Also, this could be achieved without changing the fabric of the building.

Comfort and Environmental Factors

In heritage buildings, due to its obsolete and complex architecture, comfort is often compromised over efficiency. However, for energy communities, with the motivation of making this space sustainably livable, it is an important aspect. The inferior conditions of the older buildings, due to the lack of maintenance, suffer from poor air quality, uneven temperatures, or high humidity, all of which can affect both people and the building fabric. The smart tools offer a subtle yet effective way to monitor and improve these conditions. Interviewees pointed to the growing use of environmental sensors in community and educational buildings, which measure temperature, humidity, CO_2, and even occupancy. *"They had sensors in the classrooms for temperature, humidity, and also* CO_2 *and air quality"*, I03 explained. These tools don’t just support health, they also guide the decisions for energy consumption. For example, if CO_2 or humidity levels are high (derived from the readings of the tool) or a space may need ventilation, simply opening a window could greatly help, and even reduce the temperature of the room. The experts further emphasised "CO_2 *is perhaps the best way to tell you, how well you’re doing... it tells you how much you should ventilate"*. Such insights can help communities strike a well-maintained balance for both human comfort and cultural care through smarter and more responsive energy use.

6.2.4 Barriers to Digital Integration

Even though digital technologies can help make heritage buildings more energy-efficient, incorporating them into practice brings some challenges. Across the interviews, several common obstacles came up, like strict heritage rules, unclear ownership, limited funding, and the lack in digital literacy. Such barriers can significantly slow-down or hinder the progress of the best-intentioned projects or initiatives. Sometimes the issue is not only with the technology itself, but the surrounding actors (human and non-human) relevant to the cause. To mention some, are the paperwork, the permissions, funding opportunities, high costs and the relevant skills of an individual to access and operate the digital tools. For Kopli 93, which is still in an early phase of organising itself, with the absence of any sustainable energy management systems, these barriers can often trigger demotivation and frustration. This subsection explores these barriers in detail, offering a practical perspective on why integrating digital systems is often more complex than it usually appears to be.

Cost Intensive

One of the most common barriers to integrating digital energy technologies, especially in a heritage context, is cost. While tools like smart automation systems or advanced sensors can offer long-term savings, the immediate expense is often too high for a fully operational set-up. As Interviewee I04 explained, *"it's also too expensive for mass-scale adoption"*, especially in bigger buildings or residential contexts. While in commercial real estate, decision-making is more straightforward because the building owner often considers both the cost and the benefit. *"The decision maker is also the beneficiary of that decision"*, the individuals during the ethnographic fieldwork noted. The buildings for renovation might pass through developers, construction firms, and local users, creating a chain of stakeholders who do not always share the same priorities. *"There's a built-in conflict between the two [sides]"* they added, highlighting the disconnect between who pays for upgrades and who actually benefits from them.

In the case of Kopli 93, I02 and I03 mentioned that the cost of operating such buildings with efficient energy management can make them feel out of reach. Drawing a lot of energy from solar panels, even if installed remotely, and integrating with the smart technologies to simply heat the space can be immensely cost-intensive. Experts made numerous remarks like *"You might not be able to use the building because of the high cost"* and *"As you can imagine, a lot of energy loss. It's quite costly to keep the building warm"* depicts the uncertainty of effective energy management. This highlights a deeper issue: communities may want to preserve heritage, but simply *"can't afford to"* (personal communication, 28 April, 2025) For these reasons, the financial burden of digital solutions remain one of the most significant obstacles to scaling digital energy solutions in heritage contexts.

Lack of Digital Literacy and Privacy Concerns

Not everyone feels confident and comfortable with adopting digital energy technologies. As one interviewee noted, *"The main challenge is having people understand the purpose that they serve and how they operate"*. This gap is especially visible among older residents, but it can affect anyone unfamiliar with smart systems. In energy communities, with people from diverse demographics, this becomes a real issue. "There's older people, there's illiterate people... they'll need some help and empowerment to get there", as explained by I06, who is also a member of an energy community in Greece. Beyond digital literacy, there are also concerns about privacy and trust, particularly around how personal data is handled. Without clear communication and support, even simple tools can feel intimidating or invasive. Relating to this aspect, I05 remarked *"[Monitoring] a lot about what people are doing at their home when they are installing....[such] type of smart technology. So there is this privacy gap*. Hence, making digital literacy and privacy concerns are the key factors in whether these systems are accepted and used effectively.

Potential for Modern Energy Solutions

Despite the numerous challenges, the experts shared their opinions on some improvements for catalysing the modern energy solutions. Interviewees consistently emphasised that energy communities could emerge as significant entities for the energy transition if supported by the right policies, tools, and infrastructure. I01 repetitively mentioned about the need to accelerate the digitalisation of the grid. Currently, the grids are owned by Distribution System Operators (DSOs), hence it does not allow flexibility or other benefits in the journey of energy transition for the citizens. The vision is not only developing technically, but also democratically. Further, I05 pointed out, *"Governments should actually recognise the potential of energy communities... for energy democracy, financial reasons, even for security"*. However, they were also clear that this potential remains underused due to policy gaps, limited access to the grid and lack of public awareness across countries, especially in the European Union (EU). This was further supported by I06 mentioning, *"There's an inadequate transposition of the European directives into national legislations"*. This points to the missing support systems like nationally authorised registration desks, organising information campaigns for citizens as one-stop shops, and financing mechanisms. Interviewees also highlighted the need for concrete regulations like *"Incentives for energy communities should be produced, business models for them to adopt and use cases for them to go out there for heritage building restoration*.

Furthermore, energy communities often struggle to access the central energy grid. Large-scale private projects are frequently given priority, leaving community initiatives at the back of the queue without guaranteed or timely access. Some experts also suggested on organising information campaigns for both municipalities and citizens to educate them about the possibilities of *"what are energy communities, how can they join one, and how can they create one"* (personal communication, 28 April 2025). Such initiatives have been happening to install some *"one-stop shops, in Austria"* (personal communication, 28 April 2025). Without better access to the grid, more inclusive regulations, and stronger recognition of community-led projects, much of the potential for these technologies in heritage contexts will remain untapped.

The Figure 7 below depicts the thematic analysis of the codes for the sub-research question, which was retrieved from all the conversations during the data collection method. The findings are presented in a hierarchical map starting with the theme of the research question at the top, which is Leveraging *Digital Technologies for Energy Transition*. Followed by the four themes, which are created by aggregating the identified codes relevant to achieving the objectives of this research. The first theme is *Using Smart Technology Without Changing the Building*, followed by two codes, *Non-Invasive Energy Tools and Behaviour Driven Use of Tech*. The second theme is *Sharing and Managing Energy Through the Grid*, formed from the two codes *Shared Energy from Other Locations and Smart Coordination with the Grid*. The Third theme is *Making Buildings Comfortable and Efficient*, identified from the two codes *Supporting Environmental Factors and Comfort, and Flexible Energy Use (Without Production)*. Finally the fourth theme is *Barriers to Modern Energy Solutions*, created from three codes identified *Cost Intensive, Lack of Digital Literacy and Privacy Concerns and Potential for Modern Energy Solutions*. The fourth level of the hierarchy map shows how often each point was mentioned and which expert brought it up. This helps illustrate which perspectives were most prominent and relevant in answering the research questions.

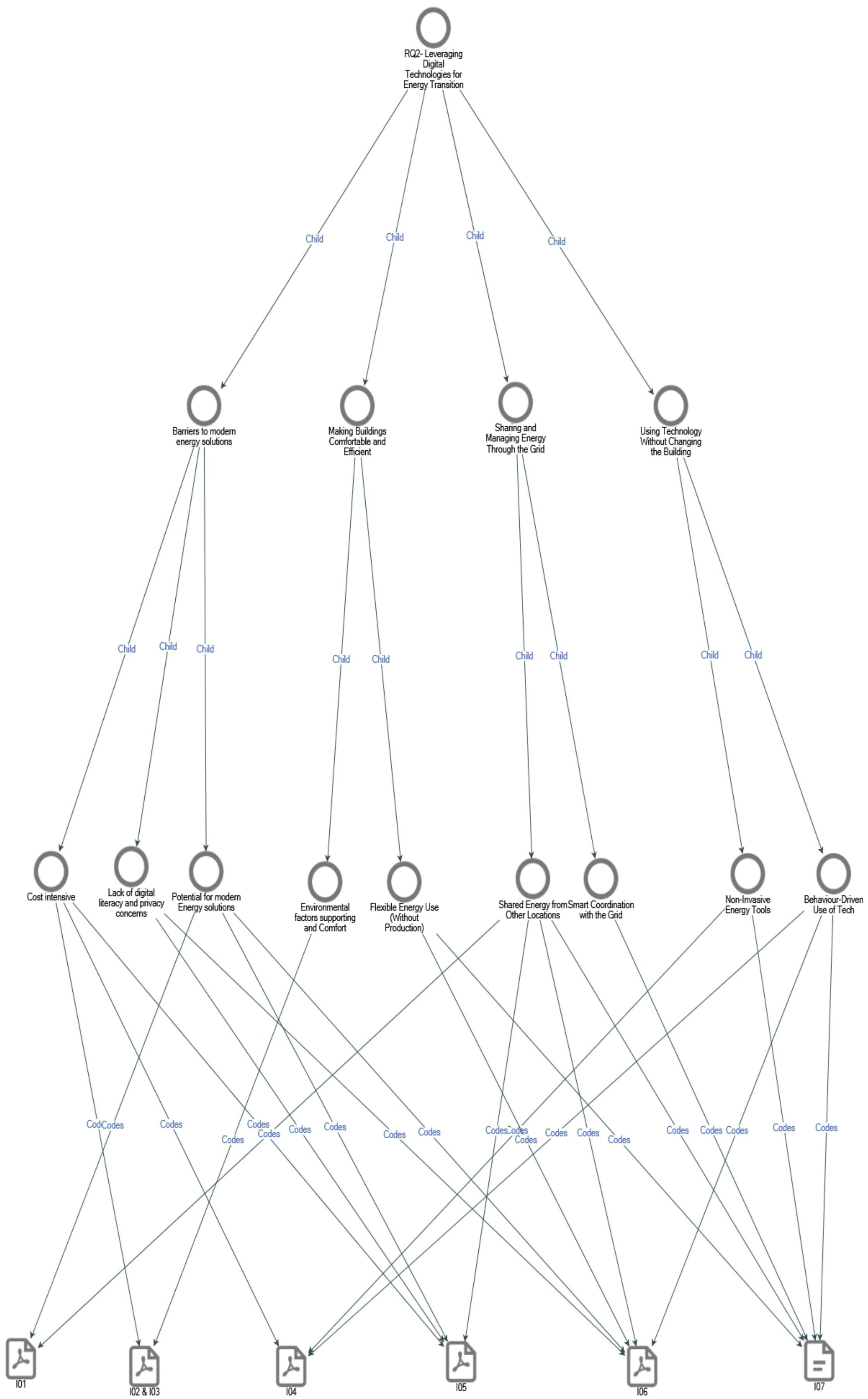

Figure 7. Thematic analysis mapping for sub-research question from NVIVO 15.

7. Discussion

The findings outlined in the previous chapter address important questions that are relevant and also reveals the further potential for the scope of this case study. This chapter reflects upon the broader implications of these results, linking them back to the theoretical and literature upon which this research has been built in the fields of community energy, heritage reuse, and digital transitions. By taking the insights from Kopli 93, this discussion also explores how some of the identified barriers, which can be addressed through more grounded, practice-oriented strategies that support both cultural preservation and sustainable energy futures.

7.1 Connecting the Results Back to the Literature: A Theoretical Synthesis

The results of the first research question, intended to uncover the potential of forming energy communities and the role various relevant actors (human and non-human). They indicate that Kopli 93 holds complex yet significant potential for the development of an energy community that supports its sustainable reuse. While the site does not yet have a formal energy system, its cooperative structure, history of communal use, and cultural inclusivity, provides a strong foundation to begin. The building already functions in many ways as a commons, and such values of shared responsibility and collective care aligns closely with the goals of community energy.

This potential is especially relevant in the context of growing interest in combining heritage preservation with climate action (Dauda & Ajayi, 2022; Foster, 2020; Mehanna & Mehanna, 2019). Kopli 93, like many heritage buildings, requires not only physical maintenance but also a sustainable model for its sustainable adaptive reuse. In this context, an energy community can provide a structure for long-term social engagement, local stewardship, affordability, and incorporating technical benefits, while preserving its historic value.

As a starting point, it is essential to understand the barriers that make it difficult to adapt and reuse heritage buildings. From interviews it became clear why forming energy communities could be such a meaningful and practical way to overcome those challenges. The insights reflect on the existing literature body of this study, where authors such as (Arfa et al., 2022; Bezerra De Sousa & Henriques Da Fonseca, 2022; Jiang et al., 2023; Mehanna & Mehanna, 2019; Spelman, 1993) highlights the restrictions of major physical renovations and emphasise on material reuse and circular practices in heritage buildings. The interviewed experts, following a similar tone added that the mapping of local waste streams suggest a broader view of sustainability that fits well with the goals of the commons and repurposing. This kind of circular processes align with the adaptive reuse of heritage spaces. In many cases, preserving cultural value does not mean keeping things exactly the same, but finding innovative and low-impact ways to care for old buildings and keep them operational. In such scenarios, a local community can offer a practical and democratic way to support the efforts.

The findings showed that, underuse of heritage buildings posed a great threat to it life and condition. Leaving the buildings abandoned, leads to increased inefficiencies of the energy systems, as they start turning obsolete. Hence, complementary to (Ahsan et al., 2024) work, there is a need for a model that not only restores physical infrastructure but also ensures that the building remains actively used. A community-led energy initiative, focusing on renewable energy systems (Barnes et al., 2022; Brummer, 2018; Rogers et al., 2008; Strachan et al., 2015; Walker & Devine-Wright, 2008; Wirth, 2014), could directly contribute to this, by making the site more affordable to operate and socially relevant again.

A prominent characteristic of heritage buildings, encircling the literature and the expert interviews, revealed the clear constraints of making major structural changes to avoid the loss of ancient or cultural detail (Arun et al., 2024; Mehanna & Mehanna, 2019). To retrofit a heritage building through sustainable energy management, installation of solar panels or internal renovations, impose strict restrictions towards technical feasibility. Due to heritage preservation rules it is often essential to navigate through the complex multi-level governance systems. This presents a strong case for showcasing the valuable potential of establishing an energy community. Rather than relying on invasive physical interventions, such a bottom-up approach can shift focus to producing, and/or sharing renewable energy or behavioural solutions that work within the existing structure.

Even though the EU directives support the energy transition initiatives and energy communities (European Commission, 2020), there is still a lack of sufficient support structure and regulations, which have emerged in the findings as well as the literature. The current laws often fail to support collective ownership or decentralised energy generation (through energy communities), causing delays in the course of energy transition. These findings point to a gap between the ambition of community-led models and the reality of institutional infrastructure, suggesting that improving policy reforms will be as crucial as community engagement. The further suggestions on improvements have been discussed later in sub-research questions section.

Finally, ownership emerged as a novel and major barrier to adaptive reuse through energy communities, only during the expert interviews. In some cases, heritage buildings are controlled by institutional or religious bodies that are disconnected from the local needs or are unwilling to share authority. In the case of Kopli 93, there is already a cooperative dynamic, but ownership and municipal authorization still holds the utmost power. For any energy community model to work, there must be both legal clarity and a willingness to collaborate from everyone who holds the title to the building.

7.1.1 Governance Structure

It is important to understand the participatory and governance structure for energy communities. The findings show that governance is the backbone of how energy communities form, function, and grow. In the case of Kopli 93, which already operates with a cooperative and community-driven mindset, this becomes particularly relevant. The site offers a social and cultural foundation that energy governance can build on. But that foundation still needs structure, tools, and a clear sense of how decisions are made and carried forward.

The findings reinforce much of the existing literature on energy communities like democratic structures, which indicates that the community belong to the members, fostering real ownership and trust (Becker & Naumann, 2017; Berka & Dreyfus, 2021; Hess, 2018). It's not just about voting. As Walker and Devine-Wright, 2008 and Bauwens et al., 2016 point out, participation is more meaningful when people also benefit from the system they help to shape. This kind of shared governance becomes especially important in heritage contexts, where the adaptive reusability requires sincere preservation of their historical, social, and emotional meaning. In the case of Kopli 93, the cooperative spirit among the caretakers of the building already makes it suitable for a community energy model. A cooperative structure offers both the flexibility to adapt to local needs and the values that align with the relevant members and stakeholders in managing energy, as well as shaping the long-term sustainable future of the site itself.

At the same time, it is important to recognise that not everyone starts with the same level of experience or confidence. Many energy communities begin informally, driven by a few enthusiastic individuals who carry a vision towards change. These citizen-led efforts show that energy transitions often start with social relationships rather than technology. In the context of Kopli 93, this approach aligns well with the ongoing transformation of the site through cultural and community-led initiatives, as observed during the fieldwork. Establishing an energy community would not introduce a completely new structure, but rather build upon the existing principles of collective and local engagement with some expertise in the energy transition.

Inclusive decision-making is essential to cater to diverse needs, which helps in building long-term resilience. By developing inclusive and transparent governance structures, the communities will gather trust and motivation to engage meaningfully in the energy transition (Burke & Stephens, 2017; Teron & Ekoh, 2018). In Kopli 93, where different members may have varying levels of knowledge or authority, designing inclusive participation would help ensure that the energy community gains from diverse perspectives. Rather than being led by a few, the energy system would be shaped collectively, where everyone feels they have a voice in the decisions about the sustainable repurposing of the buildings. However, it is also quite practical that not every member may have the relevant skills or knowledge, which can gradually shrink the participation into a smaller group.

Capacity building plays a vital role in expanding this circle, and the aspect emerged frequently during the interviews. Internally, energy communities can have limited technical or legal knowledge. Upskilling may not always be helpful, as that would require resources like time, space and money, and also cause burn-out and slow down the progress. The interviews highlighted the importance of externally hiring engineers, legal advisors, and digital tool experts, that convert complex systems into everyday understanding. Their engagement enables the smooth development and operation in the energy projects. This kind of support is essential for Kopli 93, where enthusiasm and commitment are already present, but institutional knowledge and energy expertise may need strengthening.

Further, the potential for the scalability of energy communities also emerged as a novel insight with strong governance and participatory practices. Local initiatives, when connected, often form wider networks that share knowledge, resources, and visibility, creating a *"virtuous circle"* (personal communication, 28 April 2025). Then, the new projects benefit from those already established. For Kopli 93, this means that even a small, community-led effort could tap into broader energy networks across Estonia. Scaling does not always mean expanding in size, it can also mean building stronger systems and partnerships. This is especially valuable for heritage buildings, where energy upgrades are more complex. A connected community landscape can offer support, policy influence, and technical guidance to help places like Kopli 93 move forward.

7.1.2 Network of Actors

In relations to the framework used in this research, the findings strongly echo the central idea of Actor-Network Theory. The sustainable energy transition in heritage buildings is shaped by networks of both human and non-human actors coming together (Barnes et al., 2022; Sayes, 2014; Van Summeren et al., 2021). In this context, energy communities do not emerge simply through technical innovation or political benefits. They take shape through the systematic enrollment of people, policies, devices, and even the building itself, each becoming key actors of the network for a successful formation of energy communities.

Across the interviews, it became clear that people are often the first actors to be enrolled. Enthusiastic individuals, local leaders, residents, and even municipalities play a crucial role in initiating energy communities. But their ideas do not move forward in isolation. They rely on other actors, such as institutional regulations and policies, digital platforms, funding schemes, and hardware, as a stable starting point to make it tangible. With any imbalance among the actors, the network falls apart, causing delays in the implementation. This helps explain why the emergence of energy communities and their significant impact is not quite visible. Some actors, like policymakers, heritage conservationists or grid operators, are more difficult to involve in the process, either due to institutional complexity or competing priorities. At the same time, non-human actors like heritage protection regulations or specific technologies can act as powerful mediators or sometimes even resists the change by limiting the technical or legal possibilities.

Adding to the characteristics of the framework, non-human actors are equally important in the entire ecosystem of energy transition. The interviews highlighted how tools like sensors, smart devises, solar parks, or VPPs are not just passive technologies, but are active participants in shaping energy practices like guiding decisions, enabling flexibility, and redistributing control within the systems, as also has been explained in the literature of the ANT theory (Barnes et al., 2022; Hakimi et al., 2020; Märzinger & Österreicher, 2020). For example, smart devices can automate load shifting or environmental monitoring, simply guiding the human behaviour without altering the building. In ANT terms, these are not just tools but actants that influence relationships and redistribute agency across the network. In a heritage site like Kopli 93, where physical interventions are limited, these non-human actors become especially powerful in enabling transition without disruption.

At the same time, such innovative initiatives often encounter resistance, which must be negotiated through and by the network. Resistances like, scepticism from building owners who may not see the immediate value or return on such initiatives, hesitance among residents who may feel uncertain about the technology or their role in the process. Further due to rooted misinformation, distrust, or fear of change, there is often a societal barrier against renewable energy systems. According to ANT, this kind of friction is not a failure but part of the process. Networks are dynamic in nature, sustained through ongoing processes of negotiation, trust-building, and the alignment of diverse interests. Rather than viewing resistance as an obstacle to be eliminated, it should be understood, acknowledged and strategically incorporated into the network's design and operation.

To summarise for heritage settings like Kopli 93, these characteristics encourage to recognise the building not just as a structure of bricks and stones, but as an actor in its own, that constrains, signals, and shapes the energy practices around it. Such a network of actors, reveals the interconnectedness among the various actors for the setting up of a functionality, reminding us that progress is not linear.

7.2 Steps for the Future in Digital Energy Solutions

This section of the discussion explores how digital technologies can be leveraged to support energy communities for efficient energy management. It has been developed in the case of Kopli 93, but can be extended beyond, depending on the use-case. The insights from the data collection imply that while technologies offer opportunities for better energy efficiency, it is also crucial to integrate it within the social and legal boundaries of the site. The following paragraphs will highlight the opportunities, suggestions and challenges of implementing technologies in heritage context. Relevant needs and suggestions are made based on the insights gathered and the in-depth literature review, aiming to bridge the gap between theory and practice of developing future-oriented energy community models.

Keeping the heritage buildings usable, affordable and sustainable may face preservation regulation challenges. Installing solar panels at the rooftop, or upgrading the heating systems may not be always an easy solution due to the sensitivity of the sites. As can be found in the literature of this research, the experts similarly pointed that, rather than altering the physical fabric of a heritage structure, digital tools can serve as a work-around. The tools like smart meters and smart grids operate through the modern technologies such as AI and ML. They can predict and suggest the end-users regarding the energy prices throughout the day, which appliance is consuming major or minor energy, when is the correct time to consume from the renewable energy systems etc. (Asakawa & Takagi, 1994; Haq et al., 2022). Use of the smart devices generate huge amounts of data, which allows predictive analysis and suitable suggestions. This data can then guide small behavioural shifts, like using the washing machines during off-peak hours of the day, amount of energy generation from the renewables, etc. (Aljabery et al., 2021; O'Connell et al., 2014; Palensky & Dietrich, 2011). Such practices enable significant energy savings over time. Experts pointed out such tools as non-invasive systems that can be installed without damaging the protected surfaces. Additionally, environmental monitoring tools can track indoor conditions such as temperature, humidity, and CO_2 levels, giving users a clear picture of when and where comfort can be improved. Sometimes, even small actions like opening a window at the right time can make a meaningful difference. Overall, this improves energy performance, enabling better energy management, especially in heritage buildings, without interfering with the cultural and historical significance.

This further gave rise to the energy management strategy of Demand Side Flexibility, which means adjusting energy use based on time of day or price (O'Connell et al., 2014; Palensky & Dietrich, 2011). To strengthen the arguments and procedures of demand flexibility, literature suggests implementing two types of models: price-based and incentive-based programs (Aljabery et al., 2021). In a price-based model, users adjust their energy use in response to dynamic electricity pricing, like shifting consumption to off-peak times to save money. In incentive-based programs, users are rewarded for voluntarily reducing or shifting their energy use during periods of high demand. For energy community settings like Kopli 93, these strategies could offer both economic support and behavioural motivation to engage in flexible and responsive energy practices.

The next suggestion that came up during the expert interviews was sharing and managing energy through the grid. For heritage buildings, as physical interventions like installation of solar panels are often restricted, smart grid infrastructure offers a promising alternative. As also highlighted in the literature, smart grids enable a more flexible and decentralized approach to energy management (Gungor et al., 2011; Hakimi et al., 2020; Kim et al., 2019; Olatunde et al., 2020; Zhang et al., 2018). Several communities access renewable energy through off-site (remote) solar parks, using the grid as a medium to allocate energy virtually. Although this process leads to some energy loss during transmission, the extent of the loss is subject to some external factors like the distance and condition of the building. This will allow heritage sites, like Kopli 93, to access clean energy without altering the building, while benefiting from increasingly efficient grid technologies.

Building on the concept of smart grids, led to the introduction of VPPs as a practical application of smart grid capabilities. VPPs use digital platforms to coordinate energy assets, like batteries, solar panels, and smart devices across locations, treating them as a network of energy management system. Even without generating energy, buildings like Kopli 93 can act as *"flexible loads"* (personal communication, 2 May 2025), shifting energy use in response to grid conditions or price signals through the digital platforms. Together, smart grids and VPPs offer a flexible and low-impact way for energy communities to integrate heritage buildings into broader sustainable energy networks.

In addition to the recommendations already discussed, the findings highlight a growing potential for modern approaches to energy management. There is an immediate need for accelerating the development of digital infrastructure, alongside supportive policies that ensure energy communities have equal rights to participate in emerging energy markets and strategies. This includes fair access to the grid in comparison to the large private companies, dedicated funding schemes, and clear legal frameworks that recognise energy communities as legitimate players in the energy transition. Beyond infrastructure, there is also a need to encourage and make the citizens aware of their potential in energy transition. Incentives to form energy communities, ready-to-use business models, and one-stop shops to provide practical information about where, how and why to engage with energy communities. In the context of Kopli 93, these suggestions can become powerful drivers of both climate and cultural resilience. Such energy models will provide a democratic approach through collective participation and retain historic character while building a future-ready heritage site.

Despite various opportunities for the energy communities in leveraging digital technologies, some significant barriers were also highlighted that influence the participation rate. Two of the most prominent challenges are the high upfront costs of digital infrastructure and a lack of digital literacy among users.

Installation of smart devices remains financially intensive for most of the communities. In cooperative settings, where decision-making is shared and budgets are limited, leveraging the modern digital technologies often remain out of reach. Hence, these options are often bypassed, continuing with the legacy systems for energy management. This challenge is rather amplified in heritage contexts, like Kopli 93, where restrictions on renovation, limited funds, and legacy heating systems cause major roadblocks in its progress. Without financial support or the introduction of primary business models, integrating digital solutions may discourage the communities from taking the first step.

Even though the communities may gain support through some financial aid, there remains a bigger social barrier: the digital divide or a lack of relevant knowledge to operate in the digital realm (Thunshirn et al., 2025). This highlights the importance of usability and user confidence in shaping how effectively community members can engage with digital tools. The communities consist of older, not-so-well-read, financially weaker and marginalised members. Some may not fully understand the ways a technology works or how it benefits them, which leads to hesitance or resistance. In the case of Kopli 93, where the user base includes a range of age groups and backgrounds, digital tools will need to be introduced gradually, with clear communication and support.

Further, privacy emerged as a genuine concern in the conversations. Smart technologies that monitor a person's energy use can also collect detailed data about his/her daily routines. This raises questions about data ownership, consent, and trust. For the energy communities, it is necessary to address these concerns to build inclusion within the system. Members must feel confident that their data is secure, alongside having a clear understanding and control over how it is collected and used. Without this trust, the very foundation of even the most advanced systems become weak.

7.3 Proposing a Strategic Implementation Roadmap

Based on the discussed recommendations from the findings and addressing the barriers in the Kopli 93 setting, a preliminary implementation guidance has been proposed below. The initiative can begin with lightweight interventions, such as monitoring the physical conditions of the building like emissions from the paint, CO_2 level, and existing heating and lighting systems. Installing smart meters or smart thermostats through simple plug-in systems will allow for monitoring the energy consumption and price in the current scenario. This will also prevent any tampering of the existing infrastructure.

After receiving the readings and gaining the information about energy conditions, every detail can be shared with the group of volunteers, to maintain transparency and build trust within the community.

Once the initial checks are completed, the below steps can be followed:

1. **Stakeholder Mapping & Engagement:** Identify the human and non-human actors based on the Actor-Network Theory. This includes citizens or volunteers, municipal authorities, utility providers, engineers, lawyers and heritage conservation bodies.
2. **Feasibility Assessment:** After collecting the primary monitoring data, the next step involves identifying suitable zones within the building for installing the appropriate digital devices.
3. **Technology Deployment:** Introduce a modular or customisable system of smart sensors and user-friendly website or mobile application dashboards. This will encourage and empower the members with low digital literacy.
4. **Community Training & Governance Framework:** Organise workshops on shared energy management and significance of digital tools. These sessions can support the members to share their values, motivation and vision towards the initiative. It will also allow setting clear rules about ownership, capacity building, pricing and data handling.
5. **Deployment:** Initiate primary deployment process by reaching out to the municipalities and convincing with to come onboard with the mission and vision of bringing Kopli 93 back to life and also contribute to the environment.

Hence, synthesising the findings from the expert interviews, ethnography, and the existing literature, the above-mentioned roadmap can be planned and executed as part of a sustainable energy management initiative. Sincere acknowledgement from the authoritative bodies is crucial, given the sensitivity and high regulatory constraints for heritage and energy infrastructures.

8. Conclusion

As the final chapter of this thesis, the conclusion offers a concise summary of the research goal and the key insights. Based on these findings, the chapter further discusses the potential applicability beyond this case study. It also outlines the study's main limitations and suggests directions for future research that could be based on the insights developed here.

8.1 Summary of the Research

This research aimed to explore how energy communities and digital technologies can support the adaptive reuse of heritage buildings by using the case study of Kopli 93. Kopli 93, at present, nurtures several community-based activities such as gardening, repair and makerspace, and beekeeping. However, it does not host any energy communities, nor does it include any renewable energy systems for sustainable energy transition. At the core of this study, it focuses on understanding the potential of establishing energy communities for energy initiatives as well as cultural and social revival of the abandoned heritage sites. Due to the sensitivity and restrictions to tamper with the physical infrastructure of the heritage buildings, researchers have suggested the involvement of energy communities, along with the installation of smart devices, which efficiently offer a workaround towards repurposing heritage in greener ways. This socio-technical approach contributes to the demand-side flexibility, enabling adaptive and responsive energy use.

As a first step, the literature delved deeper into the concerns of the abandoned buildings and their legacy energy systems, highlighting their impact on the environment. This was followed by the modern digital technologies that have been famously used for energy efficiency. Further, the role of decentralised energy systems introduced the concept of energy communities, describing the governance and participatory dimension to address energy poverty and energy democracy. The literature has been supported by the framework of Actor-Network Theory, which expresses the significance and interconnectedness of the various actors (human and non-humans) such as key stakeholders, beneficiaries, technologies, legal regulations etc. Followed by the Commons Theory, which emphasises towards peer-to-peer adaptability and sharing of renewable energy resources, creating an ecosystem of collective care.

Building on the above, the main and the sub research questions were formulated. The primary research question focused on the potential for establishing an energy community at Kopli 93 to promote both environmental sustainability and community resilience. The sub-questions examined how digital tools, such as smart sensors, virtual power plants, and behavioural initiatives like demand-side flexibility can be leveraged by these communities. With a lack of sufficient streamlining of all the aspects within the heritage context, the expert interviews and the ethnographic fieldwork provided a grounded, and practice-based findings along with the challenges faced in such settings.

From the results, it became clear that the potential for building an energy community, especially in a heritage context, lies in the combination of community engagement, shared values and technical feasibility. The heritage buildings face several material and legal constraints, yet through democratic governance, circularity and local ownership, the opportunities seem viable. In terms of digital integration, non-invasive technologies like smart sensors and remote energy sharing emerge as plausible alternatives to major renovation processes. Further, with the use of such digital tools, communities can also contribute through behavioural changes and demand-side strategies. To summarise, the findings underscore the impact of socio-technical coordination to address the research questions.

Beyond Kopli 93

Considering the insights from the case of Kopli 93, the reflection can also be generalised and transferred to other contexts. As EU and national policies increasingly acknowledge the role of energy communities, the findings presented here provide a flexible framework for guiding energy management in heritage or older buildings. The recommendations can be tailored to different local, social, and regulatory conditions. The energy communities are mostly scattered and concentrated over a few specific countries like the UK, Germany, Greece and Austria. This enables the extent of transferability of the obtained results to various other countries across the globe.

Supported by this context, it is expected that identifying the constraints and potential for establishing energy communities, related to the main research question, can be implemented for other countries as well. The architectural, legal and social characteristics can, however vary based on the contexts. Similarly, linking to the sub-research question, the integration of digital technologies for energy sustainability has gained massive pace around the world, to achieve the Sustainable Digital Goals, proposed by the UN. The characteristics of behavioural adaptation and flexibility of energy usage on the demand-side, can be largely leveraged across any type of community or building for energy efficiency. Although certain local dynamics, like ownership models or regulatory conditions, may affect the overall framework presented in this study. It can then serve as a basis for designing better regulations and encouraging community energy models.

Limitations and Potential for Future Research

Finally, addressing the limitations of this research, will help to identify the scope for future research in the field. First, the study is based on a limited number of expert interviews, which are, although rich in depth, but may not have captured the diverse perspectives from the varied stakeholders. A very thorough selection of stakeholders is required to capture the multifaceted insights and to avoid saturation or repetitive answers. Secondly, the method of ethnographic fieldwork revolved around only two days, which would not have captured the deeper essence of the site and community engagement. Third is the language barrier. However, the stakeholders required for this study were able to converse in English, but a few regular citizens were not comfortable in sharing their insights. This hindered gaining their perspectives into the study. Fourth, the study is very case-specific, and it cannot serve as a one-size-fits-all approach for different geographical, social or political contexts. Fifth, the insights into the data privacy framework, generated from the smart devices, also remain unexplored in this study. This threatens the user's security and privacy by compromising sensitive data about their energy consumption patterns or personal habits. Finally, while digital tools were a core area of exploration, rapid technological developments in this field may evolve faster than current frameworks can accommodate.

The above-mentioned limitations serve as opportunities for future research. Exploring the legal and regulatory contexts of sustainable energy management in heritage buildings, would provide a better understanding and recommendations for repurposing heritage buildings. Also, it is essential to understand the regulations and laws of establishing an energy community for specific sites. Additionally, building on this study, future research could expand to multiple case studies across different countries. This would allow for comparative insights into how energy communities function within diverse cultural, regulatory, and spatial contexts. Furthermore, the concept of business models for energy communities is still in its infancy. Future studies on developing such business models, the energy communities will enable the energy communities to be major players in the energy market. Finally, further exploration of data privacy regulations and governance in smart energy systems could strengthen the participatory approach in the current digital world.

Declaration of Authorship

I hereby declare that, to the best of my knowledge and belief, this Master Thesis titled: “A Socio-Technical Approach for Energy Management in Heritage Buildings: Case of Kopli 93, Tallinn” is my own work. I confirm that each significant contribution to and quotation in this thesis that originates from the work or works of others is indicated by proper use of citation and references.

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