CHALMERS
UNIVERSITY OF TECHNOLOGY

Empowering Sustainable Campuses

Exploring Energy Communities through Stakeholder Insights and Campus Johanneberg Analysis

Master's thesis in Design and Construction Project Management

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DIVISION OF BUILDING TECHNOLOGY

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2025
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MASTER'S THESIS ACEX30

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Chalmers tekniska högskola, 2025

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Cover:
AI generated image showing a potential energy community with PV and batteries,
Department of Architecture and Civil Engineering
Gothenburg, Sweden, 2025

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Abstract

This thesis explores the role and potential of energy communities especially looking at Sweden and a case study of Campus Johanneberg. Energy communities can be one part of the transition to more renewable energy sources as fluctuating production can be met with controllable demand. Through literature review and stakeholder interviews, key benefits and barriers of energy communities were identified. A case study of Campus Johanneberg was used to examine these aspects in a real-world setting, where energy data was analyzed to show barriers, benefits and potential. The study shows that different actors like residents, businesses and grid operators derive value from energy communities in different ways, including increased energy democracy, new business models and grid support and benefit where they can find common goals and align. However, legal uncertainties and technical infrastructure remain significant challenges. The findings also highlight the potential of campus environments as testbeds for energy communities due to their proximity to technology and expertise.

Keywords: Energy Communities, Renewable Energy, Campus Johanneberg, Stakeholder Perspectives, Energy Sharing, Sustainability, Barriers, Load profiles

Stärka hållbara universitetsområden
Fördjupning i energigemenskaper genom insikter från olika aktörer och analys av Campus Johanneberg
Examensarbete inom mastersprogrammet Design and Construction Project Management
Felix Niklasson
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Sammanfattning

Denna uppsats undersöker energigemenskapernas roll och potential, med särskilt fokus på Sverige och en fallstudie av Campus Johanneberg. Energigemenskaper kan utgöra en viktig del i omställningen till mer förnybara energikällor, där variationer i produktion kan balanseras genom flexibel och styrbar efterfrågan. Genom litteraturstudier och intervjuer med relevanta aktörer, identifierades fördelar och hinder kopplade till energigemenskaper. En fallstudie av Campus Johanneberg användes för att undersöka dessa aspekter i en verklig kontext, där energidata analyserades för att belysa möjligheter, utmaningar och nytta. Studien visar att olika aktörer såsom boende, företag och nätägare kan dra nytta av energigemenskaper på olika sätt, exempelvis genom ökad energidemokrati, nya affärsmodeller och nätstöd. Att samverkan mellan aktörerna kan skapa gemensamma värden. Samtidigt kvarstår juridiska osäkerheter och tekniska infrastrukturproblem som betydande utmaningar. Resultaten pekar även på potentialen i campusmiljöer som testbäddar för energigemenskaper tack vare deras närhet till både teknik och expertis.

Nyckelord: Energigemenskaper, Förnybar energi, Campus Johanneberg, Energidelning, Hållbarhet, Barriärer, Lastprofiler

Acknowledgements

First and foremost, I want to thank my supervisor, Elena Malakhatka, for all the guidance, feedback, brainstorming sessions on the whiteboard and encouragement throughout this project. Your support and belief in me have meant a lot, and I’ve learned so much during this process.

A big thank you also to Richard Block at Akademiska Hus for taking the time to share your expertise, supporting my work, and always making me feel welcome.

Thanks to everyone in the ECOM4FUTURE research project, I learned something from each of you and am truly grateful to have had a small part in your team.

I'm especially grateful to all the people who agreed to be interviewed. Your thoughts and experiences were a huge part of this thesis, and I really appreciate your time and openness.

Last but definitely not least, thank you to my friends and family for being there throughout this journey cheering me on, listening over lunches, and supporting me in countless ways.

Gothenburg, 2025

Felix Niklasson

Contents

1. Background

The European Union has set ambitious targets for renewable energy production, aiming for 42.5% of total energy generation to come from renewable sources by 2030 (European Union, 2023). This would require nearly a doubling compared to today's energy system and is driven by the EU's efforts to reduce greenhouse gas emissions, where the energy sector remains the single largest contributor. As part of this transformation, there is a significant shift from large-scale, controllable production units to smaller scale, decentralized renewable energy sources. These sources are inherently variable and intermittent, which introduces new challenges for balancing supply and demand.

One such challenge is the increase in load peaks and potential grid congestion, especially during times when renewable generation is high but local consumption is low, or vice versa. To maintain grid stability and reduce the need for costly infrastructure upgrades, improved demand side management is becoming increasingly important across all EU countries regardless of how green their energy mix already is. In this context, energy communities can play a crucial role. By enabling collective action at the local level, ECs can help shift or reduce energy demand through coordinated behaviour, flexible consumption, and shared infrastructure such as battery storage. This not only supports the integration of renewables but also helps alleviate stress on the grid, an approach actively encouraged by the European Commission (European Commission, n.d.).

Below in Figure 1 carbon emissions are illustrated in falling scale from left with countries from the European Union. Shown in the same figure is the amount of energy communities established in 2023 for each of the countries.

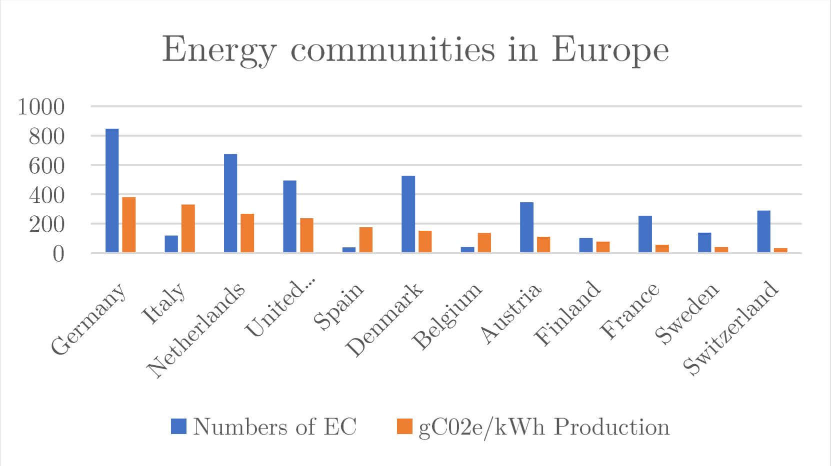

Figure 1: Showing amount of energy communities and carbon emissions from different EU countries. (Koltunov et al., 2023)

Figure 1 illustrates the relationship between carbon emissions and the establishment of energy communities across EU countries in 2023, with emissions shown on a descending scale from left to right. Notably, energy communities have proliferated in countries with high carbon intensity in their energy production, reflecting their potential to support decarbonization efforts. The carbon intensity of energy production varies significantly across the EU, with a ninefold difference between high-emission countries like Germany and low-emission ones like Sweden, as detailed in Figure 2 and Figure 3. While Germany, with its high carbon emissions, has widely adopted energy communities, countries like Spain and Italy have embraced them to a lesser extent.

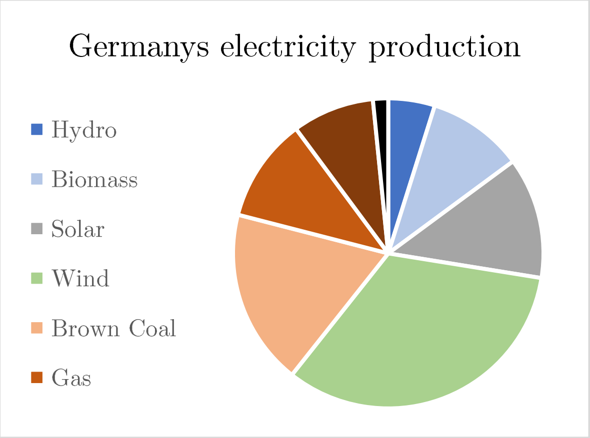

Figure 2: Break down of Germanys's electricity production by source. (Burger, 2024)

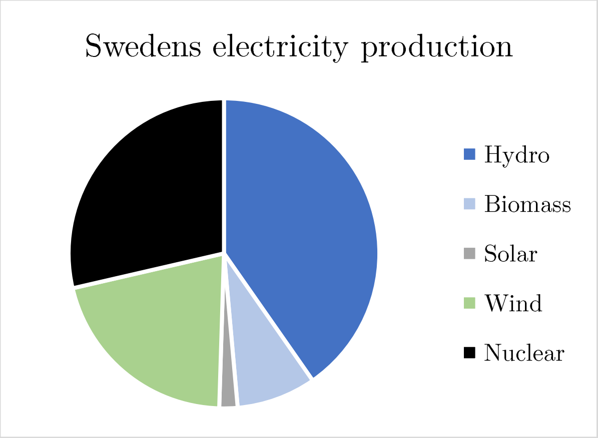

Figure 3: Break down of Sweden's electricity production by source. (SCB, 2024)

In the above Figure 2 & Figure 3, Germany and Sweden electricity production is broken down for 2023 by source, where Germany has a very different mixture from the one of Sweden. Both countries have substantial wind power, however after that there are many differences where Germany is reliant on gas and coal, Sweden instead has majority of its electricity production from nuclear and hydropower with substantially lower carbon emissions. Hence the prerequisites for countries in EU is different from each other and this will affect how Energy communities can be utilized. Here energy communities can contribute to UN sustainable development goal seven "ensure access to affordable, reliable, sustainable and modern energy for all" where more renewable energy sources can be used to ensure a more sustainable energy mix (United Nations, 2023).

Within the EU's push for sustainable energy systems, Sweden faces a projected doubling of district heating and electricity demand by 2050, driven by industrial electrification (Energimyndigheten, 2023). This surge, largely from energy-intensive sectors, strains the existing electricity grid, which lacks sufficient capacity and is deteriorating. Meeting these demands with today's centralized energy system would require costly grid expansions, making decentralized solutions like energy communities increasingly attractive for managing demand and enhancing grid resilience.

As EU countries, including Sweden, seek to optimize energy systems through solutions like energy communities, buildings emerge as a critical focus, accounting for nearly 40% of Sweden's total energy consumption (Boverket, 2025). Enhancing building energy efficiency can significantly advance Sweden's and the EU's ambitious sustainability targets. An emerging trend, spurred by the EU's 2019 Clean Energy for All Europeans package, is the rise of energy communities, which facilitate renewable integration and offer social and economic benefits

(Koirala et al., 2016)(European Commission, n.d.).

Energy communities can be done in many different ways and for many different types of stakeholders (Sveriges Energigemenskaper, 2025). It can be for villa owners who want to share their locally produced energy from PV, larger residential houses connecting and sharing energy, individuals investing in solar/wind parks, companies wanting to share and trade energy and in many other forms. Energy communities utilize many different technologies and can include production with PV or wind turbines, distribution with internal electricity grids, using the DSO's grid, pipes for sharing heat and cooling and smart scheduling of loads. Common for all is that it is the local community that owns the energy system and can choose how it is operated. This has become increasingly more popular in Sweden, where there are some cases of energy communities being setup.

Despite the growing adoption of energy communities in Sweden and their potential to enhance renewable integration and grid stability, uncertainties persist about their benefits and implementation challenges. This thesis aims to address these gaps through two research questions. The first is tackling what value energy communities can bring to different actors and stakeholders, and the second is a mapping of a case to gain a better understanding of how energy communities can be implemented and what barriers need to be dealt with.

1.1 Objectives and research questions

Based on this background, a set of research objectives was developed to investigate the concept of energy communities, with a particular emphasis on the Swedish context and its differences compared to the broader EU perspective. To support this investigation, a case study of a potential energy community was included. The study was guided by two central research questions, which are presented below. These questions focus on understanding the value that energy communities can provide to different stakeholders and examining the specific benefits and barriers associated with implementing such initiatives within a campus setting.

- **How can energy communities bring value to different actors?**
- **What are the barriers and benefits of developing an energy community in a campus environment?**

To further structure the study, three objectives were formulated to support the research questions and define the intended outcomes of the work. The first objective adopts a broader perspective, aiming to enhance the general understanding of energy communities and to identify how they impact various stakeholders. This foundational insight informs the second objective, which focuses on applying a case study approach to examine the potential benefits of energy communities, particularly in relation to stakeholder interests identified earlier. Finally, the third objective builds upon the insights from both the literature and case study to develop a strategic roadmap for energy communities, integrating knowledge from interviews and empirical analysis.

- From different stakeholders' understanding of energy communities and what might be driving forces, barriers to overcome and impacts of implementing energy communities.
- Assess the feasibility of energy communities, collect, process and analyze data on real-world case in Johanneberg to find potential problems and possibilities.
- Develop an energy community roadmap showing different scenarios of energy communities

1.2 Limitations and Ethics

The focus is on implementation in Sweden, although inspiration can be taken elsewhere. In this study, the environmental benefits will not be quantified, as that in itself can be an entire master's thesis. The focus will be on energy sharing between buildings and the implications that come with it. In the study there will be interviews conducted but due to the timeline no more than eight were carried out, however, from a large variety of stakeholders covering many of the relevant fields. The author’s own perspective can have had an impact on how the results are portrayed, although aiming to be neutral to the results and information provided, it is impossible for previous knowledge and preconceptions not to influence, this has been counteracted through discussions of topics with the supervisor and peers to make sure that the research still is credible.

In the case study mainly the electrical part of energy communities has been analyzed since there where greater amount of data and information available, and heating and cooling has not been analyzed to the same extent also from a time management perspective to be able to deliver a well based analysis rather than a broad analysis without proper depth. Data quality is something that can have had a small impact as not all data was always of the highest standard.

1.3 Methods

This study employs a mixed-methods approach, combining qualitative and quantitative methods to achieve a comprehensive understanding of energy communities, as a singular method would not fully capture the topic’s complexity (Creswell & Creswell, 2018). An explanatory sequential mixed-methods design is adopted, where qualitative findings inform the quantitative phase, and both are synthesized to address the research questions. This approach is selected because mixed methods facilitate both generalizable findings and a nuanced exploration of the problem, as supported by the literature. The research adopts an interpretivist perspective, aiming to understand and explain the dynamics of energy communities, their stakeholders, and their potential development within a campus environment.

The methodological framework, illustrated in Figure 4, adapts the Double Diamond model to structure the research process (Design Counsil, 2025). The first diamond encompasses discovery and definition phases, involving a literature review to explore the topic and semi-structured interviews to refine the problem within a Swedish context. The second diamond focuses on development and delivery, utilizing a case study to develop practical solutions and culminating in a roadmap that synthesizes all findings.

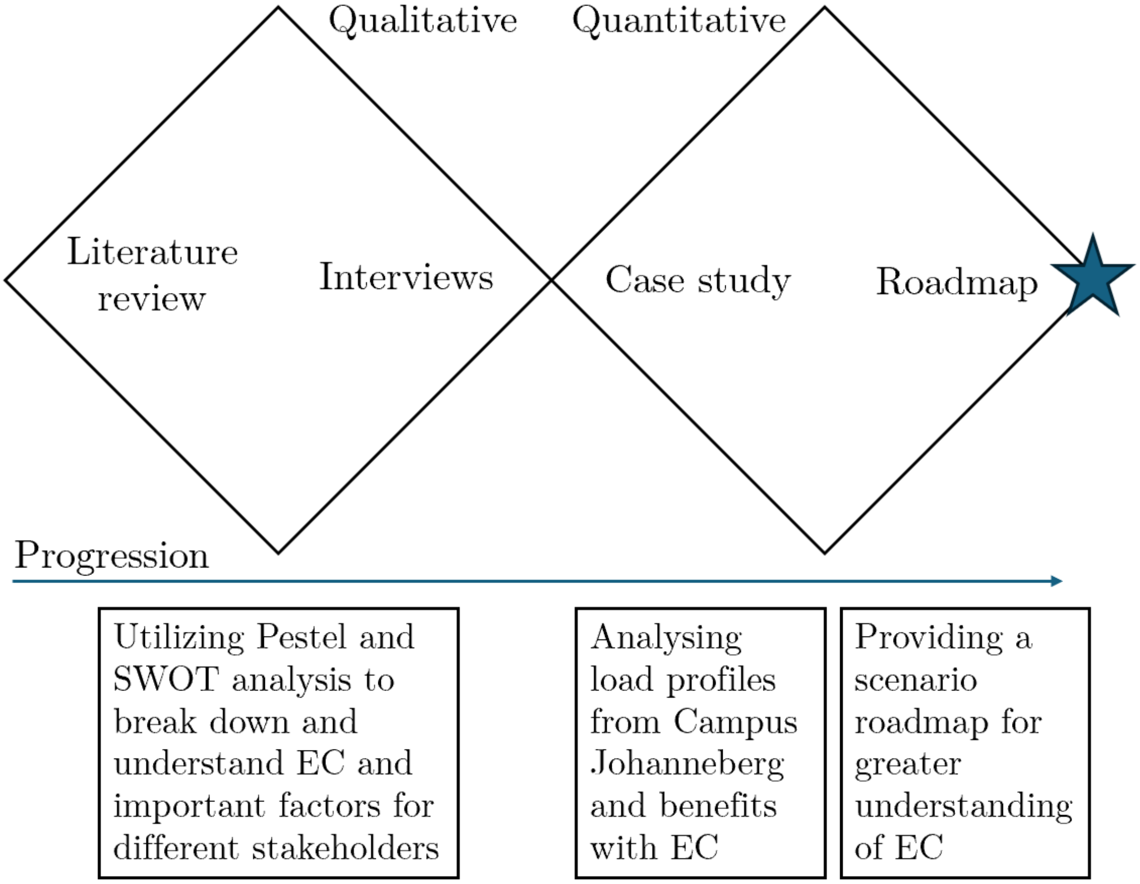

Figure 4: Illustration of Methods used with double diamond.

Beginning with the literature review gave a broad but still well-based understanding of energy communities and revealed gaps where interviews could provide additional information. Keywords related to energy community were used and newer and more cited articles were favoured. Papers highlighting the Swedish context were additionally given extra attention. For the interviews, a qualitative deductive research approach was used with themes found from the literature review further explored. The interviews were semi-structured with industry experts chosen from different stakeholders with extensive knowledge to both get broad and in-depth interviews, anonymized in Table 1, to explore energy communities in Sweden and stakeholders' perceptions. The semi-structured approach allows deeper exploration of topics raised by interviewees, enhancing the quality of insights (Patel & Davidsson, 2019). This phase primarily addresses the first research question, examining the values and barriers to developing energy communities from various stakeholders' perspectives. The analysis begins with examples from the literature of the EU and the U.S., transitions to a Swedish context through interviews, and concludes with implications for a campus environment. The Pestel framework was used to organize themes raised in the literature and interviews do enhances clarity for the reader followed by a SWOT analysis as a conclusion of the first diamond.

Table 1: List of interviewees

Code	**Explanation**
SEA	Swedish Energy Agency
DSO 1	Distribution System Operator 1
DSO 2	Distribution System Operator 2
ACA	Leading position in Academia
E1	Expert 1 (Researcher on Energy communities)
E2	Expert 2 (Researcher on Energy communities)
E3	Expert 3 (Technical advisor grids)
REO	Real estate owner

The quantitative component centers on a case study of the Johanneberg campus, where energy data, including load profiles and consumption patterns, are analyzed to explore energy-sharing possibilities within an energy community. Building on qualitative insights, this empirical approach provides a robust foundation for the analysis and lends legitimacy to the proposed roadmap. Three different scenarios are developed and compared against a baseline of current operations to highlight key findings and potential improvements. The scenarios are, one on a smaller scale with seven buildings with a great variety of use to showcase possibilities with EC, the second analyzing the whole campus, thirdly looking at the future and 2035 to see the potential EC can bring to campus Johanneberg. The case study leverages prior findings from the literature review and interviews to develop practical solutions for energy communities in a campus setting. Based on both findings from the qualitative and quantitative part, a scenario roadmap is provided for understanding of how to balance different aspects of energy communities.

The research process, guided by the Double Diamond model in Figure 4, ensures a cohesive integration of qualitative and quantitative methods. The deductive literature review and interviews define the problem, while the case study develops solutions, with key insights feeding into the final roadmap. This mixed-methods approach, grounded in an interpretivist perspective, balances detailed stakeholder insights with empirical data to effectively address the research objectives and deliver actionable recommendations for energy community development.

Use of AI tools

AI chatbots such as ChatGPT and ScopusAI have been used to find sources for information and improve selected parts of text for increased clarity. It has not been left alone to do the writing of whole paragraphs or analysis this is completely the author's own. ChatGPT has also helped with providing Python code for adding the analysis of the case study.

2. Theory and expert insights

Under this chapter energy communities will be described and in contrast to regular order literature and interview answers will be compared straight away instead of having the interviews under a later section. To begin with some definitions and language need to be defined to understand what is meant throughout the text.

2.1 Definitions

In the literature previously researched, there is still a large variation of which term is used for energy communities here is a brief explanation of them:

Renewable energy communities – This is an energy community where the members are located close to renewable energy projects and are based on open and voluntary participation (The European Commission, 2018). The members can be individuals, companies, authorities or municipalities. Where economic profit is not its main purpose but rather environmental, economic and social benefits to the community.

Citizen energy communities – Also defined by the EU is an energy community where citizens are able to participate in energy systems, not necessarily from renewable sources and often with a focus on only electricity (The European Commission, 2019). There is no need for geographic proximity instead invites all.

Local energy communities – are a group of users that collectively collaborate to meet their energy demands locally (Rana et al., 2022).

Virtual Energy Communities – These are similar to the citizen energy community, however there is no need for an actual exchange of energies between the buildings, instead it can be done virtually with meters (Di Somma et al., 2024).

In a Swedish context, it is not clear what is and should be an energy community and hence Energimyndigheten has proposed a clearer definition for the government to decide on for the coming legislation (Energimyndigheten, 2024). This definition is what will be considered in this paper and is similar to renewable energy community, and is based on three criteria, 'open and free participation where the members are located in proximity to where the renewable energy owned, secondly, the members are physical persons, small to medium-sized companies and or local municipalities, thirdly primary purpose is to give its members environmental, economic or social values rather than economic profit'.

Gjorgievski et al. (2021) propose one perspective on how to view energy communities where there are several different actors, illustrated by dividing it into three parts, consumers, energy service providers, and initiators. The different actors can however belong to more than just one part, for example, both be an initiator and consumer, and all other possibilities in some cases all three parts see Figure 5 illustrating this. A consumer is defined as a beneficiary of an energy community without any more active involvement. The energy service provider is an actor who as the name suggests provides energy which can be done in various ways, for example generation, distribution or storage. An initiator is an actor who pushes for an energy community and is part of organizing, without which the authors argue the implementation may not be successful.

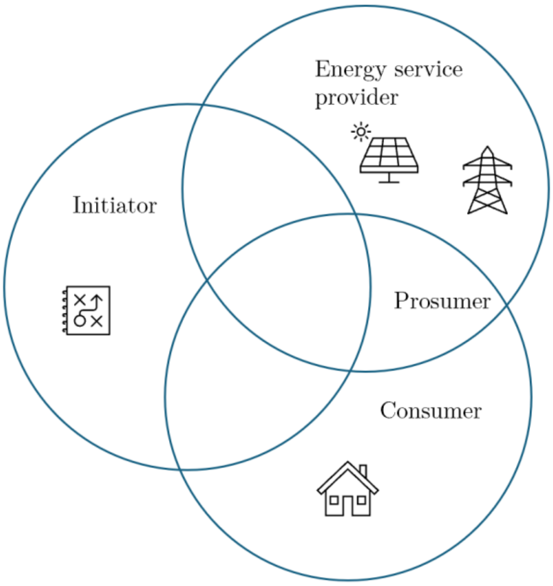

Figure 5: Illustrating different actors of energy communities. Based on (Gjorgievski et al., 2021).

One important aspect in energy communities is local flexibility, and a study by (Lund & Münster, 2006) has determined that more renewables can be included in the energy mix if flexibility is utilized. Flexibility can entail several different measures some are cogeneration, energy storage, heat pumps, electric vehicles and how the buildings are operated. Åberg (2024) highlights another important aspect with two common metrics to evaluate energy communities, self-sufficiency rate and self-consumption. Where self-sufficiency rate is to what degree the demands of the building/energy community are met with its own production, whereas self-consumption is to what degree the local production is also consumed by the building/energy community, with values closer to one indicating a well-functioning system. In Figure 6 Self-sufficiency is $\frac{C}{A+C}$ and Self-consumption is $\frac{C}{B+C}$.

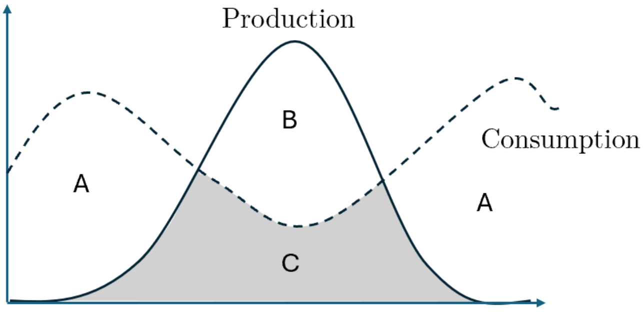

Figure 6: Showing self-sufficiency and self-consumption. Based on (Åberg, 2024)

Setting up an energy community can be done in many different ways and Esposito et al. (2024) has developed a standardized roadmap for how one can go about implementing an energy community. There are four main steps, first a feasibility study where the different users' energy profiles are mapped, a simulation for sizing of the energy system and assessments on energy, economic, environmental and social implications. The next step suggested is aggregation, where the producers, consumers and prosumers are aggregated to improve efficiency and provide flexibility to the system. Other important aspects to consider under this step are the legal settlement and investigation of what different funding options would be available. Thirdly, is looking at the operating phase which is where the previous steps are implemented both from a technical view as well as others. Here the real use data is used, construction of the generation within the energy community and agreements are made between the different parties. Lastly is the management phase where maintenance of the operation is followed up to ensure it's being run as designed, including economical management and how to share and divide the different costs and benefits and in some energy communities involving the members to increase engagement.

2.2 Literature on energy communities

The literature review results helped to indicate different aspects of energy communities. Based on papers from 2015 also containing energy communities in the keywords, abstract and/or title resulting in 3259 papers, where an increasing trend could be observed. Then the keywords were added as constraints resulting in the numbers presented in Figure 7.

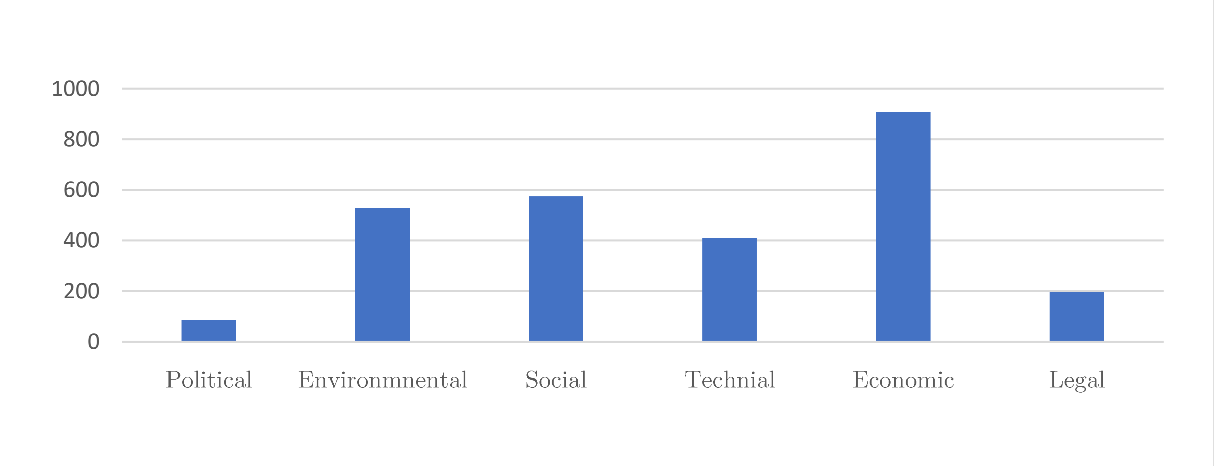

Figure 7: Aspects researched regarding energy communities. (Scopus, 2025)

As seen in Figure 7 Economic is the aspect most researched, followed by social and environmental aspects. The social and environmental aspects are something the EU emphasized with renewable energy communities and seems to have been picked up in the literature.

In Figure 8 instead the aim was to understand what are the different types that have been looked at in literature.

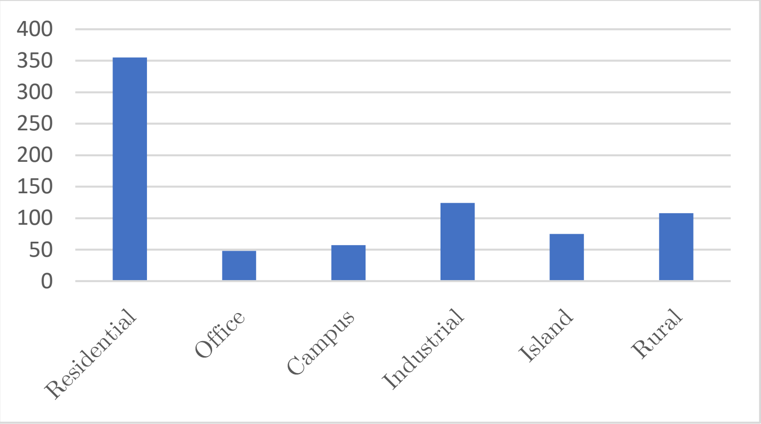

Figure 8: What type of users in an energy community (Scopus, 2025)

From Figure 8 Residential is what is most mentioned in the literature and relatively few refer to campuses. Hence might be interesting and there might be a gap to have a closer look at campuses since there still are not that many articles on it. Industrial and rural are the second and third most mentioned, where rural often means away from the grid in some cases off-grid but not necessary. Rural is something mentioned in the literature as relevant for energy communities, as it can provide green energy to places other ways having little access to energy or very polluted energy.

2.3 Value of Energy Communities to Different Actors

In the following chapter a mapping of what values energy communities can bring to different actors, where the literature primarily looks from an EU perspective and the complementary experts have a local Swedish perspective. The different actors divided by below is Individuals/residents, Business/organizations, Utilities/grids, Government/society and Academia/campus. Under each actor both relevant literature and interview results will be found for each.

Individuals/Residents:

Hackbarth & Löbbe (2022) argues that motives for joining an energy community can be different, on one hand, cost-driven and financial gains are important but also finds that other social values can be a driver. This is further strengthened with Bergek & Palm (2024) who look at a Swedish perspective, where environmental and social goals are found to be an important factor. They further argue that having a common mission is of high importance as also Oteman et al. (2014) and further contributes by the perspective on active engagement often being perceived as very important in energy communities, however, the findings somewhat contradict that since Bergek & Palm (2024) found that members are not that interested in increasing their engagement according to this study. In the Swedish context, it is noted that Sweden's relatively high level of trust may contribute to why active engagement is less necessary. The trust required for an energy community in Sweden might be fostered simply through joint ownership and a sense of cohesion.

DSO1 and E1 see advantages with the democratization of energy communities where individuals have more control of the energy they consume. In addition, DSO 1 believes it will increase the knowledge level of residents which is described as a benefit for both the individual and the company they are dealing with as they can communicate more effectively. SEA and DSO emphasize the strength of collaborating and optimizing collectively, rather than prioritizing individual benefits, which may not serve the collective good. They believe this is achievable because each entity recognizes its importance, whereas, in the national system, anonymity often obscures the benefits they can contribute. An economic benefit that REO described is lowered cost for connection where energy communities can have fewer connections to the properties which leads to lower fixed cost for the residents.

Businesses/Organizations:

The literature on energy communities is not focused on businesses but there is extensive research on different business models (F.G. Reis et al., 2021). In their article 8 archetypes are identified, and many are based on peer-to-peer trading where energies are exchanged to reduce energy costs. Collectively investing in energy production and storage are additional benefits put forward. A somewhat unconventional framework in this context is from Porter & Kramer (2011) on how to create what they called shared value for companies, meaning the connection of both societal and economic benefits, hence applicable to energy communities. In their concept there are three main aspects to creating shared value, by reconceiving products and markets, redefining productivity in the value chain and by enabling local cluster development. All three are applicable to energy communities where the first relates to how the energy market is changing and possible markets within an energy community. The second is where energy plays a large role in many businesses' value chain and reducing its cost can have large effects, thirdly relating to the local aspects of ECs and the social and economic benefits that can be achieved from working together.

SEA and DSO 1 believe that if energy communities are to gain traction there need to be professional actors with finished solutions. It’s described that they think it can be in the form of modules where it is easy to add the next prosumer/customer/production and need for standardized protocols that talk with each other. From a business perspective many actors talk about the tax benefits, two of which mention it explicitly are DSO 2 and E2 which see this as an advantage where organizations can profit from not purchasing all their energy with inherent taxation. E3 believes businesses can take part in ancillary services to gain additional revenue streams. REO sees large potential if companies own several of the buildings in proximity where they can reduce the number of connections to the DSO hence reducing costs. Adding to this REO sees a business case where, for example a grocery store that usually has a surplus in heating from all refrigeration, could sell this to nearby apartments that need the heat especially during winter. This is further encouraged by E2 and E3 which see large potential from utilizing otherwise losses as assets and can be done with these local smaller scale solutions. DSO 1 concludes that there can be a value add for businesses joined to an energy community since they are more resilient to price shocks if they have their own production and can smartly control their loads.

Utilities/Grids:

DSOs can benefit from their customers using energy communities by the communities reducing their capacity needs and can postpone or reduce the need for new infrastructure. The authors mention that all goals are not certain to align, since generation locally may conflict with the previous producer not selling that energy anymore, losing profits (Gjorgievski et al., 2021).

For the utilities SEA sees advantages in that less infrastructure needs to be built, however acknowledges that there still needs to be some more infrastructure in the future but can be built in another way from the historical way to smarter leverage the energy system. The increased knowledge level for individuals DSO 1 described can also benefit the utilities since it is their consumers and more informed discussions can be held with greater understanding from both perspectives. DSO 1 acknowledges that energy communities can reduce losses in the system which provides a benefit to the utilities, however is rather a small percentage of the whole and emphasizes that it is rather the maximum capacity which is the cost driver than losses in the transmission. If energy communities enable more solar and locally produced energy DSO 1 sees advantages that this can open up possibilities to perform maintenance on large-scale production like nuclear which could enable it to run with fewer interruptions and faults in the winter when solar does not provide as much energy. DSO 2 expands on whether energy communities can incorporate different types of users, for example a good mix of offices and apartments, they could save on the transmission capacity as the power demands are less. Notably, E1 believes that energy communities should prioritize users by focusing on their needs and actions, rather than supporting utilities, which should instead adapt to user-driven initiatives.

Governments/Society:

For policymakers Gjorgievski et al. (2021) describes that their goal might be more focused on decarbonizing rather than the economics of it. There is also an aspect of energy democracy where it is argued that with society having more knowledge about energy is beneficial from a broader perspective and can gain more acceptance.

From a societal perspective E1 describes that EC can spread ownership and increase the production of renewable energy. This is agreed with from SEA which also believes EC can increase the engagement of the citizens. ACA believes it is important from a societal perspective to use the energy more efficiently and enable the transition to green energy which EC can contribute to. DSO 2, while critical to the Energy Community, acknowledges that its current approach to enabling solar investment, though beneficial, is sub-optimal from a broader cost-effectiveness perspective. However, it's still preferable to no investment in solar power at all.

Academia/Campus:

From an academic perspective energy communities are interesting, since there is often knowledge available both from a technical and management perspective (ACA). Utilizing campuses is something ACA thinks is a smart way to use as a testbed and can lead the forefront with developing solutions that later can be applied in a more commercial setting. In addition, Academia can function well as a middleman as they have a high level of trust from many stakeholders.

Summary

In Oteman et al. (2014) they argue that for achieving success with energy communities all actors must be well aligned not only with their own goals but also those of the other actors. Since this has a direct impact on their success, they can achieve themselves. Goals can be seen as environmental, economic or social where different actors have different main objectives. Gjorgievski et al. (2021) describes that individuals joining energy communities might reap benefits of economics of scale where they can buy for example a larger battery instead of several small, increased bargaining power and be parts of a market they have not been able before. From the interviews topics of energy democratization was brough up and the possible increase in renewable energy generation was emphasized. Most interviewees takes up advantages not only for themselves but recognize that other actors might also benefit from ECs.

2.4 Barriers to Developing Energy Communities

In the following chapter barriers are discussed utilizing the PESTEL framework to guide the reader through different topics. The same logic is used as above where the experts have a more focus on the Swedish context whilst literature takes a wider approach and both literature and interview results are found under ach category.

Political:

Whilst implementing energy communities Koirala et al. (2016) has identified several key issues since the large institutions are built up to support a centralized energy system. Among other factors infrastructure of the site, grid connection, generation costs, how the feed-in tariffs are set and general distribution of costs, savings and earnings among the different stakeholders have been identified as especially important.

The experts see several barriers that still need to be solved from a political viewpoint. DSO1 highlights if some are part of energy communities and hence buy less from the normal grid, and some are not, they will need to have higher prices since the fixed costs are the same for the grid but fewer customers to share it amongst. Electrical systems are sensitive and almost everything in the buildings is reliant on that it works. ACA describes further that IT security and who has control over the energy system is very important especially in times like this when there is war in the world (Russia against Ukraine).

Environmental

From an environmental perspective, advantages have been taken up earlier with the possibility of increasing the amount of renewable energy in the energy system, there are however also drawbacks and barriers important to account for. Having a local energy supply often means it takes up space from something else, which could be a park or greenery, the use of land is an important factor to account for (Koirala et al., 2016). Energy communities in most cases also require more energy meters, PV, batteries and cables which have emissions when they are produced and some components require rare earth metals, leaving an environmental footprint that needs to be considered.

The experts add to the literature where, DSO1 highlights that some buildings might be of cultural significance and hence are limited in many ways, for example changes to the outside, can mean that no PV, renovating the façade or changing windows are allowed, limiting their potential in an EC.

Social/Behavioural

Within energy communities much focus is put on the distribution and generation of energy, whilst usage is sometimes optimized by efficiencies. One such efficiency measure described in the literature often overlooked is insulating the buildings better to require less energy to begin with(Koirala et al., 2016). This is further corroborated by Energiforsk's report by Åberg (2024) where he points to including energy efficiency measures of buildings and how this affects the heating demand. When considering energy efficiency another aspect often overlooked is the so-called quality of the energy otherwise called exergy (Åberg, 2024). When considering energy communities and the energy flows within a Swedish context using waste heat and district heating can be advantageous where available. An example of inefficient use from an exergy perspective is using electricity for heating since electricity is of higher exergy and this demand could instead be met with surplus heat from another process, whereas heat cannot as efficiently be transformed to electricity.

From a social perspective more than half of the interviewees believe EC today is reliant on so-called "eldsjälar" people who are very passionate and put down a lot of time often free of charge or for a small compensation. This is since EC needs a lot of knowledge currently and the solutions can be rather complex. This is something E1 thinks needs to change in the future, where one can simply just become a member without much more engagement. This relates to Koirala et al. (2016) framework where the Initiator where given great importance and "eldsjälar" can be just this but also continue the work after it is set up. In a campus context, however ACA describes that much of the knowledge is present among the researchers and hence can work well as a testbed for EC. DSO 2 believes that the question of responsibility is important especially connected to personal security as some of the systems in EC especially the electricity can have severe consequences if not handled correctly.

DSO 2 continues with that making people do the same in how they consume energy is possible but having them do differently from one another is very difficult and is what is needed for not having extreme peaks, instead smoothing out the demand.

Technical

Barriers are likely to occur from limitations in the distribution network for energy, due to the intermittency of renewable generation, low energy efficiency of users or mismatch between supply and demand locally (Gjorgievski et al., 2021).

Storage is one part that is important for local energy communities to deal with the match between supply and demand, especially since many renewables are variable and might not match the demand from buildings (Koirala et al., 2016). Storage needs to be addressed both on a short and long-term horizon and different available technologies are often better at certain specific areas. Flywheels, batteries and such can help with the short-term fluctuations where other measures are more fit for storing energy longer duration of time, for example pumped hydro but can be difficult to implement depending on the location of the energy community. Moreover, it is described that there can be different benefits of having storage in each building or a more centralized for the energy community. It is also suggested that the storage of electricity might look different in the future with electric vehicles parked being possible batteries for an energy community called vehicle to grid (V2G).

Advanced metering infrastructure is described as essential to sharing energy within the community between different actors (Gjorgievski et al., 2021). The metering infrastructure needs to be up to date with real-time usage as well as knowledge of current energy prices. Strbac (2008) argues that each building by itself, trying to match supply and demand is inefficient since some demand is hard to control and the total capacity would not be utilized. Instead, it is suggested that being able to use different load profiles accumulated and using demand control on these synergies can be achieved. (Belmar et al., 2023) further shows that utilizing different load profiles can lead to greater economic savings than only considering one type of load for example residential.

SEA believes there needs to be professional actors with finished solutions that solve the optimization and handle the energy systems, which still is lacking. DSO 1 highlights the importance of local energy storage since the grids cannot always handle the loads if all PV is producing at the same time. The storage with electric vehicles(V2G) is described as having huge potential, however still not available to the extent it is needed. If sufficient storage is not available many of the local power stations need to be upgraded say both DSO1 and DSO2 and is described as very costly as there are many of them and each serves a small number of customers. If one fails in having people vary their consumption and if all batteries answer the same price signal at a certain point, there will be a large surge in power which many of the mechanical components cannot handle, for example the transformers explain E3. E2 describes that in the energy discussion related to EC there is sometimes too much focus on the individual parts and a lack of understanding of the system dynamic and how everything should work together.

Economic

An important factor highlighted in a Swedish context is of the cost of internal energy exchange within the energy community (Alavijeh et al., 2019). In this study, a community manager is tasked with optimizing the whole system for the energy community with the goal of reducing cost while still meeting the demands of the different buildings participating and utilizing flexibility, batteries and additional resources. Setting a high price on the internal trade of energy in the energy community leads to high reliance on the conventional grid, where excess is exported and energy is imported when needed. The interesting case is where the internal energy exchange cost is set well and allows the energy community to share the reduced costs. In addition to this the Swedish incentive policy for micro-producer rewarding them with 0,6 SEK/kWh per sold kWh makes the internal energy exchange less attractive since selling the energy is rewarded with a flat rate no matter the actual cost on the grid that time the energy is sold, this incentive will however be removed at first of January 2026 (Finansdepartementet, 2024). The savings for the energy community mainly came from reducing the power tariff, savings on the imported and exported energy prices and savings on volatile electricity prices.

From an economic perspective many barriers are present in Sweden and SEA describes the lack of business models as one and emphasizes that there needs to be economic incentives. REO realizes that the energy companies are not set up to handle EC and this is confirmed by DSO 1 where their economic structure is not made to fit ECs. DSO 2 sees lock-in effects where one pays for being connected to the grid because if an EC decides to disconnect from the grid, the

DSO might roll back some of the infrastructure, which can be costly if the EC wants to join in again after a time or dissolves and just want the regular setup. Something DSO 2 and E2 see becoming a risk is if the self-produced energy often electricity is not taxed there can be an unfairness in the competitive conditions between district heating and electricity. This leads to a higher reliance on electricity even for demands not requiring this high energy quality for example heating. E1 builds on the economic hurdles where sharing energy with the neighbor is still the same transmission fee as if it the energy was from some other place in the country, even though utilizing the network for a much shorter distance. DSO 2 sees that there might be a business case to give economic incentives to solve these local issues on the street or under the last transformation station. EC and implementing storage are however expensive and require large investment costs which is highlighted by E1, considering this in the future E3 believes one needs to learn from other industries and understand cost curves as the price decreases rapidly with increasing volumes. As E3 describes it “One cannot interpret the future based on the present”.

Legal

There are several legal perspectives to weigh in when considering energy communities, one of the more known in Sweden is that one is not allowed to build an electrical transmission grid, if not exempted from the law with a so-called IKN (Sveriges riksdag, 2024). The law has been difficult to understand and what could be granted IKN, some more clarity came in 2024 when a residential area was allowed to connect buildings with different owners with their own low voltage internal grid (Örebro bostäder, 2024).

In addition there are some legal hurdles with how an energy community and the energy it produces should be taxed. In this question the Swedish Supreme Administrative Court, the highest instance which sets precedents, 2024 decided in a case that different properties connected with their own electrical grid should be regarded as separate production units and thereby taxed accordingly and not be seen as one big entity (Högsta förvaltningsdomstolen, 2024). This is an advantage since local energy production under 500 kW is exempted from taxes, however if all properties connected to their own electric grid were to be viewed as one entity this would mean that the energy community could maximum have 500 kW if not to be taxed as an energy producer (Skatteverket, n.d.).

The distribution fee for virtual sharing of energy and what the rules are for implementing IKN is an important factor described by SEA which still needs more clarity for EC to be able to be established more easily. DSO 1 describes there is a lack of legislation for the energy companies for business models which makes it hard for them to handle EC which can lead to them not granting more production for example.

When seven of the interviewees was asked that, on a scale 1-10 where 10 was the best, “to what extent do you believe current regulations and policies support the development of energy communities” the answers varied greatly seen in Table 2.

Table 2: Responses from interviewees on current regulation

Code	Responses
SEA	6
DSO 1	8
DSO 2	1
E1	1
E2	3
E3	1
REO	8

From Table 2 it can be seen that different stakeholders view the current regulations and perceive it very differently. Some of which believes the current regulation is a large barrier and has responded with the lowest possible response, giving it a one out of ten. At the same time two actors rate it relatively high with an eight out of ten, where different interpretations can have been a part and DSO 1 explained as “nothing that hinders the development of energy communities”, contrasting the response to the interviewees rating a one, which still believes much work needs to be done.

2.5 Energy Communities in Campus Contexts

Energy communities exist in a campus context and one such example is the University of San Diego (Sreedharan et al., 2016). Although not initially set up as an energy community it shares many similarities and is described as a microgrid, it has its own grid as well as generation of electricity, heating and cooling. The generation is done both in a more centralized plant and renewables in the form of PVs distributed on the campus, it also entails batteries to manage the energy flows, which can cover 80% of the electrical demands. This study highlighted the relevance of not only the electricity part but heating and cooling as well. When it came to economic effectiveness, the energy system for the campus in San Diego was described as “missing money” indicating it was not making a profit, much up to the local grid tariffs and incentives. For economic optimization it was important to do it both daily and monthly since the renewable generation and cost from the grid varied greatly.

TU Graz in Austria is one campus that has ambitus targets and has developed a roadmap for how they are going to be net zero by 2030 as a target (TU Graz, 2022). They take a comprehensive approach where some of their actions are to have 2MW of solar power installed and renovate and improve buildings to demand less energy. Chalmers and Campus

Johanneberg have a vision and campus plan for 2035 and 2050 however little detail is on how the energy is to be delivered or used in the buildings (Akademiska hus, 2019).

As interviewees with the experts especially ACA emphasize that much of the knowledge is present among the researchers which can take an active role in the implementation. In this case Johanneberg has been chosen to be studied more extensively since it is an IKN already present and much of the district cooling and heating is also linked to an internal network. The author is in addition to this campus and makes collecting data and general understanding of the system better.

2.6 Analysis of Theory and Expert Interviews

Based on the above theory and expert interviews a summary of energy communities is provided in the form of a SWOT analysis on both the EU and Swedish perspectives for implementing energy communities.

EU

Strength

- Low carbon from energy
- EU backed
- Cost reduction
- Stronger unity
- Societal benefits
- Educational

Weaknesses

- Needs high engagement
- Not necessarily helps the one who needs it most
- High investment costs
- Technical complexity
- Exclusion risk

Opportunities

- Business opportunities
- Energy security, redundant
- Market growth

Threats

- Large institutions are built up for the centralized system, require investments and new strategies
- Security question
- Competing interests

Sweden

Strength

- Technical knowledge
- Similar organization forms before
- Cost reduction
- Complement to other production, can help maintenance plans
- Strong public awareness of sustainable solutions

Weaknesses

- Can make buildings more electric dependent, when waste heat is available
- EU tailored not really fitting Swedish context
- Can harm the DSO infrastructure
- Time-consuming, high investment costs
- Different picture of what EC is and should be

Opportunities

- Set an example for the rest of Europe/world
- Business opportunities

Threats

- Political, and what EC is decided to be
- Sub optimizing the system
- Security question
- Legal framework, what is allowed

When analyzing the EU and Swedish context for energy communities there are some clear differences that will influence the actors and which value they can get from EC. Reducing carbon reliance is something found from a European perspective, however in a Swedish context this is not really a benefit since most of the energy is already mostly fossil free. Being founded and pushed by the European Union can be a benefit for EC, but for a Swedish context this is not necessarily a strength and might even be a weakness because Sweden is quite different and EC being formed in an EU context can be disadvantageous in a Swedish context. There are still many similarities where Both for an EU and Swedish context EC provide the same benefits or threats, for example possible cost reductions, opportunities for business, high investment costs and that the large institutions are rather built to handle centralized production and distribution than distributed small scale production. In the question of security, EC provides similar for the EU and Sweden and is both a benefit and a risk, since the increased redundant and own production makes one resilient from blackouts. On the other side being connected to an EC where one can manage the system from a platform, can come with risks if one who does not have access to control the energy system potentially does large damage. The Swedish DSO interviewed highlighted that they are not set up to handle EC and pose a weakness and threat since they are a key player. From a systems perspective EC might not always be optimal since what is optimized is for the community and the grid and DSO are left to deal with remaining issues, where a battery for example could have done more benefit in some other place than in just that EC which can afford it, hence suboptimizing. Other threats and weaknesses in a Swedish context are that it is not clear what is allowed to be done, and stakeholders have different views of what an energy community should be and deliver. Even the experts and other interviewees in this study see it from very different perspectives, where one believes it is for democratizing energy and making it available for all, while another believes it needs to deliver real benefits for the grid and DSOs. This split is something that is not benefiting EC implementation and does not provide actors with the clarity needed.

3. Case study Johanneberg

In this part a case study will be conducted on campus Johanneberg, Chalmers, where energy data has been collected for the buildings and will be analyzed if used as an energy community and what benefits that might come with alongside the barriers present. Campus Johanneberg has been built during many different time spans and the building's characteristics and energy use will be affected due to this, in Figure 9 an illustration over campus where it can be seen from which time period the different buildings were built.

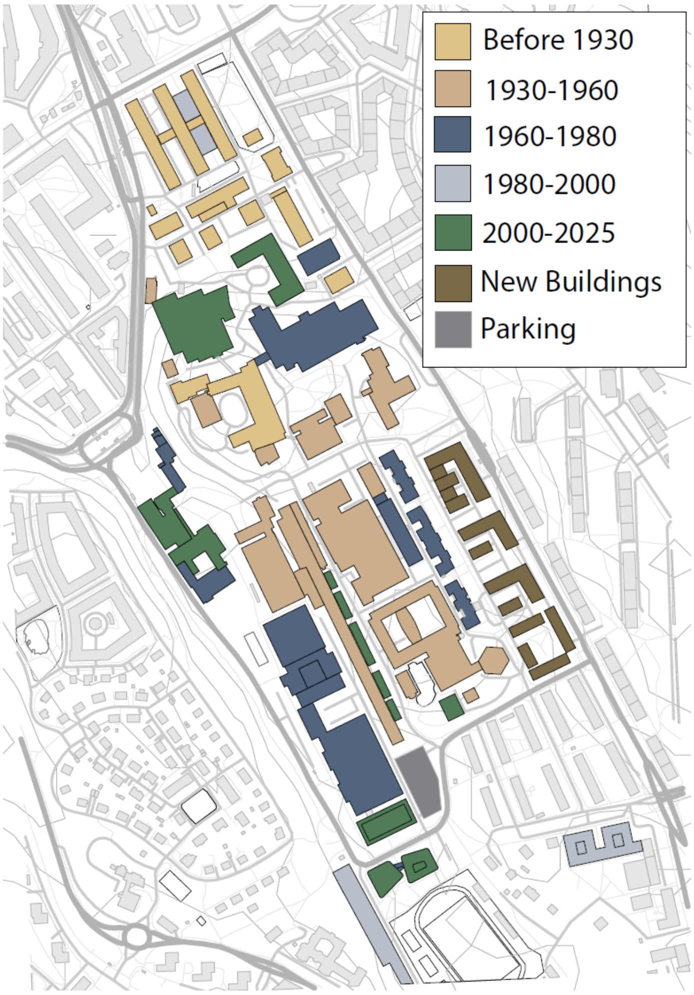

Figure 9: Map of campus Johanneberg with future building plants

The heating demand can be seen below in Table 3 where newer buildings in general has lower heating demand. The buildings from 1980-2000 is the exception and is since there are only two buildings being built during this time and one has a rather high consumption affecting the average greatly.

Table 3: Showcasing the heating demand for buildings on campus Johanneberg based on built year

Built year	Heating [kWh/m2]
Before 1930	76
1930-1960	68
1960-1980	55
1980-2000	65
2000-2025	41

Load profiles

The buildings use energy differently depending on what activities are conducted. Seven distinct use patterns have been found and are Office, Constant, Residential, Restaurant, Gym, Parking and Special. Below the different curves are presented for overview with the same normalized peak of 100 kWh for electricity and using actual buildings on campus, showcasing heat demand as well for illustrative purposes.

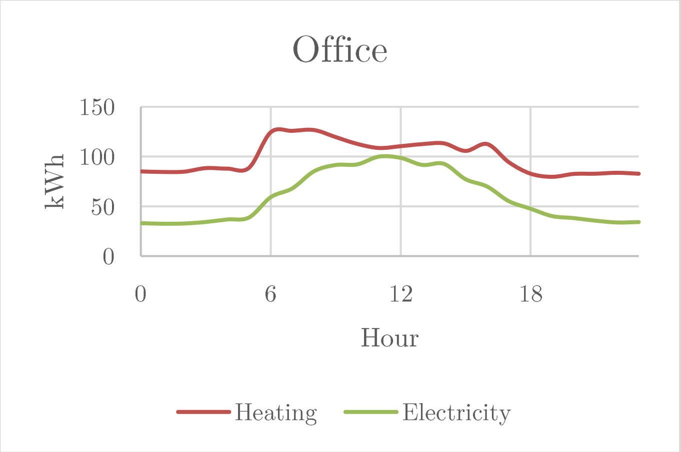

Figure 10: Load profile of office

The Office load profile, is the one for offices and standard lecture halls, where the electricity demand rises during the day and is relatively uniform, as seen in Figure 10.

The Constant load profile, instead has a relatively constant profile and is not severely affected by working hours, seen in Figure 11.

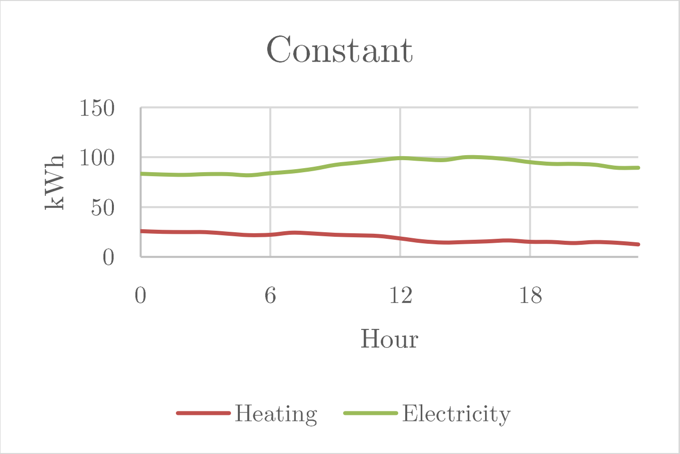

Figure 11: Constant load profile

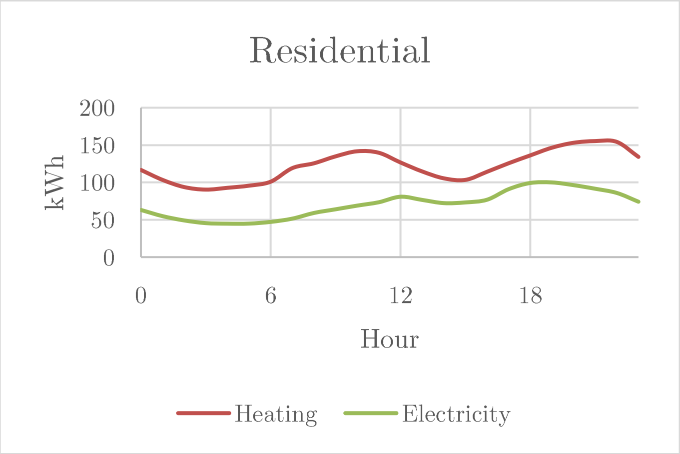

Figure 12: Load profile of residential

Residential load profile has characteristics of two tops, usually one in the morning and a larger one in the afternoon when people are back home from work/School, sometimes known as the duck curve, seen in Figure 12.

Restaurant has a distinct load profile with an early top of electricity since much of the food before lunch is prepared in advance, as seen in figure Figure 13.

Figure 13: Load profile of restaurant

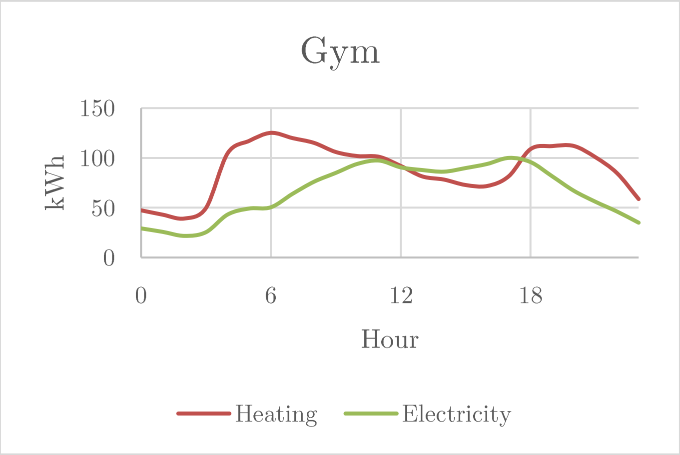

Figure 14: Load profile of gym

The gym has similarities with residential in the sense that there are top peaks in this case in heating most likely from the showers, where people are going both before and after work/School, seen in Figure 14. The gym´s curve starts relatively early and ends late which is in line with the opening hours of the gym. This curve is from a winter month, meaning there is also a need for heating before people inside the gym start contributing with large internal gains from working out.

Parking has one demand which is relatively constant feeding the electrical appliances always on. Then there are the electric vehicle chargers which are charging the cars when people are at work, seen in Figure 15

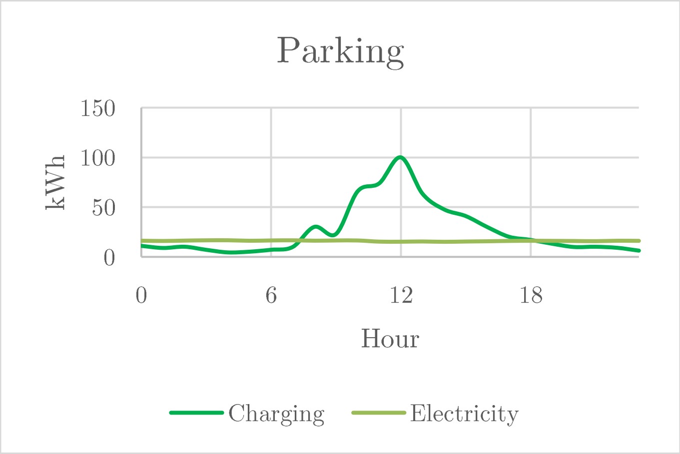

Figure 15: Load profile of parking

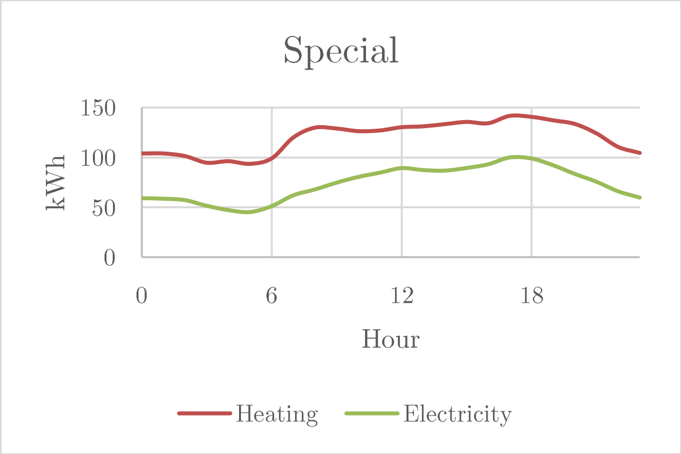

Figure 16: Load profile of special

The Special load curve is from the student union building and has an increasing demand as the day goes on. This can be attributed to both the student pub which also serves food and the two saunas which are electrically run with showers outside requiring heat, seen in Figure 16.

Looking at the whole campus, the Office load profile is the dominant load profile followed by constant and then housing see more under 3.2.

Energy hub

On campus there is an energy station, a combined heat and power plant (CHP), which is located next to the Lokalkontor on the map. This facility is used both as a research lab as well as an energy production facility, providing energy to the campus. In addition to this there are two batteries located one in AWL with 230 kWh and one in Elkraftteknik with 120 kWh and PV distributed on several rooftops. When analyzing the different scenarios below this energy hub will be utilized.

3.1 Diverse EC

In the first of three cases a variety of seven buildings have been chosen based on their different load profiles as suggested in the literature by Belmar et al. (2023) and that many of the buildings have PV installed on their roofs. In this case it is AWL, SB3, SB2, SB1, Restaurant, Emilskårhus and Guesthouse that have been analyzed below in Figure 17 the composition of the different load profiles can be seen based on the percentage of total BTA.

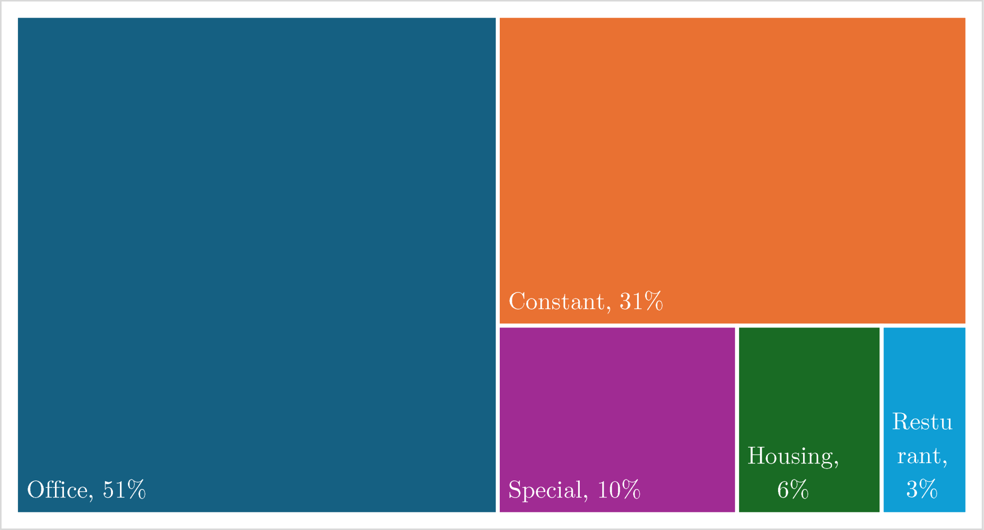

Figure 17: Showing the percentage of each load profile for case 1

Demand and Production

The yearly demand for the buildings aggregated as one EC can be seen below in Figure 18, where the heating demand varies greatly with the season and electricity is more constant. The cooling load is highest during the summer to keep the buildings comfortable. The monthly PV production is included and can be seen in purple with its peaks during summer and almost zero in December and January. The PV production is substantially lower than the electricity demand meaning these buildings would be reliant on a connection to the grid to satisfy its electrical demand.

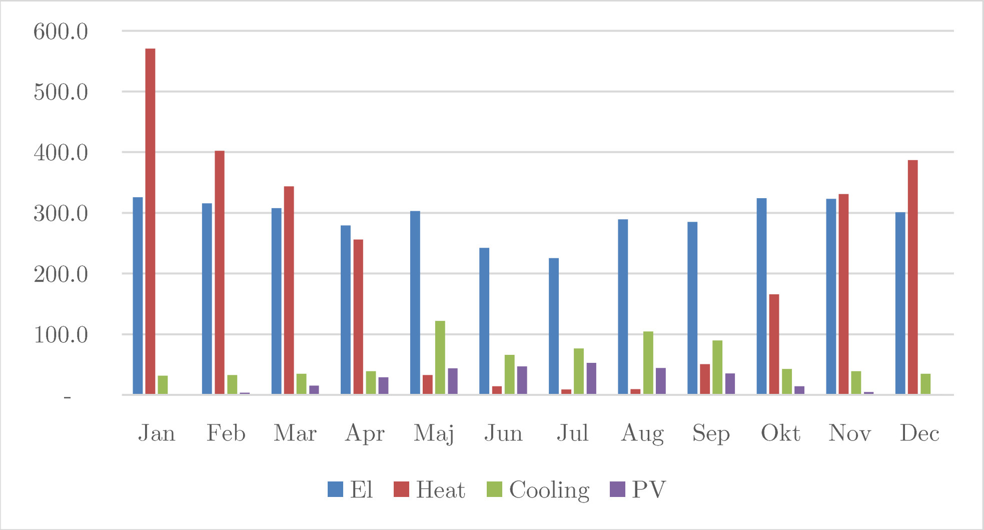

Figure 18: Demand by energy source and PV generation

Winter

Below an average day during the winter has been analyzed where the battery can help reduce the electrical peak demand and the PV is almost negligible. In Figure 19 it can be seen how the battery is charging in the early hours to be able to reduce peaks later during the day. The battery can reduce the peaks of the aggregated load curve by around 10% seen in below Figure 19, however, the actual benefits are greater than this since if each building is analyzed individually and there peaks are summed up the total peak reduction is 23% and is snice the different load profiles and building uses have their respective peaks during different hours, showing the benefit of a diverse set of load profiles.

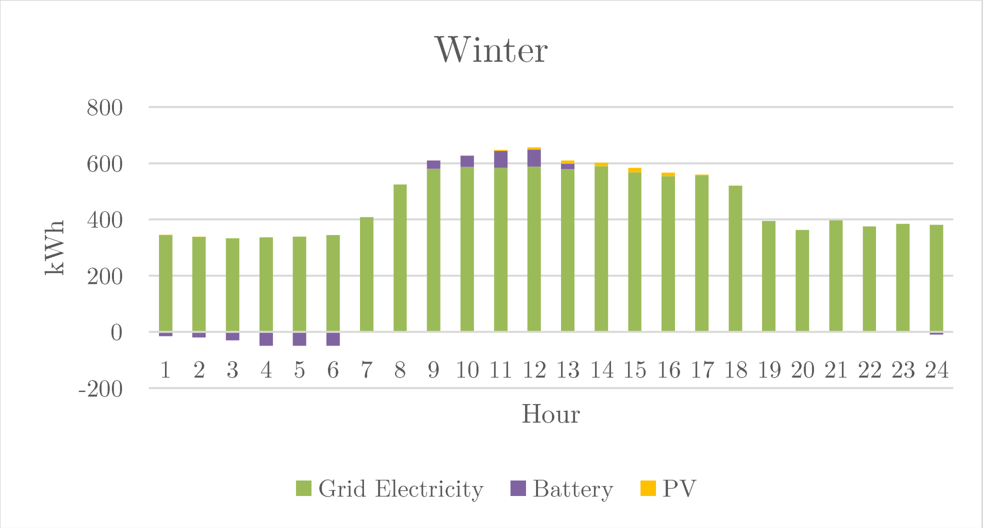

Figure 19: Illustrating each hour in a winter day and how the battery can reduce peaks

When analyzing the cost savings for this EC in case one of the electrical aspects a cost saving of 6% during the winter month can be observed. The reduction comes mainly from three different aspects of the electricity prices and is, reduced by the number of connections to the grid, reduced peak tariffs and PV/Arbitrage meaning utilizing self-produced PV and purchasing cheaper electricity in the nights to store in the battery to use when costs are high. The split can be seen in Figure 20.

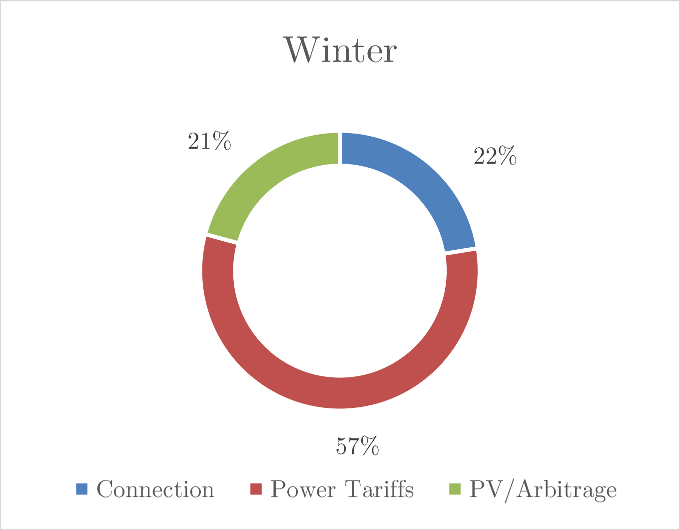

Figure 20: Cost saving distribution case 1 winter

Summer

In below Figure 21 the same buildings are analyzed but now instead in the summer where PV plays a greater role and further helps with reducing the peaks and increasing self-sufficiency. During the summer the PV can greatly reduce peaks and together with the battery reduce 27% from the aggregated demand, seen below in Figure 21. As same as in the Winter since the buildings have peaks at different times the actual total peak reduction is 39% during an average summer day if PV and batteries are utilized.

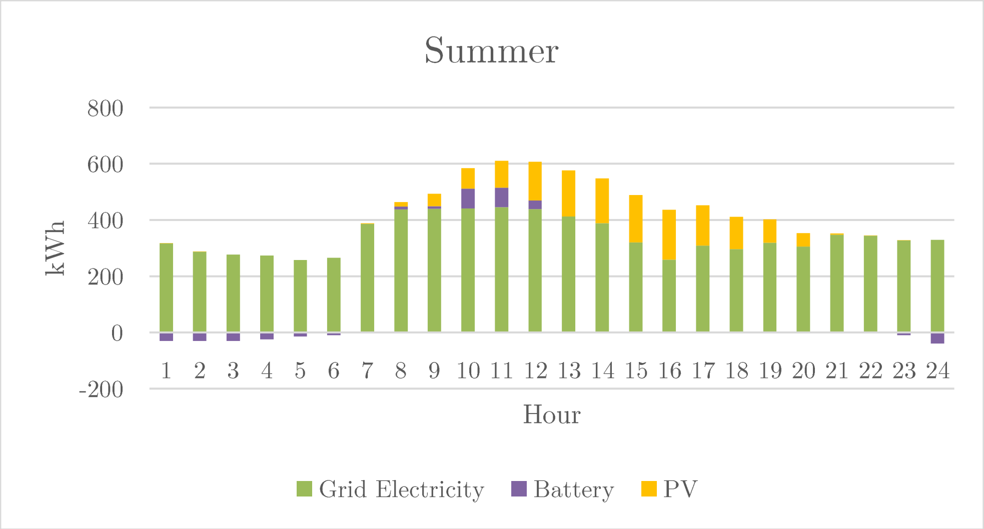

Figure 21: Aggregated load profile for case 1 summer

Utilizing the benefits of the aggregated demand with the energy hub of PV and battery during an average summer month results in a cost saving of 28% and is mainly due to reduced peak tariffs, seen in Figure 22 below.

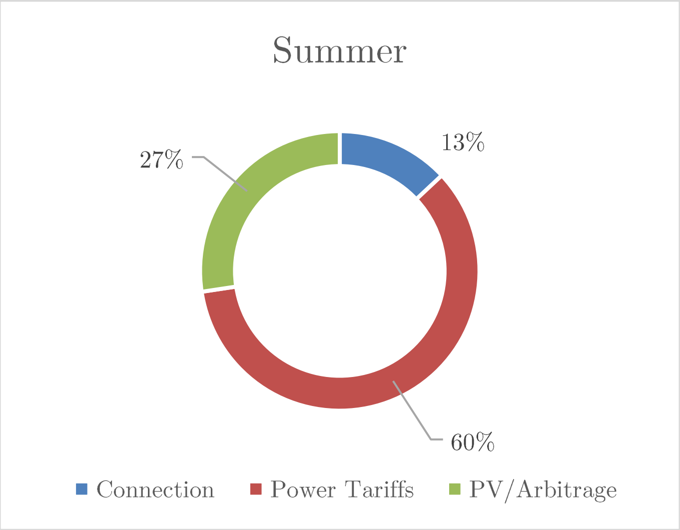

Figure 22: Cost saving distribution case 1 summer

Below in Table 4 the numbers presented for the case have been summarized where considerable peak reduction can be seen as well as cost savings.

Table 4: Summary of peak reduction and cost savings for case 1

	Reduced aggregated peak demand	Reduced total peak demand	Cost saving
Winter	10%	23%	6%
Summer	27%	39%	28%

3.2 Whole campus

When analyzing the whole of campus it is mainly offices that are the dominant load profile but others such as constant and housing have considerable shares as well seen in Figure 23 below. On campus there is an energy production facility which will be included in this chapter, seeing how it contributes to the overall energy balance.

Figure 23: Showing the percentage of each load profile for case 2 the whole campus

Demand

The demand on energy for the whole campus looks similar to the smaller case in 1, where electricity is relatively constant and heating and cooling vary depending on season seen in Figure 24.

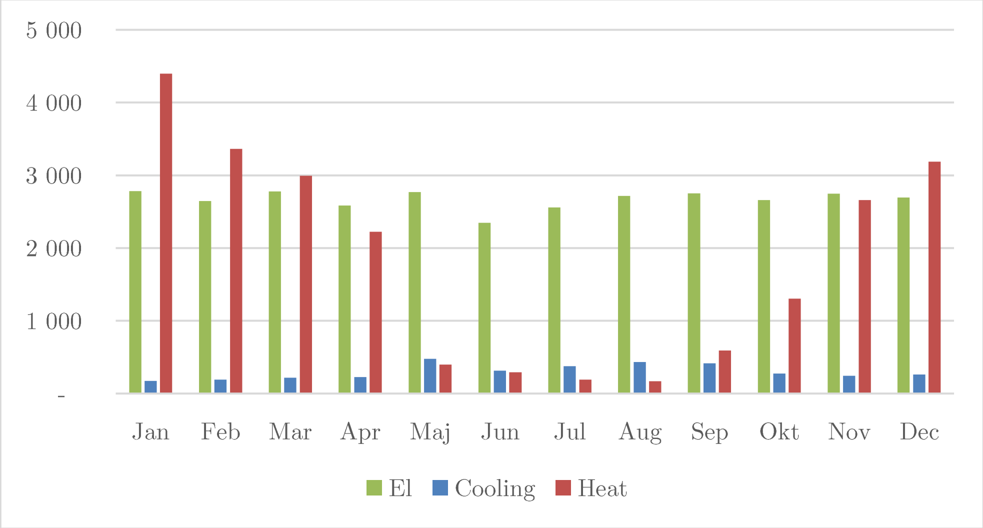

Figure 24: Demand by energy source for case 2

Production

The production of energy on campus each month can be seen in Figure 25 where Heating is on the scale to the right larger by a factor of ten compared to cooling, electricity and the distributed PV.

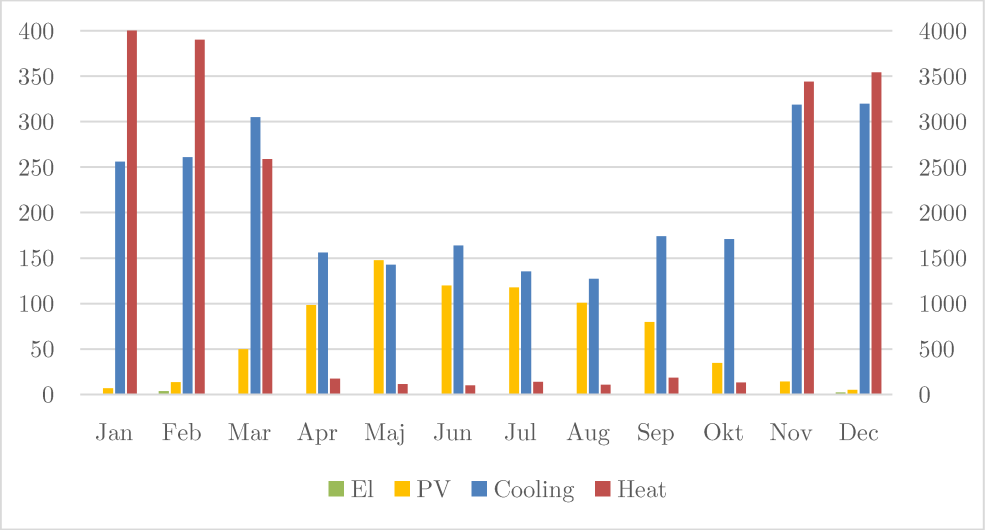

Figure 25: Production of energy on campus in case 2

In below Sankey diagram in Figure 26 the energy balance is shown where production and purchased energy are to the left and where the energy is consumed is to the right. The sold heating energy is estimated based on the information provided, however an hourly analysis has not been run for this.

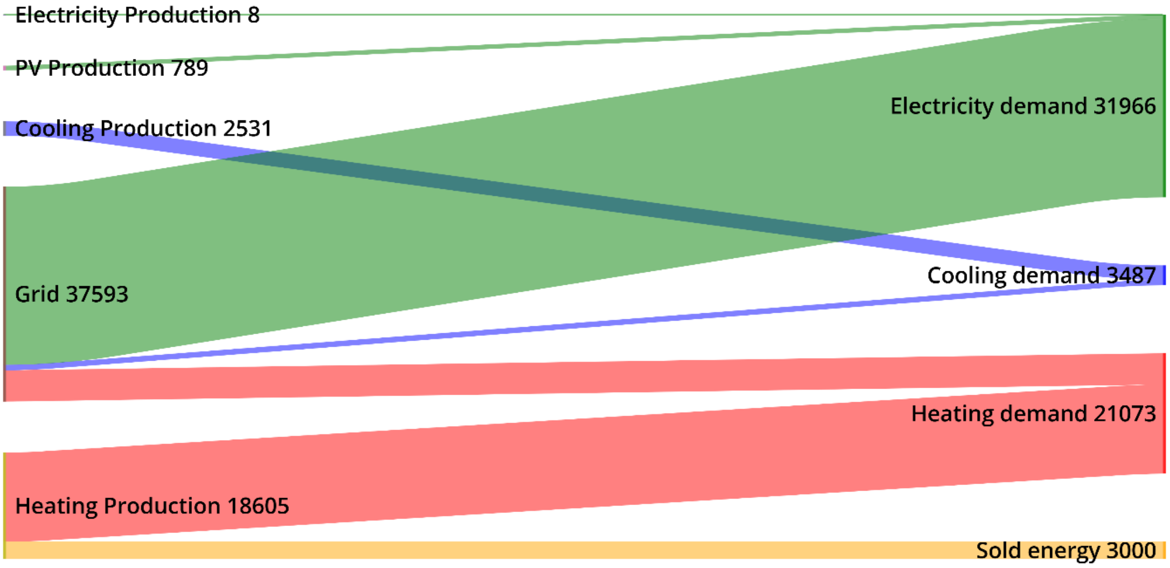

Figure 26: Sankey diagram of the energy for campus Johanneberg

Winter

During the winter the aggregated demand is shown in Figure 27 where PV and battery only can make a small peak reduction. Compared to the smaller case, relatively the effect is smaller however still noticeable, the reduction on the aggregated demand is 3% and total maximum peaks for the individual buildings 8%.

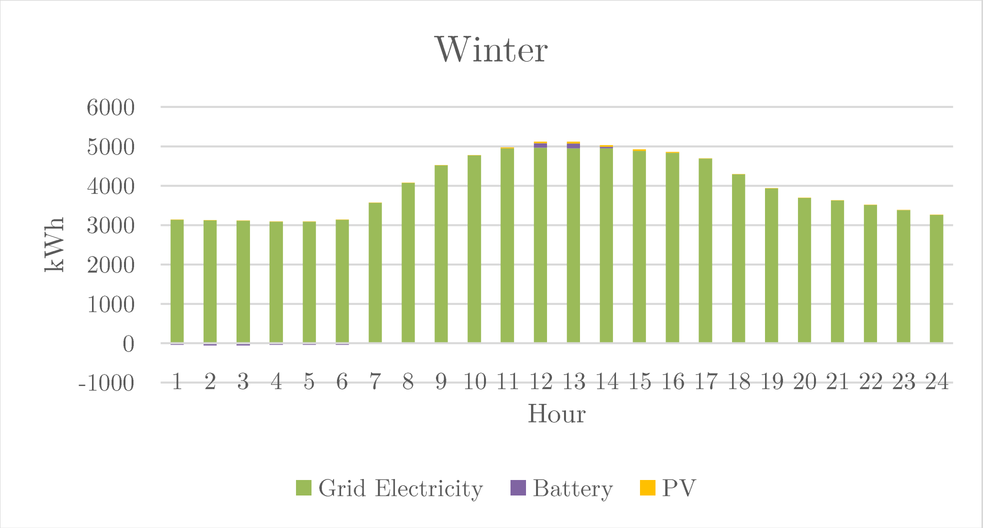

Figure 27: Aggregated load profile for case 2 winter

This results in a small cost savings of 2% during the winter, however greater returns are seen for the summer months broken down below. In Figure 28 the distribution of cost savings can be seen.

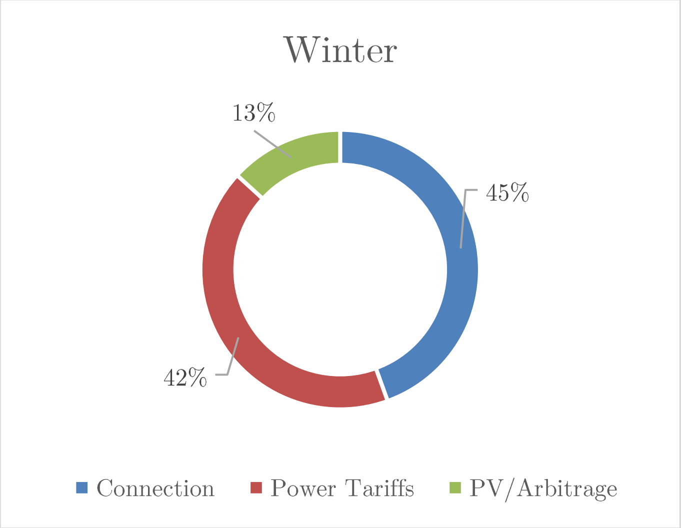

Figure 28: Cost saving distribution case 2 winter

Summer

During the summer period when analyzing an average day from the summer PV and the battery help reduce the total demand and reduce peaks. In Figure 29 the total reduction of the peaks can be seen and are noticeable compared to the winter month and the aggregated load profile sees a reduction of around 10% and the total reduction of peaks is 20%.

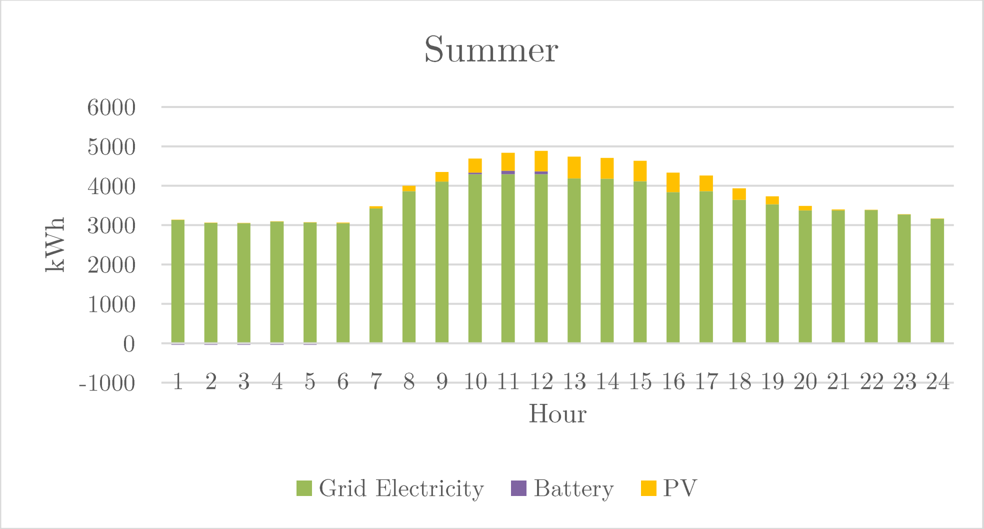

Figure 29: Aggregated load profile for case 2 summer

Resulting in a cost saving of 13% for an average summer month broken down in Figure 30 below.

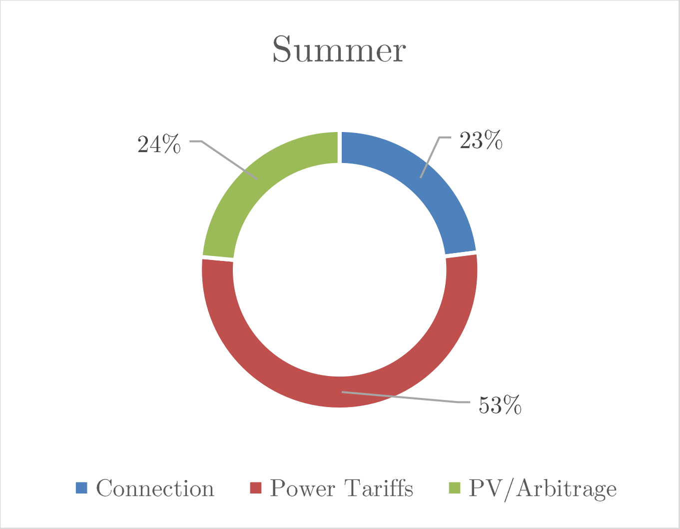

Figure 30: Cost saving distribution case 2 summer

In Table 5 below a summary of the results can be seen where the summer is considerably larger than the winter savings both on peak reduction and costs.

Table 5: Summary of peak reduction and cost savings for case 2

	Reduced aggregated peak demand	Reduced total peak demand	Cost saving
Winter	3%	8%	2%
Summer	10%	20%	13%

3.3 Future campus

Campus Johanneberg has development plans according to the detail plan with plans for new development of 150 apartments, 230-670 new student rooms and 100 000 sqm for commercial use, some of which will be placed on a current parking lot see Figure 32 (Göteborgs stad, 2021). Using an average of 50 sqm for the apartments and 30 sqm for the student rooms gives 21 000 sqm of new housing, using both this and the new commercial areas and historical profiles from the newer buildings results in below data. In Figure 31 the new split of load profiles can be seen housing has increased from 7,5% to 10,3%. For the future scenario suggestions have been done on installing more PV and batteries and more details on this will be provided under relevant sections.

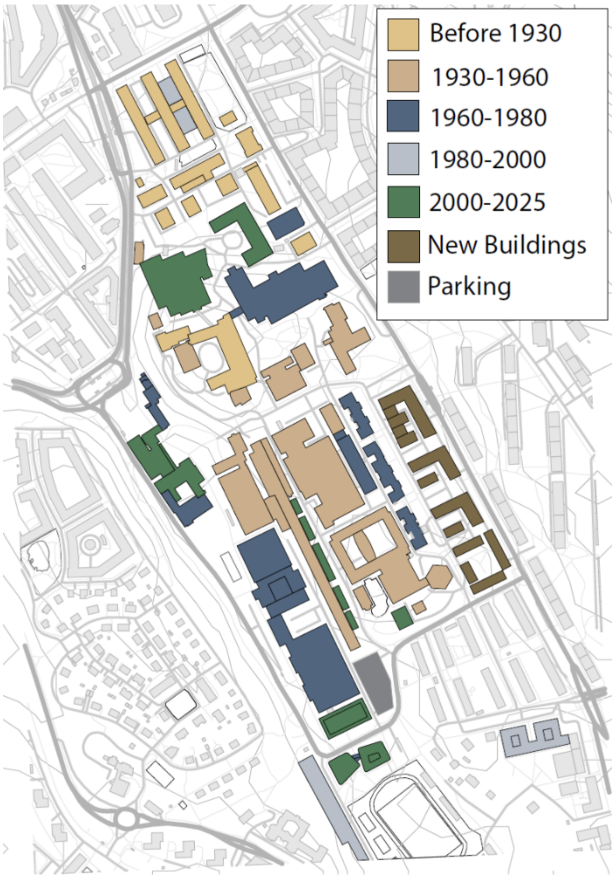

Figure 32: Map of campus Johanneberg with future build plants

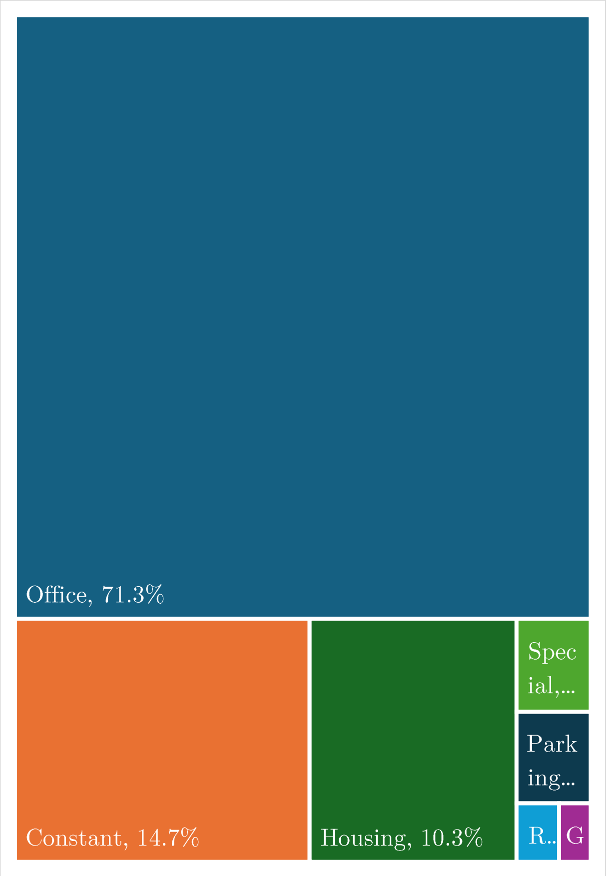

Figure 31: Showing the percentage of each load profile for case 3

The future monthly demands are similar to those in the second scenario with added loads from the future builds. This can be seen in Figure 33.

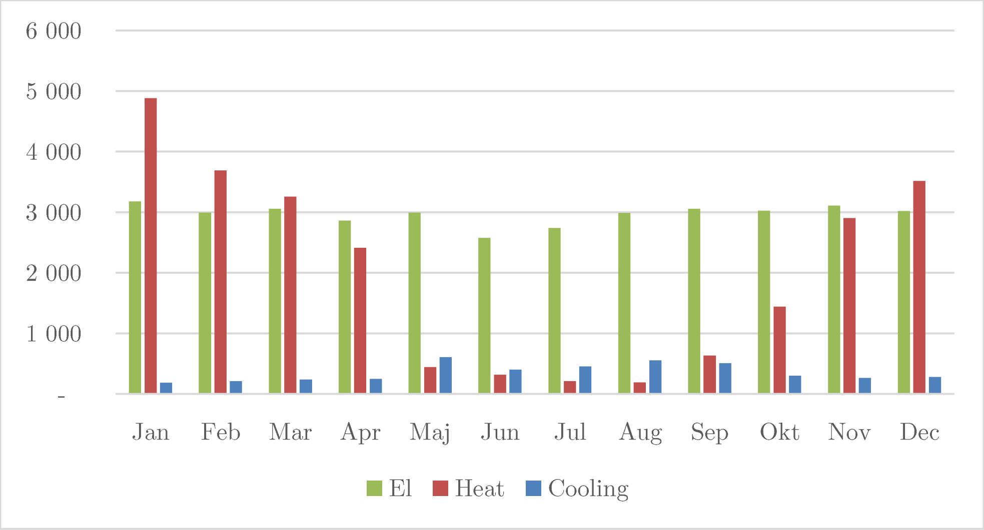

Figure 33: Demand by energy source for case 3

Production

In this case the PV production has been scaled up from the previous around 1,5 MW to 14 MW and is based on the summer month to match the average month and increase self-sufficiency. Yearly production can be seen in Figure 34.

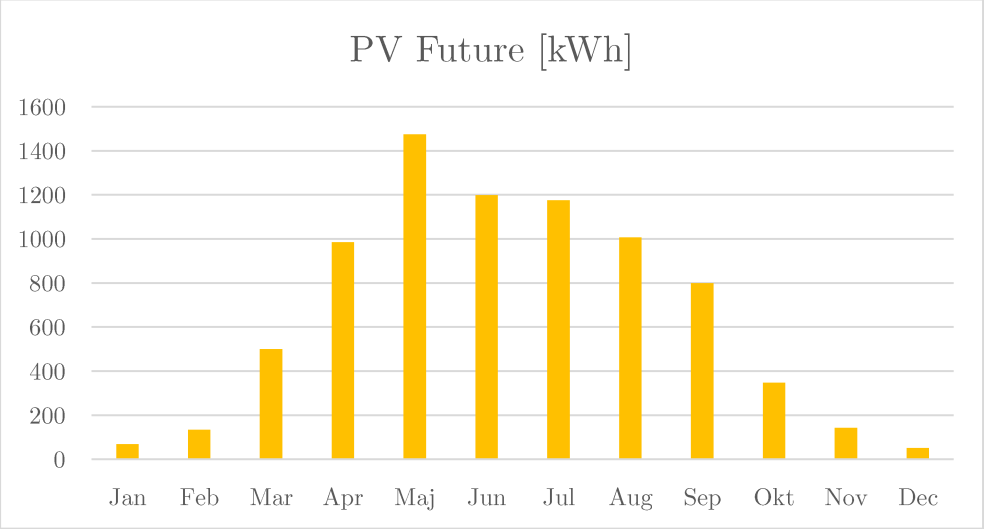

Figure 34: Production of energy from future installed PV

Winter

For the winter months an increased battery can reduce more peaks seen in Figure 35 below where the battery has been increased from 350 kWh to 1000 kWh to efficiently be able to reduce peaks and increase self-sufficiency instead of selling back to the grid. An average winter day per hour can be seen in Figure 35 where both PV and battery work together to reduce peak load.

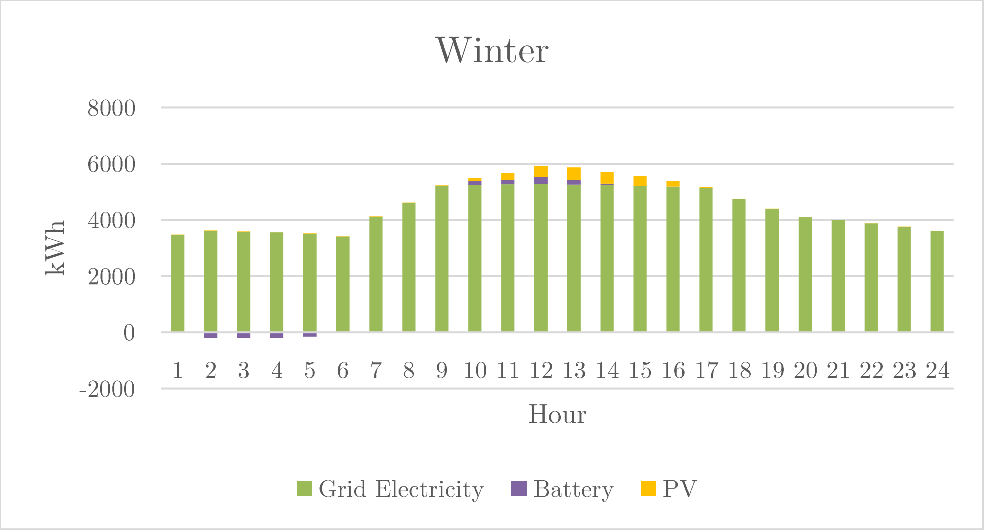

Figure 35: Aggregated load profile for case 3 winter

The cost savings in winter are on average 5% for a winter month, which is relatively low compared to the savings in the summer presented below. Savings are split according to Figure 36.

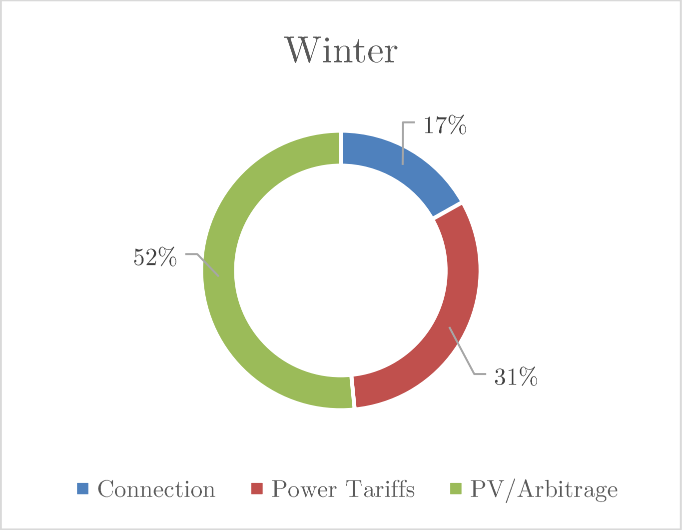

Figure 36: Cost saving distribution case 3 winter

Summer

In the Figure 37 below the increased share PV is clear where on an average summer month the PV production during the day matches demand. This is the way the amount of PV have been determined and amounts to in total 14MW.

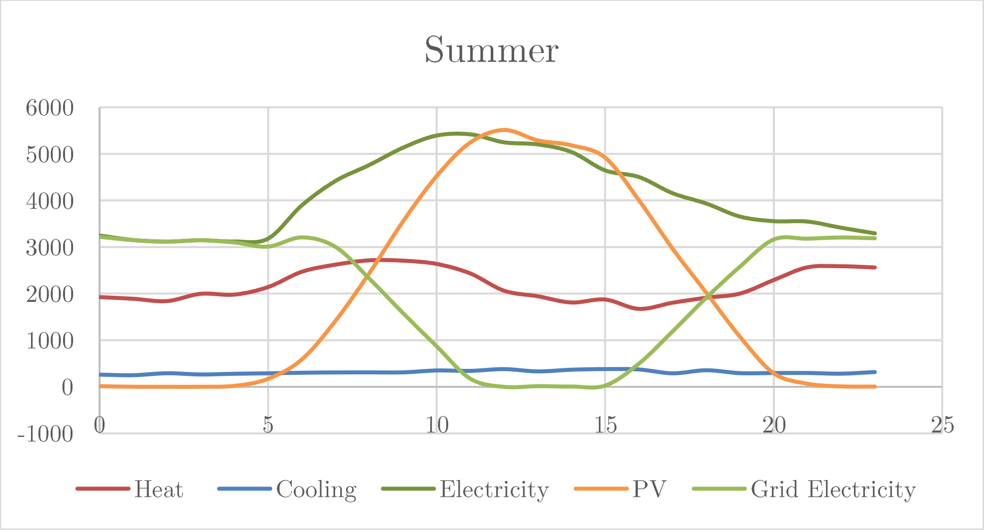

Figure 37: Illustrating the future campus energy demand and future production of PV during summer

Having this high amount of PV makes it cover the high peaks during the day and reduces the aggregated peak by 40% and by over 50% if insider all the individual peaks of the buildings. In a summer month the self-consumption is around 50% meaning half of the electricity used is produced locally with PV and can be seen in Figure 38.

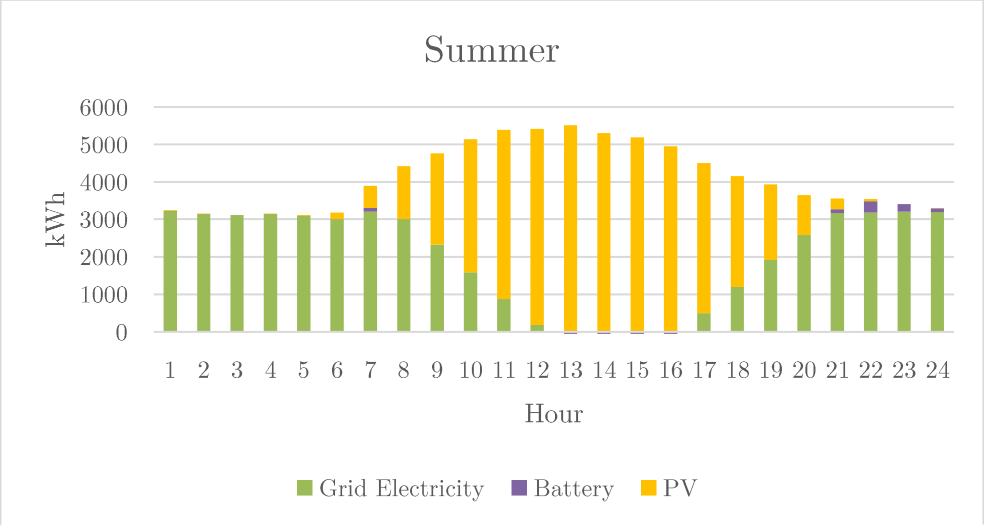

Figure 38: Aggregated load profile for case 3 summer

The total cost saving during the summer month accounts for 52% and is split according to Figure 39 below.

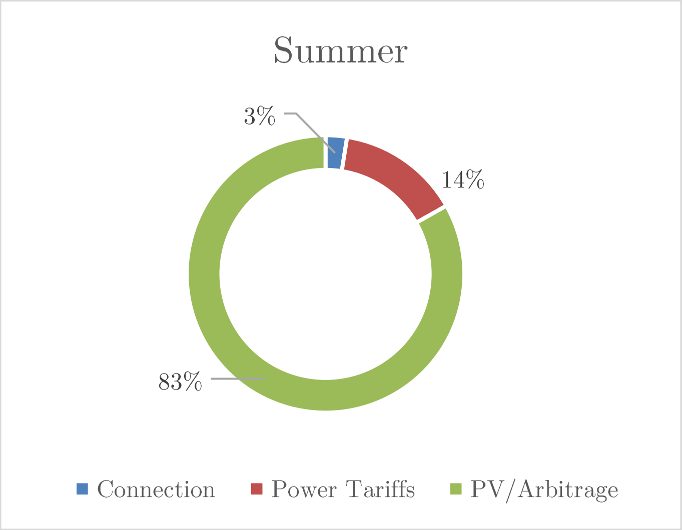

Figure 39: Cost saving distribution case 3 summer

Summary of results from the future scenario in Table 6 where much of the peak demand reduction is from increased PV and Batteries and the large cost saving in the summer is since much of the energy needed is produced locally decreasing the demand for grid imports.

Table 6 Summary of peak reduction and cost savings for case 3

	Reduced aggregated peak demand	Reduced total peak demand	Cost saving
Winter	11%	17%	5%
Summer	40%	56%	52%

Investments

Cost analysis of investments where prices have been taken from where the PV prices have been estimated from the Swedish energy agency and set at 900 € per kW (Lindahl et al., 2018). The battery price has been estimated in the same way based on (Colthorpe, 2025) and set at 200 € per kWh. This has not included any benefits of scale which might be relevant if adopting these large investments and ancillary services has not been studied which could increase the annual savings. Simple payback time has been calculated and found to be 15 years, as seen in Table 7. Noteworthy is that by 2035 there might be a more developed system where V2G can be used which would provide a great benefit explained both in the literature by Koirala et al. (2016) and found from several interviewees. When calculating cost and the annual savings, electricity price averages from the last 3 years have been used and power tariffs from Göteborg energi for 2025(Göteborg energi). The power tariff is 61,55 kr/kW for the highest peak each month for connections over 63A which would be for the energy community. Some savings are made on the reduced fixed cost from fewer connections to Göteborg Energi usually illustrated by blue in the figures above. Future changes of spot prices and increased volatility can change the payback period, where higher prices and a more volatile market would lower the payback time, making the investment more profitable.

Table 7: Calculation of investment for PV and batteries

Cost for 12,6 MW PV	11 510 000 €
Cost 650 kWh Battery	130 000 €
Total costs	11 640 000 €
Annual saving	780 000 €
Payback time	15 years

3.4 Discussion

From the analysis of these three scenarios, several noteworthy observations emerge. In the first scenario, the application of diverse load profiles results in a significant reduction of peak demand, thereby contributing to lower overall costs this is in line with findings by Belmar et al. (2023). A common thread across all three scenarios is that the savings are relatively modest during the winter months, when PV production is limited. Conversely, the most substantial benefits are evident during the summer months, when PV output is at its peak. In scenario 2, the primary advantage of aggregating the buildings lies in reducing peak consumption, as individual buildings exhibit peak demands at different times, leading to a collectively lower peak load. For the first two scenarios, cost reductions are predominantly driven by lower peak tariffs, attributable to the reduced power peaks. In the third scenario, power tariffs continue to play a role, but the dominant factor is the utilization of locally produced electricity rather than reliance on grid imports, which constitutes the largest portion of the savings. The payback period for the PV systems and batteries, estimated at 15 years in scenario 3, appears somewhat extended. However, this serves more as an indicator that a more detailed investigation is warranted, potentially involving precise site-specific assessments and further refinements, rather than relying solely on the extrapolated data derived from the existing PV installations on campus. The analyzed systems do not provide large benefits as seen during the winter, where it is mainly the battery and distributed peak loads that contribute to the small returns. The author believes that analyzing heating and cooling demand could paint another picture since the heating demand is the largest during winter whoever this was outside the scope of this thesis.

Collecting the data for each of the scenarios was made with a different amount of effort as buildings had variable quality on the data measured, here investments and improvements would be beneficial if considering implementing an energy community. The data has been collected from three different real estate companies that own the buildings on campus, hence the social aspects lifted in the literature and some interviews are not as prevalent as these are large companies not necessarily doing it for greater energy democracy but in the end are driven by financial returns.

4. Scenario roadmap

Below in Figure 40, four distinct scenarios are presented, each representing a unique orientation of energy community priorities. At the centre lies the "Sweet Spot", symbolizing a balance among the dimensions. The vertical axis spans technical to social aspects, while the horizontal axis ranges from local to societal priorities. These axes reflect the various values and trade-offs energy communities may emphasize depending on their context and purpose.

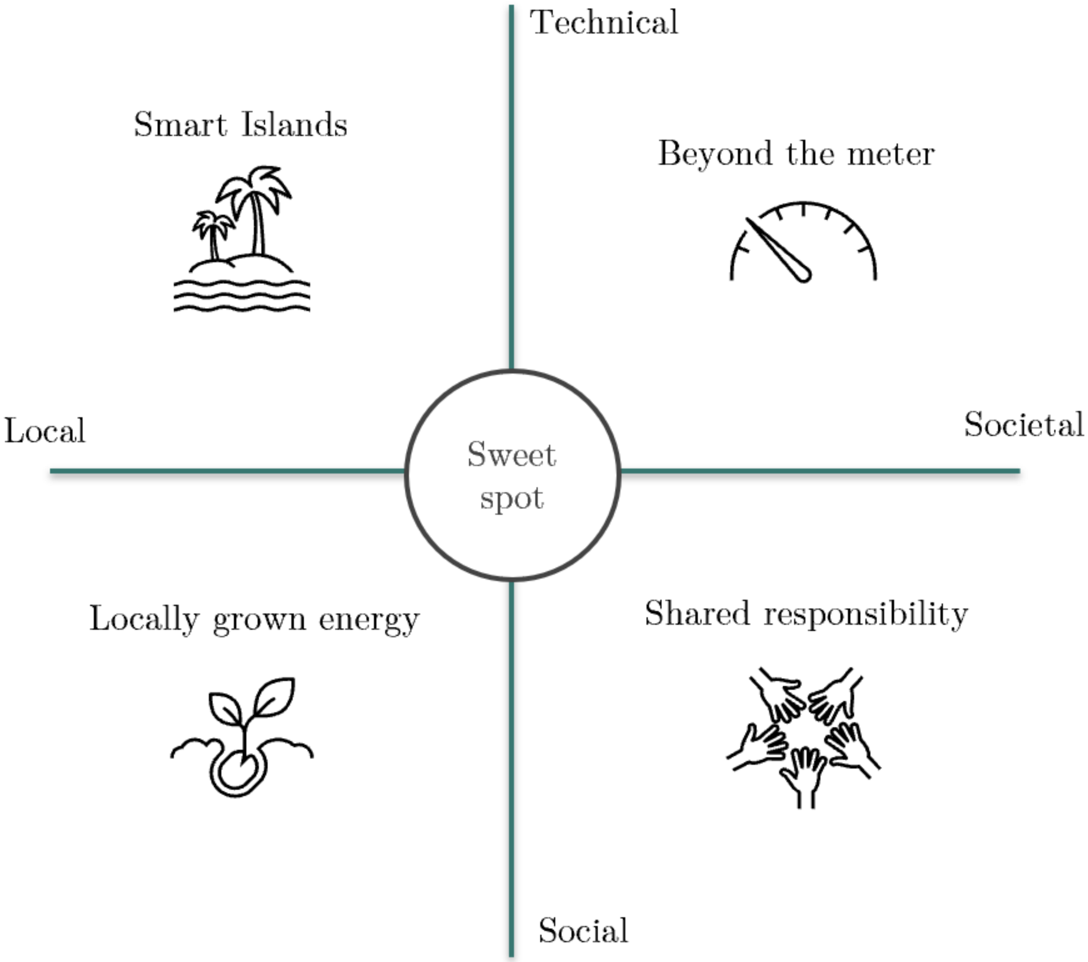

Figure 40: Scenario roadmap in a 2x2 with local vs societal and technical vs social aspects

Smart Islands

The *Smart Islands* scenario emphasizes local technical optimization. Here, smart controls and energy management systems are used to maximize the energy community's benefits, focusing on internal demands, self-sufficiency, and economic gains. For instance, photovoltaic (PV) systems and batteries are optimized to reduce grid dependency and enhance self-consumption. However, as highlighted in interviews, this approach may result in suboptimal outcomes at a system-wide level, where broader infrastructure and neighbouring buildings are not considered.

The key advantage lies in maximized local benefits for community members, even if wider system integration is limited.

Beyond the Meter

The *Beyond the Meter* scenario shifts the focus from internal optimization to broader societal benefits. Here, the energy community actively contributes to grid stability and system-wide efficiency. For example, reducing peak demand can prevent costly transformer upgrades. Smart control of generation and loads is implemented to prevent grid overload during times of low demand and high production on sunny days for example. Forecasting technologies and communication between the Distribution System Operator (DSO) and the community allow for dynamic grid support. Battery systems may be oversized from a local perspective, but strategically designed to offer ancillary services, demonstrating a strong alignment with collective needs.

Locally Grown Energy

The *Locally Grown Energy* scenario represents a socially driven, locally focused model that emphasizes energy democratization. Residents are empowered to produce and consume energy based on personal motivations and community values. Interviews and literature suggest that visible and tangible systems increase participation and investment, even when active involvement yields modest results as noted by Bergek & Palm (2024). In this model, the energy community acts autonomously, and the responsibility for adapting to its behaviour is placed on grid operators and utilities. There is little expectation for the community to account for system-wide impacts; instead, the emphasis is on removing barriers and enabling grassroots renewable adoption.

Shared Responsibility

In the *Shared Responsibility* scenario, energy communities embrace a societal mission, where participants are willing to adjust their behaviour for the greater good. Demand-side flexibility becomes a tool for supporting the energy transition, even when it comes at a personal or financial cost. Social values such as solidarity, sustainability, and collective responsibility are prioritized. Members may adapt daily routines or accept higher upfront costs in order to align with system-wide goals and fossil-free energy use, reflecting a deeper commitment to shared climate and energy objectives.

The Sweet Spot

Striking the right balance between these dimensions is complex, often involving trade-offs. While local engagement and investment can drive strong community ownership, it may conflict with broader system optimization goals. Along the vertical axis, technical and social values are contrasted yet, they need not be mutually exclusive. For instance, demand shifting can be both a socially motivated behaviour and a technically smart solution. Technical priorities focus on efficient technology deployment and grid performance, whereas social aspects emphasize inclusivity, engagement, and a sense of belonging. The “Sweet Spot” thus represents the ideal synergy, a community that is locally engaged, socially aware, technologically advanced, and systemically integrated.

5. Conclusion

This thesis set out to explore how different stakeholders perceive and can benefit from energy communities, incorporating both a review of existing literature and a real-world case study at Campus Johanneberg. The case study, supported by a quantitative approach, aimed to identify practical opportunities and barriers to implementation.

Throughout the report, both literature and interviews provided insights into the value that energy communities can offer to various actors. The case study of Campus Johanneberg emphasized not only previously known benefits and challenges but also uncovered new perspectives. Different stakeholders were shown to derive value in different ways: residents may experience increased energy democracy and participate for social reasons; businesses can identify new revenue streams; and grid operators may use energy communities to improve system performance.

Several barriers were identified, including legal and political uncertainties about what is permitted, and technical limitations such as inadequate metering infrastructure — challenges that were also observed in the case study. However, the study also demonstrated benefits, such as the aggregation of diverse load profiles and potential financial gains in a campus context. The proximity of technical knowledge and access to necessary technologies was highlighted as a key enabler, positioning campuses as suitable environments for piloting energy communities.

The findings of this study offer valuable implications. From a managerial perspective, they can inform decision-making by clarifying stakeholder priorities and identifying where value can be created. Technically and economically, the case study illustrated the potential for peak demand reductions and related cost savings. The scenario roadmap, developed in a 2x2 framework, provides an overview of different energy community models and highlights key dimensions to consider when evaluating or designing such initiatives.

That said, this thesis does not cover all dimensions of energy communities. In particular, heating and cooling were not analyzed in detail, and a broader interview base could provide deeper insights. Future research could expand on the role of other energy carriers, especially heating and cooling, and explore flexibility potential in greater depth across all energy types. Moreover, further studies could examine user participation within buildings more closely and evaluate its impact on energy community performance and engagement.

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Appendix

List of buildings

Building	**BTA [m²]**	**Built Year**
1. Fysik Origo	14100	1926
2. Nya Matte	8400	1945
3. Elkraftteknik	4900	1955
3. Bibliotek	7500	1957
5. Idelara	1100	1959
6. HC	2450	1962
7. HA	1600	1962
8. SB2	8700	1966
9. Edit	24500	1963
10. HB	2450	1962
11. SB1	16900	1968
12. SB3	22600	1969
13. Maskinteknik	29800	1968
14. Gamla Matte	9500	1980
15. AWL	11700	2019
16. Lokalkontor	1800	1969
17. IT-gymnasiet	2900	1926
18. Phus	6900	2015
19. Kemi	40130	1970
20. Vasa 1	7470	1930
21. Vasa 2-3	16100	1930
22. Vasa 4	1464	1888
23. Vasa 5	1609	1888
24. Vasa 7	2265	1907
25. Vasa 8	4473	1888
26. Vasa 9	1160	1930
27. Vasa 10	1818	1888
28. Vasa 11	4350	1929
29. Vasa 12	425	1907
30. Vasa 13	102	1911
31. Vasa 15	5930	1970
32. MC2	34700	2005
33. Friskis & svettis	1880	1930
34. Teknikparken	12600	1986
35. JSP	8000	2000
36. Kårresturangen	2510	1900
37. Kårhus entré	5194	2001
38. Emils Kårhus	6999	1945
39. CA-huset	3500	1962

40. Gibraltarvallen Guesthouse	4236	2019
41. Chabo	23561	2006
42. Rännan	2100	2004

Interview questions:

Background

1. Can you tell us a little about your professional background and how you came into contact with energy issues?
2. Have you previously worked on projects related to energy communities or similar initiatives?
3. What is your view on how energy issues have developed in your industry in recent years?

General about Energy Communities

1. How would you define an energy community, and what do you think are the most important benefits?
2. What types of actors do you most often see engaged in energy communities?
3. Are there any common misconceptions or challenges related to energy communities?

From Your Role

1. How do you perceive energy communities from your professional role? What opportunities and obstacles do you see?
2. How do energy communities affect the actors you work with?
3. Are there any specific policies, regulations, or business models that you consider particularly relevant?

Implementation

1. What factors do you consider crucial for an energy community to succeed?
2. What technical, economic, or social barriers do you see for the implementation of energy communities?
3. Are there any concrete examples of successful implementations that you find particularly interesting?

Scale 1-10 Questions (1 = No role at all, 10 = Very significant role)

1. To what extent do you believe energy communities will play a crucial role in the future energy system?
2. How strong is the interest in energy communities within your industry or organization?
3. How well do you think current regulations and policies support the development of energy communities?

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