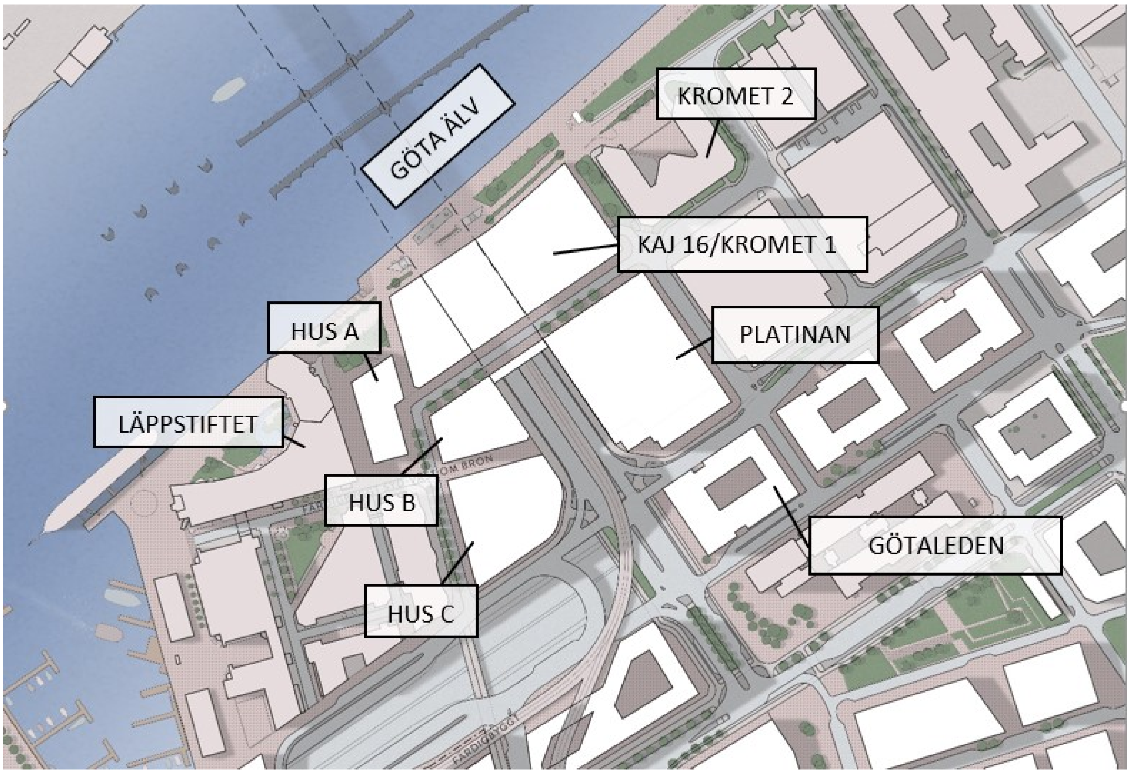

Using a sustainable business model for implementing a PED concept in terms of balancing excess heat on a district level

Case study on the district Lilla Bommen, Gothenburg

Master's thesis in Design and Construction Project Management

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Gothenburg, Sweden 2021
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Master's thesis 2021

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Cover: Overview of the area Lilla Bommen. The properties of Vasakronan which are going to be part of the micro-grid are marked in the figure. The picture was accessed through Vasakronan.

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Abstract

Following the directives of European "Horizon 2020 -10. Secure, clean and efficient energy", an European funded program called "*Positive Energy Districts and Neighbourhoods for Sustainable Urban Development*" has been developed. The program aims to integrate and balance the energy system at a district level, as there is a potential of having a holistic perspective regarding a district.

Vasakronan, a Swedish real estate company, has high sustainability aspirations. Investing in technical innovation is one way for them to move towards a decreased energy consumption. This thesis aims to help Vasakronan in their decision making process of implementing a micro-grid solution in the district Lilla Bommen, located in Gothenburg. The micro-grid will balance the recovered heating and cooling between properties in the area and thereby contribute to Vasakronan's long-term goal of transforming Lilla Bommen to a Positive energy district (PED).

To visualize and simplify the complexity of implementing a technical innovation such as a thermal micro-grid, a Sustainable Business Model Canvas (SBMC) is used as a tool to organize and understand the challenges and possibilities and how they are interdependent. Besides organizing workshops with Vasakronan, a literature study and a case study were conducted. In addition, three reference projects were contacted in order to gather inspiration for Vasakronan to use in their further development process. Finally, the empirical data was organized, analyzed and compared to the theoretical framework, in order to identify similarities and diverseness.

The main findings are presented in this paragraph. The SBMC is a helpful tool for the company and the participants gained a deeper understanding of the technical and business aspects. Additionally, several possibilities and challenges were found in terms of implementing a micro-grid. By utilizing resources that otherwise would have been considered as waste, Vasakronan saves economical and environmental resources. Their properties are valued higher due to its sustainability factors. Even though the micro-grid is a suitable solution, Vasakronan still has many challenges to solve as the project is in an early phase. For instance, legal issues must be addressed, an energy mapping of the area and a price model must be made in order to prove the financially viability of investing in a micro-grid.

Keywords: PED, positive, energy, district, micro-grid, excess heat, business model, sustainable business model, thermal energy.

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We are very grateful to have written our master's thesis on a very interesting and currently important topic. It has been educational and we found this way of working to be unique and useful.

We would like to express our sincere gratitude to our supervisors at Vasakronan, *Eric Eliasson* and *Mats Enander*. Thank you for your engagement in the topic and for taking your time to have continuously meetings with us. We also want to thank our supervisor at Chalmers, *Martine Buser*, for your support and ability to give very constructive feedback. You really have taken your time to analyze our working process and we are very grateful for your inputs as they have made the report better along the way. We got new insights in every meeting and we could not have done this without any of you.

Furthermore, we would like to thank everyone else that contributed to our thesis. Thank you to all contact persons who had meetings with us to explain and discuss your projects with unique solutions for balancing excess heating. It was really interesting and we learned a lot from you. Thank you to all the participants who took your time to be a part of the workshops. The workshops led to interesting and valuable discussion, which is a central part of our study.

Lastly, we want to thank our family and friends who has been with us during this journey. Your support and engagement means a lot to us and we are grateful for having you by our side.

Anton Avest & Emma Wahlfridsson, Gothenburg, June 2021

Acronyms

AI Artificial Intelligence. 34
BM Business Model. 19, 21–23, 26
BMC Business Model Canvas. 3, 19, 22, 25
BMI Business Model Innovation. 8, 22, 23, 25, 26, 58
DH District Heating. IV, VI, 1, 15–17, 31–33, 42, 45, 47, 48, 59
GBGE Göteborg Energi. 48, 59
HTDH grid High tempered district heating grid. 36, 38
KPI Key Performance Indicator. 17, 18, 57
LCA Life Cycle Analysis. 36
LEED Leadership in Energy and Environmental Design. 29, 30
LTDH grid Low tempered district heating grid. 9, 36–38, 56
PED Positive Energy District. 2–10, 13–16, 18, 26, 27, 29, 30, 32, 47, 55–57, 59
PSS Produce Service System. VII, 24, 57
SBM Sustainable Business Model. IV, 2, 23, 24, 42, 58
SBMC Sustainable Business Model Canvas. v, 3, 4, 7–9, 25, 26, 39, 50, 51, 56, 61
SET Strategic Energy Technology. 2, 14
SUDA Sense Understand Decide Act. 5–7, 10, 50
TES Thermal Energy Storage. IV, V, 16, 17, 33, 34, 36, 42–44, 47, 49, 56
VoC Voice of Customers. 6

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1
Introduction

1.1 Background

Since 1990, the global emission of carbon dioxide has increased with 50 %. The usage of energy is contributing to around 60 % of the total global greenhouse gas emissions (United Nations, 2021). It is clear that the world needs to find better ways of supplying energy, but also using the local existing energy resources as efficiently as possible. Energy efficiency is one of the main focus areas in the Energy Directives, defined by the European Union. By 2030, the goal is to be 32,5 % more energy efficient, compared to 1990. Furthermore, the Energy strategy also includes phase-out of fossil fuels, where the goal is to use 32 % renewable energy in 2030 (European Commision, 2021).

According to the government of Sweden, the building industry is responsible for around 40 % of the total energy consumption. More than half of the final energy use within housing and premises is used for heating and hot water preparation (Statens energimyndighet, 2020). To cover the heating demand, there is a high utilization of District Heating (DH) in Sweden, especially for multi-dwelling buildings. In order to increase the energy efficiency, the peak loads in the system should be reduced, since they create instability in the DH system. For the DH system in Gothenburg, garbage incineration and excess heat from industries are used to cover the the base load of the system, while fossil fuels mainly covers the peak load. This means that the usage of fossil fuels could be reduced by reducing the peak loads in the DH system (Kensby, 2017).

There are several viewpoints of energy systems. Each individual building represents an energy system of a smaller scale, while DH is an example of a larger scale at municipality level. Jansen, Mohammadi, and Bokel (2021) claims that there is a potential in looking at a scale between these levels, as buildings in the same district could share infrastructure and exchange energy between the buildings. Today, there are a limited amount of projects that have been constructed with this concept, but several ventures are driving the development (Jansen et al., 2021). Energy system integration is according to the European Commission (2020) an important method to achieve desirable energy transition within urban areas. Additionally, energy building codes should be developed to push the energy performance levels in the right direction (European Commission, 2020).

The European program *"Positive Energy Districts and Neighbourhoods for Sustainable Urban Development"* is an initiative within integration and efficient energy systems. The program aims to integrate and balance the energy system at a district level and is a part of the European Strategic Energy Technology (SET) Plan 3.2, which contribute and support the development of 100 Positive Energy Neighbourhoods by 2025 (Urban Europe, 2020). In order to successfully implement the concept of thermal energy exchange between buildings, there is a need of technical systems as well as a business model for relevant stakeholders within the district (Lane, 2019). Further investigation is required regarding how to support the utilization of recovered heat and cooling. For a company to invest in a Positive Energy District (PED), the concept must be economically profitable. This can be visualized with the help of a sustainable business model where new insights can be developed. The new sustainable business model could support the decision making process when implementing a PED concept (Monti et al., 2017).

1.2 Purpose

The Swedish real estate company, Vasakronan aims to be climate neutral across their whole value chain by 2030. The purpose of the thesis has been developed by discussing with Vasakronan, reading literature and gathering inspiration from the European work program "Horizon 2020 - 10. Secure, clean and efficient energy". According to the European Commission (2020) the projects within a Positive Energy District (PED) should contribute to several areas, including increased share of:

1. Renewable energy
2. Waste heat recovery
3. Storage solution and how they are integrated within the local energy system. (European Commission, 2020).

These goals have been interpreted within the sustainability goals of Vasakronan. To achieve this, several pilot projects have been chosen, where the company is making investments in order to reach their environmental goals. One of them is a city development area called "Lilla Bommen", located in Gothenburg. In this area, Vasakronan wants to form a strategy for sharing thermal energy (heating and cooling) between facilities in the district, and thereby recover waste heat. The aim of the thesis was to help Vasakronan identify the possibilities and challenges with this concept by developing a Sustainable Business Model (SBM) for sharing energy savings and investment costs in this area. The business model aims to visualize the implementation and operation of a micro-grid system and be a tool for finding challenges when integrating a technical innovation within the business of Vasakronan (Osterwalder & Pigneur, 2009; Joyce & Paquin, 2016).

1.3 Problem formulation

Reflecting back to Horizon 2020, the increased usage of energy is a problem that needs to be solved (European Commission, 2020). For Vasakronan, investing in technical innovation is one way to move towards a decreased energy consumption and their long-term goal of developing a Positive Energy District (PED) in Lilla Bommen. They want to recover excess heat from their facilities in the district Lilla Bommen. By doing so, they can increase their energy efficiency and prevent most of the thermal energy within the area of going to waste. There are already plans for implementing a technical innovation such as a thermal micro-grid to transport recovered heat and distribute where it is needed. Although, the Lilla Bommen district is still in an early development phase and which technology to use has not yet been decided. This means that the technology exists, but how to implement it and integrate it into the business model of Vasakronan is not yet explored.

To visualize and simplify the complexity of implementing a technical innovation such as a thermal micro-grid, a Sustainable Business Model Canvas (SBMC) is used to organize and understand the challenges and opportunities. The SBMC was used since it has the same layout as the traditional Business Model Canvas (BMC), but with additional focus on environmental and social sustainability. Its flexibility and holistic traits create good prerequisites for this thesis' purpose. Research questions that have been investigated towards the goal are:

- What are the possibilities and challenges that Vasakronan are facing when implementing a PED concept in terms of a thermal micro-grid in Lilla Bommen?
  - What can Vasakronan learn from similar projects that have implemented technical innovations to move thermal heat on a district level?
- How can Vasakronan, with help of a SBMC, proceed towards their long-term goal of implementing an economically successful PED concept in Lilla Bommen?
  - How can a sustainable business model be applied in order to successfully implement a micro-grid system for utilizing waste heat at district level?

1.4 Limitations

Throughout the project, several limitations have been established to follow the purpose of the master thesis.

- The thesis is focused on a single case study called Lilla Bommen, located in Gothenburg, Sweden. This means that the resulting Sustainable Business Model Canvas (SBMC) can not be copied for any project, since all project have their own prerequisites. The SBMC in this report is not focused on Vasakronan as an organization, but rather on applying the long-term goal of implementing a PED concept in Lilla Bommen.

- The thesis is focusing on balancing thermal energy (heating and cooling). The usage of electricity is outside of the scope and will only be regarded in the discussion chapter, in terms of its scarcity. However, since electricity is required to run the system, this should also be included when further analyzing the potentiality of the micro-grid solution later on.

- The micro-grid project in Lilla Bommen is at an early planning stage. Vasakronan has not yet decided upon which technology they want to use in their micro-grid solution. For this reason, technologies will only be discussed on a system level of implementations challenges. No comparison between different technologies will be made in this case study. Which water temperatures that are in the system will not be regarded at this stage. Potential risk for legionella and how the temperature affects the efficiency of the micro-grid system is, for this reason, outside of the scope of this thesis.

- No calculations have been made since all buildings in the district are not yet planned nor constructed. Although, moving waste heat is assumed to be achievable and beneficial since the buildings are planned to include businesses with different energy patterns. For this reason, there should be an energy surplus respective deficit in the district, which is an essential prerequisite for a micro-grid solution to work. Additionally, the Sustainable Business Model Canvas (SBMC) is focused on implementation of the concept and operation of a micro-grid, which means that LCA or CO2 production calculations are not considered.

- The energy production is outside of the scope for this thesis. This means that the micro-grid will not be enough to generate an annual total energy surplus in the district. However, the district could be further developed for Vasakronan to reach their long-term goal of achieving a Positive Energy District (PED). This also means that no investigation regarding the potential of transferring energy back to the district heating network will be made.

- The work process have been following the SUDA (Sense, Understand, Decide, Act), see section 2.1. Within this framework, focus has been on the sensing and understanding phases. The other phases have been neglected because of the early stage of the project and it is Vasakronan's mandate to decide and implement the solution later on.

- Comparison of more than three different business model canvases will not be made. Two alternatives to the original BMC are presented, but no in depth comparison or analyze will be done.

2
Methodology

This master's thesis was built upon a literature review, a case study, workshops and meetings with reference projects. A qualitative research method has been used to interpret theoretically based concepts and put them into context in the case study. An action research method was adopted to have a distanced interaction with the company by conducting workshops and discussions.

Throughout the project, A SUDA (Sensing, Understanding, Deciding, Acting) framework has been as an iterative method. This was done in order to reflect about the process and to get a clearer view of how to undertake the problem. The different phases of the SUDA are explained in section below 2.1.

2.1 SUDA framework

Sense Understand Decide Act (SUDA) is an improvement methodology, which has been followed throughout this thesis. The purpose of using a SUDA framework is to support the process by dividing the action research into four phases, which are presented in subsections below. Within each phase there are techniques, methods and tools that can be applied to achieve the main goal of the project improvement. According to Monti et al. (2017), the four main pillars, that are seen in figure 2.1 are crucial when implementing a Positive Energy District (PED)(Monti et al., 2017). The focus in this thesis was on the second pillar, *Business model development*.

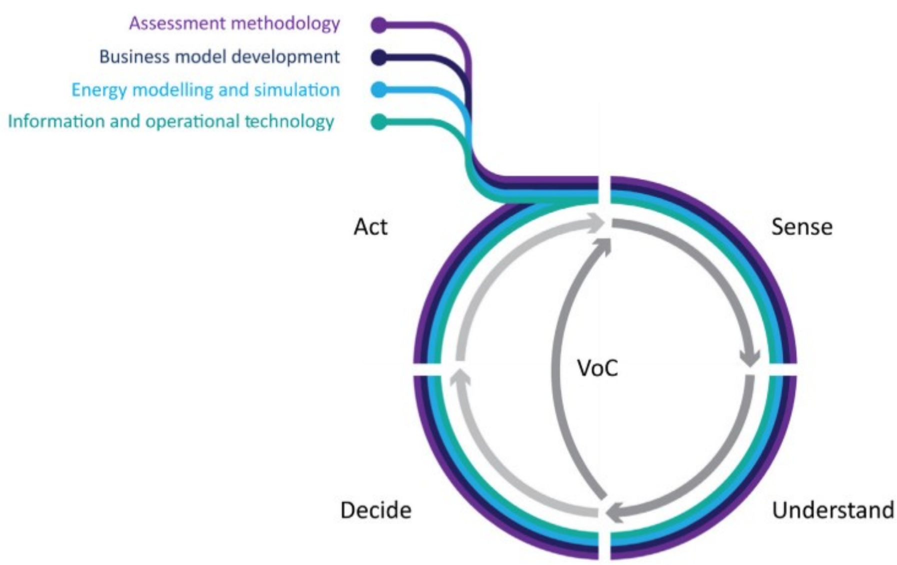

Figure 2.1: SUDA framework for PED (Monti et al., 2017)

2.1.1 Sensing

The first phase focuses on identifying the problems and opportunities for improvement. This includes literature studies, eventual interviews and amongst others. Since the SUDA framework is an iterative process in a loop, the sense phase also consist of sensing if implemented improvements had a desirable effect or not. If not, the process continues (Monti et al., 2017).

In order for us to investigate and identify a problem formulation, we conducted a literature study on the topic and discussions with our supervisor from Chalmers. We also had several discussions with our supervisors from Vasakronan. Both of them works as Property Developers, but one of them is focused on technical solutions as well.

2.1.2 Understanding

The understanding phase is closely linked to the sensing phase, since this is the process where information from the sensing phase is analyzed. The iterative process between these two phases is represented in figure 2.1, where there is a smaller loop within the SUDA framework. The smaller loop connects sensing and understanding through the Voice of Customers (VoC). One of the main goals with the understanding phase is to identify the most important aspects and actors in the project with respect to keeping on track towards the end goal. This can be done through workshops, interviews and additional literature review (Monti et al., 2017).

2.1.3 Deciding

The next step in the SUDA methodology is to decide what improvement actions can be taken. These decisions should be based on the gained knowledge from the two previous phases. In the decision phase, different actions should be evaluated and the aim is to find the most beneficial solutions and a strategy of how to get there. Questions to be answered are for example: which stakeholders are important? what are the key activities and what is the value of this innovation? (Monti et al., 2017).

2.1.4 Acting

The acting phase is about implementing the solution. To name a few examples, this includes actions as planning, executing and controlling the innovation. Once again, there is a interaction within the SUDA framework. In order to tell if the effect of the implemented solution, it is necessary to once again address the sensing phase, as SUDA is an iterative process.

2.1.5 SUDA system boundary

In this master's thesis, focus was primary on the Sense, Understanding and VoC phases, which are connecting in a smaller loop within the SUDA framework. Since the aim of the thesis is to support Vasakronan in their ongoing work with the PED concept, the iterative process was a central part. The SBMC workshops could help Vasakronan to answer questions as mentioned in the decision phase of SUDA.

After receiving inputs from this thesis, Vasakronan will hopefully have gotten more insights and could thereafter move on towards the deciding and acting phase of the SUDA framework.

2.2 Literature review

The literature review was mainly focused on Positive Energy District (PED), micro-grid at a district level, green business models and business model innovation. Challenges and possibilities within previous PED projects were identified and used as a base in the development of a sustainable business model for Vasakronan. This was done to get different viewpoints, by extracting relevant possibilities and challenges from previous projects within the area of PED. Above that, literature about different business models and their features were found and analyzed. Reliable databases such as Scopus and Google Scholar were used to find relevant literature. Keywords were used and combined to find suitable literature. Later on, the information was compared and reviewed to get a non-bias viewpoint. The following keywords were searched upon for the literature review:

- PED, positive, energy, district, local, grid, micro-grid, balance, excess heat, business model, sustainable business model, implementation, thermal energy, integration

2.3 Case study

The case study was based on the city development project of "*Lilla Bommen*", which is located in Gothenburg, Sweden. Vasakronan has a long-term vision for the building district that includes a PED concept to maximize the usage of local existing energy and thereby minimize the need of externally imported energy. There is a long way to go, since most of the buildings in the area are not yet constructed. Although, there are local detailed plans for the district, which includes various operations as future tenants in the buildings. These operations have different thermal energy patterns. This is a prerequisite for the PED to work, since there must be a surplus and deficit of thermal energy within the district to balance the energy between the properties. By combining information from the inputs and knowledge from Vasakronan, a Sustainable Business Model Canvas (SBMC) was developed as a tool for the company. The aim of this was to visualize the value of implementing a micro-grid system and to identify challenges and possibilities. This was done by organizing two workshops with Vasakronan.

2.3.1 Workshops with Vasakronan

As a part of the understanding phase in the SUDA framework, two workshops were organized to discuss the business model for a micro-grid solution in Lilla Bommen. This was done in order to identify the aspects of interest and to use the opinions of the team as a base when analyzing the sustainable business model. One of main goals of organizing the workshops was to make the challenges of implementing the micro-grid and to make a business out if it more tangible for the employees of

Vasakronan. This is an iterative process, which followed the SUDA framework. The first workshop was analyzed and improved before organizing the second workshop. When organizing the workshops, Business Model Innovation (BMI) was used to further see the potential of including environmental and social sustainability in the business model, see section 3.4. It was practical to use this, since it gave a more tangible angle for the value proposition of Vasakronan. A characteristic of this thesis is that we as authors were participating in the development of what we studied. With this, we contributed to the study that we look at by acting as moderators in the workshops.

Workshop 1: 2021-02-05
Participants:

- Authors of the Master's thesis (We)
- Property Developer within Technology, Vasakronan (Supervisor 1)
- Property Developer, Vasakronan (Supervisor 2)
- Team manager sustainable building, AFRY (Consultant)

The participants were chosen due to their working area and knowledge of the area Lilla Bommen. AFRY, a consultant company, was represented in the first workshop to gain a more technical perspective. The representative from AFRY is an energy consultant within the Lilla Bommen project. This meant that he had knowledge about the energy system, and could contribute to the business model of Vasakronan by looking at it from an outside perspective. Due to not being an employee in Vasakronan, he gave comments as a technical consultant without having the organizational knowledge of Vasakronan.

During the workshops, we acted as moderators to lead the discussions forward. Before the workshop, the participants were supposed to individually reflect about challenges and possibilities with the PED concept at Lilla Bommen. In the beginning of the workshop, the Sustainable Business Model Canvas (SBMC) was explained briefly. Thereafter, all the eleven elements of the business model were discussed, one by one. For each element, the team members had time for individual reflection (2-3 minutes). Afterwards, the participants wrote their thoughts in a shared document. This was considered to be the base point for the open discussion. In the discussion, we asked questions about the reflections that were written in the document to lead the discussion forward. However, we did not engage in the discussions ourselves, since we wanted the participants to develop their own thoughts and opinions without being affected by us. In the end, our reflections were added and discussed with our supervisors, which then resulted in the first SBMC.

Workshop 2: 2021-04-21
Participants:

- Authors of the Master's thesis (we)
- Property Developer within Technology, Vasakronan (Supervisor 1)
- Property Developer, Vasakronan (Supervisor 2)
- Technical Chief within Technical Development, Vasakronan (new participant)
- Property Developer, Vasakronan (new participant)

Starting over in the SUDA framework, the sensing phase was applied for analyzing opportunities of improvements before moving on to workshop 2. To generate a finished sustainable business model, a more holistic approach was required in order to see things from different perspectives. For this reason, more people with relevant competences were invited to the second workshop. These people were chosen in discussion with the workshop 1 team in order to get a broader view of the project. Their inputs were important, since the resulting Sustainable Business Model Canvas (SBMC) is supposed to support their future work in the project.

2.4 Meetings with reference projects

Several meetings were held with representatives from projects that have similarities with the PED concept of Lilla Bommen. The projects were chosen to get a broader view and to gain understanding of how similar systems for balancing excess heat are working. Moving forward, these projects were handled as reference projects to address possibilities and challenges, when discussing the micro-grid in the case study of Lilla Bommen.

During each meeting, each contact person described their project. Thereafter, questions about the implementation and collaboration of actors within respective project were asked. The meeting were semi-structured where some questions were planned in advance, while other appeared in the discussion within each meeting. In every meeting, there was a focus on stakeholder collaboration, business models and price models of their system. The following projects were included in this part of the thesis:

- **Kista Terrass, Vasakronan**
  City development project in Kista, where a local thermal energy network has been implemented and in operation during the last 10 years. This project is owned and developed by Vasakronan. Contact person for this meeting was the a property developer within technology, situated in Stockholm, who is involved in the Kista project.

- **Ectogrid, Eon**
  Ectogrid is a technical system, innovated by EON. The contact person was a person who is in charge for the Ectrogrid system. Ectogrid is a low tempered micro-grid, that balances heating and cooling demand between properties within a specific district. The system is used in several projects all over Europe.

- **Cool DH in Brunnshög, Kraftringen**
  Cool DH is a project funded by EU Horizon 2020. The aim of the program is to support the utilization of low tempered local energy by implementing a low tempered district heating solution. Kraftringen is the local energy company in Lund and they are contributing to this program in their project of implementing a large scale Low tempered district heating grid (LTDH grid) in the area of Brunnshög, Lund. In this project, excess heat from research facilities is recovered and used as a heat source for a residential and business area which

is under development. Contact persons for this project were a business developer, who is specialized in strategic development and a construction planner, specialized in district heating and district cooling.

2.5 Data analysis

The trustworthiness of this paper is essential. To achieve this, a qualitative research should be assessed accordingly to the following criteria: *credibility, confirmability, dependability and transferability.* (Korstjens & Moser, 2018). Firstly, the topic of the master's thesis was found and developed with one of the supervisors at Vasakronan. All supervisors continuously gave feedback and comments on our progressing work, which strengthened the credibility of our result.

Positive Energy District (PED) is a relevant topic on an global level as it follows the European work program "*Horizon 2020 - 10. Secure, clean an efficient energy*", which proves its importance. Since this master's thesis is exploratory, we have followed the SUDA framework's iterative process between the workshops, discussions, observations, empirical data and the literature. The same topics reoccurred several times, in discussion with both Vasakronan and with the reference projects. In the workshops it was important to get the opinions of the company, without affecting them in their discussion. Since we acted as moderators during both workshops, we did not affect the result perceptibly. The dependability could be improved if more workshops would have been conducted and if more employees from Vasakronan would have been involved. However, this would require a longer time-period than what this master's thesis corresponds to. It would also be beneficial to organize workshops later on, when Vasakronan has come further in their development of the micro-grid system. With the time span in mind, there was a value in organizing two workshops as they included a diverse group of people. The workshops enabled us to gather the participants experiences and opinions regarding the implementation of the micro-grid and the long-term PED goal. The workshops, discussions and all meetings were recorded and afterwards thoroughly analyzed. Afterwards they were discussed once again with our supervisors in order to strengthen the confirmability of the study. Additionally, the workshops were also compared to get a more trustworthy result.

Several references were studied and used during the work process. Trustworthy research databases such as Scopus and Google Scholar were used to find literature. Following a Sense Understand Decide Act (SUDA) framework, the document study is based on numerous international papers, books and companies' websites. All information about the case study was collected from Vasakronan, which is a reliable source since they have knowledge about their own company and projects. Although, some information could be biased, since Vasakronan wants to promote their own company as well. The aim of this master's thesis was to help Vasakronan to conceptualize their micro-grid work process in Lilla Bommen. For this reason, the company was committed to show both weakness and strengths of their project development. The representatives from the company were open to receive input from us, which speaks for them being honest about their work and thereby increase the credibility of the study. All participants of the workshop have inspected the report before it was published. This strengthens the credibility and quality of the report as well, since they stand by what we have written.

In the discussion, the empirical data was organized, analyzed and compared to the theoretical framework, in order to identify similarities and diverseness. This was done to investigate if Vasakronan are working for sustainability according to the eight archetypes of sustainable business models, developed by Bocken, Short, Rana, and Evans(2014). Following this structure increased the confirmability of this thesis.

The confirmability was also increased when comparing the case study with reference projects. When doing this, it was important to consider the local prerequisites and which key partners that were involved. As this thesis aims to help Vasakronan and specifically their long-term PED ambitions in Lilla Bommen, the transferability was not a main focus. Although, having the local prerequisites in mind, other researchers could use Lilla Bommen as a future reference project to gather inspiration for their own projects.

3
Theory

In this chapter, literature is presented to gain a deeper understanding of the concept Positive Energy District (PED) and its connection to sustainable business model innovation. The first part of the chapter focuses on technical theory, while the second part is about different business models and sustainable business model innovation.

Starting with the technical theory, there are many similar expressions related to Positive Energy District. All concepts involve more or less the same criteria. Firstly, they all deal with interaction between buildings in the same neighbourhood, by looking at a system boundary on a district level rather than an individual building. Secondly, each concept also aims to implement smart solutions to optimize the utilization of accessible energy and decrease the need of fossil energy resources. Some of the found concepts are presented in the list below. Literature has been collected from papers where the concept is described with these names, but from now on, the concept will be called PED in this thesis to avoid confusion.

- **PED** - Positive Energy District (Urban Europe, 2020)
- **PEB** - Positive Energy Blocks (European Union, 2021)
- **EPN** - Energy Positive Neighborhood (Monti et al., 2017)
- **SUI** - Smart Urban Isle (von Wirth, Gislason, & Seidl, 2018)
- **ZEN** - Zero Emission Neighborhood (Kjendseth Wiik et al., 2018)

3.1 Positive Energy District (PED)

Cities are continuously increasing their environmental impact in terms of higher levels of carbon dioxide emissions and more energy usage. In order to face these environmental problems, RISE (2020) claims that system solutions at district level should be further developed and that relevant stakeholders must cooperate. As an example, energy systems could be shared between property owners and that is the base point of a Positive Energy District. Today, there are great development opportunities regarding utilization of surplus heat, solar energy and heat storage capacity. These opportunities should be further investigated to optimize the energy usage at a district level(RISE, 2020).

JPI Urban Europe are developing a project where 100 Positive Energy Neighbourhoods aims to be constructed by 2025. The project aims to balance the energy systems at district level and is a part of the European Strategic Energy Technology (SET) Plan (Urban Europe, 2020).

3.1.1 Definition of PED

The concept of a Positive Energy Districts is relatively new and there are several definitions of a PED.. The Horizon 2020 work programme provides the following definition:

> *"Positive Energy Blocks [and] Districts consist of several buildings (new, retro-fitted or a combination of both) that actively manage their energy consumption and the energy flow between them and the wider energy system. Positive Energy Blocks [and] Districts have an annual positive energy balance. They make optimal use of elements such as advanced materials, local [renewable energy sources] RES, local storage, smart energy grids, demand-response, cutting edge energy management (e.g. electricity, heating and cooling), user interaction [or] involvement and ICT. Positive Energy Blocks [and] Districts are designed to be an integral part of the district [or] city energy system and have a positive impact on it. Their design is intrinsically scalable and they are well embedded in the spatial, economic, technical, environmental and social context of the project site."* (European Commission, 2020, p.171)

This means that a PED requires interaction and integration between buildings in the same district, but also between the users and the regional energy. The aim of a PED is to achieve a net zero energy import and net zero CO2 emissions, by implementing renewable energy systems and allowing the buildings to share energy between each other (Urban Europe, 2020). The buildings within a PED should consist of different operations (offices, housing, commercial areas etc.) to make use of the differences in the energy consumption pattern and thereby create an energy balance in the system. Moreover, there should be at least three connected buildings next to each other and there must be a local energy surplus to distribute within the district. For this concept to work, there is a need for technical solutions as well as an active management and a developed business model (European Union, 2021).

3.1.2 PED functions

JPI Urban Europe (2020) describes three main functions of the Positive Energy District (PED) framework:

- **Energy Efficiency Function**
  - One of the main goals within the PED concept is to optimize energy efficiency by balancing out energy needs between different sectors in the district and to make use of existing energy resources, such as recovered waste heat.
- **Energy Flexibility Function**
  - Another goal is to successfully manage the interaction between local energy system for the neighborhood and the regional energy system. Controllability, management of supply and demand and energy storage are tools for this function.
- **Energy Production Function**
  - Local production of renewable energy is a part of a PED system. It will contribute to reducing green house emissions as well as creating an economic value for the neighbourhood (JPI Urban Europe, 2020).

These functions need to be considered in order to successfully implement a Positive Energy District (JPI Urban Europe, 2020). However, Monti et al.(2017) express that there is a clear motivation for neighbourhoods to become energy flexible, even if they are not energy positive. Instead, the focus should be on making the system flexible to increase energy efficiency in a PED. An ambition level should be chosen to make sure that everyone in the project is aware of the goals and limitations (Monti et al., 2017). Hence, there is still a value for implementing a micro-grid, even if the system does not recover enough heat for the district to be independent from the District Heating (DH) system.

3.2 Micro-grid for balancing thermal energy

Local prerequisites determines the interpretation and implementation of a PED solution. This means that there can be different types of innovation within different projects. A thermal micro-grid is an example of a technical innovation, which stands in line with the concept of a PED. Jansen et al.(2021) claims that there is a potential of looking at a district level, since property owners could collaborate to generate both economical and ecological value. This is the baseline of implementing a micro-grid solution, since the system covers not only one building, but a whole district (Jansen et al., 2021).

The main benefit of a micro-grid is that a PED concept allows waste heat to be utilized and used where there is a heating demand in the district (Jansen et al., 2021). By recovering waste heat, the energy efficiency could be increased, which results in a lower environmental impact (Brange, 2015). A prerequisite for a successful micro-grid is that the local energy demand is more or less met by available excess heat. Surplus energy only gains a value if it can be used directly, or be locally stored until there is a demand(Ala-Juusela, Crosbie, & Hukkalainen, 2016). For this reason, a seasonal storage should be included in the infrastructure of the system in order to reach full potential with the micro-grid solution of balancing thermal energy (Brange, 2015).

The flexibility of a micro-grid system is an important aspect as it is one of the three PED functions (JPI Urban Europe, 2020). Besides TES, Monti et al.(2017) mention that flexibility could also refer to shifting consumption between thermal energy and electric energy. The micro-grid is operated by heat pumps, which require electricity. This means that electricity is needed in order to utilize and transport the thermal energy within the system. Thermal energy brings some flexibility in itself if compared with electricity. There is a time delay in the thermal energy system as energy is stored in materials, while the load and generation must be in balance constantly in an electrical grid(Kensby, 2017). For this reason, there is a potential in utilizing the thermal inertia of the buildings to store thermal energy for a shorter period. By making use of the thermal inertia it is possible to shift the energy consumption to periods when the electricity prices are lower, which would result in an economical profit (Monti et al., 2017). Heat source shifting is another way to increase the flexibility. According to Kensby(2017) it is possible to shift between using District Heating (DH) and using heat pumps. By doing so, there is flexibility added to the DH system. Kensby(2017) claims that peak loads could thereby be reduced by using an alternative heat source when there is a high pressure on the DH system. For this concept to work, hourly price variation is required to ensure flexibility in the system (Kensby, 2017). When applying this concept in a micro-grid where excess heat is balanced out, this implies a reduced environmental impact.

When operating the system, there are lots of developed technology available. Smart software can be utilized to interpret information, analyze and thereby enable optimization of the control system. Looking at the system from a holistic view, a well functioning control system could minimize the total cost for the micro-grid (Kensby, 2017).

The micro-grid can be combined with solar panels to generate electricity for running the system. In this way, the customers are able to produce their own electricity to run the heat pumps in the micro-grid system. When customers are both producing and consuming energy, they are called prosumers (Brange, 2015). Brange(2015) also mentions that prosumers are able to adjust their energy consumption and become less energy dependent. Through this, it is also possible to gain environmental certifications such as BREEAM and LEED, since these certification systems give extra credit if the building is energy efficient and even more if it is generating its own heating and electricity (Brange, 2015). Lastly, innovation is part of developing a PED concept, and thereby the micro-grid. Consequently, business models should be elaborated to find new ways of creating value (Kjendseth Wiik et al., 2018).

3.2.1 Thermal Energy Storage (TES)

Thermal Energy Storage (TES) could improve the local micro-grid, since it allows energy to be used when it is needed. The possibility of energy storage adds flexibility to the system and simplifies the match between supply and demand in the micro-grid. In other words, having a TES simplifies the balancing of heating and cooling in the micro-grid. Using thermal energy storage could reduce peak loads from the regional district heating and cooling system, by choosing when to make use of the DH system and when to use the micro-grid (Ala-Juusela et al., 2016). Alva, Lin, and Fang (2018) listed three main aspects of how thermal energy storage can reduce the gap between supply and demand of thermal energy:

- **Time difference**
  Storage allows energy to be consumed after the energy is produced.
- **Minimized cost**
  The cost for thermal energy is different depending on if the demand occurs during peak hour or not. Since thermal energy storage allows flexibility regarding when the energy is used, peak hours could be avoided.
- **Geographical distance between supply and demand**
  Thermal energy storage could be used to better match not only when but also where the energy is consumed (Alva et al., 2018).

According to Alva et al.(2018), there are both economical and environmental benefits of installing a thermal energy storage in the micro-grid system by reducing need of fossil fuel and utilizing excess heat. The insulation of the thermal energy storage is crucial to minimize transmission losses and thereby improve the efficiency of the system. Moreover, for the investment to be economical viable, the system needs to be analyzed in terms of material cost and implementation cost (Alva et al., 2018).

3.2.2 Challenges of implementing a micro-grid system

Besides many possibilities of a micro-grid system, there are also numerous of challenges, both in terms of implementation and regarding technical aspects. Neighbourhood innovations, such as a micro-grid, requires transparency and collaboration between stakeholders in the district. If there is lack of transparency, the collaborative process will become insufficient for the system to work successfully (Proka, Hisschemöller, & Loorbach, 2020). The companies that are involved in the micro-grid must be willing to share energy data to enable balancing thermal energy within the district. To achieve this, privacy and safety are two key aspects for allowing free flow information between stakeholders(Monti et al., 2017).

Key Performance Indicators (KPIs) are a quantifiable indicators to measure progress by defining values based on data from the project. These values could be used to track the performance over time as well as to simplify the comparison with other similar projects. According to Kjendseth Wiik et al. (2018), an aspect which needs to be considered is how energy consumption can be integrated in the urban planning of a city on a municipality level and not only on a single building level. There is also a challenge in defining KPIs and how to make an objective comparison between several PEDs in order to further develop the concept (Kjendseth Wiik et al., 2018).

For the micro-grid to run as smoothly as possible, there should be adaptions of existing information communication technology. Each building have their own monitoring and controlling equipment and there is an implementation challenge in connecting all components into a shared network (Monti et al., 2017). Further investigations should be made of how to implement these technical values into the business model of a company.

Apart from technical barriers, there are also management challenges. There must be qualified technicians to operate the system as well as a solid plan regarding the ownership of the system. When combining multiple actors within a micro-grid, there should not be uncertainties regarding responsibility issues and ownership rights (Proka et al., 2020). Since energy management is a relatively new area, these problems need further investigations. Creating a suitable business model for a functional micro-grid is difficult (Monti et al., 2017). The aspects above have to be considered and integrated in a business model in order to simplify a the complexity of implementing a new technical innovation.

3.3 Business Models

The technology of a micro-grid is available. However, the main issue that companies are struggling with, is implementing and integrating new technology with their business and management. Generally, companies are lacking the knowledge on how to integrate between the stages of design, production and operation (Brady, Davies, & Gann, 2005). In order to successfully integrate the technology, the company must identify the available resources and coordinate the associated activities. Furthermore, Brady et al.(2005) explains that the relationship between the client and the customer is important. Both parts should be able to benefit from the value proposition and that is a challenge when applying technical innovations within the construction industry (Brady et al., 2005).

One way to integrate technology with management and business is to use a business model. There are several definitions of a business model and how to use it. Osterwalder and Pigneur (2009) creators of the original Business Model Canvas (BMC), describes a Business Model as “the rationale of how an organization creates, delivers and captures value" (p.14). In addition, Fox (2019), a PhD researcher and lecturer at Cranfield University, describes a Business Model (BM) as: "a framework to understand, design, and test your business idea. It provides a systematic way to identify how you can profitably generate revenue while creating value for your customers."

When creating a BM, the user has to consider four key areas; Customers, Offerings, Infrastructure and Financial Viability (Osterwalder & Pigneur, 2009). Furthermore, Osterwalder and Pigneur(2009) and Joyce and Paquin(2016) claim that the Business Model Canvas (BMC) is a practical tool that captures the four key areas and can help people understand the term and the company’s Business Model. By creating a visual canvas, the user can understand the different elements of a BM easier and grasp the understanding of value creation and its fundamentals. By visualising the different elements and creating interconnections between them, the BMC creates opportunities for discussions and debates (Joyce & Paquin, 2016). As a result, users can develop a deeper systemic perspective of a company’s business model and the value creation (Bocken et al., 2014; Barquet, Pigosso, & Rozenfeld, 2013).

3.3.1 Business Model Canvas (BMC)

The Business Model Canvas (BMC) consists of the four key areas of a business model, which are then divided into nine elements, see figure 3.1 (Osterwalder & Pigneur, 2009).

- **Customers**: Customer Segments, Channels, Customer Relationships
- **Offer**: Value Propositions
- **Infrastructure**: Key Resources, Key Activities, Key Partners
- **Financial Viability**: Revenue Streams, Cost Structure

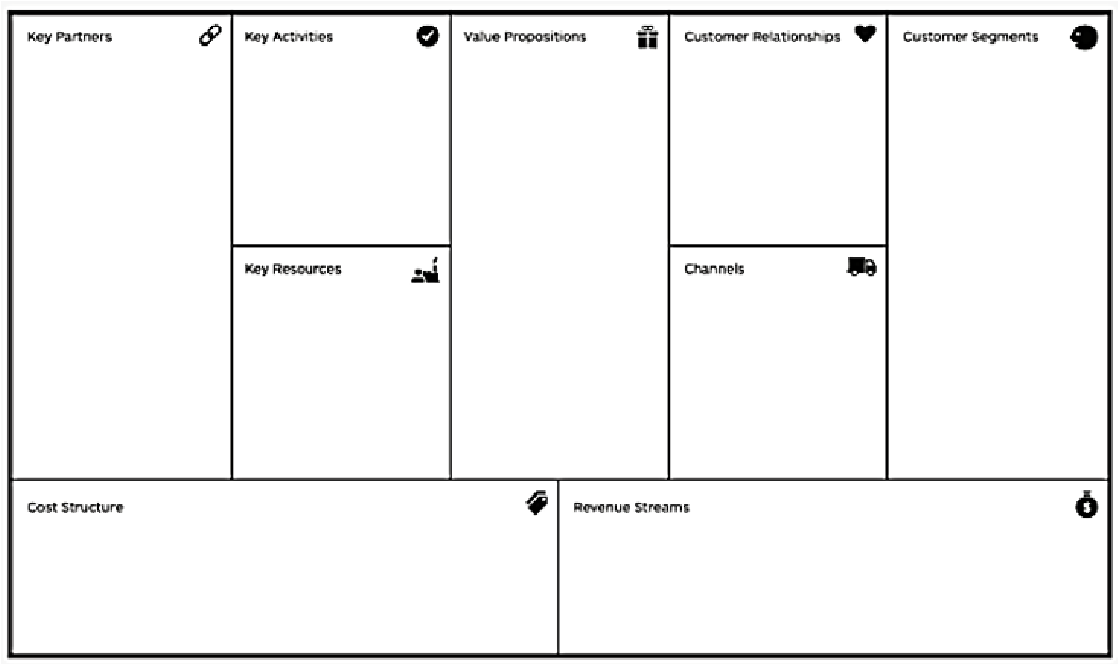

Figure 3.1: Business Model Canvas (Osterwalder & Pigneur, 2009)

Customer Segments
In order for a company to enhance its ability to satisfy their customers, they can divide them into different segments. It is crucial that a company makes conscious decisions regarding which segments they want to focus on (Osterwalder & Pigneur, 2009). Examples of customer segments are; Mass market, Diversified market and Niche market. For instance, niche market is when the company focuses on a small and specific customer segment. Diversified is when the company has unrelated customer segments with different value propositions. Finally, a mass market is when the company delivers its value proposition to as many customers as possible. Customers can be divided into segments by investigating:

- Their specific requirement demands and gives incentive for a distinct offer
- If they are reached by a separate distribution channel
- Their requirement of different types of relationships
- If the revenue stream is different
- Their preference to pay for different aspects of the same offer

Value Propositions
The value propositions are the reasons a customer chooses a specific company over the other. It can be divided into *quantitative values*, such as price or speed of service and *qualitative values*, such as customer experience or design. Furthermore, it could solve a problem or satisfy a specific need that the customer has. Each of the value proposition that the company offers consists of a combination of products and/or services that targets a specific customer segment (Osterwalder & Pigneur, 2009). In order to reach the customers with value propositions it is crucial that all the other blocks are integrated within the business model (Lane, 2019).

Channels

A company needs to find channels in order to reach out to existing and potential customers. By doing so, they can communicate and reach their customers with the intention of delivering the value proposition and thereby create the contact between company and customer (Osterwalder & Pigneur, 2009). Channels have several functions such as:

- Alert the customer's perception of the company's product and/or services
- Help the customers to make a decision regarding their view of the value proposition
- Make it possible for the customers to buy specific products and/or services
- Being able to deliver value propositions to the customers
- Being able to deliver support to the customers after the purchase has been made

Customer Relationships

A company should be specific when it comes to the type of relationship they want to have with their customers. The business model and customer relationship have a direct relation and a crucial role when it comes to the customer's perception of the company (Osterwalder & Pigneur, 2009). Some examples of categories of how customer relationships are handled are:

- Personal help (Human interaction)
- Exclusive personal help (Customer has a specific contact person)
- Self service (No direct relation with customers)

Revenue Streams

Revenue streams are the money that comes from successfully delivering value propositions to the customers. It is important to know how much a certain customer segment are prepared to pay (Osterwalder & Pigneur, 2009). There are two types of revenue streams that a Business Model can consist of:

- Transactions which are made from single payments by the customers such as; books, music and cars.
- Consistent revenue streams which are made from continuous payments such as gym membership and Spotify premium.

Key Resources

The chosen resources are a basis for creating a successful value proposition, entering a market, nurture the relationships with the different customer segments and produce a good revenue. Furthermore, the key resources are divided into different categories; Physical, economical, intellectual or human resources (Osterwalder & Pigneur, 2009)..

Key Activities
Key activities and Key resources are connected and dependent on each other. Examples of key activities are problem solving or product production. After identifying the key resources, the next step is how to use them. When the Key Activities are identified, the company is one step closer to delivering their value proposition (Osterwalder & Pigneur, 2009).

Key Partners
Having partnerships is becoming a fundamental part of a business model. By developing strong partnerships, a company could simplify the process of optimizing their BM. This could help them to reduce their risk and to acquire new resources(Osterwalder & Pigneur, 2009). There are four types of partnerships companies can create:

- Partnerships with competitors and non competitors in order to reduce risk and gain competitive advantage
- Joint venture company in order to develop a new business and/or idea
- Partnerships between supplier and buyer in order to secure continuous transactions and deliveries

Cost Structure
By creating successful value propositions, relationships, revenue streams and so on, the company can estimate the cost structure. Furthermore, it is also crucial to consider if the business model is aiming towards being *Cost driven* (low cost, lesser quality) or *Value driven* (higher quality, more expensive). Fixed costs, variable costs and economics of scale are examples of how cost structure are featured (Osterwalder & Pigneur, 2009).

3.3.2 Critics

While the Business Model Canvas (BMC) is a great tool to visualize the values and profits of an organization, it does not however take into consideration regarding the social and environmental questions since it has a 'profit first' orientation (Upward, 2013; Coes, 2014). Furthermore, Lozano (2014) also explains that if an organization is seeking Business Model (BM) that stretches beyond solely economical aspects, more creative tools are needed such as Business Model Innovation (BMI).

Consequently, this has led to new innovations and several versions of how a business model canvas can look like. New demands have risen in order to face today's challenges within sustainability. This means that the business model innovations have to address all three aspects of sustainability and integrate them into the corporate sustainability (Joyce & Paquin, 2016).

3.4 Business Model Innovation (BMI)

Business Model Innovation (BMI) can be defined as how a company can make use of their resources by changing their existing business model. It is about finding new value proposition and methods of handling their resources (Yang, Evans, Vladimirova, & Rana, 2016).

Yang et al. (2016) mention a method for BMI called "*Value Mapping Tool*", which includes a concept called *"Value uncaptured"*. Value uncaptured is defined as a potential value that has not yet been captured within the Business Model. Furthermore, Value uncaptured is divided into four forms:

- **Value surplus**
  Existing resources that offers more value than needed.
  Examples: overproduction, under-utilized human resources and excess heat
- **Value absence**
  Value that is required in the value creation process but does not exist.
  Examples:Lack of resources such as space, material or even human resources with required competences
- **Value missed**
  Value that is not used to its full potential. The value is created, but it is not fully exploited. No negative impact is generated, but there could be improvements.
  Examples: Inefficient use of material and human resources
- **Value destroyed**
  This is when value actually is destroyed and thereby cause negative impact on the business and stakeholders within the value network. These could be negative affects in terms of economic, environmental or social sustainability.
  Examples: Usage of fossil fuel, poor quality of product or service and health problems (Yang et al., 2016).

When developing a business model, these aspects of value uncaptured should be analyzed to successfully implement a new or improved BM (Yang et al., 2016).

3.5 Sustainable business model (SBM)

To facilitate innovation from an sustainable point of view, it is important to consider all three pillars of sustainability - economic, environmental and social. There are several definitions of a Sustainable Business Model (SBM), where one of them is:

> "a business model that creates competitive advantage through superior customer value and contributes to the sustainable development of the company and society" (Yang et al., 2016) p.1175.

It is a challenge for companies to include all three types of sustainability in their Business Model, as they are interdependent. The aim is to capture economic value for their business while they are facilitating environmental and social benefits (Bocken et al., 2014).

3.5.1 Eight sustainable business model archetypes

Relating to previous section, Bocken et al. (2014) has introduced a famous concept where SBM is categorizes into eight archetypes to support Business Model innovation (Bocken et al., 2014).

1. **Maximize material and energy efficiency**
   This category seeks to reduce environmental impact by optimizing the existing resources, such as material and energy. In short, a reduction of the resources and energy demand is desirable (Bocken et al., 2014).

2. **Create value from 'waste'**
   Creating value from waste means closing the resource loop by utilizing a resource that normally would go to waste. This concept generates environmental benefits by reducing waste to landfill, reducing emissions and decreasing the demand of primary resources. Under-utilized products and services could also be shared between different stakeholders to improve the value stream ant to utilize the full capacity or the resource (Bocken et al., 2014).

3. **Substitute with renewables and natural processes**
   In order to reduce environmental impact further, renewable resources should be chosen before finite resources. According to Bocken (2014) it is also preferable it the renewable energy solution is locally available. (Bocken et al., 2014).

4. **Deliver functionality rather than ownership**
   This archetype is based on the concept Produce Service System (PSS), where the business model has changed from producing a product to offering a product in combination with a service instead. The customer might not need to own the product in order to create value (Bocken et al., 2014).

5. **Adopt a stewardship role**
   Ensuring a long-term, well functioning relationship between different stakeholders is crucial within a SBM. Adopting a stewardship role means that the company should actively try to contribute to the well-being of all stakeholders within the value network. It is beneficial to combine this archetype with one or several others to generate best possible result (Bocken et al., 2014).

6. **Encourage sufficiency**
   It is not enough to only focus on the supplier side when aiming for a more sustainable future. The over-consumption in the western world is neither morally nor environmentally defensible (Bocken et al., 2014).

7. **Re-purpose the business for society/environment**
   Social and environmental benefits are prioritized rather than making economic profit (shareholder value)(Bocken et al., 2014).

8. **Develop scale-up solutions**
   Scale-up solutions is a relevant category within Sustainable Business Model (SBM) for maximizing environmental and social benefits and make a significant difference for a sustainable future (Bocken et al., 2014).

3.5.2 Sustainable Business Model Canvas (SBMC)

As earlier mentioned, it is crucial to adapt an organization towards the continuously changing market and sustainability demands. There are a few options to the original Business Model Canvas (BMC) which includes more than exclusively economical aspects. Some of them are considered to be more product oriented, while other are more broad. As a product of Business Model Innovation (BMI), the Sustainable Business Model Canvas (SBMC), created by CASE (2018), was chosen for this thesis due to its flexibility and focus on all three aspects of sustainability. As seen in figure 3.2, it is a complement to the original BMC. However, in order to address the sustainability demands of today, two extra elements have been added: *Eco-Social Costs* and *Eco-Social Benefits*.

Eco-Social Costs

This element tries to create an understanding of how the product or project is going to negatively affect the ecological and social aspects of sustainability. Organizations can ask themselves questions such as:

- What ecological or social costs is our business model causing?
- Are there any Key Resources which are non-renewable?
- Which Key Activities use a lot of resource?

Eco-Social Benefits

This element touches upon the same topic. In contrast to 'Eco-Social Costs', this one tries to create an understanding of what the positive effects are in terms of environmental and social sustainability. CASE(2018) ,mention that organizations can ask themselves questions such as:

- What ecological or social benefits is our business model generating?
- Who are the beneficiaries? Are they potential customers?
- Can we transform the benefits into a Value Proposition? If yes, for whom?

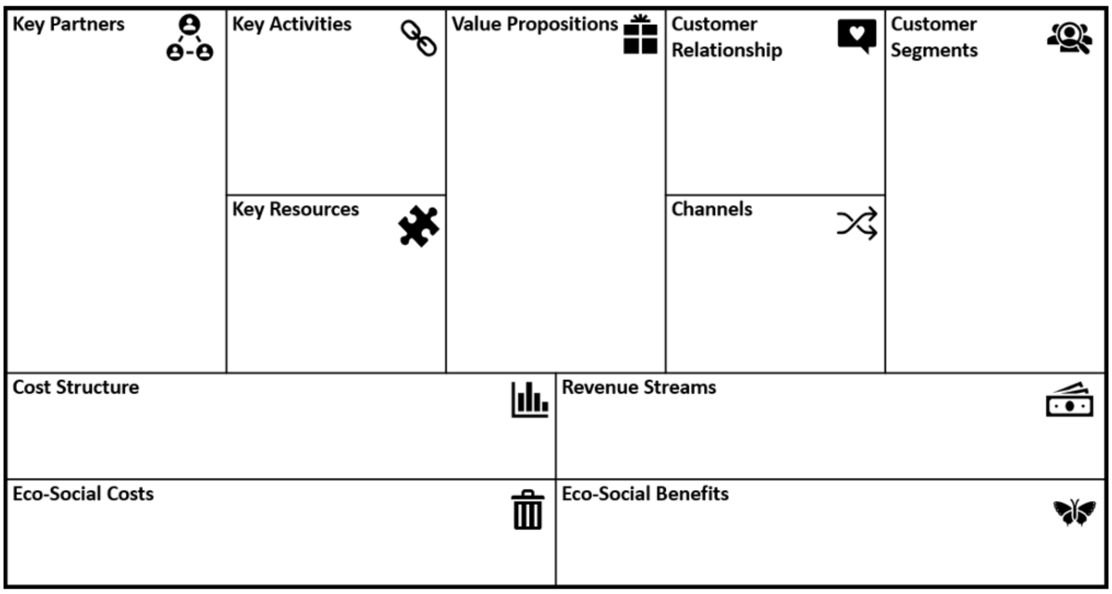

Figure 3.2: Sustainable Business Model Canvas (CASE, 2018)

3.5.3 Triple Layered Business Model Canvas

As mentioned before, it is crucial to adapt an organization towards the continuously changing market and sustainability demands. Another option to the original BMC that includes more than exclusively economical aspects, is the Triple Layered Business Model Canvas (TLBMC), see figure A.1 and A.2 in appendix. The TLBMC is built upon the original BMC, but with two additional canvases focusing on environmental and social sustainability respectively (Joyce & Paquin, 2016). It connects all three aspects of sustainability by following a triple-bottom line approach which in turn creates a vertical and horizontal coherence between them. Consequently, more and deeper discussions can arise, connections can be made and a more creative exploration of innovations that are focused on sustainability (Joyce & Paquin, 2016).

3.6 Conclusion of theoretical framework

The concepts which have been explained in this chapter have been used to find connections between the Positive Energy District (PED) concept, Business Model Innovation (BMI) and the implementation of a business model for a micro-grid solution. After investigating these topics, they will be addressed to the case study of Lilla Bommen to answer the research questions.

Throughout the thesis, the theoretical concepts from the literature review have been used in several ways. The technical theory have been used to confirm and reflect about possibilities and challenges of implementing a micro-grid in Lilla bommen, while the Business Model (BM) theory has been used to evaluate Vasakronan's business model. For instance, the *Value mapping tool*, developed by Yang et al. (2016) has been used to organize a Sustainable Business Model Canvas (SBMC) workshop for a selection of employees at Vasakronan. Bocken et al.s *eight sustainable business model archetypes* (2014) are reflected back to in the discussion chapter. The reason for this is to see in what way the micro-grid solution of Lilla Bommen could contribute to a sustainable city development.

Finally, the SBMC was chosen due to its flexibility and holistic coherence. Furthermore, the TLBMC is focusing more on production and product specific aspects, which makes it less suitable for this thesis' purpose.

4

Empirical study

Firstly, the empirical study includes information regarding Vasakronan and the Lilla Bommen area. Secondly, the empirical study also consists of data collected from meeting with the reference projects.

4.1 Case Study

From the literature review, it has been clear that there are different ways of interpreting and implementing a Positive Energy District (PED). There is no perfect solution that fits all contexts due to that all implementations are project specific, with their own prerequisites.

When describing Vasakronan and Lilla Bommen, information has been gathered from discussions and meetings with relevant employees within the organisation of Vasakronan. Internal documents have been investigated and data were also collected from Vasakronan's website.

4.1.1 Vasakronan

Vasakronan is one of the largest real estate companies in Sweden, with a property portfolio consisting of 171 properties and a total area of 2,3 million square meters. They own, administrate and develop office and retail properties in central areas of Stockholm, Gothenburg, Malmö and Uppsala. Furthermore, Vasakronan is also working towards developing their service portfolio. An example of a service that they are providing is coworking spaces. Rather than owning the office space, from customer perspective, they can rent the right to use the space.

Vasakronan is an organization that works intensively with sustainability and they use an international standard made by Greenhouse Gas Protocol that divides the CO2 emissions into three scopes; Scope 1, 2 and 3 (Ranganathan et al., 2015).

- **Scope 1:** Direct. Emissions connected to their organization such as company facilities and vehicles.
- **Scope 2:** Indirect. Emissions indirectly connected to their organization, such as usage of purchased energy and electricity.
- **Scope 3:** Similar to scope 2. However, this is further away. These are emissions from construction materials, production, employees travelling and the customer's facility usage.

Vasakronan has been climate neutral in scope 1 and 2 since many years back and is now focusing on reducing the emissions in scope 3. The plan for improving scope 3 is divided into three key areas:

- **Their own organization**
  - Reduce the numbers of air travels
  - Reduce emissions from their own commute travels
- **The tenants' organization**
  - Helping the tenants with reduction of waste and increase waste separation degree
  - Helping the tenants with reducing the energy usage and purchasing renewable energy
- **The project and contractor's organization**
  - Reduce the amount of construction and demolition waste
  - Reduce the material consumption and decline materials with high environmental impact
  - Reduce the emissions from the construction related transports

Vasakronan stresses the importance of gradually decreasing the CO2 emissions instead of postponing it and taking action a few years prior to 2030. By taking action now and gradually decreasing it will result in a lower amount of CO2 emissions in the span of ten years. The company has an action plan called "*Färdplan 2030*", which was finalized early 2020. The goal for this plan is to become a climate neutral organization across the whole value chain by 2030. The action plan consists of nine focus groups; Construction Materials, Logistics and Transport, Re-usability and circular construction, Design Processes, Cooperation with Different Stakeholders, Digitization, Production Methods, Sustainable Business Models, Project Steering Group and finally Administration and Procurement. We have had close contact with the 'Sustainable Business Models' group and discussed further actions in order to achieve their goals. They work primarily with two key areas to reduce the CO2 across the value chain, 'Green project planning and procurement' and 'Green customer journey'. These two are also categorized in Scope 3.

Green project planning and procurement
As a developer, Vasakronan can implement certain goals and regulations for the procurement phase. By doing this, they can implement liability and incentive contracts for CO2 levels. For example, if the contractor surpasses the agreed CO2 emission level for the production, Vasakronan can deduct a percentage of the agreed contract price. Likewise, if the contractor finishes the production with a CO2 level lower than agreed, they will receive an incentive. Vasakronan can also apply requirements regarding energy levels used by the machines, vehicles and so on.

Green customer journey
The operation of a building is an important part of the CO2 emission calculation. Vasakronan wants to have close contact with their customers and educate them on how to be energy efficient among other important factors that contributes to lowering impacts from scope 3. Vasakronan is implementing green rental agreements in order to "force" the customer to be aware of their own CO2 emissions. For example, the customer is offered incentives if they use sustainable solutions and reused materials. During the usage period, Vasakronan can demand measurements of consumption and waste management amongst others.

4.1.2 Project description - Lilla Bommen

As mentioned before, the case study investigated Vasakronan's city development project called "*Lilla bommen*, which is located in connection to the river *Göta älv* in central Gothenburg. The project consists of several sub-projects, where most of the buildings are not yet constructed. Figure 4.1 below shows how the area of Lilla Bommen will look like in the year 2030. The white buildings are representing planned buildings while the grey show buildings that exist today. The marked buildings are presented further down in the text.

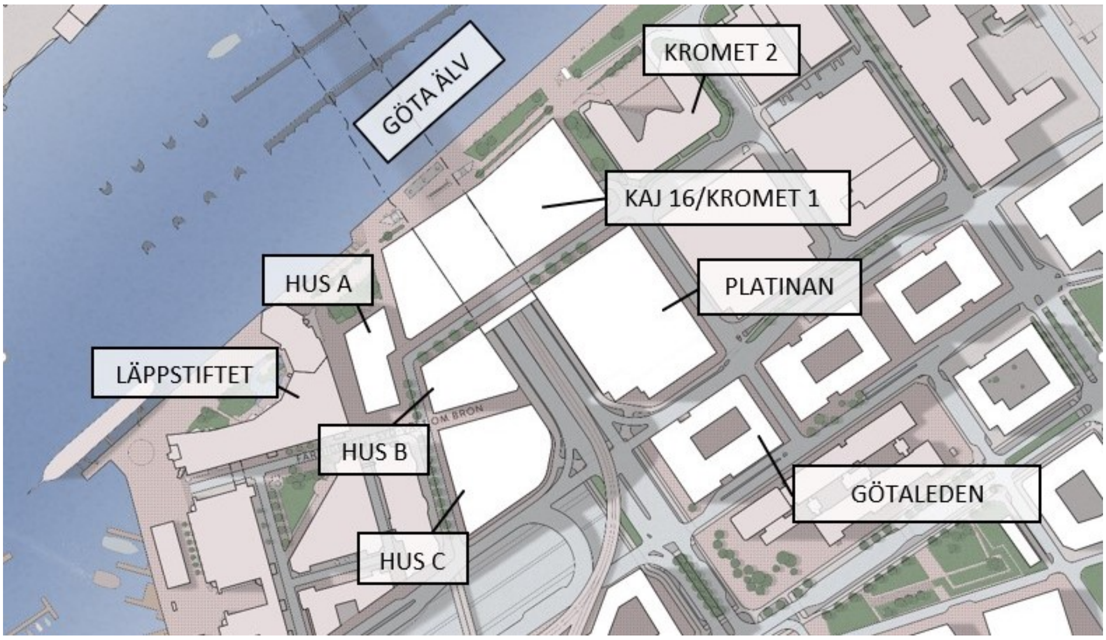

Figure 4.1: A map of the planned projects in Lilla Bommen by 2030.

- **Platinan**
  The first facility, Platinan, is planned to be finished at the end of 2021 and has an area of 60 000 square meters, whereof 25 000 sqm is going to be hotel activity and 25 000 sq.m. are planed for offices. The building is expected to be a part of the PED concept at Lilla Bommen. Besides hotel, Platinan will also be used for offices, co-working, restaurants and hotel.

- **Kaj 16/Kromet 1**
  Kaj 16/Kromet 1 is going to be constructed in the next phase of city development, after Platinan, and is still in the planning phase. However, the early design of the building is finished. According to this design, both the core structure and the facade will consist of wood. The facility is going to have an area of 30 000 square meters, where of 20 000 sq.m. office, 7000 sq.m. residential area and about 3000 sq.m. of non-residential premises. Furthermore, Kaj 16 will be certified according to LEED Platinum.

- **Building A, B and C**
  Buildings A, B and C are not yet planned. There is a detailed local plan of each building lot to follow, but yet no architectural or structural drawings. The detailed local plan allows similar activities (offices, commercial and residential etc.) as for Kaj 16 and Platinan.

- **Läppstiftet**
  Läppstiftet is an existing building with an interesting design in the area of Lilla bommen. It was constructed in 1989 and have been renovated and modernised since then. The building has an total area of approximately 32000 square meters, where about 27000 sq.m. is office area. Besides office area there is also about 2000 sq.m. of commercial area, such as restaurants. After some renovations, the building was certified with LEED platinum certification in 2019. Additionally, Vasakronan are currently installing solar panels on the roof of the building.

- **Kromet 2**
  Existing building which includes 11 000 square meters of office area. As of today, there are no plans to change anything regarding office space or renovations.

- **Götaleden**
  Götaleden will consist of offices, stores and apartments. It will stand on five building blocks with a total of 140 000 square meters, where half of it is office spaces. As of now, Vasakronan does not own the properties and is still in the process of purchasing.

The goal is to integrate all of the projects listed above in the micro-grid in order to move towards Vasakronan's environmental goals. Moreover, they also want to investigate the possibilities to involve other property owners in the district for a stronger collaboration. As it is now, the micro-grid will not be enough to cover the total energy demand. Although, it is a partial solution towards the long-term goal of achieving a PED with an annual positive energy balance. In order to achieve this goal, additional technical solutions and ways of including them in the business of Vasakronan are required.

4.1.3 Energy potential mapping

Before implementing a micro-grid it is essential to analyze the energy usage for the buildings within the neighborhood. This should be done to visualize the potential of implementing a micro-grid system. Although, the district of Lilla Bommen is not yet finalized and thereby there are no measurements of energy usage available. The buildings in the district will include several operations (hotel, offices, dwellings etc.), which have different energy patterns and requirements. For this reason, the neighborhood is expected to benefit from a micro-grid system. When the planning phase of the whole area has progressed, an energy potential mapping should be conducted to fully establish the potential of transforming Lilla Bommen to a Positive Energy District. The key is to identify the heating respective cooling demand in order to balance the thermal energy system efficiently.

4.1.4 Gothenburg District Heating system

The micro-grid is supposed to be connected to the District Heating (DH) in Gothenburg in order to cover heating demand when there is a deficit of thermal energy in the district of Lilla Bommen. In order to do so, it is important to know the basics about the DH of Gothenburg. To further discuss the heat load, it is also important to understand the terms power load and energy load.

- **Power load**: The maximum power which is delivered to customers
- **Energy load**: Amount of energy which is delivered to customers over a specified period of time

In terms of spacial heating, the power peak load is mainly dependent on the outdoor temperature, since it determines how much heating that must be supplied to achieve a good indoor thermal climate. For this reason, the power peak load occurs during the same period for most customers that live in the same area. For hot water preparation, it is harder to predict when the power peak loads occur, since customers are using hot water relatively irregular on a annual basis (Kensby, 2017).

The DH network of Gothenburg uses mostly renewable resources in their heat production. Excess heat is covering about 29 % of the total annual heating demand, which corresponds to a large part of the base load in the system (Göteborg Energi, 2020). Figure 4.2 shows the heat generation of the DH system in Gothenburg and the delivered heating power to Arkaden, a property owned by Vasakronan. The values are from a typical winter week in 2013 (Appelgren & Erlandsson, 2014). Since the buildings in Lilla Bommen are not yet constructed, this data is not yet available. The figure is presented to show the connection between power peaks in the DH network and heat usage in a typical property of Vasakronan. From the figure, it is clear that these power peaks are often occur during the same time period.

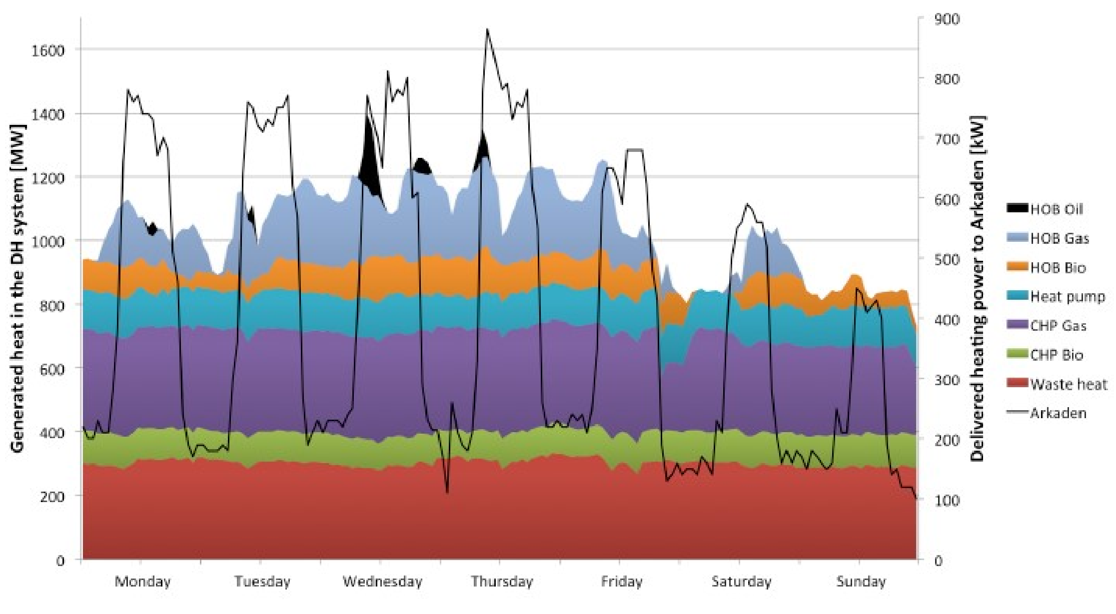

Figure 4.2: Heat Generation in Gothenburg DH system and the property Arkaden during a typical winter week in 2013 (Appelgren & Erlandsson, 2014)

Fossil fuels are mainly used to cover the peak loads in the DH system of Gothenburg (Göteborg Energi, 2020). There are constantly developments done to decrease the energy usage in buildings, but as seen in figure 4.2 below, there is a need of shifting the demand as well. By using different technologies and concepts, the control systems of the buildings could be optimized and thereby reducing the peak loads of the heat generation in the DH network of Gothenburg (Kensby, 2017).

This is one of the main goals of implementing a micro-grid in the area of Lilla Bommen. With an effective micro-grid, the power loads could be shifted and the DH system would only be used during periods when the base load is enough to cover the heating demand. This require a well implemented and optimized micro-grid and there must be a clear business model of how to operate the system as well.

4.1.5 Micro-grid of Lilla Bommen

The PED system of Lilla Bommen is not yet planned in detail nor constructed, since there is a lot of city development going on in the area. The local energy central is supposed to be located in the building *Kaj 16*. From the energy central, an infrastructure of pipe systems, cooling machines and heat pumps are planned to build up the micro-grid network and connect the surrounding buildings. The District Heating (DH) system is going to be connected to the area as a backup system to cover thermal energy demand when there is not enough internal energy within the local energy grid. Since the outdoor temperature is higher during summer, the cooling demand increases. In order to fully utilize the excess heat air that is transferred away to achieve a desirable indoor climate, a geothermal energy storage is planned to be constructed. This will make it possible to store thermal energy and utilize it when there is a higher heating demand. Moreover, the micro-grid is also going to utilize the cold water of the river *Göta älv* as a source for free cooling.

4.2 Meetings with reference projects

To get a broader perspective and inspiration for how to successfully implement a micro-grid solution for Lilla Bommen, meetings were held with three projects. Within these projects, they understand the value of looking at a district level instead of only a single building level when it comes to optimizing energy usage. These projects have been used for inspiration in terms of technical solutions as well as business models and price models for the different systems. Results from the different meetings are presented below.

4.2.1 Kista terrass, Vasakronan

Vasakronan has a city development project called Kista terrass, located in central Kista, Stockholm. The project consist of four properties called *Hekla*, *Modemet*, *Bredbandet* and *Hårddisken*. Within this area, there is a focus on sustainability and utilization of available energy. There is a local system for heat recovery, which among other things is based on that process cooling from the buildings is recovered. Vasakronan owns all the buildings that are connected to this system and has managed the energy system successfully during their ownership.

The energy central of the system is located in a separate building, but it is not its own property. This means that if the company want to sell the building, but keep the energy central, some legal changes must be made. Easements could be enforced in order to secure the usage right of the system, even after selling one or several properties.

The local energy system covers the base load of thermal energy demand by around 60-70 % in winter time. The remaining 30-40 % is covered by District Heating (DH). Building design and outdoor temperature are two of the main factors that determine the efficiency of the system. During the summer, the local energy system in Kista is turned off, since there is not enough heating demand for the system to be profitable. There is no seasonal Thermal Energy Storage (TES) at the moment, but it is a potential development opportunity that is under investigation. By installing a TES, the efficiency of the system could improve since waste heat during the summer would be utilized as well.

One of the success factors that were mentioned in the meeting is to have qualified operating technicians. They should preferably have a holistic view of the system and be able to optimize the operation process by creating strategic solutions. This is even more important if multiple property owners are involved, to ensure best possible collaboration. Besides having the competence, it is also crucial to have good knowledge transfer within the system. For a person who has been working with the system for several years, the strategic solutions might be crystal clear, but what happens if that person suddenly leaves the project? To secure the system, knowledge should be transferred to more people. With sufficient knowledge transfer, the company can keep the system in ongoing operation, even if the person with longest experience leaves the project. However, a strategy for this was not mentioned.

4.2.2 Ectogrid, EON

Ectogrid is a micro-grid system where heating and cooling energy is balanced where it is needed in the area that is connected to the system. The concept is invented by EON and it is a low tempered network with a modular infrastructure. New technique has made it possible to use only two pipes (one for heating and one for cooling) instead of four pipes, since the direction of the flow can be controlled. This implies that Ectogrid is an effective system and a relatively cheap investment. Ectogrid is a heat pump distributed solution where heat pumps are placed in each facility that is included in the system. Thanks to a decentralized system, it is possible to optimize and adjust the water temperature in each building. This is a significant difference if compared to a District Heating system, which delivers water at pre-specified temperatures, even when it often would have been enough with lower temperatures. The DH system does not take into consideration which temperature is actually needed. As an example, preparation of hot water requires higher temperatures than heating the indoor air. This also means that a Ectogrid solution requires more interaction between stakeholders within the system, compared to a DH system.

A modular system makes it possible to expand the grid and connect more buildings gradually. Moreover, the Ectogrid system uses connections that already exists in the building when connecting it to the grid. The pipe system includes pipes made of plastic, which is relatively inexpensive and maintenance-free, according to EON. Due to the low temperature in the system, insulation of the pipes is rarely needed. All these aspects make the system cost efficient.

For controlling the system, EON has implemented a smart cloud system called Ectocloud, which is an Artificial Intelligence (AI) software. By using Ectocloud, it is possible to predict and collect data to optimize the operation of the micro-grid. The AI software adjusts flow direction and temperature of the water in the pipe system to increase its efficiency. Moreover, forecasting weather, wind and electricity prices could be done with this system as well. Another advantage of Ectocloud, is that it can be used to monitor the system and notify if any deviation arises.
Since the heat pumps are run by electricity it is important to consider both thermal and electrical energy, by having a holistic view of the system. Customers are able to become prosumers into the Ectrogrid system. As an example, they could invest in solar energy. By installing solar panels, the customers are able to generate electricity for running their heat pumps. This could decrease their electrical bill while their usage of renewable energy increases. Regarding the electricity, it is also possible to turn the Ectogrid system off for a couple of hours when electricity prices are high. The customers could make use of the thermal inertia of the buildings during this period, which make it both a cost efficient and flexible solution.

Within Ectogrid, EON usually use water tanks as accumulators for balancing the supply and demand of thermal energy within the district. For seasonal Thermal Energy Storage (TES) it is according to EON possible to use a geothermal storage. This is a solution that EON is currently investigating and further developing to further optimize the system.

Ownership of Ectogrid
Regarding ownership of the Ectogrid, EON is relatively flexible, depending on what their customers prefer and seeing that as an important aspect for the solution to be competitive on the market. During the meeting with EON, two types of ownership were discussed:

- **Build and own**
  In this agreement, EON builds, installs and runs the Ectogrid. This means that they are responsible for everything and a long-term contract is signed between EON and the property owner. The time span of this contract is determined for each individual project but could be as long as 25 years for a large district. When the system is in operation, the customer pays for used energy (both heating and cooling as well as electricity for running the system).

- **Joint Venture**
  Some of the property owners find the concept interesting, and wants to be a part of owning the solution. This means that both parts share the risks and profits of selling heating and cooling to the end customers. According to

> EON, it is hard to specify how these contract are written since it is very project specific and among other things it is determined by the property owner's willingness to collaborate.

The question of ownership is important to consider in a local energy grid solution. The problem can be complex, since it is built on communication and collaboration between several stakeholders. There should be a contract which includes the questions of ownership and responsibility, but at the same time it is not desirable to force customers to use the system. There must exists a plan for what happens to the system if a property owner decides to sell their property. As an example, the property owner could start a new firm for the joint venture agreement. In that case, the property and the local energy grid could be separated. That would be an advantage when selling properties in the areas, since the property owner still could run the local energy grid. As of now, EON does not work with multiple property owners that shares the same Ectogrid, but EON thinks that it could be a relevant in the future development of the system.

Price model and Business model for Ectogrid
According to EON it is important to look at the whole system when designing a price model. The end customer wants a low total price that is competitive on the market. It is preferable that the price model is responsive and flexible for the customers. As a reference, EON offers prices that are about 10-20 % lower than the market price to attract customers. Today, the price model is mainly based on energy and power demand but for the future it could be beneficial to include more key elements. As an example, the price model could be adjusted to benefit customers who accept lower water temperatures, in order to increase the efficiency of the system. If it is less expensive to settle for lower water temperature, more customers might adjust their energy usage. This could optimize the the micro-grid system, since lower temperature in the system results in less energy distribution losses.

EON highlights that the collaboration between stakeholders is crucial for the micro-grid to work efficiently. For this reason, business models that focuses on integration between stakeholders will be further developed. Today, EON uses different business models for the Ectrogrid solution, which all look different depending on project specifics.

4.2.3 Cool DH in Brunnshög, Kraftringen

The local energy company in Lund, Kraftringen, is developing one of the largest low tempered district heating grids in the world. The solution is implemented in a residential area called Brunnshög, a district that will be continuously developed over the next coming 30 years. Kraftringen is part of the European innovation project called Cool DH, which stands for "*Cool ways of using low grade Heat Sources from Cooling and Surplus Heat for heating of Energy Efficient Buildings with new Low Temperature District Heating (LTDH) Solutions*". This is a project which is funded by European Horizon 2020 and in addition to Brunnshög the EU program also includes a danish project, located in Høje-Taastrup, Denmark.

The aim of implementing a Low tempered district heating grid (LTDH grid) in the area of Brunnshög is to recover excess heating from research facilities in the local area by allocating thermal energy to the surrounding residential and business area. There are two research facilities which are part of this project. Firstly, an internationally financed research facility called European Spallation Source (ESS) and secondly a national financed one called Max IV. These research facilities generates huge amounts of excess heat. Max IV is already built and in operation, while ESS is not yet implemented in the low tempered solution of Brunnshög.

Within the Brunnshög area, there is a great potential in implementing a large scale LTDH grid. The research facilities are generating a huge amount of thermal energy (excess heat) to be recovered into the LTDH grid. This amount of energy is about eight times more than the total energy demand of the residential area when it is fully constructed. Moreover, the energy source is relatively time consistent, which means that there is a continuous flow of available thermal energy. Another potential with this system is that the research facilities are located right next to the city development of residential area, which entails low distribution losses in the system.

Besides being close to the residential area, Brunnshög is also closely located to the High tempered district heating grid (HTDH grid) of Kraftringen. Since the supply of excess heat is higher than the heating demand from the residential area, there is a lot of additional excess heat available. There is no Thermal Energy Storage (TES) in the area of Brunnshög. Instead the LT system is balanced with the HT system to optimize the utilization of excess heat. Excess heat that is not used in Brunnshög, can be allocated to the HTDH grid, which is beneficial both for Kraftringen and the environment. In the summer, the research facilities have planned downtime. When this happens, the LTDH grid must be supplemented with the HTDH grid to cover the heating demand of Brunnshög.

Within the project of Cool DH, new technologies and innovations are tested. In Brunnshög, they are using new plastic pipes, which have been developed in collaboration with a danish company. Normally, steel pies are used in systems like this, but there are several advantages with using plastic pipes instead. Although, there was a need for developing new pipes since previous plastic pipes that existed on the market were only available in small dimensions and they were not very resistant to the high pressures which occur in a system of this scale. Today, the newly developed plastic pipes are used in the Cool DH projects, but steel pipes are still used when required dimensions are missing for the plastic pipes. A Life Cycle Analysis (LCA) has been made in order to compare plastic and steel pipes. The steel pipes emit considerably more carbon dioxide during the production and transportation phases, if compared to the plastic pipes. During the construction, it is easier to work with plastic pipes due to their lighter weight and flexible design. There is no need for welded joints every 12th meters and the workers do not need to deal with perpendicular angles when using plastic pipes as they are delivered in coils of 100 meters. As of today, the thermal losses slightly increase when using plastic pipes compared to steel pipes.

For this reason, the environmental stress is considered to be relatively similar for both pipe types when measuring a life span of 30 years. Plastic pipes are quite new on the market and when they are further developed, these heat losses hopefully will decrease and it would thereby become the most sustainable option in terms of both environmental and economical aspects.

Price model and customer relationship

Representatives from Kraftringen highlight that customer relationships are important, since well functioning secondary systems are crucial to ensure efficiency in the LTDH grid. Most property owners are very curious of the LT system in Brunnshög, but they also have a lot of questions, since this is a new concept that they are not used to. Some of the property owners are afraid of raising their total cost if not being able to reach low return temperatures. Mostly, this is due to lack of understanding the price model and for this reason it is important to contact the property owners early on and to present the price model thoroughly. The price model for the LTDH grid in Brunnshög is designed to be as simple as possible and is based on which return temperature the customers can send back to the grid, to encourage low temperature and thereby increase the efficiency of the grid. Similar to the HT grid, there is a connection fee which varies depending on how far from the grid the property is located. Secondly, there is a minimum and maximum price for the variable cost, which only depends on the return temperature of the customers. Kraftringen mentions that it is possible to adjust the price model according to more key factors, but they have chosen to have a simple price model to stress the importance of low return temperatures in the LTDH grid. Moreover, Kraftringen are offering services to help the customers in the optimization of their own systems. In an early stage, this service can imply helping with design solutions when optimizing their secondary systems. Later on, Kraftringen can offer service agreements to maintain the secondary grid at the customer side. A well maintained system is beneficial as it can increase the efficiency of the system and lower the total price for the customer.

Challenges of Cool DH

Kraftringen mentions several challenges within the Cool DH project in Brunnshög. In terms of planning, there is a challenge of implementing a LTDH grid for an area under construction. The area of Brunnshög will be continuously developed during many years to come and for this reason the LT system must be over dimensioned to cover the future demand. There is an economical risk of this project since it is crucial that property owners keep on connecting to the LTDH grid. A key factor is to contact the property owners early in the building process. Kraftringen offers a possibility for property owners to connect to the LTDH grid as early as during the construction phase. By doing this, the customers can buy heat from the LTDH grid instead of using electrical heating sources for the workers at the construction site.

Another challenge is the technical challenge of using a brand new technology. Even though all required tests have been conducted, the developed plastic pipes are still a brand new technology. No one knows their long term resistance in practice. Kraftringen explains that it is necessary to test new technology in order to promote innovation and for developing the industry. Knowledge transfer is a significant part of the Cool DH project and by sharing information and experiences with other similar projects, Cool DH supports new innovation.

Success Factors of Cool DH
In order to successfully implement a large scale LTDH grid it is important that relevant key partners are driving in the whole process. The investing company must be prepared to take some risks to develop the system in practice. Since customers are more involved in a LTDH grid grid than a HTDH grid, the customer relationship is crucial for the system to be successful. Investments are made in advance and for it to be economically financed, property owners must connect to the energy grid. For this to happen, Kraftringen highlights early contact, clear communication and flexible agreements as important success factors.

Above that, it is important to have a clear internal project organization. Open communication and good collaboration with key partners were other aspects that Kraftringen found relevant. They also mention that local prerequisites are significant and all projects should first of all analyze the opportunities respective challenges for that specific location, before moving forward in the implementation process.

4.3 Conclusion of empirical study

The empirical study includes the case study of Lilla Bommen as well as information about reference projects. These are later compared in the discussion chapter, see chapter 6. For instance, Vasakronan are able to gather inspiration from the reference projects regarding ownership issues, how to balance the micro-grid, technical challenges as well as business model and price model solutions. Although, it is important to consider local prerequisites before making decisions regarding what kind of solution Vasakronan wants to implement in the area of Lilla Bommen. Another aspect which was highlighted in the case study section is Energy potential mapping. This is important, since a diversified energy pattern is a prerequisite for balancing excess heat within a district.

5
Result from workshops

As mentioned, one of the goals for this master's thesis was to contribute with different perspectives regarding how to work with business models for Vasakronan. This chapter includes the results from the two workshops, both regarding the process and what the participants filled in the elements of the Sustainable Business Model Canvas (SBMC). Moreover, challenges and possibilities of implementing a PED concept in terms of a micro-grid and a business model in Lilla Bommen are presented. All the results in this chapter have been collected from the organized workshops and discussions.

5.0.1 Workshop 1 & 2

The process of workshop 1 was analyzed according to the SUDA framework, to identify possible improvements before organizing workshop 2. The process was also discussed with the participants of workshop 1. Some organization changes were made when moving on to workshop 2. This resulted in a first draft of a SBMC for the micro-grid and the long-term goal towards a PED in Lilla Bommen. The results are presented in table A.1 in the Appendix.

Before having WS2, the first workshop was discussed with the original team which resulted in three elements of the SBMC being altered. *Channels* were removed for WS2 due to the fact that it reflected Vasakronan as an organization and not the project specific aspects of implementing a micro-grid in Lilla Bommen. Furthermore, the WS1 group predicted that the results of Channels would be the same which meant that WS2 group could focus on more important elements such as *Value Proposition* and *Eco-Social Benefits and Cost*. *Customer Segment* and *Customer relationship* were put together since these could be discussed as a single element.

Osterwalder and Pigneur (2009) presents that there is a flexibility in terms of which order to address the different elements in the canvas. In the first workshop, the elements were addressed according to the order they were presented when described in the literature. This order was not best suited for the context of implementing a micro-grid in Lilla Bommen. We wanted the attendants in the workshops to reflect about the project specifics of Lilla Bommen, rather than veering of to discuss the organization as a whole. Consequently, the order of the SBMC elements were changed to better match the purpose of the workshops, see table 5.1. As an example, we saw a value in discussing the element *key partners* right after the customer element, since the collaboration between key partners and customers is significant in a micro-grid. When moving that element it became convenient to move *Key Resources* and *Key Activities* as well. All members of WS2 did not have the technical knowledge about the micro-grid nor the area of Lilla Bommen. For this reason we wanted them to reflect about the elements mentioned above, before moving on to the economical aspects. The changed order resulted in the participants being more focused on the project rather than Vasakronan as an organization. When comparing the results from both workshops, technical aspects were more dominating in the first workshop, while participants in the second workshop contributed with more business orientated aspects. Hence, the workshops complemented one another. Even though, some aspects reoccurred in both workshops, which speaks for the importance of these aspects.

	WS1	**WS2**
Order of elements	Customer segments	
	Channels	Value proposition
	Value proposition	Customer
	Customer relationship	Key partners
	Revenue streams	Key resources
	Key resources	Key activities
	Key activities	Revenue stream
	Key partners	Cost structure
	Cost structure	Eco-social costs
	Eco-social costs	Eco-social benefits
	Eco-social benefits	

Table 5.1: Order of when the elements were addressed in workshop 1 & 2

5.0.2 The Sustainable Business Model Canvas

The results from workshop 2 were combined with the results from workshop 1 and merged into a final SBMC, which is presented in table 5.2, starting on next page. In this table, all relevant aspects which were found are mapped out in the SBMC. The table is presented to gain a holistic perspective of the results from the workshops. In order to gain a deeper understanding of each aspect, further analysis of the table and its content are presented in sections 5.0.3 and 5.0.4 further down.

Table 5.2: SBMC developed from Workshop 2

Sustainable Business Model Canvas **Workshop 2 - A PED concept in terms of a micro-grid in Lilla Bommen**	
Value Proposition	• Top class real estates, sustainability certificates (LEED, Gresb) - Climate neutral and self sufficient real estates - Selling point for Vasakronan and the customers • Organization focused on development - Sensors, AI, data driven knowledge → increased awareness of customers → decreased energy usage and costs • High service standards and knowledge about the customers • Optimizing usage of already available energy (waste heat, cooling from the river) - Reduced need of bought district heating and cooling - Reduce the effect/energy tops → Reduced costs to the district heating network • Services, adding additional services Ex: Coworking, carpool, waste management, sharing energy • Expandable PED system • Possibility for a cheaper loan for Vasakronan due to the properties using fully green energy delivery
Customers	• Three markets - Renting, Real estate and Finance • Tenants (office, commercial operation and housing markets) - Importance of central location and sustainability • Other real estate organizations - Real estate transactions - Prosumers - Energy transactions • Accessible service depending on customer need • Clear communication • Loyal, transparent and long term customer relationship
Channels	• Direct (Phone, email, customer app, meetings) • Vasakronan.se • Social Media (LinkedIN, Facebook, Instagram, Twitter) • Branch newspapers • Newsletters via email • Customer meetings • Sustainability certificates → People sees that Vasakronan is a real estate company that focuses on sustainability • Innovation pioneers → One of the first with a PED system results in more attention • Podcasts with focus on sustainability

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Table 5.2 – *Continued from previous page*

Sustainable Business Model Canvas **Workshop 2 - A PED concept in terms of a micro-grid in Lilla Bommen**	
Key Partners	• Municipality (Gothenburg City) • Consultants • Entrepreneurs for construction and control system • Energy company (Gothenburg Energy) - Risk for more expensive agreements due to lower energy volume • Property owners in the area of Lilla Bommen • Academic (Universities etc). • Customers/Tenants - Prosumers, e.g their own solar cells
Key Resources	**Resources for management and implementation** • Competence (co-workers, consultants, operating technicians, entrepreneurs) • Agreements, construction documents, licence and easements • Sustainable Business Model • Research and development • Interest - Ambition from the top - External stakeholders **Technical resources** • Infrastructure (culvert system, pipe system, cooling machines, heat pumps etc.) • Seasonal Thermal Energy Storage (TES) • River Göta älv - Permission to extract cooling from the river • Businesses with different thermal energy demand • Control system • Energy central • Back-up system: Connection to the District Heating system • A non-complex system in order to reduce the operation costs as much as possible

Continued on next page

Table 5.2 – *Continued from previous page*

Sustainable Business Model Canvas **Workshop 2 - A PED concept in terms of a micro-grid in Lilla Bommen**	
Key Activities	• Investment decisions, profitability calculations • Creating a holistic perspective, relation between thermal energy and electricity • Comparison between a technically complex or a simple one • Calculations and pre-studies - Circular economy - LCA • Planning, execution and control of the PED system • Operation and Maintenance - Extract cooling from the river Göta Älv - Balance thermal energy between organizations with different need of heating and cooling energy. Make the most out of the waste heat - Seasonal Thermal Energy Storage (TES) • Juridical processes - Development of new and existing agreements - Easements/servitude - Economic association • Communication between stakeholders - Cooperation with other stakeholders and real estate owners • Further research and development - Digital twin - AI and sensors - Further development such as installing solar panels • Marketing • Competence development and knowledge transfer

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Table 5.2 – *Continued from previous page*

<table>
<tr><td colspan="2">Sustainable Business Model Canvas
Workshop 2 - A PED concept in terms of a micro-grid in Lilla Bommen</td></tr>
<tr><td>Revenue streams</td><td>Real Estate market
• Income from real estate transactions and development
• The value of real estate could increase by investing in energy efficient solutions
• Lowered operating costs → Increase property value
Rental market
• Base rent and rental surcharge for heating, electricity etc.
• Higher rents → More profit since lower operating costs
Finance market
• Loans and bonds

• Subsidies, environmental funding, tax reduction
• Community fees - Connection and "subscription" fees</td></tr>
<tr><td>Cost structure</td><td>Investment costs
• Developer costs
• Agreement costs, e.g land contracts
• Consultant costs
• Construction costs
• Infrastructure for the local energy grid (cooling machines, heat pumps, pipe system, control system, TES etc.)
• Extending PED system phase-wise creates risks

Operating costs
• Bought energy
• Service and maintenance
• Operating technicians

Replacement and removal costs
• What happens after the life-time of the micro-grid?

How is the investment financed?
• Loans from financial market
• Depreciation of system
• Economic association to promote the economic interest of multiple property owners.
• Rental income</td></tr>
</table>

Continued on next page

Table 5.2 – *Continued from previous page*

Sustainable Business Model Canvas **Workshop 2 - A PED concept in terms of a micro-grid in Lilla Bommen**	
Eco-social costs	**Ecological Costs:** • CO2 emissions from production, transportation and installation of system • LCA perspective - some materials are not yet recyclable • Ecosystem in the ground or in the river might be affected - Higher temperature in river? - Further research is needed • Increased usage of electricity needed for heat pumps etc. - Electricity is a scarce energy type, should be considered - A system analysis should be made **Social Costs:** • Working environment during implementation and operation of the PED should be good • Negative behaviour pattern regarding energy usage due to cheaper heating and cooling • The PED system require transparency and communication between property owners, which might be difficult due to sensitive information that companies do not want to share
Eco-social benefits	**Ecological Benefits:** • Lower CO2 emissions - Locally produced heat and cooling - Reduced amount of bought energy - Lower stress on DH and DC - Reduced peak loads and thereby less usage of fossil energy - Larger amount of free cooling - More usage of renewable energy **Social Benefits:** • Better image for companies that invest in sustainability - Environmental certifications - Inspire other companies to invest in similar projects - Green rental agreements - Locally produced heat and cooling • More collaboration between property owners could lead to implementation of more shared systems (such as shared waste disposal, car pools, share electricity etc.) • Encourage changing behaviour patterns regarding energy use

5.0.3 Possibilities and Challenges

Several challenges and possibilities for implementing a PED concept in terms of a thermal micro-grid and a business model in Lilla Bommen were identified and highlighted during the workshops. The first part of this section explains some of the most significant possibilities from the final SBMC in table 5.2. The highlighted possibilities have been divided into the areas of financial, environmental and social sustainability.

The second part of this section explains the main challenges which where highlighted during the workshops. These challenges are divided into financial, management technical and legal challenges.

Financial possibilities

Implementing a micro-grid in Lilla Bommen is financially beneficial for several reasons. Firstly, according to the participants of the workshops, costs for heating and cooling could be reduced in a long-term perspective. By utilizing the locally available resources, Vasakronan does not need to buy the same volume of energy and therefore saves economical resources. Nevertheless, they need to make profitability calculations in order to see exactly how beneficial the system is. Depending on how Vasakronan decides to allocate their revenue stream. Even though the thermal energy becomes cheaper, Vasakronan must make decisions regarding their rental surcharges for their tenants. This means that it may even be economically beneficial for the customers, after the initial investment has been paid. Additionally, the properties of Vasakronan can gain higher value due to their sustainability factors and certifications. There is a customer segment that are willing to pay more to have their operation in a top class sustainable building. Vasakronan's properties are above the average market price and still they have their share of customers. This means that organizations are prioritizing sustainable properties to rent.

Moreover, economical resources can be saved by optimizing the micro-grid system, to make it as efficient as possible. Vasakronan wants to further develop within the area of smart building technology. By including smart features such as sensors and AI technology, the buildings become more automatic. As a result, less human resources are needed and the system can be optimized accordingly. Thereby, less economical resources will be needed to obtain the same amount of energy. As seen from the canvas, by investing in sustainable solutions, several economical benefits arises. More examples can be found in table 5.2.

Environmental possibilities

Utilizing resources that are locally available to create a value is one of the main benefits of implementing a micro-grid in Lilla Bommen. These resources are defined as waste heat from the district and free cooling from the nearby river. By utilizing the resources that would otherwise go to waste, Vasakronan could with this technology reduce their CO2 impact.

Additionally, a Thermal Energy Storage (TES) is allowing seasonal storage of thermal energy. In Lilla Bommen, Vasakronan will probably integrate a borehole solution. This could help them to increase the flexibility of the micro-grid by using heat source shifting. In theory, this means that Vasakronan can choose when to use the DH system and when to use the local micro-grid as a heat source. Vasakronan would thereby be able to use the locally stored heating/cooling when the demand on the DH system is high. This is environmentally beneficial since the peak loads in the DH system is partially covered by fossil energy. This means that Vasakronan could contribute to a lower environmental impact.

Implementing a micro-grid in Lilla Bommen stands in line with Vasakronan's environmental goals as well. This is an important aspect for the company as they want to be at the forefront of innovation and environmental sustainability within the building sector. Implementing a micro-grid implies that Vasakronan are one step closer towards their goal of being climate neutral across the value chain.

Networking possibilities

Besides financial and environmental benefits, the micro-grid solution also brings social benefits for Vasakronan and Lilla Bommen. The society is also positively affected, since Vasakronan is investing in innovation that contributes to the sustainability of the building industry. However, in order to tackle complex problems such as social sustainability, it is crucial that organizations work together towards a common goal. If Vasakronan is able to find other interested property owners as partners when developing a fully functional Positive Energy District (PED), they could inspire new ways of collaborating and creating district solutions. Vasakronan also highlights that the common areas between buildings should be designed to facilitate a safe and pleasant environment that people want to stay in. For this to happen, the surrounding property owners should work together. Consequently, Vasakronan could be the driving force in the innovation process and by addressing sustainability seriously, more organizations will hopefully follow in their footsteps.

Another possibility that was mentioned during the workshops is that innovative and sustainable properties are attractive for the tenants. The implementation of a micro-grid shows that Vasakronan invests in a sustainable city development. The company wants to work towards a Positive Energy District (PED) and by doing this, they might attract a new customer segment and improve the image of the company. These customers can be proud of their contribution because they are investing in sustainability as well. Furthermore, the customers can feel that they are part of something positive and in turn inspire other organizations to rent from Vasakronan's sustainable properties.

Moving on to the challenges which were identified during the workshops. These challenges are divided into the following areas: financial, management, technical and legal challenges.

Financial challenges
One of the main and most important prerequisites in order for this to work is having energy surplus and different energy patterns in the district. Lilla Bommen has to consist of different operations in order have different energy patterns. This is also connected to Vasakronan's choice of tenants. The company must conduct profitability calculations and see what scenario that yields the highest revenue. The office operation yields highest direct revenue. However, by having only office operations, a micro-grid solution would not be possible. Consequently, Vasakronan must consider everything and adapt a holistic perspective in order to find the best case.

For the project to be economically beneficial, the collaboration with key partners, such as Göteborg Energi (GBGE), is very important. Since Lilla Bommen is not going to be energy independent when the micro-grid is implemented, it is crucial that that the area can still be connected to the DH network. A challenge that must be tackled is; how is GBGE reacting towards the PED concept. What happens when other real estate organizations join and the PED area expands? Göteborg Energi might not want to maintain the pipe system which is connecting Lilla Bommen to the DH system of Gothenburg. This is due to GBBE being a backup plan when the micro-grid system does not cover the energy demand. If not being further analyzed, this could jeopardise the whole micro-grid project and thereby result in an expensive deal for Vasakronan.

A Successful implementation of a PED concept also requires financial investments. There is a challenge in how to finance these initial investment costs and several choices must be made. For instance, customers could be a part of the investment and thereby strengthen the customer relationship by attracting long-term customers. Vasakronan has are considering different options for how to make this investment, but no decisions are made yet as the project still is at an early stage.

Since this is a city development area which is not fully planned nor constructed, there is an investment risk in implementing a micro-grid. Vasakronan has to predict the volume and plan the logistic and dimensions accordingly. One of the challenges that was highlighted during the workshops was phase-wise extension of the micro-grid. Due to this, the dimensions have to be planned accordingly. Customers must connect to the system in order to make it economically profitable for Vasakronan. Furthermore, Vasakronan must have a competitive price model to attract customers. Today they aspire to own all of the properties which are planned to be connected to the micro-grid. This means that they have the advantage of setting their own terms. However, this might change in the future as the company are active in the real estate transaction market as well.

Management challenges
Since Vasakronan is a real estate company, they are not allowed to make a profit from selling energy. To face this challenge, they must relocate how they are making revenues.

Additionally, Vasakronan might want to invite other property owners in the district into the micro-grid later on. For this agreement to work, an energy surplus is required and a specific price model must be developed. Introducing more property owners into the micro-grid also requires trust and transparency, since the organizations would have to share information that might be sensitive. If other property owners connects to the micro-grid they will probably connect as prosumers. This means that they would both be producers and consumers in the system, depending on their energy pattern. To optimize the micro-grid, customers, prosumers and key partners must be willing to share their information and energy. This means that trust is a key factor in order to develop a good collaboration between key partners in Lilla Bommen. For instance, the relationship between Vasakronan and their prosumers could be improved if the prosumers are able to influence the price model. To further improve the relationship, Vasakronan needs to have an open and transparent communication. However, they also need to explore more possibilities for improving the relationship with their customers and prosumers.

Technical challenges

When it comes to the implementation of technical innovation, there are obviously technical challenges as well. In the Lilla Bommen area these challenges are mostly related to the Thermal Energy Storage (TES) and the control system of the micro-grid. However, Vasakronan does not think that the placement of the pipe system etc. will be a problem. Regarding the TES, Vasakronan wants to drill a 1-2 km deep borehole for storing thermal energy. The ground consists of clay and this soil condition is challenging since it does not allow many smaller boreholes, which is the normal course of action. Instead, a deeper borehole must be drilled to cover the storage demand in order to create a seasonal storage of thermal energy.

In order to increase the efficiency of the micro-grid system, the control system must be optimized. This can be done with sensors and by further automating the system. Although it is still a challenge to operate the system as smoothly as possible. Technicians with knowledge about the system must be available to operate and maintain the system, but Vasakronan wants the system to be as automatized as possible. This is a challenge that needs further investigation.

Legal challenges

Ownership and legal challenges are found to be key aspects from several points of views. Firstly, there is a challenge in acquiring permission to build the micro-grid. Clear agreements must be created in order for the micro-grid to be successful. For instance, Vasakronan must acquire permission to utilize the river for free cooling, since they do not own the river. Additionally, the municipality must give permission to enable Vasakronan to connect the pipe system between the buildings, since Vasakronan does not own the ground in between their properties.

Another challenge regarding ownership is to consider both the rental market and the real estate transaction market. This means that Vasakronan must be able to to sell their properties without affecting the micro-grid system, since real estate transaction is one of their markets as well. Legal agreements are required to separate the properties from the micro-grid. Without these agreements, the micro-grid is bound to the properties and Vasakronan would not be able to control the micro-grid if the property would be sold.

As seen above, several challenges and possibilities can occur within more than one aspect of sustainability. For instance, Vasakronan are working towards their environmental goals in order to reduce their environmental impact. Additionally, this also improves not only the social image of Vasakronan, but also the image of the customers who rents facilities that includes sustainable solutions. The continuous city development is another aspects which is both a financial challenge, but also a management challenge. It is crucial to be aware of these connections in order to get a holistic perspective. Looking back on the Sense Understand Decide Act (SUDA) framework, these inter-dependency is important to consider when making decisions further on.

5.0.4 Contribution of the workshops

After evaluating the workshops together with Vasakronan, it can be stated that using a Sustainable Business Model Canvas (SBMC) as a first step in the implementation process of a micro-grid in Lilla Bommen was useful. It helped Vasakronan to see the challenges and possibilities from different angles by discussing them together in the workshops. The structure of the SBMC was lifted as a positive aspect. By structurally going through all elements and questions in the SBMC, "hidden" aspects were also captured - aspects that are easily missed when initially discussing innovation projects from an overlooking point of view. By sorting each element and asking several questions within it, the same issue was viewed with different perspectives. As a result, the "hidden" aspects were easier to highlight.

Participants of the workshops found the structure of the SBMC to be helpful since it brought up essential questions to discuss in all elements. This made it easier to sort all important aspects such as cost, resources and how to make value of them. Due to the horizontal and vertical coherence in the canvas, several aspects were highlighted more than once. Furthermore, each element forced the user to reflect about the same topic but with different questions and point of views. As a result, the participants reflected about the same topic several times, which helped them to get a deeper understanding and a holistic view.

Since the sustainable business model canvas was used instead of the original one, the participants were also focused on the environmental and social perspectives. For instance, this meant that they already had sustainability in their thoughts when looking at 'Value Proposition'. Eco-social benefits and costs were last in the workshop order, which also helped the participants to, once again, think about the value propositions. Sustainability is part of Vasakronan's core business and they found it as a matter of course to include these aspects into their business model. Eco-social parts were even highlighted as two of the most important elements in the developed SBMC.

The SBMC have been a useful tool for the attendants to understand fields that normally are outside of their individual working areas. For instance, after being part of the workshops, supervisor 2 now understands the PED concept and the technical aspects significantly more than before and he also sees the possibilities with it thanks to both workshops and discussions. Supervisor 1 has a technical background and was for this reason mostly focused on the technical questions in the beginning. However, after being a part of the workshops he now sees the value of using a business model for complex projects. Moreover, he is also more interested in the business aspects as well, especially in terms of the connection between technical innovation and business. The workshops gave him insight in how to work with a business model in order to see the holistic perspective regarding resources, costs, values, revenues and most importantly, the connection between technical and business issues. Additionally, the structure of the workshop also helped the Vasakronan team to break down the complexity of the project and address the issues such as licence, autonomy, future sales and logistics.

Before the workshops, one of the attendants had trouble with understanding the context and purpose of the SBMC. Furthermore, he did not have much knowledge about the PED concept nor the micro-grid system prior to the workshops. By structurally going through each question and element he learned about both PED and micro-grid. He also understood the context of it by acquiring a holistic perspective. It was easier to discuss and visualize the different challenges and possibilities when trying to implement a micro-grid system specifically for Lilla Bommen.

Since none of the participants in the workshops had worked specifically with the SBMC before, some of them found it a bit challenging to know where to put their reflections. According to Vasakronan, this could have limited the brain storming a bit as they wanted to make sure that they were discussing suitable aspects within each element. The SBMC is a new tool for them and in order to make the most of it, it would have been preferable to have more workshops which were spread out over a longer period of time. It takes some time to get used to the new tool and for the learning curve of the participants to be further developed. Several participants of the workshop highlighted the importance of identifying connections between different aspects. Some of them found it hard to see the inter-dependency in the SBMC but mention that the reason for this probably is because it is a new tool to manage.

When first presenting a new project, Vasakronan mention that the focus is mostly on specific numbers, investment calculations and the most direct advantages. Instead, the SBMC linked all elements to provide a holistic perspective. Within the SBMC, a deliberate list of identified costs and revenues could be created to visualise the PED concept for the company. Aspects which are harder to monetize are further addressed as intangible aspects. It is sometimes difficult to put an economical value on actions that contributes to social or environmental sustainability. The intangible aspects can be used on to defend investments that does not provide the an initial economic value. An example of this can be found in the decision process regarding what type of tenants to include in a property. Having a restaurant for example, yields a lower initial revenue compared to the rental of offices. However, the restaurant creates an additional value for the people who use it. As a result, Vasakronan can use these additional values to increase the renting price for the offices. In this way, cost can be allocated to another tenant which makes the restaurant deal profitable. Another example of this is marketing in news and industry papers. It is hard to tell how many customers this attracts or how much the payback is when comparing revenue to advertisement cost. However, Vasakronan is convinced that it yields value in one way or another.

Vasakronan are continuously working towards achieving LEED certifications for their buildings. By acquiring sustainability points from the LEED qualifications, Vasakronan receives several benefits. For instance, investing in a sustainable property reduces the interest rate as banks and the capital market sees it as a lesser risk. Furthermore, these certifications could lead to more attention, higher value of their properties, new customer segments, amongst others. By having a holistic view, several benefits arises. Although, the interest for sustainability on a society level has increased in the recent years and with this the demands from the customers have increased as well. Vasakronan mentioned that LEED platinum was considered to be a large achievement five years ago, but today it is almost a basic condition to keep up with the sustainability demands in the building industry. If a company does not build to fulfill the requirements of LEED platinum, they are considered to be behind in their sustainability development. Vasakronan is aiming beyond the requirement values in LEED platinum and investing in technical innovations such as a micro-grid is one step towards that goal.

During the workshops, Vasakronan mentioned that it is difficult to translate intangible values into profitable value propositions and there is also a challenge in how to monetize them. There is no black and white solution and all different aspects such as environmental certificates, usage of sustainable energy etc. must be considered in order to make a decision of including these aspects or not. Vasakronan knows from experience that their customers (tenants) value sustainable properties since they choose to rent premises of Vasakronan even though they are not cheapest on the market. An example of this is a project in Uppsala called Magasin X. This building is constructed with a wooden framework to lower the CO2 emissions from the construction phase, compared to if the framework would have been made of concrete. This sustainability initiative was very successful since it attracted customers who wanted to have their business in a sustainable environment to promote their image. In this project, all premises was already rented out when the construction phase started. This is quite unusual and speaks for the fact that customers value sustainable buildings.

Vasakronan are also aware of that communication is a key factor to attract suitable customers. Sustainability is a buzz-word that is widely used. For this reason it is important to explain to the customers in what way Vasakronan and their properties are sustainable. When doing this, Vasakronan must translate technical aspects to make them more understandable for their customers, who might not have the knowledge to understand certain investments. As an example, the amount of CO2 level reduction might mot tell so much to the customer due to the fact that they often are unable to relate to those numbers. Standardized environmental certification system, such as LEED, has made it easier for customers to address the sustainability of a building, but sometimes this is not enough since most customers do not know which aspects that are included in the certification system. Vasakronan mentioned that there is a challenge to find suitable ways of communication with their customers and they strongly believe that there is room for improvement when it comes to communicate their value proposition to their customers.

When asked about how the company are dealing with transferring intangible aspects into business, the answer was that Vasakronan makes assessments in each specific case. They do not see this as an issue, but rather as a potential of further developing a method to deal with it. During the recent years, the view of addressing sustainable values has changed significantly. 15 years ago, questions such as surrounding area, partnering with other real estate companies, value of certifications, sustainability values were not even addressed. The focus was on the individual building and its properties, nothing else. An example of how it has developed is the collaboration between two real estate organizations. They have developed a surrounding street or the district together in order to create a good atmosphere. Vasakronan stresses the importance of adopting a holistic perspective, which includes properties and infrastructure on a district level. They consider this as a huge potential towards a sustainable city development and to implement a micro-grid solution could be one step in the right direction.

6
Discussion

As described in the theoretical framework, Positive Energy District (PED) is a concept that contributes to reduction of CO2 emissions. However, it requires many different and rather complex technical solutions. As of now, the district of Lilla Bommen is going to be developed according to a PED concept, but initially a micro-grid solution is not going to be enough to achieve an annual positive energy balance. In order for Vasakronan to achieve their long-term goal of a PED, further development regarding the energy production function of a PED is required. As of now, there can be diverse opinions weather if it is defensible to put the PED label on Lilla Bommen. With or without this label, a micro-grid solution would still be beneficial since it recovers energy that otherwise would have gone to waste. Both literature and the empirical material mention that there is a potential in looking on a district level instead of only a single property level, and this is the main concept of a micro-grid solution.

By implementing a micro-grid system, the electricity usage will increase in the district of Lilla Bommen. For this reason, it is not enough to look solely on thermal energy and a system analysis should be conducted for a holistic perspective. Integrating solar panels to cover the electricity that is required for the heat pumps is a potential improvement of the system and one step further towards a PED. By doing this, the customers could become prosumers into the micro-grid and Vasakronan could facilitate an additional value proposition for their customers. With this, the flexibility of the system would increase, since it would not be as dependant on the national electricity grid. The flexibility is significant as it is one of the main functions of a PED and found as a success factor according to the literature. Even though we have not looked into electricity in this study, it is an important area for further research, since electricity is a far more scarce energy resource than thermal energy.

Regarding the efficiency function of the PED concept, data have been collected from reference projects. Inspiration can be gathered from these projects, but it is very important to consider local prerequisites as they determines what applications can be applied in the area of Lilla Bommen. Both the Ectogrid concept and the Cool DH project are owned and managed by energy companies, which gives other prerequisites than for Vasakronan. Since Vasakronan is a real estate company, they are not allowed to profit from selling energy. As of today, the micro-grid system will not have enough surplus energy for the area itself, so the question of selling energy is distant. Although if energy production will be implemented in the district later on, this issue must be dealt with. If comparing to Cool DH's project in Brunnshög, the prosumers of Lilla Bommen are generating much smaller amounts of excess heat. The research facilities in Brunnshög creates excellent prerequisites regarding transferable excess heat.

One of the aspects which were discussed in the meetings with the reference projects was Thermal Energy Storage (TES). For the project in Kista, this was not yet implemented. They considered their micro-grid to be a bonus rather than a way of utilizing as much excess heat as possible. Although, they saw the potential of implementing a TES and are currently working on that to make their system more efficient, hence contributing to both the flexibility and efficiency functions of a PED. EON are also investing in TES to further optimize their Ectogrid system, which speaks for this technology to be a good option for Vasakronan. As mentioned in the results from the workshop, TES could in theory reduce peak loads in the DH system, through heat source shifting. This means that less fossil energy would be used and responds to the archetype *Substitute with renewables and natural processes*. How this will work in practice is to be discovered, since Vasakronan have not yet chosen which technical solutions to apply in the micro-grid.

As mentioned before, the city development is a challenge for the Lilla Bommen area in terms of implementing a micro-grid. An ongoing city development carries uncertainties that could affect the long-term PED goals of Vasakronan. No one knows exactly how the district will look in the future, which the relevant stakeholders will be or what other prerequisites that might have changed. Both EON and Kraftringen have encountered similar challenges in their projects, since they are mainly working with new areas that are not fully developed yet. EON have solved the expansion challenge by making Ectogrid a modular system that is easy to develop later on. Kraftringen are thinking differently by over-dimensioning their LTDH grid in order to prepare for future city development. These are two ways of handling one of the challenges and Vasakronan must make a decision in how they want to move forward in the area of Lilla Bommen. It is not an easy task to know when and how to take decisions when having a new idea. The company want to take decisions as late as possible since the project will be shaped after these decisions while the surrounding prerequisites continues to change. By mapping out all elements in the SBMC, it becomes easier for Vasakronan to set short-term strategies as well as long-term strategies to deal with the decision process. When dealing with new technology, these decisions can't be made too early as well since the technology is rapidly developing. Solutions that are high-tech today, might be outmoded in a couple of years. For this reason, it is crucial that the micro-grid system is easily accessible and that Vasakronan put away financial resources for maintaining and updating the system in the future.

When comparing the projects, the Kista project differs from the others in terms of city development, since some of the buildings were already constructed when Vasakronan implemented the micro-grid solution. In that project, the energy central is located in its own building but is still a part of another property. This becomes a problem when taking the real estate transaction market of the company into account. The challenge of ownership appears in both the PED literature and within reference projects. This is very relevant in the area of Lilla Bommen as well and it is not an easy task to solve. A long-term plan for legally separating the micro-grid from properties is required in order to not compete with the potential future real estate transaction ambitions of Vasakronan in the area. To face this challenge, further investigations in legal frameworks are required.

The question of ownership is also important when or if Vasakronan wants to include other property owners into their micro-grid. One solution that has been highlighted regarding legal ownership and real estate transactions is for Vasakronan to start an economical community. This community would be responsible for the micro-grid and several stakeholders would be able to join the community. The price model for this could be that the other stakeholder must pay a connection fee as well as a periodically fee to make use of the micro-grid. This could work as a Produce Service System (PSS) where Vasakronan owns the system, but offers a service to other property owners and thereby facilitating an additional value. Applying this concept would stand in line with the Bocken et al.s (2014) archetypes "*Delivering functionality rather than ownership*" and "adopting a stewardship role". An economic community could also make room for further development in other areas. In the core business of Vasakronan, they are working with expanding their service portfolio. This is stands in line with the fourth of Bocken et al.s (2014) archetypes as well.

Vasakronan is constantly working with sustainability, and investing in innovation projects, such as a micro-grid, is one way of doing this. By investing both financial and human resources, they hope to inspire other property owners to join the PED or to implement similar solutions in other districts. In this way, they contribute to *developing scale-up solutions*, which is another of Bocken et al.s (2014) archetypes, aspiring to a sustainable future. According to the literature, Key Performance Indicators (KPIs) should be defined in order to compare different PED projects. This must be considered in the future if Vasakronan want to expand the system or when they are going to implement similar solutions in other districts. Furthermore, as mentioned in the empirical chapter, Vasakronan is working towards being climate neutral across the whole value chain in accordance to Scope 3. Examples of this are their green rental agreements and green procurement. These aims to inspire both contractors and customers to take more sustainable actions. As a result, they are *Encouraging sufficiency*, according to Bocken et al. (2014).

Going back to the sustainability archetypes of Bocken et al. (2014), the most obvious connection to Lilla Bommen is to *create value from waste*, since that is the main goal of implementing a micro-grid in the district. Besides utilizing excess heat and free cooling from the river, Vasakronan also wants to share resources with other property owners in the future. For instance, future collaboration between stakeholders could result in property owners sharing multiple resources and offering new services to their customers. Examples of these services could be shared car pools and shared waste management with an underground network. By sharing resources

Vasakronan are, according to Bocken et al.(2014), able to utilize the full capacity of the resources and this stands in line with the eight archetypes of sustainability as well.

For a successful collaboration, EON mentioned that there is a potential in looking at how to develop business models that includes integration of multiple stakeholders. Vasakronan could apply this by *adopting a stewardship role* in Lilla Bommen. According to Bocken et al. (2014), this archetype refers to actively contributing to well-being of all stakeholders within the value network. Above that, a business model that includes multiple stakeholders could be beneficial for Vasakronan to identify new customer segments and value propositions.
Moreover, Vasakronan mentioned that they do not have a specific method for translating and monetizing environmental and social value propositions. According to the literature, Business Model Innovation is required to identify new value propositions that could be implemented into the business of a company. As seen in the results from the workshop, Vasakronan has come quite far in *re-purpose their business for society/environment*, which is another of Bocken et al.s (2014) Sustainable Business Model archetypes. However, there are several ways of improving their current business model to further integrate environmental and social aspects. Utilization of excess heat is an example of an uncaptured value that Vasakronan should integrate into their business model. As seen in the literature, Yang et al.(2016) divides the uncaptured values into four categories, when talking about BMI. These categories makes it easier to question the existing business model of the company. In the case of Lilla Bommen *value surplus* is relevant since it captures the value of under-utilized resources such as excess heat. Additionally, *Value missed* and *Value absence* should also be considered. With this in mind, AI, smart buildings and collaborations are important aspects of efficiently using the materials and human resources to its full potential. This also stands in line with the first of Bocken et al.s (2014) archetypes *maximize material and energy efficiency.* As mentioned in the Kista project, it is important to have human resources that are knowledgeable about the system, which follows (Yang et al., 2016)'s (2016) *Value absence.* Finally, *Value destroyed* is not as relevant for the Lilla Bommen project, since they are creating ways of utilizing already existing resources. However, the quality of the solution must be assessed later on, to make sure that all of the expected benefits are captured. Value mapping tool was used when organizing the workshops with Vasakronan. We think that there is a potential for Vasakronan to use similar measures themselves within their business model innovation. The value mapping tool is relatively straight forward and would help the company to find values within their business that normally are easy to miss.

From Vasakronan's earlier experiences, investing in sustainable innovations are proven to be financially beneficial for Vasakronan, since the value of their properties increases with these investments. An example of this is the Magasin X project that gained a lot of attention. Although, how to mediate these values to the customers is not an easy task. During the discussions with our supervisors from Vasakronan, the importance of communication with current customers and potential ones was addressed. Vasakronan also mentioned communication with their customers as an area that they want to improve in their business model, but did not mention any specific suggestions in how to do it. It is important for them that the customers have knowledge regarding Vasakronan's unique selling propositions and how they are applied in their properties. Vasakronan wants to include the customers in the process and make them feel included and proud of being part of a great sustainable investment. Furthermore, by having easily understood information regarding sustainability and its complexity, new customers can be attracted as well. How to improve the communication is a difficult topic that requires further investigation, but inspiration could once again be collected from the reference projects in this thesis.

Learning from reference projects, it is important that customers know what they are committing to when connecting to the micro-grid. For instance, Kraftringen are talking with their customers in an early phase and are offering more services that can be beneficial for their customers. EON mentioned that their customers want to get the opportunity to influence the price model in order to create a loyal relationship. Thanks to Vasakronan being a real estate company, they are able to own and maintain the technical systems in their buildings to optimize the operation phase of the micro-grid. Vasakronan should invest more resources in developing their communication process in order to get the most value of their business. They should also make effort to hire competent operation technicians and find ways of transferring knowledge between stakeholders as well as within the company.

Even though a PED in Lilla Bommen may be a great concept with its benefits, it also brings uncertainties. As mentioned, Göteborg Energi (GBGE) is one of the most important key partners. The micro-grid project is depending on that GBGE wants to maintain their DH system, since Lilla Bommen will not be self sufficient of energy. It may be financially unfeasible for GBGE to invest and maintain their system for Lilla Bommen when it is only needed during the critical times. If GBGE would erase the DH connection to Lilla Bommen, the micro-grid solution would have to cover the whole heating and cooling demand, which is not possible as of now. Although, even if the energy company choose to keep the access to the DH system, the price plan for Lilla Bommen is probably going to change as the energy company have their own business model as well. This means that both the connection cost and the running cost per energy unit might increase for the external energy that is required from the DH system. Finding a solution that is beneficial for both parties is a key for the collaboration to work.

After evaluating the results of the workshops together with Vasakronan, most of the archetypes of Bocken et al.(2014) are found to be relevant for Lilla Bommen. This speaks for the sustainability of the micro-grid solution. The PED concept could contribute to several of the eight archetypes within the sustainable business model. Table A.2 shows more specifically how this could be addressed to the PED of Lilla Bommen. To face the sustainability challenges it is important that all stakeholders are contributing. We as engineers are doing this by investigating the possibilities and challenges of PED. Vasakronan as a real estate company has a great potential of contributing, as highlighted in the results from the workshops. Bocken et al.(2014) mention that the aim is to capture economic value for they business while they are facilitating environmental values and social benefits. By using the sustainable business model, Vasakronan could further address the environmental and social values rather than solely economical benefits.

Vasakronan has a long way to go in the process of transforming Lilla Bommen into a PED. In this thesis, we have only just begun to scratch the surface in terms of implementing a micro-grid solution in the Lilla Bommen area. As mentioned, there are a lot of aspects that must be further analyzed before taking the plan into action. For instance, several legal agreements are required for the arrangements to work and Vasakronan must know which key partners and customers they want to include in the project. Moreover, Vasakronan must make investment calculations, an energy mapping of the area and a price model to prove that it is financially viable to invest in a micro-grid. It is now up to Vasakronan to develop their own project. They need to identify the success factors for implementing a functional micro-grid in Lilla Bommen and make decisions accordingly.

7
Conclusion

After finalizing this thesis, we can state that is was useful to work with a Sustainable Business Model Canvas in order to simplify the complexity of implementing technical solutions within the business of Vasakronan. Lilla Bommen is at an early stage and is not at its peak regarding its complexity. This means that as of now, it is hard for Vasakronan to make decisions with the help of the sustainable business model. However, SBMC is a great basis for the company to use when discussing the project. By applying a sustainable business model and working with workshops, the participants gained a deeper understanding of the PED concept, its complexity and its connection to the business of Vasakronan. Same aspects were viewed from different angles and employees with different working experiences were able to learn from each other.

The main possibility of implementing a micro-grid is to utilize resources that otherwise would have gone to waste. By utilizing these available resources, Vasakronan does not need to buy as much external energy and therefore saves economical resources. This can also be further applied for the customers, if Vasakronan decides to reduce the costs accordingly. Another important aspect is to consider that Vasakronan's properties and districts are valued higher due to its sustainability factors and holistic solutions. Customers are becoming more aware of what they are renting and therefore choosing properties that are more expensive in order to be a part of the sustainable solution.

Nevertheless, Vasakronan still has many challenges to solve in order for the PED concept to be successful. Financial investments are needed and this brings uncertainties. The question of ownership must be taken into consideration, both in terms of getting permission to build the system, but also in terms of being able to sell the properties without affecting the micro-grid. Real estate transaction is part of the core business of Vasakronan. Hence, the micro-grid solution can not be allowed to compete with this.

Even if there is a potential in including more property owners in the micro-grid, Vasakronan should initially focus on their own customer segment and how to reach out to them with their new and developed value propositions. They should continue to develop, translate and monetize the environmental and social value propositions into their business. This could be simplified with the help of a SBMC. Vasakronan does not consider translating and monetizing intangible values as an issue. In fact, even though they do not verbalize their way of working as a method, they have a strategy to deal with these values. We believe that the company has their own method of finding solutions for each specific project. This flexibility in their working process could be highlighted as a success factor where different parameters are taken into account for each project. It is important to see the connections between economical, environmental and social sustainability. There is no single solution, but rather a compromise between these three areas. Vasakronan does not try to streamline the challenges and this could be beneficial since there is a complexity in connecting the different aspects of sustainability in a fixed model. Moreover, once the environmental and social values have been established for Lilla Bommen, the next step for Vasakronan is to make investment calculations. Additionally, an energy mapping of the area and a price model must be made in order to prove that it is financially viable to invest in a micro-grid.

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A

Appendix 1

A.1 Triple Layer Business Model Canvas

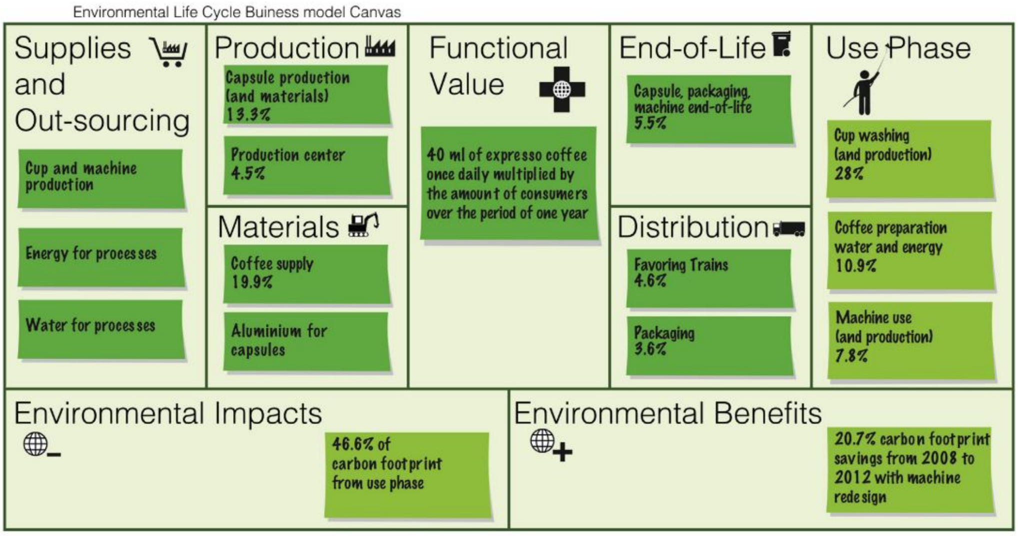

Figure A.1: Environment Life Cycle Business Model Canvas (Joyce & Paquin, 2016)

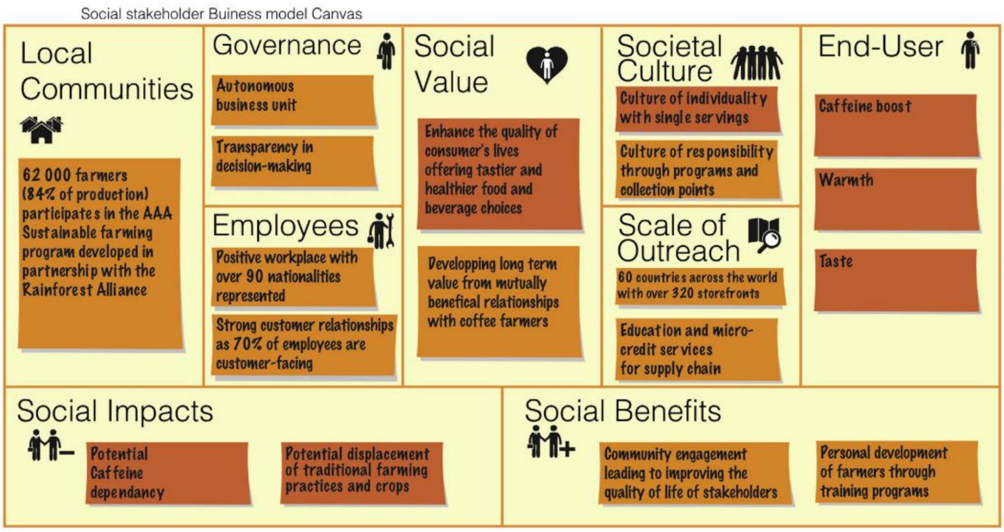

Figure A.2: Social Stakeholder Business Model Canvas (Joyce & Paquin, 2016)

A.2 Sustainable business model canvas

Table A.1: SBMC developed from Workshop 1

Sustainable Business Model Canvas **Workshop 1 - A PED concept in terms of a micro-grid in Lilla Bommen**	
Customer segments	• Three markets - Renting, Real estate and finance • Tenants (office, commercial operation and housing markets) - Importance of central location and sustainability • Other real estate organizations - Real estate transactions - Prosumers - Energy transactions
Channels	• Direct contact - Phone, email, customer app, meetings • Vasakronan.se • Social Media - LinkedIN, Facebook, Instagram, Twitter • Branch newspapers • Newsletters via email • Customer meetings • Sustainability certificates → People sees that Vasakronan is a real estate company that focuses on sustainability • Innovation pioneers → One of the first with a PED system results in more attention • Podcasts with focus on sustainability

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Table A.1 – *Continued from previous page*

Sustainable Business Model Canvas **Workshop 1 - A PED concept in terms of a micro-grid in Lilla Bommen**	
Value Proposition	• Top class real estates with sustainability certificates (LEED, Gresb) - Climate neutral and self sufficient real estates - Selling point for Vasakronan and the customers • Organization focused on development - Sensors, AI, data driven knowledge → increased awareness of customers → decreased energy usage and costs • High service standards and knowledge about the customers • Optimizing usage of already available energy (waste heat, cooling from the river) - Reduced need of bought district heating and cooling - Reduce the effect/energy tops → Reduced costs to the district heating network • Services, adding additional services Ex: Coworking, carpool, waste management, sharing energy
Customer relationship	• Accessible service depending on customer need • Clear communication • Loyal, transparent and long term customer relationship
Revenue streams	**Real Estate market** • Income from real estate transactions and development • The value of real estate could increase by investing in energy efficient solutions • Lowered operating costs → Increase property value **Rental market** • Base rent and rental surcharge for heating, electricity etc. • Higher rents → More profit since lower operating costs **Finance market** • Loans and bonds • Subsidies, environmental funding, tax reduction

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Table A.1 – *Continued from previous page*

Sustainable Business Model Canvas **Workshop 1 - A PED concept in terms of a micro-grid in Lilla Bommen**	
Key Resources	**Resources for management and implementation** • Competence (co-workers, consultants, operating technicians, entrepreneurs) • Agreements, construction documents, licence and easements • Sustainable Business Model • Research and development **Technical resources** • Infrastructure (culvert system, pipe system, cooling machines, heat pumps etc.) • Seasonal Thermal Energy Storage (TES) • River Göta älv • Businesses with different thermal energy demand • Control system • Energy central • Back-up system: Connection to the District Heating system
Key Activities	• Calculations and pre-studies • Planning, execution and control of the PED system • Operation and Maintenance - Extract cooling from the river Göta Älv - Balance thermal energy between organizations with different need of heating and cooling energy - Seasonal Thermal Energy Storage (TES) • Juridical processes - Development of new and existing agreements - Easements/servitudes - Economic association • Communication between stakeholders • Further research and development - Digital twin - AI and sensors - Further development such as installing solar panels • Marketing • Competence development and knowledge transfer

Continued on next page

Table A.1 – *Continued from previous page*

<table>
<tr><th colspan="2">Sustainable Business Model Canvas
Workshop 1 - A PED concept in terms of a micro-grid in Lilla Bommen</th></tr>
<tr><td>Key Partners</td><td>• Municipality (Gothenburg City)
• Consultants
• Entrepreneurs for construction and control system
• Energy company (Gothenburg Energy)
• Property owners in the area of Lilla Bommen
• Academic (Universities etc).</td></tr>
<tr><td>Cost structure</td><td>Investment costs
• Developer costs
• Consultant costs
• Construction costs
• Infrastructure for the local energy grid (cooling machines, heat pumps, pipe system, control system, TES etc.)

Operating costs
• Bought energy
• Service and maintainance
• Operating technicans

How is the investment financed?
• Loans from financial market
• Depreciation of system
• Economic association to promote the economic interest of multiple property owners.
• Rental income</td></tr>
</table>

Continued on next page

Table A.1 – *Continued from previous page*

Sustainable Business Model Canvas **Workshop 1 - A PED concept in terms of a micro-grid in Lilla Bommen**	
Eco-social costs	**Ecological Costs:** • CO2 emissions from production, transportation and installation of system • LCA perspective - some materials are not yet recyclable • Ecosystem in the ground or in the river might be affected - Further research is needed • Increased usage of electricity needed for heat pumps etc. - A system analysis should be made **Social Costs:** • Working environment during implementation and operation of the PED should be good • Behaviour patterns might change • The PED system require transparency and communication between property owners, which might be difficult due to sensitive information that companies do not want to share
Eco-social benefits	**Ecological Benefits:** • Lower CO2 emissions - Reduced amount of bought energy - Lower stress on DH and DC - Reduced peak loads and thereby less usage of fossil energy - Larger amount of free cooling - More usage of renewable energy **Social Benefits:** • Better image for companies that invest in sustainability - Environmental certifications - Inspire other companies to invest in similar projects • More collaboration between property owners could lead to implementation of more shared systems (such as shared waste disposal, car pools, share electricity etc.) • Encourage changing behaviour patterns regarding energy use

A.3 Eight archetypes of sustainability

Table A.2: Eight archetypes of sustainability addressed on the PED Lilla Bommen

Eight archetypes of sustainability **PED Lilla Bommen**	
Maximize material and energy efficiency	• Heat recovery → increase energy efficiency • Competent operating technicians
Create value from 'waste'	• Recover excess heat • Utilize free cooling from river • Share resources with other stakeholders to utilize the full capacity of the resource
Substitute with renewables and natural processes	• Reduced peak loads → reduced usage of fossil energy • Free cooling from the river → local energy
Deliver functionality rather than ownership	• Depending on price model and ownership - Stakeholders might be able to own their own equipment - Produce Service System (PSS) • Economic community • Partnership multiple property owners
Adopt a stewardship role	• Vasakronan should actively try to contribute to the well-being of all stakeholders within the value network • Good collaboration between stakeholders • Owner of the economic community
Encourage sufficiency	• Encourage behaviour change regarding energy use
Re-purpose the business for society/environment	• In Vasakronan's core business model, society and environment are priorities. is an sustainable innovation project
Develop scale-up solutions	• Inspire other property owners to join the PED or implement similar solutions

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