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# Energy transition in Knivsta: Nothing but hot air?

– A pilot study of energy system solutions and organizational forms of ownership in Nydal

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# Abstract

Climate change is a global challenge, but impacts such as combustion of fossil fuels are caused on a local level. Sweden's primary energy per capita demand is one of the highest in the world and objective of the 20/20/20 goals, which focus on the enhancement of energy use. The residential sector accounts for 40% of Sweden's energy demand, but has good chances to decrease more than a quarter of its demand at no costs. The construction sector plays a major role, which is seen as critical to accomplish this task.

This study analyses energy system solutions and organizational forms of ownership for Nydal, Knivsta. The aim of this project is to minimize energy demand as well as to secure and favour the implementation of environmental friendly energy systems. The study of energy system solutions focuses on modifications of temperature data and heat power demand.

A simulation and optimization in the form of a secondary data analysis is carried out for four energy system solutions. A sensitivity analysis of the impacts of climate change is conducted and connected to a qualitative analysis of 'Baugemeinschaften' as an organizational form of ownership. That analysis is based on a literature review and the results of interviews with persons responsible from the municipality in Knivsta.

The energy system solution A that includes electricity generation by solar cells is optimal from a cost-perspective. Variations in system costs due to changes in temperature data are recognized. The expectation of decreased system costs due to an increase in temperature cannot completely be fulfilled for all energy system solutions. One reason for that is the sensitivity of some of the energy systems, especially to changes in peak load for small-scale heat supply. 'Baugemeinschaften' are seen as a favourable option for the implementation of energy efficient buildings and energy system in Nydal, but its form is not yet clear. The implementation of environmental friendly energy systems will be a cornerstone in the successful achievement of the sustainability vision of the municipality.

*Keywords:* Baugemeinschaften, Climate Change, Residential Community, Passive Housing, Sustainable Development

# Popular summary

The climate is changing and effects such as temperature rise are threatening ecosystems. One of the reasons for climate change is the emission of greenhouse gases such as carbon dioxide by the combustion of fossil fuels, which are used to generate energy. In Sweden the primary energy demand per capita is one of the highest in the world and measures are taken to decrease the energy usage in order to reduce the impact on the global climate. The residential sector accounts for 40% of the total energy demand in Sweden.

In the residential sector, the planning of energy systems is important. This study looks at energy system solutions for Nydal in Knivsta with the goal to minimize energy demand. Furthermore, it analyses how a certain form of organization for the implementation of buildings and energy systems affect the implementation of the systems and how favourable the implementation of it is in Nydal.

Four different energy systems are examined and costs for all systems are calculated and compared. Different projections of future temperatures are taken into consideration and analysed. Interviews with persons responsible from the municipality laid the foundation to evaluate how favourable the successful implementation of the investigated organizational form, also called ‘Baugemeinschaften’, is for the implementation of the energy systems.

The study identifies an energy system that has lower costs than all other energy systems, even though the costs differ for the different projections of the future temperature. Not all energy systems have lower costs at higher future temperature. Some systems are more sensitive to changes in the peak load, which is defined as a period with a significantly higher demand, i.e. in winter. Especially systems that generate energy on a smaller scale show this characteristic. ‘Baugemeinschaften’ are seen as a favourable option for the implementation of energy efficient buildings and energy system in Nydal, but it is not yet clear in which form. The implementation of environmental friendly energy systems will be a cornerstone in the successful achievement of the sustainability vision of the municipality.

*Keywords:* Baugemeinschaften, Climate Change, Residential Community, Passive Housing, Sustainable Development

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# Abbreviations

| | |
|---|---|
| BBR21 | Boverkets byggregler Nr.21 (Building regulations Nr.21 by the National Board of Housing, Building and Planning) |
| BG | Baugemeinschaft / Byggemenskap (residential community) |
| °C | Degrees of Celsius |
| CHP | Combined Heat and Power |
| EC | European Commission |
| ESS | Energy system solution |
| EU | European Union |
| GHG | Greenhouse gases |
| HPD | Heating Power Demand |
| IPCC | Intergovernmental Panel on Climate Change |
| kWh | Kilowatt hour |
| M | Million |
| $m^2$ | Square meter |
| MW | Mega Watt |
| MWh | Mega Watt hour |
| PP | Power plant |
| PS | Pellet stove |
| SC | Solar cells |
| SP | Solar panels |
| ST | Stirling motor |
| SCB | Statistiska Centralbyrån (Statistics Sweden) |
| SEK | Swedish Krona |
| TPS | Thermal power station |
| UNEP | United Nations Environment Programme |
| W | Watt |
| WCED | World Commission on Environment and Development |

# 1 Introduction

‘Risks and impacts of climate change have been nothing but hot air!’ This could be the heading of an article published a few hundred years from now about the fears and dangers that climate change is causing at the moment. Climate change is not hot air, but a serious threat to humanity. The theory of climate change is one of the most popular and discussed topics in the past decade. As mentioned in the fifth assessment report by the Intergovernmental Panel on Climate Change (IPCC) (2014), greenhouse gas (GHG) emissions compared to pre-industrial times have increased significantly due to anthropogenic activities and contribute to climate change. Combustion of fossil fuels is one of the major contributions to this rapid increase in GHG emissions; it accounts for 78% of the total increase in GHG emissions from 1970 to 2010 (IPCC, 2014).

Current energy systems are highly reliant on fossil fuels (GEA, 2012; Mathiesen *et al.*, 2015). Even though society is not in danger of diminished fossil fuel reserves yet, the combustion would have substantial consequences, not only for the global climate, but also for wildlife and natural habitats. Construction and prospection for fossil fuels have harmful impacts on ecosystems (Chow *et al*., 2003). As described by the IPCC (2014), the forecasted impacts are likely to occur on a global level and focus on natural systems, ranging from hydrological (e.g. shift in weather patterns) to biological systems (e.g. abundances of marine species). Negative impacts on crop yields have been reported as well and are likely to worsen in the future (IPCC, 2014).

In the 1970s, after the outbreak of energy crises, society began to tackle these problems. The results were energy improvements as well as technological progress and development (Fawcett, 2012). In the European Union (EU), where GHG emissions per capita are comparatively high and the total share of GHG emissions amounted to 14% of global emissions in 2007, targets were set to work with climate change (European Parliament, 2007). In 2007 three targets with a focus on 2020 were established (EC, 2015). The first target aims to reduce GHG emission by 20% from 1990 levels. The second target has the goal to raise the share of renewable energy sources within the whole energy consumption in the EU to 20%. The third goal is to improve energy efficiency in the EU by 20% (EC, 2015).

Energy efficiency is an important factor, not only in tackling climate change, but also to improve energy security (EC, 2009). The residential and building sector accounts for around 40% of the energy consumption in our society (EC, 2009; Fawcett 2012; Horne, 2012). At the same time, the fourth report of the Intergovernmental Panel on Climate Change states that 29% of energy can be saved within the residential sector at low or zero cost (IPCC, 2007). The room for improvement was also recognized by the EU and led to the implementation of measures to optimize energy efficiency in this sector (EC, 2009). One of the measures was the adoption of the EU directive on energy performance of buildings (2002/91/EC). The current EU directive on energy performance on buildings (2010/31/EU) lays out the objective for new buildings to comply with the nearly zero-energy standard by the end of 2020 and to promote the implementation of buildings that meet these requirements for climate mitigation (EC, 2014).

However, the challenge of increasing energy efficiency comes with other wicked problems, such as guaranteeing access to energy and security in energy supply (GEA, 2012). At the same time population growth and current consumption patterns put more stress on natural resources, which are used at a higher pace than they can be regenerated (UNEP, 2007b; Global Footprint Network, 2010). Walker and Cass (2007) lay the focus on local actions and see local forms of energy supply, such as community energy as one of the leverages for renewable energy technologies. The authors stress the importance of private engagement in the supply and organization of energy. Multi-stakeholder process and the interaction of all involved actors will be needed to address the larger issue of climate change. The building sector is expected to increase its environmental impact, if business is continued as usual. Smart energy system solutions (ESSs) for residential areas are needed in order to support the building sector in coping with an expected population growth of 1.0 to 3.5 billion people by 2050 (United Nations Department of Economic and Social Affairs, Population Division, 2011). At the same time ESSs should aim at meeting "the needs of the present without compromising the ability of future generations to meet their own needs" as introduced by the Brundtland Committee (WCED, 1987, p.43). The following section presents the problem background for this study, where the focus will be on the energy and building sector in Sweden and relevant connections to this study.

## 1.1 Problem Background

Energy efficiency and consumption are important issues in Sweden. Sweden's goal is to lower the total final energy demand by 20% by 2020, compared to 1990

(Regeringskansliet, 2009). Sweden ranked among the best three in the Energy Sustainability Index by the World Energy Council. The index looks at environment impact mitigation, social equality and energy security (World Energy Council, 2013). On the other hand, Sweden's primary energy per capita demand is one of the highest in the world (The World Bank, 2015). Even though Sweden in 2012 only accounted for 2.9% of the final energy consumption in the EU (Eurostat, 2014a), the household consumption of electricity per capita is among the top three and with 4.1 MWh almost three times as high as the average consumption in the EU (1.6 MWh) (Eurostat, 2014b). The service and residential sector is the most energy-demanding sector in Sweden and amounts to approximately 40% of the total final energy demand (Energimyndigheten, 2011).

The population in Sweden has a dense concentration in urban areas. More than eight million people, which accounts to 85% of the population, inhabit only 1.3% of Sweden's land area (SCB, 2012). In 2010, 43.9% of the residents were living in apartment blocks, and 55.7% in small houses (*Ibid.)*. More than 30% of Sweden's population live in rental housing, of which more than half are accommodated in public housing, owned by the municipalities (SABO, 2013). Many of the current public housing was built in the Million Homes Programme ('Miljonprogrammet') in the end of the 1960s and beginning of the 1970s (*Ibid.*). Many of the buildings face requirements and need to invest in and improve energy efficiency to decrease the energy consumption in the residential sector and to support Sweden's goal to lower the total final energy demand (Formas, 2006; SABO, 2013).

A critique that came up in recent years is that there is a shortage of housing in Sweden and at the same time high costs for conventional housing, which makes housing affordable only for people with a higher income (SABO, 2013). The amount of available apartments has decreased since the end of the 1990s (SCB, 2012). In 2014, Sweden had with 8.7%, compared to 2013, the third highest increase of the deflated housing price indexes in the EU. The deflated housing price index is defined as the ratio between an index of the inflation of the consumption prices and the nominal housing price index (Eurostat, 2014c).

As mentioned before, the municipalities in Sweden own a large share of the housing. In the development phase of new buildings, the role of the municipality is to create local plans to sell land, which is set aside for building, and to install the infrastructure in new building areas (Knivsta kommun, 2014e). As recognized by several authors (Love, 2006; Boethouwer & Hoeksta, 2012; Horne, 2012; Adams *et al.*, 2013) municipal policies in the forming of housing can have a positive impact on environmental issues in the city planning. This can affect current energy systems towards more sustainable and environmental friendly energy systems. At the same time there is a need for the examination of changes in profitability of conventional energy systems due to external variations such as the required and planned reduction of energy demand (Värmemarknad Sverige, 2013).

The building area Nydal in the municipality of Knivsta was selected for this project. A student project at Linköping University in 2014 studied possible energy system solution (ESSs) for Nydal (Hagelberg *et al.*, 2014). In addition to that, this study examines a small-scale form of residential community ownership of buildings. The idea of 'Byggemenskap' (BG) has its origin in Germany, where it is called 'Baugemeinschaft' (BG) and contributed to the increase of energy efficiency of buildings (Schuster, 2005; BVBG, 2011). According to Gephart (2013), a translation of this concept is 'residential community'. Recently, the concept became more popular in Sweden and is discussed as an alternative to conventional organizations of building (Tväråna, 2013).

## 1.2 Problem

Two main problems were identified for this study. The first problem is linked to energy consumption and efficiency and focuses on ESSs in the residential sector. As listed by the Swedish Energy Agency (Energimyndigheten, 2011), about 40% of the energy demand is consumed within the residential sector. Space heating is the largest consumer of energy in this sector (Fawcett, 2012). The current situation formulates the first problem, which is a high consumption of energy in the building sector.

The second problem is linked to the implementation of sustainable energy initiatives. The only sustainability efforts that can be measured are the ones that have been implemented (Boswell *et al.*, 2012). In order for a sustainability plan or strategy to be implemented, the strategy has to be embedded and a planning committee needs to be set up (*Ibid.*). In times of fast growing city developments and constructions of new buildings, Tväråna (2013) claims that current construction is not coping with future requirements and needs for sustainability, flexibility and integration. Only a few actors are present in the construction sector in Sweden, which leads to the forming of more and more large-scale buildings that are not focussing on implementing sustainable energy initiatives (*Ibid.*). Large-scale and standardized construction projects are criticized for creating homogenous and monotonous city- and landscape designs (Love, 2006; Adams *et al*., 2013; Tväråna, 2013). This situation can be seen as a problem for the implementation of existing technology in the field of energy efficiency and decrease of energy consumption.

## 1.3 Aim and research questions

The aim of this thesis is to compare and identify cost-effective and sustainable ESSs for Nydal and to analyse an organizational form of ownership that secures the implementation of the suggested ESSs. The first part of the study focuses on ESSs and looks at developed ESSs by the student project at Linköping University in order to find a solution for the first problem described in section 1.2. The aim is to modify the ESSs and analyse the changes of the modifications in order to find the most cost-effective ESS, as described in the first two research questions below. The modifications focus on changes in the temperature data and heat power demand (HPD). The second part of the study focuses on the implementation of a BG in the context of Nydal to address the second problem. The three last research questions are linked to this part of the work. The research questions are:

- How does a change in temperature data and HPD affect the results of the ESSs in regard to total energy system costs?
- Which of the proposed ESSs can be seen as the most cost-effective one?
- What is the attitude towards the implementation of BGs in Nydal in the municipality of Knivsta?
- Which forms of a BG can be seen as favourable for a successful implementation of BGs in Nydal?
- What would be required for successful implementation of BGs in Nydal?

## 1.4 Delimitations

The first part of the study focuses on ESSs, which includes buildings and elements of the systems to provide energy. Other important aspects in the planning of the building area (e.g. property right and planning of the infrastructure and area around the buildings) are not taken into consideration. Furthermore, the focus is on the building area Nydal in Knivsta and energy solutions are excluded that do not seem to be feasible for this location. The study about ESSs focuses on economic costs. A thorough analysis of social and environmental impacts is not conducted. The second part of the study focuses on BG as an organizational form of ownership. Other organizational forms of ownership are not included in this study. Furthermore, legal forms of ownerships for a BG are not discussed in this work. Analysis of possibilities for the implementation of a BG are analysed in close collaboration with the municipality. Citizens and potential members of a BG are not included in the analysis.

## 1.5 Outline

The first of seven chapters introduces the study and describes the problem and its background, the aim and the delimitations of the study. The second chapter presents the information and theories from the literature review. In the third chapter of the thesis, the methods that are used for the development of ESSs and the evaluation and analysis of a BG are presented. The results are documented in the fourth chapter, analysed in the fifth and discussed in the sixth chapter. The work concludes with the seventh chapter. An overview of the research outline and the links between the different parts of this study is presented in Figure 1. The next chapter introduces the municipality of Knivsta, ESSs and BGs.

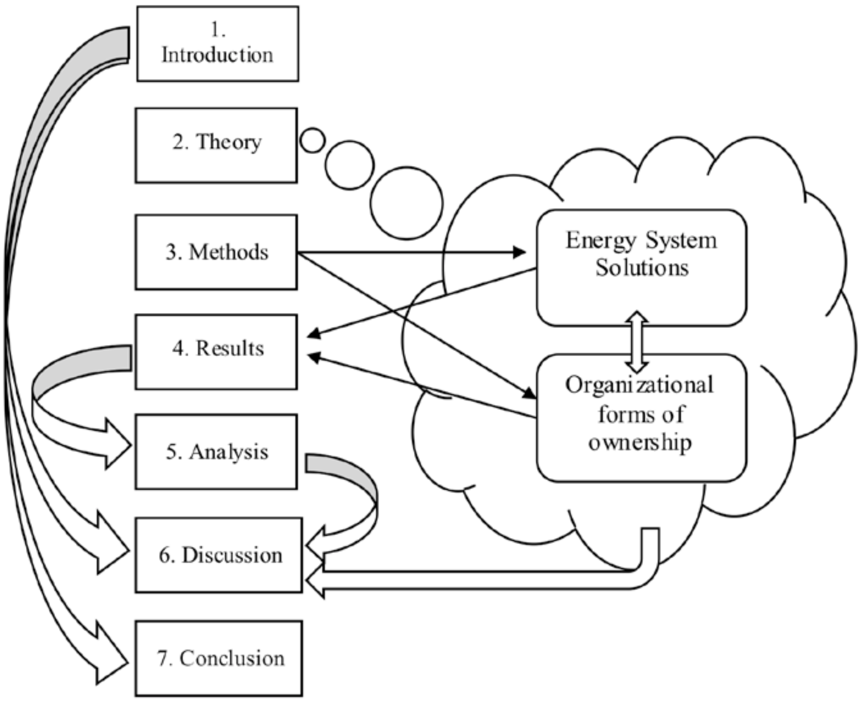


*Figure 1.* Outline of the study.

# 2 Literature review and theoretical framework

This chapter gives an overview of the concepts and information from the literature review. After an introduction to Knivsta and Nydal, the theoretical frameworks of energy systems and the theory of organizational forms of ownership including BG are introduced.

## 2.1 Nydal in Knivsta

The municipality Knivsta is located in Sweden, between Uppsala and Stockholm. The municipality was established in 2003 in the process of a referendum and division of Uppsala municipality into Knivsta and Uppsala municipality. Knivsta is one of the municipalities with the highest population growth in Sweden and has about 16 000 inhabitants in 2015. Development and population growth are parts of the 2025 vision for the municipality. The goal is to expand to approximately 25 000 inhabitants in 2025. One of the areas that play a key role in this development is the building area Nydal (Knivsta kommun, 2015b). The building area Nydal is planned to give space for up to 10 000 new inhabitants and 3500 new apartments (Knivsta kommun, 2014b). An aerial photograph and illustration plan over Nydal can be found in Annex 1.

The role of the municipality is to create local plans to sell land set aside for building, and to install the infrastructure in new building areas, including streets, roads and other forms of infrastructure (Knivsta kommun, 2014e). The planning process for Nydal is described in more detail in section 2.1.2.

### 2.1.1 Sustainability vision for Nydal

Creating a sustainable community is part of the vision and identity for the new building area in Knivsta. The sustainability efforts are divided into three parts: social, ecological and economic sustainability. This division is also known as the concept of the three pillars of sustainability (Elkington, 2004). Environment, economy and society are the three parts of sustainability and need to be balanced in decision-making processes in order to assure sustainability in the long run (Lehtonen, 2004; Zbicinski *et al*., 2006).

The sustainability vision for Nydal regarding environmental aspects focuses on the conservation of water, land and ecosystem services as well as to decrease the anthropogenic impact on nature. Goals in the field of social sustainability are securing to satisfy human needs and to build a community, which is stable in the long run. Economic sustainability in Nydal aims to cover the long-term management of human and material resources (Knivsta kommun, 2014f). Specific examples for those sustainability aspects in the areas work, learning and quality of life are presented in Table 1.

*Table 1.* Sustainability vision for Knivsta (Knivsta kommun, 2014f)

| | **Ecological** | **Economic** | **Social** |
|---|---|---|---|
| **Work** | Energy and environment | Developed infrastructure | Development of rural areas |
| | More jobs in Knivsta | Good communications | Tourism industry and local tourism |
| | | Entrepreneurship | |
| | | Local energy production | |
| **Learning** | Life-long learning | High quality of education in schools | Teaching and learning |
| **Quality of life** | Public health | Participation | Democracy |
| | Effective public transport | Active collective activities | Work-life balance |
| | Locally produced food | Diversity of forms of housing | Living environment |
| | | | Leisure and culture |
| | | | Freedom of choice |

### 2.1.2 Planning process

The planning of Nydal is divided into five phases: development of an urban construction plan and vision (1), detailed investigations (2), the process of developing local plans (3), legal force of the plan (4), and implementation (5) (Knivsta kommun, 2015c).

The first phase of the planning for Nydal is divided into three steps and each of these steps involved dialogs and discussions with citizens by using workshops and questionnaires (Knivsta kommun, 2014e,f). In the first planning step the municipality did an assessment of basic values that are characteristic for Knivsta. The second planning step involved the dialogue and feedback on the visual plan that was developed as a first step of the development of the urban construction plan. This plan was the focus of the third step in the planning phase. After the end of this final feedback round and dialogue in the planning process, the municipal council took the decision upon the urban construction plan and vision, which was published in April 2015 (Knivsta kommun, 2014c,f). The overall goals of this plan and vision are to develop a sustainable urban district that provides possibilities and facilities for citizens to live, work and stay; to form a district with a high quality architecture; to create meeting places and areas for activities that centre the goals and flows of the citizens; to offer accessible recreation and nature areas for everybody; to offer diverse possibilities for living and service; and to create infrastructures and condition for industrial life with opportunities for growth (Knivsta kommun, 2014f).

After the completion of the first planning phase, the next phase entails of detailed investigations. This phase contains for example detailed planning and investigations of flows of traffic, street grids, inventory of nature or water and sewage (Knivsta kommun, 2015c).

The third planning phase consists of the development of local plans. The preparation of an urban construction plan is closely related to the creation of the local plans and is estimated to be completed within one to two years (Knivsta, 2014c). The goal is to improve knowledge and information exchange before an actual decision has to be taken. This process might be influenced and steered by the inclusion and exchange of information with other parties (Knivsta kommun, 2014e). The municipality is able to decide whether a few local plans for larger areas or a higher amount of local plans for smaller areas will be developed (Knivsta kommun, 2014d). The plans regulate rights and responsibilities for the use of land- and water. These rules apply for the municipality as well as for companies and other organizations and individuals. Regulations include decisions about which parts of the land can be used for which purpose (e.g. parks, streets, building area for buildings) and also how this purpose can be conducted (e.g. how tall buildings are allowed to be) (Knivsta kommun, 2015a,c). Decision in the local plans for building areas are legally binding and plans are valid for a time from five to 15 years. Changes in the local plans do not affect already existing buildings and no legal measures can be taken against them (Knivsta kommun, 2015a). The process of developing local plans is regulated in the fifth chapter of the planning and construction law (Plan- och bygglagen) (Knivsta kommun, 2014a).

The fourth step involves the legal phase and acceptance of the plans by the municipal council. Once these plans are accepted, the local plans can be implemented. The implementations are at the same time the fifth and last phase in the planning process. Infrastructure, such as street grids, water and sewage systems and other things as green areas, are built and realized. Constructors start building offices and dwellings. The ground-breaking ceremony in Nydal is planned for 2017 (Knivsta kommun, 2015c).

## 2.2 Energy system solutions (ESSs)

One central concept in this work is systems. Young (1964) identifies a system as a set of objects that are connected to other objects and their attributes within a certain boundary. This boundary separates the system from its environment. Rhodes (2012, p.134) defines a system 'as a related set of elements with specific attributes whose interactions result in identifiable outcomes'. When dealing with a system, the author stresses the importance to understand the elements of a system and their attributes and interactions with other elements of the system. Likewise, it is important to grasp the boundaries within and outside the system. Everything outside the considered system is defined as the environment of a system (*Ibid.*). After a definition of and introduction to the concept of energy systems, ESSs for Nydal are presented in this section.

### 2.2.1 Energy system

According to Nationalencyklopedin (2015) an energy system is 'the interconnected devices and installations needed for the supply and use of energy in every moment within a certain limited user area'. Central aspects in that definition are installations and devices, the existence of a demand, supply and use of energy within an allocated area or boundary. Two forms of energy are particularly relevant for this study: heat and electricity. An energy system secures the supply, transformation, transportation and use of energy for a certain purpose. Systems of distribution exist on a local (e.g. a building), regional (city), national (Sweden) or multinational (Scandinavia) up to global scale (Nationalencyklopedin, 2015).

The highest existent load is usually the measure for the dimension of the power of the energy system. The load is usually varying over time and the change of the load can increase (e.g. heat demand in winter) as well as decrease (heat demand in summer). But also changes on shorter time scales are likely to occur (e.g. temperature changes from day to day or even from hour to hour). Loads are usually divided into different categories, base load, season load and peak load. The base load is defined as the load that is usually existent over the whole year. The seasonal load is the one, which is introduced seasonally and does not cover all parts of the year. The peak load is occurring only in parts of the year and in Sweden plants that are combusting fossil fuels and biomass mainly cover the energy demand of the peak load. The energy system has the goal to cover the total energy demand for the whole planning period (Nationalencyklopedin, 2015).

On a global level, most energy systems are still dominated by the use of fossil fuels. One big advantage of fossil fuels is the flexibility. Fossil fuels have a high energy density and simplify the transport of large amounts of energy. At the same time combustion plants that use fossil oil and gas can easily regulate and adapt the amount of produced heat and electricity. One aim with the introduction of renewable energy is to decrease the use of fossil fuels. The management of renewable energy and its capacity to be a flexible and easily transportable energy source is one of the key concerns (Mathiesen *et al.*, 2015). In order to create an energy system that is environmentally and economically feasible, it is important to merge the electricity and heating sector. Energy systems need to make allowances for solutions that combine the production of heat and electricity (Pensini *et al.*, 2014).

Energy systems include not only production plants but also buildings. It is important to take into account all components of the system and not only examine and analyse parts of them. The system boundary is therefore the whole building area and not parts of it, to be able to include the complexity and links between different parts of the system (Beradi, 2013 & Turcu, 2012). Tools to deal with complex system are necessary to secure a holistic approach on the system (Henning, 1999). Especially as Rhodes (2012) mentions, the planning of housing and energy systems in the context of governmental existence shows many of the characteristics of a complex system. As Liljenström and Svedin (2005) describe, a complex system is determined by the amount of information, where an increase of information leads to an increase in the complexity of the system. Energy systems can be seen as complex systems as they consist of a large amount of components that are usually connected and show signs of uncertainty (e.g. in consumption behaviour or energy production by sun) (*Ibid.*).

### 2.2.2 ESSs for Nydal – Linköping University report

A student project at Linköping University (Hagelberg *et al*., 2014) developed ESSs for Nydal. The approach combined different building categories and forms of energy supply to an energy system. Three different building categories were chosen: buildings according to the standard by the National Board of Housing, Building and Planning (‘BBR21’) (1), minimum houses (‘Minimihus’) (2), and houses that are conform with the international standard for passive houses (‘Passivhus’) (3). The energy requirements for each building category are divided into heating for the building, heating of water and electricity for the buildings (Table 2). Household electricity demand is not included in this study and therefore left out in the overview of energy requirements.

*Table 2.* Energy requirements for the building categories (adapted from Warfvinge, 2005, as cited by Hagelberg *et al*., 2014)

| | BBR21 | Minimihus | Passivhus |
|---|---|---|---|
| **Heating of the building (kWh/m$^2$, year)** | 65 | 47 | 15 |
| **Heating of the water (kWh/m$^2$, year)** | 25 | 25 | 25 |
| **Electricity for the building (kWh/m$^2$, year)** | 5 | 5 | 5 |
| **Total energy consumption (kWh/m$^2$, year)** | 95 | 77 | 45 |

According to the goals set by Knivsta municipality, the forming of possible production options for the supply of heat and electricity was restricted and regulated to fulfil goals in the field of sustainability and resilience. The following eight restrictions and regulations were made (Hagelberg *et al.*, 2014):

- Base the energy system as much as possible on renewable energy (1),
- Achieve the highest possible degree of self-sufficiency (2),
- Examine opportunities to include solar panels and solar cells (3),
- Examine opportunities to include heat-driven household appliances (4),
- Examine opportunities for decentralized and centralized heat- and electricity production (5),
- Do not consider waste as a fuel for energy generation, due to the conflict of the classification of waste as a renewable energy (6),
- Examine the building categories: BBR21, Minimihus and Passivhus (7),
- Do not consider wind power for energy generation, due to the closeness of Arlanda airport (8)

Seven different methods of production and supply of energy were considered in the student project. Those forms of production were divided into centralized and decentralized solutions. Decentralized solutions are systems that can be installed at the individual house level. The pellet stove and furnace with Stirling motor use wood pellets as fuel. Centralized solutions are central solutions within Knivsta. The power plant and thermal power station are driven with wood chips as an energy source. An overview of the classification of those energy production methods is given in Table 3. Detailed information about the production methods are presented in the report of the student project at Linköping University (*Ibid.*).

*Table 3.* Production methods of energy supply (Hagelberg *et al*., 2014)

| **Centralized** | **Decentralized** |
|---|---|
| Power plant (PP) [electricity] | Pellet stove (PS) [electricity & heat] |
| Thermal power station (TPS) [heat] | Furnace with stirling motor (ST) [electricity & heat] |
| Combined power and heating plant (CHP) | Solar cells (SC) [electricity] |
| [electricity & heat] | Combination of solar panels and solar cells (SP & SC) |

The available ESSs were divided into three energy scenarios (A, B, C). The division was based on the use of kitchen appliances and stoves. Scenario A included electricity-driven kitchen appliances and stoves. The second scenario (B) used heat-driven kitchen appliances and electricity-driven stoves. Scenario C had heat-driven kitchen appliances and gas-driven stoves (*Ibid.*).

The demand for the heating of the building and water was allocated to monthly values for the heating power demand (HPD). The yearly energy demand for heating was allocated to the separate month according to the difference in outside average-temperature and a base temperature of 17°C (*Ibid.*). The results of the monthly HPD for the whole planning area are illustrated in Figure 2. Detailed numbers are listed in Annex 2.

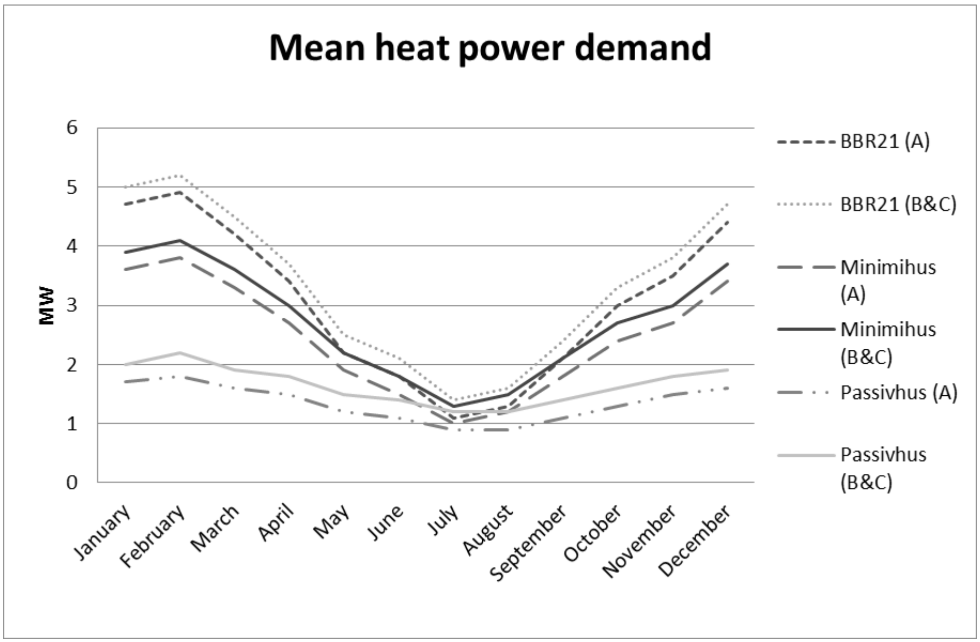


*Figure 2.* Monthly mean heat power demand (adapted from Hagelberg *et al*., 2014).

The optimization was solved towards the target variable, which was the lowest energy system cost. The costs that are considered in the optimization are investment costs for buildings and energy systems, as well as costs for energy production (fuels, e.g. wood pellets). The target variable was chosen due to the fact that all alternatives were not emitting carbon dioxide. The optimization was done for one year due to different life spans of the different parts of the energy system while using annuity method. This makes it possible to compare parts with different life spans (Mattson, 2006).

The prices for electricity and fuels for the production sites are at risk for change (Olsson *et al.*, 2001; Holmgren *et al.*, 2005). Due to that, a simplification was done and an increase of the energy prices with the same amount as the discount rate (4%) was assumed. Changes in prices for fuels for the production sites were illustrated with the help of sensitivity analyses. The following sensitivity analyses were conducted: subsidies for solar cells (35% of the investment costs); 50% increase in wood chips price; 50% decrease in wood chips price; 50% increase in wood pellets price; 50% decrease in wood pellets price; geothermal heating; 100% increase in price for building a district heating grid (Hagelberg *et al*., 2014).

The results of the optimizations were quite close to each other and therefore additional special cases of energy systems were examined: two alternatives for the energy system with solar cells, one with solar cells on the whole and one with solar cells on half of the roof; a combination of solar panels and solar cells; a decentralized system with the production of electricity and heat in every single house with and without the opportunity to sell electricity; only own production of electricity and heat with and without the opportunity to sell electricity; energy demand was supplied completely with bought electricity and heat from the district heating grid (Hagelberg *et al*., 2014).

From this setting of the parameters, three types of buildings with three types of scenarios for the supply of energy for kitchen appliances and the stove; nine different profiles for the energy system and another seven sensitivity analyses lead to 55 different ESSs and 24 sensitivity analyses. Not all of the options (e.g. BBR21 and geothermal heating) were used for all combinations (Hagelberg *et al*., 2014).

ESSs that were worse than other from an economical and environmental point of view were filtered out and not taken into consideration for further applications and analysis. Due to that, ESSs with minimum house as a building category were filtered out as well as solutions with scenario C (Hagelberg *et al*., 2014).

Table 4 gives an overview of the yearly costs for the whole building area of the ten most cost-effective ESSs that were developed. The only alternative from the sensitivity analyses that was considered and added in the compilation is the one with the subsidies for solar cells (Hagelberg *et al*., 2014). An overview of all developed ESSs can be found in Annex 2. The listed solutions differ only slightly in the total costs per year and per square meter.

*Table 4.* Overview over most cost-effective ESSs (adapted from Hagelberg *et al*., 2014)

| | Yearly costs (SEK) | | | |
|---|---|---|---|---|
| **Energy system solution** | **Energy system** | **Building** | **Total** | **per m2** |
| BBR21 (CHP, TPS) | 16.24 M | 328 M | 343.86 M | 1160 SEK |
| Passiv B, subsidies for solar cells (SC, PP, TPS) | 11.07 M | 335 M | 345.79 M | 1166 SEK |
| Passiv B (PP, TPS) | 11.33 M | 335 M | 346.05 M | 1167 SEK |
| Passiv B, own electricity production (PP, TPS) | 11.56 M | 335 M | 346.28 M | 1168 SEK |
| Minimi B, subsidies for solar cells (SC, CHP) | 14.97 M | 333 M | 346.61 M | 1169 SEK |
| Passiv B, own production without selling electricity (PP, CHP) | 11.90 M | 335 M | 346.62 M | 1169 SEK |
| Minimi B (CHP) | 13.75 M | 333 M | 346.80 M | 1170 SEK |
| Minimi B, own electricity production (CHP) | 13.80 M | 333 M | 346.85 M | 1170 SEK |
| Passiv A, subisdies for solar cells (SC, CHP) | 12.27 M | 335 M | 346.99 M | 1170 SEK |
| Passiv A (PP, TPS) | 12.55 M | 335 M | 347.27 M | 1171 SEK |

The ESS BBR21 was added as a reference system, since it does not comply with the goals of the project to build as energy saving as possible. It was therefore not chosen for further analysis. The ESS passive house B with subsidies for solar cells was selected as the best solution. Due to the unlikeliness of getting subsidies for the whole area of the roof (Hagelberg *et al*., 2014), the two second best solutions from a sustainability perspective were considered and named as well: Passive house B with solar cells on half of the roof and passive house B with a combination of solar cells and solar panels. The best decentralized ESS has been the one with the combination of passive house B. The best centralized solution was the one with passive house B and own production of energy. All of the mentioned best solutions were a combination of an energy system with the building alternative passive house and scenario B, which includes heat-driven dishwashers and washing machines and electricity-driven stoves.

## 2.3 Organizational forms of ownership

The study of an organizational form of ownership is the other central aspect of this work. According to Stern (2011) acceptance of a new form of technique is to a high extent dependent on the opinion and perception of the technique and the trust for the responsible organization and the decision process. In the following section organizational forms of ownership for energy facilities as well as housing are presented.

As concluded by Walker and Simcock (2012) organizational forms of ownerships can be diverse. The authors list six different organizational arrangements for a part of an energy system: public-private partnership (1), community cooperative (2), public sector and local council (3), village hall committee (4), development trust (5), company invited by guarantee with charitable status (6) (*Ibid*.). Statistics Sweden distinguishes four categories of organizational forms of ownership of housing: state, county or municipal ownership (1); non-profit ownership (2); housing cooperatives (3); and private ownership (4) (SCB, 2012). In 2012, 2% of the apartments were owned by the state, county or municipality, 13% by non-profit organizations, 30% by housing cooperatives and 56% privately (*Ibid.*).

Walker and Simcock (2012) mention community projects as an organizational arrangement for the ownership of energy projects. According to the authors, an organizational form of ownership for an energy generating facility involving community projects is characterized by a “high degree of involvement of local people in the planning, setting up, and, potentially, the running of the energy project” (Walter & Simcock, 2012, p. 196). This degree of involvement may lead to a higher acceptance of the introduced energy project and even to a higher level of awareness of own consumption patterns by education in the field of sustainable energy. Community projects as an organizational form of ownership might also have a positive effect on local social capital (Walker & Simcock, 2012). Hinders of community projects can be the complexity of installation, funding and operation of the energy systems. Guidance, assistance and handholding were proposed as ways to enable the upstart of community projects, especially in more complex, risky or larger projects with limited local experience and skills (*Ibid.*). Community projects are similar to the organizational form of ownership BG, which are the focus of this study and described in the next part section.

## 2.4 Baugemeinschaft (BG)

A BG is defined as an association of private people, which have the intention to buy, build or redesign a house in order to be able to live in it (BVBG, 2011; Svensson, 2012; Gephart, 2013). The idea of a BG can be traced back to the 1970s and has its origin in Germany, where people organized in order to plan and build their own houses for living (Schuster, 2005). The motives for the creation of a BG have changed over the years. Whereas people in the 1970s tried other forms of living, modern BGs mainly seem to have more rational motivations for the acting (e.g. reduction of costs; participative management in the conduction and planning; desire for a special form of housing; getting to know potential neighbours at an early stage) (Schuster, 2005; Svensson, 2012; Gephart, 2013).

This section will provide more information about characteristics of a BG including phases of development, classification of different BGs as well as advantages and disadvantages of a BG. The section concludes with an overview of realized projects and important measures of support for a BG.

### 2.4.1 Characteristics and forms of a BG

As mentioned in the definition of a BG, one of the key characteristics of the BG is the constellation of its group members and their goal of the common activity. The core of this activity is to manage and oversee the common project, which includes ‘the planning and building phase’ of a house, but also the ‘living phase’ (BVBG, 2011 & Svensson, 2012). In most of the cases projects by BGs realize apartment houses, where each part of the community is living in a separate apartment (Svensson, 2012). Due to the complexity of most of the projects, most BGs get some support in form of guidance, development and design or in the construction phase (*Ibid.*). The characteristics of a BG are somewhat dependent on its form. Schuster (2005) distinguishes three forms of BGs: free and private BG (1), assisted and private BG (2), and a BG that follows the model of a cooperative (3).

The free and private BG is characterized by a high degree of flexibility and responsibility. The BG acts as an independent building contractor, which implies that all contracts and plans need to be developed and negotiated within the group and mostly without external consultation. The high degree of self-organization is also reflected in the total costs of the planning, which are usually 25-30% lower than the local prices for comparable apartments (*Ibid.*). The invested time is usually 20% higher than in comparable projects. The community is liable as a whole and every member needs to be able to show that liability for the part of the membership is given (Heinzmann, 1998 as cited by Schuster, 2005).

The assisted and private BG has the same main basic characteristics as the free and private BG. The main difference in this form is the initiation, management and organization of the group, which is usually done by somebody else (Schuster, 2005). Assistance simplifies the starting and formation process, including the long preparations in finding land, coordination of all legal, financial and contractual arrangements. Table 5 gives an overview of the services that the advisor usually helps with in the first phase of the BG (*Ibid*). The professional support of the BG enables a clear and well-structured steering of the building- and planning process, which leads to a secure and well-budgeted steering of costs and the progress of the building process. Those characteristics make this form of a BG an attractive solution for municipalities and others that are involved in the project. The total costs are usually 20% lower than for comparable apartments (*Ibid*).

*Table 5.* Overview of services in an assisted and private BG (adapted by Schuster, 2006)

| Finding phase | Planning phase | Implementation phase |
|---|---|---|
| Finding of the land | Compilation of the involved actors in the planning | Point of contact for all involved actors and stakeholders of the BGS |
| Compilation of the space allocation plan | Coordination with administrative bodies and neighbor planning | Contact person for all involved actors |
| Initiating search for new members for the BGS | Searching for additional members for the completion of the planning community | Coordination of the standard of the house building |
| Collection of all costs | Organisation of the allocation of the apartments | Planning of payments |
| Moderation of the group process | Evaluation of the locations of the apartments within the building project | Coordination of dates |
| Preparation of the contractual bases | Coordination of financial adjustments | Auditing and approval within the scope of financial authorization |
| | | Possibly administration of the deposit |

The BG that follows the model of a cooperative can be seen as a form of BG that enables supply of housing space for people from a low-income sector (Schuster, 2005). The main difference to a free and private BG is the financing principle, which is solidary based. No individual property is created in this form of the BG. It remains centrally shared. Members of this form of the BG can secure a life-long right for living with their shares in the cooperative. The administration of the cooperative fulfils the same task as in the other forms. The cooperative shares the same legal and financial rights, liabilities and responsibilities. This form of a BG usually commands a secured financing due to diversified finding of capital (*Ibid*).

### 2.4.2 Development phases of a BG

Gephart (2013) distinguishes four phases of development that are connected to the creation of a building by a BG: finding phase (1), planning phase (2), implementation phase (3), and living phase (4).

The first step of the finding phase is getting to know interested people. The second step is the search for a suitable area of land or object. The last step is usually the decision on an architect for the project (*Ibid*). Typical problems in this first phase are varying degrees of engagement among participants, lack of criteria or invisible criteria for the inclusion of new community members and different motives and interests within the community (*Ibid*).

The second phase of the project is the planning phase. This phase consists of a large amount of decisions and many decision-making processes are involved in this phase. Whenever it comes to decisions, the question of power and influence is important and can possibly lead to problems within the decision making process. A delay of decisions is one possible outcome of this (*Ibid*).

After the successful completion of the first two phases, the third step is the implementation of the plans and the construction of the building. Similar to the second phase, this phase contains many details that need to be considered. The coordination of the different interests within important questions is crucial. One possible problem is different recognitions for different working groups within the community. Members that do not abide by an agreement that was made in the beginning of the project state another problem. Changes in life events for parts of the community may occur in this phase of the process and need to be addressed and solved by the whole community (*Ibid*).

After the implementation phase, the living in the new apartments can be started. This is the goal of the whole project, but even at this level problems can occur. In the living phase questions about distribution of autonomy and intimacy may come up and could possibly differ to what was communicated before (Gephart, 2013).

### 2.4.3 Advantages and disadvantages of a BG

BGs feature advantages and disadvantages on the individual as well as the community level. An analysis of the strengths, weaknesses, opportunities and threats is conducted. The internal factors (strengths and weaknesses) affect only the members of the BG, whereas the external factors (opportunities and threats) affect non-members of the BG as well (e.g. other citizens in the municipality or city). Figure 3 presents the results of this analysis.

### 2.4.4 Experiences from other countries

Many examples of BGs have its origins in Germany. Places like Freiburg, Tübingen, Munich, Stuttgart and Hannover were pioneers in this field (Schuster, 2005). In


*Figure 3.* Analysis of strengths, weaknesses, opportunities and threats of BGs.

Hannover, the first projects were realized at the end of the 1970s. So far 164 apartments were created in a total of ten projects. Another six projects are in the planning phase to provide up to 150 apartments. Munich counted more than 470 apartments in 2005 that were implemented by BGs. Hamburg had 40 realized projects by BGs in 2005. The city made the decision to invest in the support of BGs and made a prognosis in 2005 to build approximately 170 apartments in the short run. In the long run, Hamburg has the vision to reach around 300 new apartments built by BGs (*Ibid.*). Stuttgart started with BGs in 1989 and has since then realized at least 95 apartments in the form of a BG. In 2005, it was predicted that more than 500 BGs and up to 2500 new apartments could be realized (*Ibid.*). Even though Tübingen started six years later with the implementation of BGs, more than 110 projects summing up to more than 500 apartments were created. One of the reasons for this rapid growth was the central support from the city, which coordinated the allocation of parcels and time management (*Ibid.*). Freiburg, with the quarters Vauban und Rieselfeld, was highly successful with the implementation of BGs. Starting in 1996, 150 BGs realized more than 750 apartments. Freiburg offers the same support for BGs as Tübingen and has a special forum for the realization of BGs in Vauban (*Ibid.*). Table 6 gives an overview of some of the projects that were realized by BGs. The majority of the projects are located in Germany, but also projects from Sweden are included in this list.

Experiences from different countries and research conclude that professional support is needed in order to promote the forming of BGs (Schuster, 2005; BVBG,

*Table 6.* Overview of realized projects by BGs in Germany and Sweden

| Name | City | Costs [€/m2] | Form | Year (constr.) | Size | Source |
|---|---|---|---|---|---|---|
| Nudelfabrik | Rohracker | - | - | 1989 | 22 apartments | Schuster, 2005 |
| Neues Wohnen und Arbeiten | Stuttgart | - | assist. & priv. | 1994 | 27 apart. | Schuster, 2005 |
| BGS Understenshöjden | Björkhagen | - | assist. & priv. | 1995 | 44 apart. | FFBGS, 2015 |
| Projekt 14 | Tübingen | - | - | 1998 | 30 apart. | Svensson, 2011 |
| Lofthaus | Tübingen | 1,870 | free & priv. | 2001 | 2 apart. + 1 office | Schuster, 2005 |
| Wabe | Burgholzhof | - | cooperative | 2001 | 15 apart. | Schuster, 2005 |
| Werkstadthaus | Tübingen | - | - | 2001 | 14 apart. | Svensson, 2011 |
| Passivhaus Eichbühlstraße | Konstanz | - | assist. & priv. | 2003 | 4 apart. | Schuster, 2005 |
| Waldhäuser | Berlin | 1,000 | free & priv. | 2003 | 5 apart. | Ring, 2007 |
| Wohnen am Haveleck | Berlin | 1,445 | | 2003 | 42 apart. | Ring, 2007 |
| 2 Doppelhäuser in Weissensee | Berlin | 1,477 | free & priv. | 2004 | 4 apart. | Ring, 2007 |
| Baugruppe Weststadt | Karlsruhe | 2,050 | assist. & priv. | 2004 | 16 apart. | Schuster, 2005 |
| BGS ''vis-à-vis'' | Freiburg | - | assist. & priv. | 2004 | - | BVBGS, 2011 |
| Haus am Platz | Tübingen | 1,590 | assist. & priv. | 2004 | 7 apart. + 2 offices | Schuster, 2005 |
| Wohnetagen Steinstrasse | Berlin | 2,094 | free & priv. | 2004 | 22 apart. + 5 offices | Ring, 2007 |
| Dragonerkaserne | Karlsruhe | - | free & priv. | 2005 | 16 apart. | Schuster, 2005 |
| Eureka | Freiburg | - | - | 2005 | - | BVBGS, 2011 |
| Gandhi | Burgholzhof | 1,830 | assist. & priv. | 2005 | 8 apart. + day nursery | Schuster, 2005 |
| Ten In One | Berlin | 1,570 | free & priv. | 2005 | 10 apart. | Ring, 2007 |
| Baugruppe Hufelandstraße | Berlin | 2,000 | free & priv. | 2006 | 15 apart. + 1 office | Ring, 2007 |
| Marienburger Straße 31a | Berlin | - | free & priv. | 2006 | 15 apart. + 1 office | Ring, 2007 |
| C53 | Berlin | 1,752 | assist. & priv. | 2007 | 6 apart. | Ring, 2007 |
| Haus & Hof | Berlin | - | assist. & priv. | 2007 | 7 apart. | Ring, 2007 |
| RuSc | Berlin | 1,837 | free & priv. | 2007 | 12 apart. | Ring, 2007 |
| Strelitzer Straßer 53 | Berlin | 2,050 | assist. & priv. | 2007 | 10 apart. + 1 office | Ring, 2007 |
| Wohnen an der Marie | Berlin | 1,830 | assist. & priv. | 2007 | 23 apart. + 1 office | Ring, 2007 |
| stadt:raum | Tübingen | - | - | 2008 | 29 apart. | Svensson, 2011 |
| UrbanaVillor | Malmö | - | free & priv. | 2008 | 5 apart. | Svensson, 2011 |
| Blau | Freiburg | - | - | 2010 | - | BVBGS, 2011 |
| WIR wohnen anders | Dortmund | - | - | 2010 | - | BVBGS, 2011 |
| Baslerstr. 38 | Freiburg | - | - | 2011 | - | BVBGS, 2011 |
| BGS Prager Straße | Potsdam | - | - | 2012 | - | BVBGS, 2011 |

2011; Kasioumi, 2011; Gephart, 2012; Svensson, 2012). Not only the choice of legal forms, but also other aspects such as managing group dynamics within the BG are difficult for non-experts and professional support is therefore highly important (Svensson, 2012). The measures of support can be distinguished between internal support and assistance of processes within the BG and external support that aims at underlying conditions.

Internal support measures are according to Schuster (2005) discriminated into three fields: realization ability (1), legal covering (2), and financial security (3). In order to increase the ability to realize the project of a BG, it is important to improve and streamline internal organisation structures. Furthermore, commitment to development agencies is crucial to enable a manageable building process. It helps to secure the planning and realization for all involved members (*Ibid.*). In the field of legal covering, Schuster (2005) mentions that it is necessary to oblige all members to prove their eligibility for financing before the start of the construction in order to avoid difficulties with the financing from the banks. This is a precondition to ensure the financial security of the process, but it also requires streamlining of internal and external planning processes. Apart from that, contractual agreements throughout all planning- and implementations phases need to be fixed and costs need to be calculated in detail (*Ibid.*). Credits might be a potential factor for financing the project and credit guarantees need to be checked with relevant institutions (e.g. Bostadskreditnämnden in Sweden) at an early stage (Svensson, 2012). An early determination of standards with the help of room books as well as consistent scheduling helps to increase the financial security (Schuster, 2005).

External support measures imply extensive political planning support. Assistance comes mainly from external actors, such as municipalities or cities (Schuster, 2005; BVBG, 2011). Schuster (2005) divides those measures into structural support and support in the form of a city development project. Structural support includes fixing a share of all building activities that should be realized in the form of a BG (*Ibid.*). Help in finding land, financial support with buying land or selling municipal owned land at a lower price than usually are forms of external support measures. Counselling of people that are interested in BGs, for example in the fields of land acquisition or joining architects and members of a BG via a contact point, are defined as structural measures of support (*Ibid.*). A city development project fits city building planning to the needs of the BG (e.g. via local plans), which is often the case for new building areas. Typical ways of support are the forming of parcels of land in the right size (parcelling) and at the right time (lead time) (Schuster, 2005; BVBG, 2011, Svensson, 2012). The lead and conduction of organization, distribution and management by the municipality or city is another measure of support (Schuster, 2005). Other infrastructural support measures are to make land available and improve activities of the sphere (e.g. support for the enhancement of public spaces, improvements of supply offers, or qualitative and quantitative expansion of open space offers) (*Ibid.*).

According to Svensson (2012) not all of the infrastructural support measures that were implemented in Germany are available yet in Sweden. One example is the matchmaking in the starting phase. Architects might not be used to deal with private persons instead of professional partners. In Germany this was solved by the implementation of municipal and urban contact points to support the junction of BGs and architects (e.g. "Agentur für Baugemeinschaften" in Hamburg; "Stadtsanierungsamt" in Tübingen or the "Bürgerbüro Stadtentwicklung" in Hannover) (Schuster, 2005). In the following, examples of implemented support measures from Tübingen, Karlsruhe, Freiburg and Stuttgart will be presented.

Tübingen pursues the policy of supporting BGs with an urban development plan. The city leads an own urban project in the fields of preparative land-use planning, coordination of development activities, plot management, marketing of parcels, and initiating and control of BGs (*Ibid.*).

Karlsruhe organizes the planning for the support of BGs according to regulations of the city in the starting phase of the BG. Requirements to decide on a legal form and to hand in the building application after a certain amount of time structure the starting phase of a BG (*Ibid.*).

Stuttgart implemented the three-point-programme 'Urban Living in BGs' (Schuster, 2005). The first point of the programme is a development programme, which supports building projects that are initiated by BGs. A launching event informs about the programme, as well as procedures and organisation of a BG including timing. Finally, a brochure with relevant information is created. The second point of the programme is the creation of a contact point for BGs. It helps with information and initiating of group finding processes as well as junction of architects, members of a BG and other supporters. The contact point holds information events, gives assistance and support for single initiatives of BGs and executes public relations activities (e.g. daily press). The last point in the programme is the realization of a model project, which has the concept of town planning on urban owned land. In this project, the contact point coordinates the wishes of members of a BG regarding buildings and apartments, distribution and control of land options, proves projects if they are according to the development programme and is in charge of time management. Coordination of land acquisition, building application and building implementation were managed by the city in this project.

Freiburg introduced several measures to support BGs. Apart from directed allocation of parcels to BGs (Schuster, 2005), information exchange between all involved actors and financial incentives to promote renewable transport solutions, strategies are targeted to all interest groups, including public agencies and developers and prospective residents and members of BGs. These strategies have the goal to improve social as well as environmental outcomes of the projects (Kasioumi, 2011). One of the most important measures of support in the start of the BGs is Forum Vauban. The exhaustive list of support by the forum includes organization of information fairs, biking tours, workshops, and excursions for potential architects, builders, homeowners, craftsmen, and financial institutes; publication of brochures, a bimonthly magazine, and manuals with instructions on how to save resources in the construction process; support of BGs on financial, legal, and technical aspects; cultivation of partnerships with research centres, universities, and institutions in order to increase and spread knowledge about technological choices (*Ibid.*). A major publicity campaign in 1996 awoke serious interest of more than 1500 households that wanted to build or rent accommodation in Vauban. Advertisements, brochures, public meetings and information stalls presented the vision of Vauban. This campaign was financed by the city council (Scheurer & Newman, 2009).

Due to the extensive support of the forum, many ideas from the members of the BG were realized. As a result, most heating systems are supported by solar panels and intelligent ventilation. But also alternative sewage treatment systems were installed, such as rainwater collection facilities or vacuum converters, which produce biogas out of organic waste and sewage. BGs in Vauban are continuously pursuing additional social and environmental objectives, which lead to a high degree of diversity in architecture and solutions for open space, but also strengthen social aspects of the community by initiating common activities and cooperation between neighbours (Forum Vauban, 1999; Wirtschaftsministerium Baden-Württemberg, 1999 as cited by Scheurer & Newman, 2009). Vauban is one of the European regions in the temperate climate belt with the highest amount of plus-energy and passive houses. From an ecological point of view, Vauban exceeded all expectations and it is seen as a successful example of the implementation of energy efficient solutions at low-levels of material consumption and low-dependency of cars (Scheurer & Newman, 2009). In the next chapter the methods that are used for the study of ESSs and BGs are presented.

# 3 Methods

The following chapter gives an overview of the methods that are used in this study. A literature review lays the basis of the study in order to gain more information about the background, relevant theories and to make a justified choice of methods. The study is divided into two parts: simulation and optimization of ESSs (1), and evaluation and analysis of an organizational form of ownership for the proposed ESSs (2).

The simulation and optimization of ESSs is done in the form of a secondary data analysis. The data for the analysis and recommendations for ESSs are developed by a student project at Linköping University. This research is quantitatively based and typical features of such a research are presented in section 3.3.

The evaluation and analysis of an organizational form of ownership is based on the literature review. In connection to that, interviews are conducted to apply the findings of the literature review to the underlying case study and requirements of the project. This research is qualitatively based and typical features of such a research are presented in section 3.4.

The work is designed and structured in the form of a pilot study, where minor aspects (in this case energy systems and organizational solutions) of a larger and more complex reality (Nydal) are studied to check the feasibility of the proposed solutions and forms (Robson, 2011).

## 3.1 Literature review process

The literature review process is the starting point for the study of ESSs and organizational forms of ownership. The majority of the articles are peer-reviewed and published in academic journals. The information about the municipality and its connection to the project has a high importance to the study and is reviewed as well. This information is not peer-reviewed and published online. The literature review is done systematically and divided into three steps: searching for relevant literature including scanning of reference lists of important literature for other relevant literature (1), separating relevant from irrelevant literature (2) and reviewing the relevant literature (3).

The information from the literature review is used to gain a deeper understanding of the concepts of energy systems and organizational forms of ownership. Due to the complexity of the concepts and close relations to other important fields (e.g. housing, renewable energy sources, etc.), the search was conducted with many different terms in order to cover all relevant aspects. This leads to the fact that the literature covers a wide range of journals and sources.

## 3.2 Choice of the theoretical framework

The choice of the theoretical framework is an important part of a study. The focus of this study is on energy systems and organizational forms of ownership. The focus area is influenced by the goals of the project from the municipality in Knivsta. The theoretical framework, which includes the concept of energy system and organizational forms of ownership, therefore covers the fields of the study that are chosen for further investigation and that are given by the aim of the study.

## 3.3 Simulation and optimization of ESSs

The simulation and optimization of ESSs follows the principles of quantitative research. A typical feature of quantitative research is quantification and simulation of measurable data (Robson, 2011). Important factors for the collection and handling of the data are precision and accuracy as well as validity and reliability of measurements. A detailed specification of the design of research process is done at an early stage and results are expected to be analysed statistically (*Ibid*.).

In the case of Nydal a model for ESSs is simulated and optimized. The goal of a simulation is to gain more knowledge about a real world system by constructing a system, which contains essential structural elements (Robson, 2011). The simulation is a simplification of the real world settings in order to get information about the system that is otherwise inaccessible and intractable (*Ibid*.).

In this study a secondary data analysis is conducted, based on the results and the data from a student project at Linköping University (Hagelberg *et al*., 2014). A secondary data analysis is defined as 'any re-analysis of data collected by another researcher or organisation' (Hakim, 2000, p. 24). The choice of this method is based on one of the advantages that are named by Robson (2011): the possibility to focus on interpretation and analysis of the data.

The simulation and optimization of ESSs is divided into three steps: the identification of data improvements and gathering of the required data (1), the modelling of new ESSs (2), and the optimization of those new solutions (3).

### 3.3.1 Identification and gathering of improved data

Four of the five ESSs, selected in section 2.2.2, are chosen for further development and modification. The solution with passive house B and subsidies for solar cells is not taken into account, since it is regarded as a special case and a variation of the passive house B with solar cells, which is included in one of the systems that is selected for modifications. All selected ESSs are a combination of passive houses and heat-driven kitchen appliances and electricity-driven stoves (scenario B). Energy system A, B and D receive their energy supply from a combination of a power plant and a thermal power station. Furthermore, ESS A has an additional energy supply by solar cells that cover half of the area of the roof. ESS B gets additional energy supply by solar panels and solar cells, each covering half of the area of the roof. ESS C is the only system satisfying its energy demand just by decentralized energy production methods with a Stirling motor and half of the area of the roof covered with solar cells. Table 7 gives an overview of the energy production methods for the selected ESSs, which are introduced in Table 3.

*Table 7.* Selected ESS and their energy production methods

| Name | Energy System |
|---|---|
| ESS A | Power plant (PP), thermal power station (TPS), half of the roof covered with solar cells (50% SC) |
| ESS B | Power plant (PP), thermal power station (TPS), a combination of solar cells and solar panels on the whole roof (SC & SP) |
| ESS C | Stirling engine (ST), half of the roof covered with solar cells (50% SC) |
| ESS D | Power plant (PP), thermal power station (TPS) |

In order to work on improvements on the accuracy of the optimizations, potentials for improvements of data need to be found. This process is done together with the student group at Linköping University that conducted the optimizations of the ESSs and Martin Wetterstedt, an energy adviser at Knivsta municipality, who assisted the development of the ESSs. New data for temperature is the base for the modification of the existing data. In addition to that a sensitivity analysis for the effects of climate change is conducted. Different scenarios for global temperature rise are taken into consideration.

Extreme temperatures are not represented in the initial models of ESSs, due to the fact that monthly average temperatures are used as temperature data. This leads to the fact that peak loads are not represented realistically and the capacity of production plants is not dimensioned accordingly. Higher capacity of production plants is assumed to have a significant impact on the total energy system costs and the reason for adapting the temperature data. The adaption of the temperatures for the heating power demand is calculated for the housing category of the passive houses and for scenario B, since those are the only alternatives that are taken into account for further modifications.

The adaptions of the temperature data aim to change the peak load requirement, while at the same time keep the yearly heat demand. The coldest 12-day-mean temperature for the Stockholm-Bromma region (-12.7°C) is used as a mean average temperature for January. To balance the heat demand of the whole year, the surplus of heating degree days from January (232.5) is allocated to the months of February and December. Table 8 shows the difference for the data of the temperature of the initial (Temperature) and the modified model (Temperature').

The shift in the temperature data influences the numbers for the heat power demand (HPD). In order to adapt the HPD, the existing data needs to be modified and the overall heat-transfer coefficient, U-value, of the building needs to be determined. The U-value is defined as a coefficient in an equation of heat transfer with the rate '$\dot{q}$'. Various thermal resistances of separating areas, which have a temperature difference '$\Delta T$', characterize the system. The U-value is determining the heat transfer, which is dependent on the area A of the heat transfer. The unit of the U-value is $W/m^2$ °C (Atkins & Escudier, 2013). Equation 1 elucidates this correlation.

$$\dot{q} = U \times A \times \Delta T \; (1)$$

After the determination of the U-value, it is possible to solve equation 2 and 3. These equations provide the heat requirement for every month, based on the factor of the U-value and the difference of the outside-temperature ($T_N$) and the set base temperature (in this case 17°C) (Zabeltitz, 2011 & Kempkes, 2006). In addition to the energy demand for the heating of the building, the energy demand for the heating of hot water ($TW_N$) is added. The sum of this term needs to fulfil the energy requirements for the building category, which in the case for passive house standard is 40 kWh per year and square meter. The solutions of the equations do not contain the energy demand for the household appliances. This demand is added afterwards. The results for the initial (HPD) and new heat power demand (HPD') are presented in Figure 4. Detailed numbers are given in Annex 2.

$$15 + 25 \; {}^{kWh}\!/_{year} \times m^2 = \sum_{N=1}^{n} [(17 - T_N) \times U + TW_N] \; (2)$$

$$U = \sum_{N=1}^{n} \frac{15}{17 - T_n} \; (3)$$

Another modification is a sensitivity analysis and adaptation of the temperature data including the effects of climate change. The IPCC (2013) projected a raise in average global temperature by 2100 by 0.9°C to 5.4°C. This projected change in mean global average temperature is used to modify the temperature data for the

*Table 8.* Temperature data for different scenarios (in °C)

| Month | Temperature | Temperature' | Temperature'' | Temperature''' |
|---|---|---|---|---|
| January | -5,2 °C | -12,7 °C | -11,8 °C | -7,3 °C |
| February | -6 °C | -1,1 °C | -0,2 °C | 4,3 °C |
| March | -2 °C | -2 °C | -1,1 °C | 3,4 °C |
| April | 3,3 °C | 3,3 °C | 4,2 °C | 8,7 °C |
| May | 10,8 °C | 10,8 °C | 11,7 °C | 16,2 °C |
| June | 14 °C | 14 °C | 14,9 °C | 19,4 °C |
| July | 18,1 °C | 18,1 °C | 19 °C | 23,5 °C |
| August | 16,7 °C | 16,7 °C | 17,6 °C | 22,1 °C |
| September | 12 °C | 12 °C | 12,9 °C | 17,4 °C |
| October | 5,9 °C | 5,9 °C | 6,8 °C | 11,3 °C |
| November | 3,1 °C | 3,1 °C | 4 °C | 8,5 °C |
| December | -3,1 °C | -0,5 °C | 0,4 °C | 4,9 °C |
| **Mean** | **5,6 °C** | **5,6 °C** | **6,5 °C** | **11 °C** |
| **MAX** | **18,1 °C** | **18,1 °C** | **19 °C** | **23,5 °C** |
| **MIN** | **-6 °C** | **-12,7 °C** | **-11,8 °C** | **-7,3 °C** |

calculation of the heating demand and heat power demand. The average monthly temperatures are adapted according to the projections to generate new average temperature data for the projection of a 0.9°C (Temperature") and 5.4°C (Temperature"') increase in global mean temperature (Table 8).

The shift in the set of the temperature data changes the heat power demand for the lower projection with a 0.9°C increase in global mean temperatures (HPD")

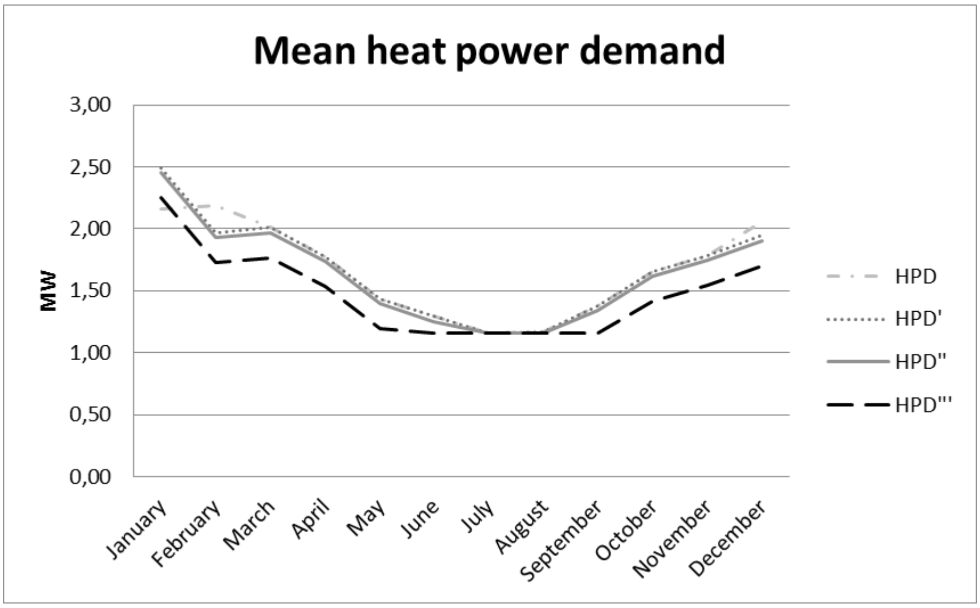


*Figure 4.* Mean heat power demand for Nydal and different temperature scenarios.

and with the 5.4°C increase (HPD'''). Equation 2 and 3 are used to calculate the values for the heat power demand for the planned building area in Nydal for the modified data of outside temperature. The results and comparisons of the calculation are presented in Figure 4. More detailed numbers are given in Annex 2.

### 3.3.2 Modelling and linear optimization

The modelling of the system is done with the modelling program reMIND. The open access program is developed for optimization tasks of resource usage in production and factory lines. Especially the generation of information for the optimization of energy systems is one of the strengths of the program. Another advantage of the program is the possibility to create graphical models with a large amount of nodes (Figure 5). reMIND generates a set of equations for the optimization problem, which is based on mixed integer linear programming and solved with the help of another optimization software (Tremind, n.d.).

The data for the modelling contains nodes and links. The nodes represent access to resources, methods of production for electricity and heat as well as energy demands. Information about investment costs, boundaries and limitations, operating and maintenance costs, maximum production capacities and degrees of efficiency can be added to the nodes. Links show the connection between nodes.

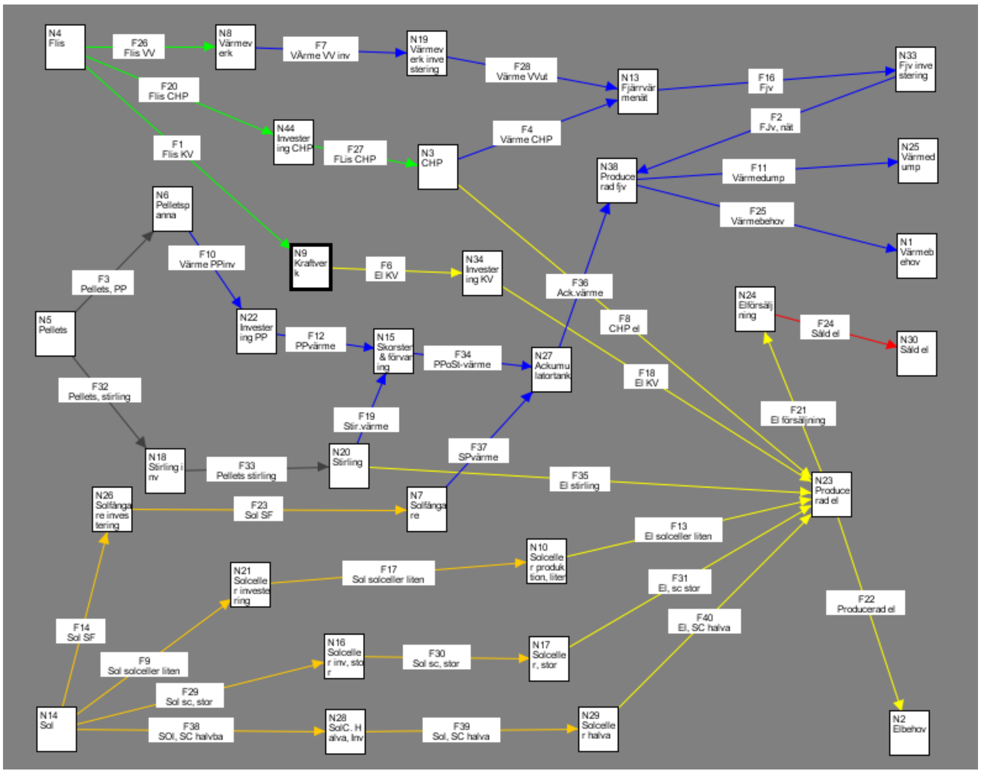


*Figure 5.* Screenshot of a model of an energy system in reMIND.

The calculations for the linear optimization problems modelled by reMIND are solved with the optimization software IBM ILOG CPLEX Optimizer. The program was chosen due to its capacity of solving mixed integer linear programming and large optimization problems. The equation-systems that are modelled with reMIND consist of more than 10 000 equations, constraints and variables. IBM ILOG CPLEX Optimizer is embedded in the interface of reMIND, which eases the optimization (IBM, n.d.).

## 3.4 Evaluation and analysis of an organizational form of ownership

The evaluation and analysis of an organizational form of ownership is based on qualitative research methods. A characteristic of qualitative research is that the presentation of findings is done in verbal or other non-numerical form. The data collection is a starting point for the emerging of concepts and theoretical ideas (Robson, 2011). The findings are usually presented verbally, which entails that context of a situation is important as well as values of involved actors (*Ibid.*). This leads to the fact that the research design is flexible and often emerges throughout the research process (Robson, 2011 & Coolen, 2012). A lower level of structure, richness of detail, extensiveness and high data content characterize the obtained data in qualitative research (Coolen, 2012). The data in this study is gathered by the conduction of semi-structured interviews.

### 3.4.1 Interviews

According to Blaxter *et al.* (2006) interviews are platforms where issues can be discussed and questions asked. Interviewing is considered as a technique of data collection that reveals and presents rich data that are not accessible by questionnaires or observations (*Ibid.*). Interviews are a widely used form of data gathering and give the opportunity for investigation of a phenomena and in-depth study with a high level of detail from an individual perspective (Coolen, 2012). The aim of the interviews is to get information about the situation in Knivsta in regards to the prerequisites for the implementation of a BG. This type of information requires flexibility and adaptation of the information flow and cannot be observed or acquired in a questionnaire. A possible limitation of the interview format is the language, since the interview is highly dependent on the language for securing the flow and accuracy of the information. The interviews are planned and prepared carefully in order to minimize the risk of losing accuracy.

Robson (2011) distinguishes three types of interviews: structured interviews (1), semi-structured interviews (2) and open interviews (3). The semi-structured interview is more flexible than a structured interview and can be adapted to the flow of the interview. Even though an interview schedule is used to structure the interview and to prepare questions and topics that should be covered, the semi-structured interview allows for the adaptation and addition of more questions that are not planned in order to react to the answers given by the interviewee (*Ibid.*). The mentioned characteristics of the semi-structured interview are the decisive factor for choosing this type of interview for this study.

Three different types of questions that can be used in an interview are made out by Robson (2011): closed questions, where the interviewee chooses from at least two given alternatives (1), open questions, which do not restrict the content (2) and scale item questions, which ask for a degree of disagreement or agreement in connection to a certain issue (3). The questions that are used in the interview and prepared in the interview schedule are mainly open questions. Open questions are more flexible and allow for in-depth information and clarification of information and potential misunderstanding (*Ibid.*). The interview is aiming to gather the type of information that open questions offer in order to be able to answer the three last mentioned research question that are presented in section 1.3.

The participants of the interview were chosen together with Martin Wetterstedt, who is highly involved in the planning process of Nydal and familiar with the structures and contact networks in the project. All of the four interviewees were selected because of their affiliation and expertise in the project and planning process of Nydal. All interviewees gave their consent to be named in the paper. The following persons were interviewed:

- Martin Wetterstedt, energy adviser at Knivsta municipality
- Klas Bergström, politician, local government commissioner and chairman in the New Moderates in Knivsta ('Knivstamoderaterna')
- Anders Carlquist, responsible for land- and exploitation at Knivsta municipality
- Lena Fransson, local government head of Knivsta municipality

Prior to the interview, requests with more information about the project as well as relevant fields and topics for the interview were sent to the interviewees. All interviews were conducted face-to-face and took approximately 30 minutes. The language of the interview was Swedish and audiotaping was used to record the interviews. All interviewees were asked for permission to audiotape the interview. After the conduction of the interviews the context was summarized and sent to the participants for validation. The interview guide contained three main blocks: general attitude towards an implementation of a BG in Nydal (1), evaluation of which form of a BG is more likely to be implemented (compare division in section 2.4.1) (2), and possible forms of support by the municipality for the implementation of a BG (3). A more detailed overview of the content of the interview guide is presented in Annex 3.

### 3.4.2 Analysis

Robson (2011) stresses the need for systematic analysis of qualitative data. Not only are the results from the qualitative part of this study systematically analysed, but also connected to the results of the first part of this study. The junction of the results and the systematic analysis of it are important to be able to answer the research questions and to make well-reasoned conclusions for the project.

The data from the interviews is clustered and compared to the information that is reviewed in section 2.4. Reflections and comments are added to the information gathered in the interviews and possible problem fields.

## 3.5 Choices related to the pilot study – units of analysis

The pilot study focuses on the building area Nydal in Knivsta. The choice of the municipality in Knivsta is made because of the existing collaboration and execution of related student projects at Linköping University and the Swedish University of Agricultural Sciences. The building area in Nydal is the planning and is therefore considered highly suitable for the analysis of the introduction and implementation of ESSs and BGs.

The selection of ESSs is argued by its relevance to current issues in society, such as environmental effects and its impact on larger problems such as climate change. The supervisors of this study as well as a discussion point that came up in the starting phase of the work with people that are involved in relating studies suggest choosing BGs as an organizational form of ownership.

## 3.6 Ethical considerations

The conduction of the interviews in this study is linked to ethical considerations. When doing a research process Kvale (1996) highlights three areas: informed consent (1), confidentiality (2) and consequences (3).

All interviewees had the opportunity to remain anonymous. All participants gave their consents to be named in the paper. Confidential information is respected and not published.

The participation in the interview and the answer to every question was voluntary. In order to validate the information from the interview, a summary of the interview, which is the foundation for the analysis, was sent to the participants for validation. In the next chapter the results from the interviews and the simulations of the optimizations of selected ESSs are presented.

# 4 Results

This chapter presents the results of this study, which are based on the presented theories and methods. The main division of this study into the simulation and optimization of ESSs and the analysis of BGs as an organizational form of ownership is continued in this chapter. After the presentation of the results for the ESSs, the outcomes from the interviews about BGs are presented.

## 4.1 Simulation and optimization of ESSs

Four ESSs were chosen for further optimization and modification (Table 7). The modifications lead to new outcomes of the total system costs and the results are presented in this part. The modifications are based on three sets of temperature data (Table 8), which result in new mean heat power demands for the energy system (Figure 4). The first modification is based on the adjustment of the monthly mean temperature for the existing model. The second modification presents the results for a change in the monthly mean temperature with the lower projections of temperature variations due to climate change. The third alternative presents the results of this modification with the higher projections of temperature changes.

### 4.1.1 New results for chosen ESSs

The results that are presented in Figure 6 are divided into four groups: the initial numbers for total system costs of the energy system solutions A, B, C and D with the initial temperature data and heat power demand (Costs), and the three modifications that are presented above (Costs', Costs'', and Costs'''), which are calculated based on the changes in the temperature data and heat power demand.

ESS A has the lowest system costs followed by system C and D. ESS B has the highest costs for the energy system of the four considered alternatives. Detailed numbers for the system costs are presented in Annex 4.

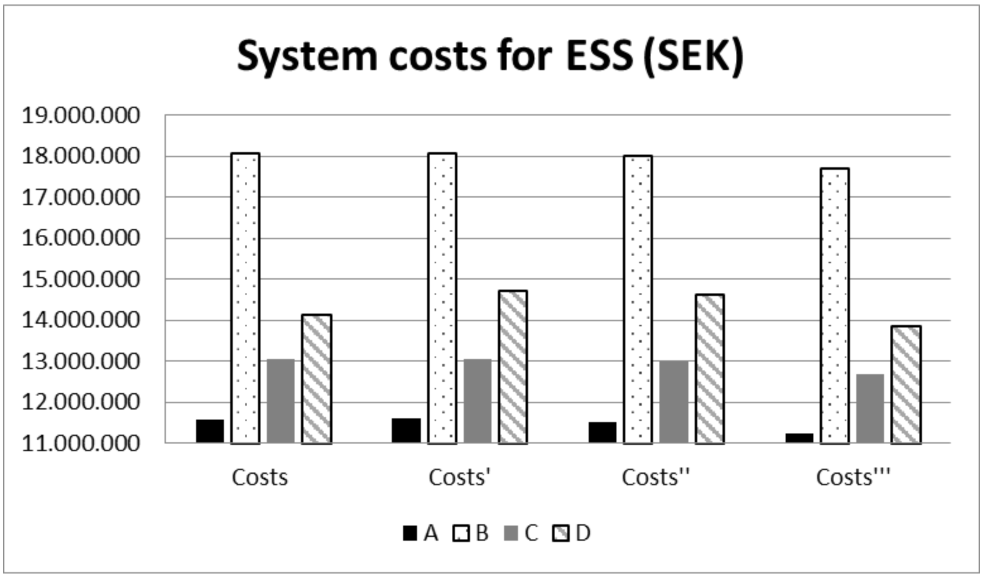


*Figure 6.* System costs for ESSs.

### 4.1.2 Changes in total energy system costs

As indicated in the previous part, total costs of the energy systems changed due to modifications. All changes of the total energy system costs are illustrated in Figure 7 and are further explained in this part. The changes are expressed as differences to initial total system costs (Costs). Exact numbers are presented in Annex 4.

The first modification increased the total energy system costs for the ESS A, B and C marginally. Total system costs of ESS A and C increased by 0.02% and by 0.01% for ESS B. The increase for ESS D was much higher with 4.14%.

The adjustment of the temperature data due to a rise in temperature due to climate change (lower projection) led to a decrease of the total system costs for ESS A (-0.55%), B (-0.35%) and C (-0.48%). However, the total system costs for ESS D were 3.35% higher than the initial value.

The third modification, using the higher projections for a change in temperature data due to climate change, resulted in a reduction of total costs for all considered energy systems. ESS A had the highest decrease with 3.16%, followed by ESS C, which had lowered costs by 2.81%. ESS B and D had almost the same reduction of systems costs on a percentage basis with 2.03% and 2%. The absolute decrease for ESS D was with 282 961 SEK lower than for the other ESS (366 529 SEK).

## 4.2 Interviews about BGs

The answers from the interviews are clustered and divided into three aspects: general attitude towards the implementation of BGs in Nydal (1), evaluation of forms

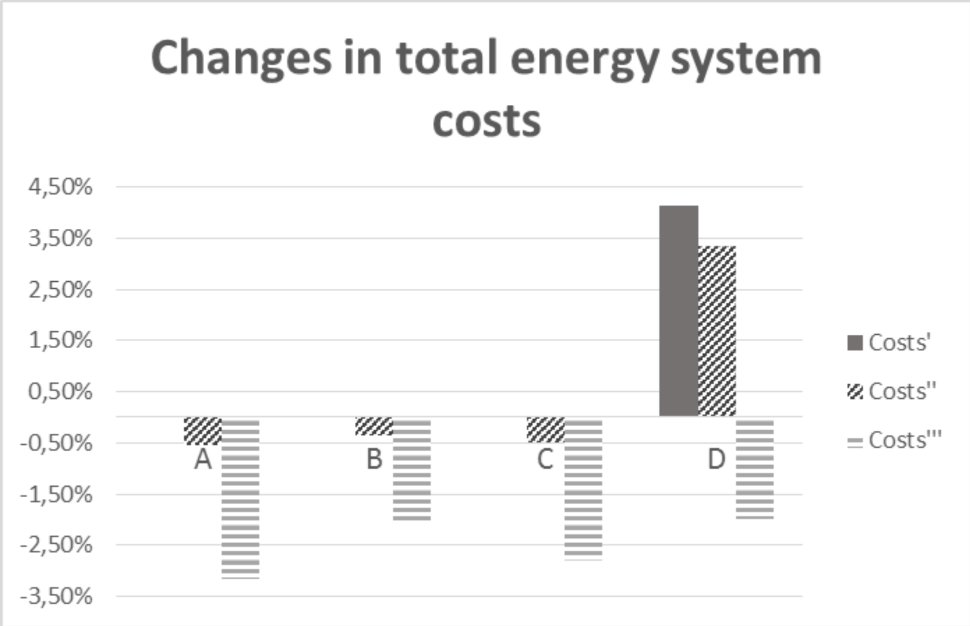


*Figure 7.* Changes in total energy system costs compared to initial total costs for HPD.

for BGs in Nydal (section 2.4.1) (2), and possible ways of support by the municipality to promote BGs (Table 5 and three-point programme in section 2.4.5) (3). An overview of the answers of the interviewees is given in Table 9.

### 4.2.1 Attitude towards the implementation of BGs

While asking the interviewees about the attitude toward the implementation of BGs, not only personal stands on BGs were taken into consideration, but also additional information in connection to Knivsta was revealed. This part summarizes general attitudes, expectations, advantages, obstacles and needs for support in relation to BGs that were named by the interviewees.

The general attitude towards BGs among the interviewees is positive, with three out of four replying they could imagine BGs as an alternative for Nydal. All respondents considered the allocation of land to try BGs as a realistic option. No one expressed direct negative attitudes towards an implementation of BGs in Nydal. Comments that were made in connection to this are that no disadvantages with BGs could be seen and that BGs seemed desirable for Nydal. Positive attitudes from politicians and a desire to try the implementation of BGs by politics were mentioned as well by two interviewees. But it was also named by two respondents that there is a different attitude towards BGs in Sweden compared to Germany.

The participants of the interviews mentioned expectations for BGs and its members. The need for personal engagement and investment of time and resources by the members of a BG was brought up twice.

The time aspect is a concern that was highlighted by all respondents especially in the context of obstacles for the implementation of a BG. Time was seen as a scarce resource for the residents by one interviewee. Three of four answered that they see an obstacle with the high amount of time for the development and implementation of a BG. Building up acceptance of BGs, but also practical aspects such as getting housing as soon as possible were put in connection to the time aspect. Another obstacle that was pointed out by three interviewees is securing financing for the project of a BG. Being able to pay from the beginning of the project without having the chance to delay payments is seen as an obstacle. In addition to that it was mentioned that forms of financing the projects are not implemented yet. A third large area of concern is knowledge and expertise. The level of expertise and knowledge of potential members of BGs is seen as important and evaluated as rather low by all interviewees, which is specified in the fact that BGs are not well known and popular. It was mentioned by one interviewee that a market and interest for BGs needs to be created first. Another one stated the problem of finding and identifying interested people in a BG. When it comes to the expertise and knowledge about certain parts of the projects, it is assumed that only highly educated and skilled residents, which are mentioned to be represented in the municipality, are likely to be involved in a BG. Two responses assessed the level of expertise and knowledge within the municipality as low, especially in comparison to other examples in Germany. It was also mentioned that the practical conduction of a project in the form of a BG is yet unclear. It was stated that new knowledge and expertise has to be gathered and that not only existing knowledge from other countries can be transferred and applied on the Swedish system.

Despite those obstacles, all participants of the interviews identified advantages of the implementation of a BG. Higher involvement into the building process and by that an increase of the quality of the buildings, as well as advantages within energy efficiency, was stated twice. Advantages with interesting architecture as a result of building in the form of a BG were named as well.

Those advantages combined with the positive attitude toward BGs lead to the suggestion that BGs need to be supported. All participants of the interviews emphasized this and two mentioned that presentations of successfully conducted projects are important. Particularly the support in the starting phase and the important role of the municipality to support this phase was stated by half of the interviewees. It was brought up that the municipality was contacted some time ago by a group of families, who were interested in building in the form of a BG.

### 4.2.2 Evaluation of forms for a BG

The answers on the question about possible forms of a BG are not as clear as the attitude towards an implementation of a BG and BGs in general. No one of the interviewees decided on one form and there is no consensus on which form seems to be more realistic for the implementation of BGs in Knivsta. None of the forms were excluded and all participants said that they are not sure about this. One person brought up the idea that it might be realistic to have a hybrid of the three forms in the beginning. Another participant of the interviews answered that either the assisted and private form of a BG or the BG in the form of a cooperative is most likely. In contrary, another respondent stated that cooperative forms existed in Sweden before and were not that popular and wide spread. The conclusion of that person was that this form is rather unlikely.

### 4.2.3 Support by the municipality for BGs

Answers in the field possible forms of support are clustered in five fields: general conditions for support in the municipality (1), subsidies (2), support in the field of land allocation and land use (3), support in the fields of information and counselling (4), and support of a model project (5).

An important condition for the support in the municipality is the positive attitude towards BGs. This is also reflected in the possibilities to support BGs within the municipality. One interviewee recognized the willingness by the municipality to support and market BGs since it is an upcoming idea and trend. However, this support needs to follow certain legal boundaries. One of them is the principle of equal treatment, which was mentioned by three respondents. It says that every citizen and also all building forms need to be treated equally. It was stated that is not allowed to assign resources to a certain form of building. Another point that was mentioned by half of the participants of the interview is related to financing. The municipality has tight economic constraints and it was mentioned that the availability of support is dependent on costs and resource use. Recruitment of new employees to help supporting BGs is therefore seen as too expensive. Due to that it was concluded that external support is in general more realistic (e.g. development projects or sharing of regional or state resources) than intensive support by the municipality. On top of that, one interviewee responded that the municipality could not compete with the private industry.

None of the respondents saw subsidies as a possible form of support. One person argued that low land prices in the municipality make subsidies for the land unnecessary.

Reserving and allocating land for projects by BGs is the support in the field of land allocation and land use that was mentioned the most. Three respondents stated that this form of support is likely. They mentioned that the land should be adapted to the needs of a BG, which means forming of smaller parcels. One interviewee clarified that the municipality owns large parts of the land in Nydal. Another respondent mentioned that it might be difficult to determine the market price.

However, three people answered that the land needs to be sold at market price. One answer stated that it is not possible to sell land cheaper than the market price. On the contrary, two respondents mentioned directed selling of land to private people and BGs as a possible support for BGs. Even though it is not possible to set special requirements on buildings, which two participants of the interview said, there is no land competition in the distribution process for the selling of land in Nydal.

The only answer that was given by all participants of the interviews in the field of information and counselling is that the municipality is willing to support and develop information and information material for example spreading information about BGs. Simultaneously, three respondents highlighted that the support is highly dependent on the costs of the support and possibility to use or redistribute already existing resources. Especially setting up a contact point was seen as critical in the light of economic constraints. One interviewee answered that it is not possible to establish a contact point. Half of the answers stated that general advice is available to everybody and can be seen as a support for example handing in the right documents in the building permit process. Other support, such as counselling, was not cited that often and was seen as a more realistic way of support if external support of funding would be available (e.g. by the Swedish Energy Council, Energimyndigheten). Lack of knowledge in the field of BGs within the municipality is something that was stated in connection to that. One respondent said that the municipality would try to contribute and help to develop an infrastructure for the support in the field of information and counselling. Another interviewee stated that interested people (i.e. families and groups that showed interest in BGs earlier) would be contacted to initiate the start of a project by a BG.

A model project was viewed as an interesting project to market BGs by all interviewees. However, no participant saw a model project as a realistic and feasible option for support that could be implemented by the municipality. The degree of scepticism varied between the participants of the interviews. One respondent stated the need to answer the question on how skills can be obtained. Three interviewees stressed the importance of external funding and the need to involve several actors, as for example a collaboration project with other municipalities, which the municipality got experience in with another project for the development of regional action plan with the municipalities in the Arlanda region (Sigtuna, Upplands Väsby, Vallentuna). The results for the simulations and optimization of ESSs as well as the results from the interviews are analysed in the next chapter.

*Table 9.* Summary of the answers of the interviews

| Attitude towards the implementation of BG | Possible ways of support by the municipality | Evaluation of forms of BG |
|---|---|---|
| positive aspects: increase of building quality & higher involvement in the building process | develop information and information material | possible to have a hybrid of the three forms |
| positive & desirable | support limited by equal treatment principle | none of the forms were excluded |
| no disadvantages with BG | general advice | |
| different attitude in Sweden than in Germany | reserving and allocating land | |
| critical towards obstacles (time aspect; securing financing; building up acceptance for BG; knowledge and expertise rather low; identifying interested people) | establishment of contact point unlikely, external support more realistic | |

# 5 Analysis

The analysis of the results from this study is divided into two parts. In the first parts the outcomes from the modifications of the ESSs are analysed. In the second part the results from the interviews are parsed.

## 5.1 Analysis of the results for modified ESSs

The results for the modified ESSs are evaluated in two steps. In the first step, the results for the modifications are put into context with the initial values for the system costs of the ESSs. This analysis concentrates on the differences of the system costs and examines the underlying structures for these results. The second part of the analysis of ESSs focuses on the modifications that were made in connection to the projections of a temperature change due to climate change. A sensitivity analysis was conducted for the results of this modification.

### 5.1.1 Results of the new and old optimizations

The aim of the modifications is to get an answer on the two first research questions. The first question aims to examine the effect of a change of temperature on the energy system costs of the proposed ESSs. The change in temperature and the increase of the peak load was assumed to lead to higher capacities of the production plants, which in turn leads to an increase of the total energy system costs. As presented in section 4.1.2 this was true for all considered ESSs. ESS D showed the expected increase in total energy system costs. The other ESSs increased marginally in total costs. Examining the compilation of the energy systems of the proposed ESSs helps to explain the behaviour of the total system costs. The three ESSs that hardly showed an increase in total system costs for the first modification of temperature data get their basic energy supply by a power plant (electricity) and thermal power station (heat) as well as by solar cells (electricity) and solar panels (heat). The ESS that reacted most sensitively on the change of the temperature data and peak load gets its energy supply by a combination of a furnace with Stirling motor (heat & electricity) and solar cells. Since the change in temperature mainly has an effect on the heating demand, the supply of heating is crucial and needs to be focussed on. According to the results of the first modification, the ESS with the Stirling motor showed more visible reactions to the changes in temperature data. It can be concluded that this system is more sensitive to changes in temperature data especially in the rise of peak loads in relation to total system costs. One of the reasons for this effect is the dimensioning of the different heating supply methods. Whereas a thermal power station reaches higher dimensions of capacity, Stirling systems usually have a lower sizing of capacity and more units need to be combined to reach a higher capacity. This implicates a higher sensitivity to changes of peak loads in relation to total system costs, due to the instalment of a whole new unit instead of an adaption of the initial dimension.

Another outcome that is related to the first research questions are the relations of the behaviour of changes between the different ESSs. ESS D showed a different behaviour than the other ESSs. It is worth examining the relation between those ESSs. Even though the change expressed in percentage differed between those systems, it is noticeable that the difference was the same in absolute terms. Similar as in the first part of the analysis, this result can be explained due to the fact that all ESSs have the same main supply for heat. ESS B has another supply method for heat. One clarification for the fact that there were no changes in absolute terms for the energy system costs can be that solar panels in ESS B cover a base load and not the peak load, which was changed in the first modification. The peak load is covered by the thermal power station and therefore the changes in a variation of capacity had the same effect as for the other ESSs.

The second research question has the goal to find the most cost-effective ESS. Since ESS A has the lowest total energy system costs before and after the modifications, this becomes the most cost-effective ESS. A remaining question is if this system is the most economical solution even for other modifications of the systems. To analyse this question a sensitivity analysis for temperature changes due to different projections of climate change was conducted. The results of this analysis are presented in the next section.

### 5.1.2 Sensitivity analysis for climate change

The modifications of temperature data due to projected changes in the climate led to new results for the total energy system costs of all ESSs. Whereas three ESSs (A, B and C) showed a decrease in total energy system costs for the modification of the lower projection of climate change, the costs for the energy system for ESS D were still higher than in the initial case. Looking at the absolute and relative figures of this change in the numbers reveal that ESS D is affected the most of all other ESSs by the change in the temperature data. This is linked to the analysis in section 5.1.1 about the sensitivity of the systems. The same trend is visible for the changes for the higher projection and the third modification. ESS A is the most cost-effective solution, but the decrease rate in total energy system costs from ESS D is approximately twice as high as for the other ESSs. This means that the difference in absolute terms is decreasing between ESS D and the other ESSs. For higher projections of temperature increase due to climate change, this implies that at some point ESS D has lower total energy system costs than ESS A. This argument can further be strengthened by the fact that heat for ESS D is supplied by a small-scale form of heat supply, which becomes more economically profitable in energy systems with lower dimensions and capacities. As mentioned in section 5.1.1, ESSs A, B and C changed in the same way in absolute numbers. The results of the sensitivity analysis for all ESSs are presented in Table 10.

*Table 10.* Sensitivity analysis for impacts of climate change

| ESS | Difference Costs'' to Costs' | | Difference Costs''' to Costs'' | |
|---|---|---|---|---|
| | SEK | % | SEK | % |
| A | -65697 | -0,57% | -303241 | -2,63% |
| B | -65697 | -0,36% | -303241 | -1,68% |
| C | -65697 | -0,50% | -303241 | -2,33% |
| D | -111824 | -0,76% | -757046 | -5,18% |

## 5.2 BGs in the context of Nydal

The results from the interviews are compared to the information from the literature review (section 2.4). Reflections on this comparison are made and comments added. The analysis of the results aims to give an answer on the research questions that are linked to BGs. In accordance with the research questions, the analysis is divided into three parts: analysis of the attitude towards the implementation of BGs in Nydal (1), evaluation of realistic forms of a BG for the implementation of BGs in Nydal (2), and a concluding analysis of the likelihood of the implementation of BGs in Nydal (3).

### 5.2.1 Attitude towards the implementation of BGs in Nydal

The attitude towards the implementation of BGs in the municipality of Knivsta is positive according to the answers from the respondents. BGs were considered as a desirable option for Nydal and politicians share a positive attitude towards BGs. This was reflected in the willingness to know and do more about BGs. Support for

BGs was seen as important and there is a willingness and awareness that the municipality needs to support the starting phase of a BG. Little support is implemented yet, which can be compared to the situation in Freiburg at the start of the first projects. As Kasioumi (2011) describes it, there was little interest and support in the beginning from the city planners of the German city. Even though supporting those projects was time consuming, first successfully conducted projects opened up for more projects and possibilities for collaborations, which eventually ended up in the development of the Forum Vauban. The respondents of the interview mentioned the presentation of successfully conducted projects as an important point.

At the same time it was stated that attitudes differ between Germany and Sweden and that it takes time to build up acceptance and knowledge. Respondents stated that expertise could not be transferred and applied easily from another country. These aspects can be linked to the history of BGs in Germany in the 1970s (Schuster, 2005). Since then BGs, its forms and motivations have evolved. The same need for change and adaptions must be accepted when introducing the concept of BG to another country. Scepticism was seen as a natural part of the process and takes time to overcome.

The interviewees showed awareness of basic characteristics of a BG, as they were able to name advantages that are stated in the literature. Higher involvement in the building process, increase of the quality of buildings, interesting architecture and advantages with energy efficiency is mentioned as important advantages of a BG. It is not surprising that wishes form the residents were known to the interviewees as well, for example the desire that was expressed in the citizen's dialogue to have a higher level of variation in the forming of the buildings (Knivsta kommun, 2015d). This showed that there is an interest to develop BGs and adapt the process of getting there by taking into account knowledge from other sources (e.g. conduction of dialogue with residents (Knivsta kommun, 2015c).

#### 5.2.2 Favourable forms of a BG for successful implementation of BGs in Nydal

Answering the question which form of a BG seems to be favourable for Nydal was not clear. The interviewees did not agree on one or more forms and neither did all respondents exclude one form. One participant named that assisted and private BGs or BGs in the form of a cooperative are most likely, another one said that BGs in the form of a cooperative might be rather unlikely. A third person stated that in the beginning a hybrid of the three forms might be most likely. According to the overview in the literature review, free and private (ten examples) and assisted and private (eleven examples) forms of BGs are the most popular ones. Only one example is from a BG in the form of a cooperative. These numbers strengthen the argument that BGs in the form of a cooperative might not be that popular and realistic for Nydal. However, since those numbers do not claim to be comprehensive, other ways of analysis must be conducted.

Two respondents mentioned that members of the BG have to invest a lot of time, resources and personal engagement into the project. They also predicted that high-educated residents would lead the way. Comparing those requirements from the interviewees to the characteristics of the different forms helps to identify forms that are more likely than others for Nydal. The free and private form of a BG requires a high level of expertise from the members (Schuster, 2005) and therefore fits to the requirements well. Even the assisted and private form of a BG requires expertise and a high personal engagement from the members and is seen as an attractive solution for municipalities (Schuster, 2005). Those two forms can be seen as more realistic than the third form from a municipal point of view. In addition, both forms have in Germany resulted in 20-30% lower housing prices compared to comparable apartments (Schuster, 2005). Under the current circumstances of the housing market in Sweden, which faces high costs of housing and an increase of prices (SABO, 2013), those options seem more likely.

The cooperative form of a BG was valued less probable for the implementation of BGs in Nydal. The results from the interviews stated that land in Nydal had to be sold at a market price with no potential for subsidies. Facing the situation in the Swedish housing market with a shortage of housing, high demand and prices of housing (SABO, 2013), the cooperative form, which usually supplies housing space for people from a low-income sector (Schuster, 2005) is not assessed as a realistic option. Another argument for this conclusion is connected to the finding of financing for this form of a BG. The form is characterised by a diversified finding of capital (Schuster, 2005), with a municipality as a key part in the support of financing. Respondents stated that BGs are not yet known in Knivsta and that the municipality has a tight budget. This constitutes a problem in the financing, which is one of the most important aspects of the whole project.

### 5.2.3 Requirements for a successful implementation of BGs in Nydal

One important factor for evaluating the likelihood of the implementation of BGs in Nydal is the general situation and infrastructure towards BGs in Nydal. The first part of this analysis focuses on those aspects. Another important factor that needs to be assessed to make a qualified statement on the requirements for a successful implementation of building projects by BGs in Nydal is the development phases of a BG (Gephart, 2013). After an assessment of the likelihood for the initiation of BGs in the finding phase, the likelihood for success in the planning phase and implementation phase are analysed.

The positive attitude towards the implementation is an advantage for the realisation of projects by BGs in Nydal. It is important to take into account that the situation in Sweden is different compared to other countries. As recognized by Walker and Simcock (2012) it is important to have political support to favour grassroots activities such as BGs. Austria, Denmark and Germany are named as good examples for such a support. As concluded earlier, the popularity of BGs is lower in Sweden than in Germany and also legal frameworks differ (e.g. equal treatment principle). Motivations for starting a BG differ and evolved throughout several years in Germany (Schuster, 2005). The same process might occur in Sweden in the future and especially the reduction of housing costs and the desire for special forms of housing can be seen as reasonable motives for the start of a BG (Schuster, 2005; Svensson, 2012; SABO, 2013).

Gephart (2013) mentions three potential critical parts in the finding phase: finding of interested people (1), search for a suitable area of land (2), and the decision on an architect (3). As stated by the participants of the interview, a market for BGs needs to be created first and it is acknowledged that it is difficult to identify and find interested people for a BG. The housing sector in Sweden experiences a shortage of housing intensified by a decreasing amount of available apartments since the end of the 1990s (SCB, 2012; SABO, 2013) and one of the highest increases of housing prices in the EU (Eurostat, 2014c). Given those circumstances, it might be easier to find interested people that are looking for new ways to get affordable options of housing. As reported by one of the interviewees there was some interest expressed in the past by a group of families, which strengthens this estimation. Professional support is named as one important factor to promote forming of BGs (Schuster, 2005; Kasioumi, 2011; Svensson, 2012; Gephart, 2013) and could improve the situation of finding interested people.

Finding land is another crucial aspect in the finding phase. The distribution of small parcels is considered as an effective support instrument (Schuster, 2005). Forming parcels of land in the right size, which is also referred to as smart parcelization, is one factor for promoting BGs (Schuster, 2005; BVBG, 2012; Svensson, 2012; Adams *et al.*, 2013). A smaller parcelling of the land in Nydal was valued by the participants of the interviews as a highly probable initiative to promote BGs. Schuster (2005) identifies financial support in form of subsidies or selling municipal owned land at a lower price in connection with the fixing of a share of building activities that should be realized in the form of a BG as a powerful tool to support the implementation of BGs. Even though financial support or subsidies are not a realistic option for Nydal due to the equal treatment principle, the support for the implementation of BGs is strong in terms of finding land, because a separate allocation of land to try a BG was seen as extremely likely by the interviewees. This is strengthened by the fact that the interviewed people are responsible for the decision making of the land allocation in the municipality.

Gephart (2013) identifies the decision on an architect as one obstacle in the finding phase. This problem is also acknowledged by Schuster (2005), who sees a problem in the match making in the starting phase between architects and private persons. One possible solution to this problem is the creation of contact points (Schuster, 2005; Svensson, 2012). As it is described more thoroughly in the next part, a contact point is not established in Knivsta and the prognosis for the future is therefore less promising. Other aspects that can be a hinder in the finding phase are group dynamics that are difficult to manage (Svensson, 2012; Gephart, 2013), problems with engaging sufficient amount of members in the starting phase (Svensson, 2012), and the high risk carried by members of a BG (Svensson, 2012). The participants of the interviews mentioned that even for those hinders no measures are implemented yet, but a majority of the interviewees were aware of those risks.

The most critical part in the planning phase is the amount of decision-making processes that need to be done by the members of the BG (Gephart, 2013). Suggestions to overcome those critical parts are counselling of interested people, setting up contact points and the conduction of organization, distribution and management by the municipality (Schuster, 2005). Once again, when it comes to support in Nydal, the interviewees mentioned that the municipality has to follow the equal treatment principle. Subsidies are therefore not possible and would also be problematic without the existence of the equal treatment principle, due to tight economic constraints in the municipality. The respondents of the interview highlighted that the availability of support is depending on costs and resource usage. Creation of a contact point was seen as problematic or even impossible. According to the interviewees the municipality is willing to support and develop information material (e.g. for promoting BGs). It was stated that general advice from the municipality is available to everybody. Comparing those statements to the ideal support measures mentioned in section 2.4.4, it could be concluded that support in the best possible form is highly unrealistic and that most of the support will be limited due to economic constraints. As a consequence, intense financial means of support are unlikely, which was also stated by the interviewees. External support was seen as more realistic. Existing collaborations with external partners as well as the fact that BGs were considered as an upcoming trend in Knivsta lend credence to the opportunity to get external support and funding. In line with the statement from the interviewees, the municipality is willing to help building up an infrastructure and counselling was seen as a more realistic option with external funding.

The implementation phase benefits from support in the parts of the implementation and construction (Gephart, 2013). The situation for the support in Nydal is described in detail for the planning phase and does not differ from the situation in the implementation phase. Schuster (2005) names the realization of a model project, where contact points helps with the distribution and control of land options, proving of projects, coordination of land acquisition, building application and implementation as a possible way of support by the municipality. This way of support is introduced in Stuttgart and is part of the three-point programme (*Ibid.*). The respondents of the interview considered the model project as an interesting alternative. Similar as in the planning phase, this measure was only seen as a possible support method with the help of external support.

All in all, some of the requirements for the successful implementation of BGs in Nydal can be seen as fulfilled. The municipality owns large parts of the land in Nydal and it is possible to sell land directed to private people and BGs, since there is no requirement to have a land competition. Together with a positive attitude and awareness of advantages and risks of BGs within the municipality, initiation of BGs can be seen as likely. However, it is still unsure if the project will be successfully completed. One reason for this assumption is the lack of support structures (e.g. contact point, counselling, subsidies, etc.). At the moment the successful completion of the projects depends highly on the expertise and motivation of the members of the BG, which is rated as high in Knivsta by one of the respondents. However, judging from the amount of conducted examples of BG in Sweden, the knowledge spread and expertise seems to be not as high as in Germany yet. Furthermore, it is not sure if residents from Knivsta will be the ones, who will start a BG or if it will be people from other municipalities. There still exists uncertainty about the degree of support by the municipality or other external support. External support in form of financing or knowledge transfer is seen as a realistic option and this makes the model project a possible option and means of support. Nevertheless, the low awareness of BGs in Knivsta and major parts in Sweden is a problem for finding important partners in the construction and financing of the project, which is a risk (Gephart, 2013). Therefore, the overall probability of successful conducted projects by BGs in Nydal is moderate or eventually likely, but not highly likely. Even though ESS A is the most cost-effective ESS, ESS C as a decentralized ESS can be seen as more likely for the implementation of a BG in Nydal. The decentralized system offers the opportunity to control the supply of energy to a higher degree than with a centralized system, which is unlikely to be implemented and managed by BGs in Nydal due to the goal to realize only a few BGs. The desire to have a high degree of control and influence is in line with the motivations for starting a BG. The results and the outcomes of the analysis of this study are critically discussed in the next chapter.

# 6 Discussion

This chapter discusses the outcomes of the analysis with a special focus on sustainability. There is a tension in the combination of quantitative and qualitative research, the ‘incompatibility thesis’. Sale *et al.* (2002) cited by Robson (2011) claims that quantitative and qualitative methods cannot be combined since they are not studying the problem in the same manner and therefore are distinct and incompatible (Robson, 2011, p.162). However, Howe (1988), also cited by Robson (2011), states that the combination of qualitative and quantitative methods can have positive effects especially when important factors of the study cannot be separated. The comprehensive argument made by Howe (1988) can be applied to this study. The study about the ESSs is quantitatively based, whereas the study of BGs follows a qualitative approach. The combination of the simulation and optimization of ESSs with the outcome of the evaluation and analysis of an organizational form of ownership plays a key role in the feasibility assessment of introduction and implementation of the proposed system. Additional limitations are discussed in section 6.2.

## 6.1 Sustainability

The simulation and optimization of investigated ESSs identify ESS A as optimal from a cost-perspective in all cases. It has to be acknowledged that not all initially developed ESSs were chosen for further optimization. The energy supply for all ESSs is generated by renewable energy sources, which makes the production phase of all ESS climate neutral. The ESS with the housing type ‘BBR21’ is the most cost-effective solution and likely to be chosen from conventional constructors if not regulated other than by the market. Even other building types (e.g. ‘Minimihus’) that have higher total energy system costs might be favourable for conventional constructors under market conditions. The reason for this lies in the division of fixed costs of the buildings (e.g. investment costs for the building) and operational costs (e.g. costs for the supply of energy). Conventional constructors and landlords only earn on the net rent, but not on the service charges (BVBG, 2011). A higher consumption of electricity and heat in the above-mentioned housing types, still leads to a lower total system cost under current circumstances. This situation poses a dilemma between the choice of optimizing energy usage or total energy system costs.

One approach to tackle this dilemma is to provide incentives such as subsidies, taxes or payments for those who improve the energy performance of a building (Horne, 2012). These economic incentives and instruments have the purpose to change market conditions in order to promote energy-efficient buildings (UNEP, 2007a). Another approach to tackle this problem is not to change the market conditions, but to look at the initial problem of the dilemma: the division of fixed and operational costs. The organizational form of a BG solves this problem by the removal of this division. Constructors and landlords act also as tenants of the buildings and have an incentive to minimize the total system costs and not only one part of the costs (Horne, 2012).

Even if this dilemma can be solved, is the most cost-effective ESS also the most sustainable one? The concept of resilience is an important concept to name in this discussion. Some of the more expensive systems (e.g. ESS with Stirling motor) are not as vulnerable to defects in the supply system as some of the more cost-effective ones (e.g. ESS with a thermal power plant). Larger production plants with higher capacities enable economies of scale and lower total system costs. At the same time the system gets more dependent on a lower amount of supply units, which decreases the resilience of the system.

Resilience is an important concept, which in times of volatile prices of fuels for energy production, increases in importance. ESSs that are running on fuels that need to be bought (e.g. wood pellets) are more vulnerable to changes of fuel prices than ESSs that are not dependent on those fuels (e.g. solar cells). All ESSs consist at least of one energy production method that is dependent on fuels that need to be bought. The ESSs that use the least amount of those fuels can be seen as more resilient to changes in fuel prices.

Another important discussion point in relation to sustainability issues is the question of a holistic approach of energy systems. According to Horne (2012), 80-85% of the energy use in the residential building sector is linked to the operational phase. This justifies the focus on this phase, but it also reminds of the importance not to forget the construction and demolition phase of an energy system Even if systems for the energy supply are made more efficient, there is still another 15-20% of the energy use, which lies outside the system and considerations of energy efficiency improvements.

Focussing on energy efficiency improvements brings up another risk in the context of sustainability: increase in total energy demand. As recognized by Horne

(2012), improvements in the buildings heating and insulation systems led to a drop in energy use per household. Nevertheless, energy demand in the residential sector in developed countries increased by more than 30% between 1970 and 2001, due to an increase of households and a growing trend of people living alone in smaller households or larger houses with larger areas per person. While solving problems with energy efficiency, this might still mean stagnation for solving the problem with climate change.

One may ask if energy planning in the building process needs to be connected to larger concerns such as climate change. Especially in the planning of building by projects of a BG, broader concepts and goals might seem too far away to grasp and block one's view on more concrete and important aspects such as planning of the building, legal forms, financing, functionality or comfort of the building. Focus on larger global problems might not be satisfying and sufficient, as "people often do not behave consistently with their level of concern about environmental problems" (UNEP, 2007a, p.23).

Sustainability of a building area is coined by more than only the sum of the infrastructure and buildings (Haapio, 2012). Public meeting places, large green areas and other shared resources and infrastructure are socially and environmentally linked in a complex system (Schuster, 2005). It is important to look at all pillars of sustainability. If the focus is only on environmental aspects of energy efficiency and reduction of resource use, this might lead to solutions that are becoming more expensive and exclusive for some part of the community. In that case, improving the environmental pillar of sustainability would at the same time imply a decrease in economic and social sustainability for some other groups. Because of this, an important question to discuss is if projects by BGs are more sustainable than conventional buildings. This question cannot be answered generally, but experiences from Vauban show promising results: the economic pillar is affected in a good way, as building costs are 25% lower than comparable solutions (Kasioumi, 2011). At the same time, energy efficiency is improved and energy systems switch to renewable energy systems. Resource consumption decreases and architecture improves. Also social sustainability efforts are made with solutions for open space and strengthening of social aspects in the community by common activities (Forum Vauban, 1999; Wirtschaftsministerium Baden-Württemberg, 1999 as cited by Scheurer & Newman, 2009).

## 6.2 Limitations

The simulation and optimization of ESSs is based on general data, which is converted and adapted. One limitation is the uncertainty of the system boundaries (e.g. distribution) of the data for the simulation from the initial student project. Not all parameters are clearly known and data might be inaccurate. For specific and unique projects such as building of houses, accurate data is often first available after the end of the construction phase. In this study, major components of ESSs are identical and have only minor differences in the composition of the systems. Inaccurate data within those major parts (e.g. costs of the building type, which are the same for all) have therefore no impact and affect all systems in the same way.

Planners from the municipality that are involved in the project of the new building area were interviewed for the study of BGs. Even though different perspectives within the municipality are considered, the interviews have a bias on the leading members of this project. As stated in the results, it is seen as a difficulty to identify and find interested people. Inclusion of comments from interested people for starting a BG can add fruitful insight for the planning process and the needs in the finding and planning phase as well as motives for starting a BG from a resident point of view. The project is in an early stage and potential interested people in a BG are unknown.

As mentioned in section 6.1, sustainability efforts can be divided into several aspects. This study compares ESS, which are seen as equally optimal from an environmental point of view. It was mentioned that all production methods for the energy supply are climate neutral. However, other environmental impacts were not taken into account and impacts on the climate in the construction and deconstruction phase of the production methods are not part of this study. A holistic life cycle analysis assessing all environmental impacts gives a comprehensive overview of the environmental impacts. This analysis has not been conducted in this study.

# 7 Conclusion

Developing sustainable ESSs for Nydal and evaluating the possibility to secure their implementation through BGs was the main aim for this study. Findings show that changes in temperature data with higher peak loads result in an expected outcome of increases of total energy system costs. A most cost-effective ESS is found (ESS A), but also an unexpected sensitivity to changes of peak load for ESSs for small-scale heat supply production plants. The outcome has important implications for the evaluation of the adaptability of a decentralized ESS with a higher degree of self-sufficiency. The analysis of a BG as an organizational form for Nydal reveals a positive attitude within the municipality towards the implementation of BGs, but also the insight that free and private as well as assisted and private forms of a BG are most realistic for the implementation of BGs in Nydal in general.

Positive examples from Germany show that projects by BGs contribute to tackling local problems, which in their turn assist in solving global challenges such as climate change. Local measures are essential and contributions by BGs in the field of energy efficiency, environmental impacts, community collaboration and development support the work with local problems and needs. Development of feasible and practical ESSs facilitates the planning of municipalities towards the 20/20/20 goals. BGs play an important part in securing the implementation of ESSs, while at the same time strengthening social urban planning efforts. This study examines the situation in Knivsta and helps to adapt the support of the municipality.

More research in the planning and implementation phase of a BG is needed. One suggestion for further research is the analysis of the environmental and social performance of successfully conducted projects of BGs in Sweden. An analysis about the applicability of the different forms of a BG in relation to legal frameworks, institutional and municipal support can give more insights about the different development phases throughout the BG and their importance for and dependence on specific means of support. Besides acquiring more empirical data about the implementation of BGs in Sweden, one important research field is the analysis of motives from members to join a BG.

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# Annex 1 – Overview and plans of Nydal

*Figure 8.* Aerial photograph over Nydal (Photo: Knivsta kommun, 2014c).


*Figure 9.* Illustration plan over Nydal (Knivsta kommun, 2015c).

# Annex 2 – Data for developed ESSs

*Table 11.* Monthly mean heating power demand [in MW] (adapted from Hagelberg *et al*., 2014)

| Month | BBR21 (A) | BBR21 (B&C) | Minimihus (A) | Minimihus (B&C) | Passivhus (A) | Passivhus (B&C) |
|---|---|---|---|---|---|---|
| January | 4,7 | 5 | 3,6 | 3,9 | 1,7 | 2 |
| February | 4,9 | 5,2 | 3,8 | 4,1 | 1,8 | 2,2 |
| March | 4,2 | 4,5 | 3,3 | 3,6 | 1,6 | 1,9 |
| April | 3,4 | 3,7 | 2,7 | 3 | 1,5 | 1,8 |
| May | 2,2 | 2,5 | 1,9 | 2,2 | 1,2 | 1,5 |
| June | 1,8 | 2,1 | 1,5 | 1,8 | 1,1 | 1,4 |
| July | 1,1 | 1,4 | 1 | 1,3 | 0,9 | 1,2 |
| August | 1,3 | 1,6 | 1,2 | 1,5 | 0,9 | 1,2 |
| September | 2,1 | 2,4 | 1,8 | 2,1 | 1,1 | 1,4 |
| October | 3 | 3,3 | 2,4 | 2,7 | 1,3 | 1,6 |
| November | 3,5 | 3,8 | 2,7 | 3 | 1,5 | 1,8 |
| December | 4,4 | 4,7 | 3,4 | 3,7 | 1,6 | 1,9 |
| **MAX** | **4,9** | **5,2** | **3,8** | **4,1** | **1,8** | **2,2** |

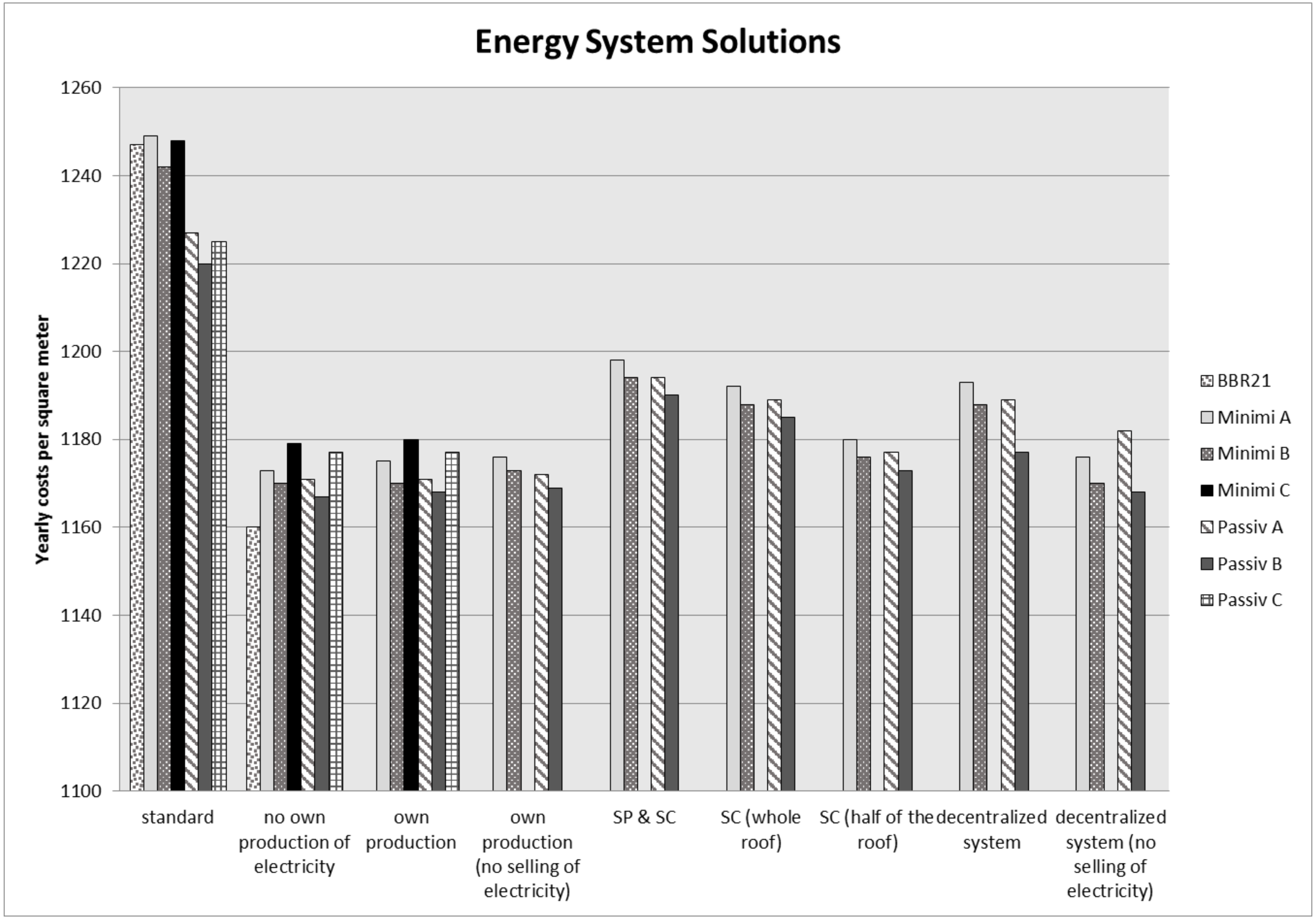


*Figure 10.* Overview of costs for ESSs (adapted from Hagelberg *et al.*, 2014).

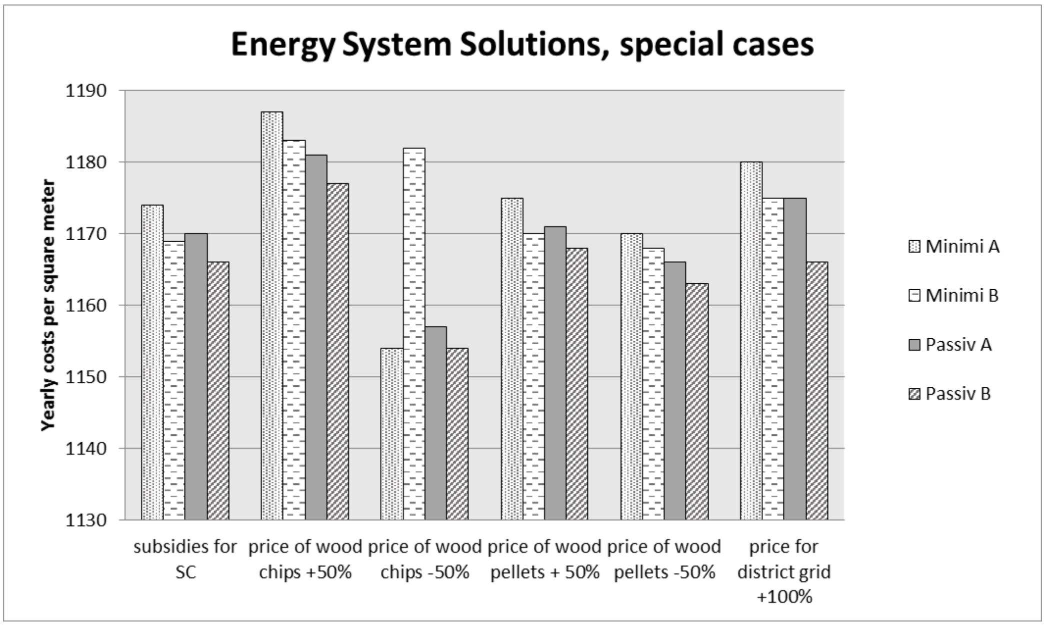


*Figure 11*. Overview of costs for special cases of ESSs (adapted from Hagelberg *et al.*, 2014).

*Table 12.* Mean heating power demand [in MW]

| Month | HPD | HPD' | HPD'' | HPD''' |
|---|---|---|---|---|
| January | 2,16 | 2,49 | 2,45 | 2,25 |
| February | 2,19 | 1,97 | 1,93 | 1,73 |
| March | 2,01 | 2,01 | 1,97 | 1,77 |
| April | 1,77 | 1,77 | 1,73 | 1,53 |
| May | 1,44 | 1,44 | 1,40 | 1,19 |
| June | 1,29 | 1,29 | 1,25 | 1,16 |
| July | 1,16 | 1,16 | 1,16 | 1,16 |
| August | 1,17 | 1,17 | 1,16 | 1,16 |
| September | 1,38 | 1,38 | 1,34 | 1,16 |
| October | 1,66 | 1,66 | 1,62 | 1,41 |
| November | 1,78 | 1,78 | 1,74 | 1,54 |
| December | 2,06 | 1,94 | 1,90 | 1,70 |
| **MAX** | **2,19** | **2,49** | **2,45** | **2,25** |

# Annex 3 – Interview guide

Aim of the interview:

- Gather information on the situation in Knivsta regarding the implementation of BGs
- What possibilities does Knivsta have to promote the implementation of BGs?

Introduction of the interview:

- Introducing the project and the aim of the study
- Securing & laying a common understanding of BGs
  - Define a BG (section 2.4)
  - Distinguish different forms of a BG (section 2.4.1)
  - Name typical development phases of a BG (section 2.4.2)

Conduct of the interview:

- General attitude towards BGs: BGs in Nydal, yes or no?
- Which of the above-introduced forms seem to be most realistic/feasible in Knivsta?
- If BGs are promoted and supported by the municipality, which form of support is conceivable (Table 7 and three-point program in section 2.4.4)?
- Could you think of other ways to support BGs in Knivsta?

# Annex 4 – Results of modifications and optimizations of ESSs

*Table 13.* System costs for ESSs [in SEK]

| ESS | Costs | Costs' | Costs'' | Costs''' |
|---|---|---|---|---|
| A | 11.592.827 | 11.595.236 | 11.529.539 | 11.226.298 |
| B | 18.078.169 | 18.080.577 | 18.014.880 | 17.711.640 |
| C | 13.054.550 | 13.056.959 | 12.991.262 | 12.688.021 |
| D | 14.146.097 | 14.732.006 | 14.620.182 | 13.863.136 |

*Table 14.* Changes in total system costs

| ESS | Difference Costs' to Costs | | Difference Costs'' to Costs | | Difference Costs''' to Costs | |
|---|---|---|---|---|---|---|
| | SEK | % | SEK | % | SEK | % |
| A | 2408 | 0,02% | -63289 | -0,55% | -366529 | -3,16% |
| B | 2408 | 0,01% | -63289 | -0,35% | -366529 | -2,03% |
| C | 2408 | 0,02% | -63289 | -0,48% | -366529 | -2,81% |
| D | 585909 | 4,14% | 474084 | 3,35% | -282961 | -2,00% |

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