BIOCLIMATIC, SITE SPECIFIC ARCHITECTURE

Passive design strategies in a local context

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ACEX35

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Figure 1: Picture of the green space south of Söderbro 10. (Author, 2023)

ABSTRACT

This thesis investigates how to lower the energy demand of a residential building located in a temperate climate of Kungsbacka, south of Sweden.
To get an understanding of the relevance of passive design strategies and the possibilities, literature research is conducted. Relevant topics are explained such as thermal comfort, passive house and bioclimatic design. Furthermore, built examples that can relate to the climate of Kungsbacka are shown as references.

The design strategies will in addition to the literature research be evaluated through simulations in IDA ICE which is a simulation software that is used to simulate thermal comfort in a building. The simulations tempt to give an understanding on how to use the passive design strategies in a suitable way according to the local climate. This is important since the relevance of different passive design strategies differ depending on which climate the building will be built in.

The results of the simulations shows that due to the conditions of the chosen site Söderbro 10, all except one of the chosen passive design strategies is suitable. The excluded one was thermal inertia which was found to have little impact on the energy demand. This was resimulated and found to be more suitable on wooden floors than concrete. A dense and well insulated building envelope is important, and to use the sun as an energy source. This is possible at Söderbro 10 since the site does not have any buildings that block the solar radiation from the south. An angling of the design proposal towards the street allows for better conditions for solar radiation.

The conclusion shows how integrating passive design strategies can reduce the energy consumption by 15%. The work provides a good basis for the understanding of how passive design strategies can be applied in a local context and highlights the importance of deeper study of aspects such as life cycle analysis, economy and values, and settings for simulation.

Keywords: Bioclimatic, Passive design, passive house, thermal comfort, energy

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STUDENT BACKGROUND

Education

Bachelor
Chalmers University of Technology
2018-2021

Master
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Courses taken during master program:

- ARK153 Architectural competitions
- AUT164 Future visions for healthcare, housing and work 1: residential health care - Housing for seniors
- ARK590 Building climatology for Sustainable Design
- ACE110 Public Buildings
- ARK263 Future visions for healthcare. housing and work 3: Healthcare architecture

Relevant work experience

Bostadslyftet
2022-ongoing

Residential architecture with focus on small scale project

"In our - the architects' - case, we must firstly increase our knowledge in the energy sector, so that we can communicate with the technicians, secondly acquire the ability to cooperate on the same terms, thirdly we must never forget that we are building houses for human beings. Energy-saving must not become an end itself. One must not waive other qualities relating to living in and using the houses, nor architectural qualities." -Hans Eek

Motivation

The possibility of building with lower energy demand using passive design strategies has been of great interest to me, especially since the ARK590 Building Climatology course. The topic is very relevant given the current climate and electricity crisis.

For me, it is fascinating how design choices affect a building's energy use. And as Hans Eek said in the quote above, it is relevant for us architects to know how this works and to be able to discuss and communicate in our team of different disciplines.

With this thesis I want to get a deeper understanding of how passive design strategies can be used in the design process. How they affect the building and how they can be used in a local context.

I think the concept of passive design strategies will be more important than ever to integrate in both new buildings and renovation projects. And the interesting thing is how we can make this part of the design.

INTRODUCTION

Figure 2: Illustration showing the SDGs, with those relevant to this project highlighted. (The global goals, 2023).

BACKGROUND

According to statistics, we tend to spend almost 90 % of our time indoors (Boverket, 2023). Hence to this large amount of time spent indoors, thermal comfort is particularly relevant. To regulate the indoor climate, we often use devices such as heating or cooling systems which use a large amount of energy.

In 2015, the sustainable development goals and Agenda 2030 were set (FN, 2023). To reach the global goals and Agenda 2030, we need to adapt, and energy consumption is one of the most prior issues to deal with.

The global goals that this work touches on are sustainable cities and communities, as lower energy consumption for buildings reduces climate impact. It also addresses affordable and clean energy as there is a strong focus on solar energy which is both free and carbon neutral. Except from those, there is a possibility to increase good health and well-being by aiming for good thermal comfort, prevent cold indoor climate in winter and indoor overheating in summer.

Since the beginning of the 20'th century, the energy consumption for residential buildings has decreased due to more efficient systems and energy efficient building solutions (Energimyndigheten, 2023). In that case, the developments are moving in the right direction, but there is more work to be done.

It is interesting to take inspiration from the vernacular architecture in order to decrease the energy demand of buildings. In history, there were no heating or cooling systems, but they needed to adapt and work together with the local climate to gain thermal comfort. As energy systems were developed, one could focus on a building design that was not in harmony with the local climate and instead use energy systems to ensure thermal comfort.

To lower energy demand for buildings, we need to adapt the buildings to the local climate and use passive design strategies so that the need for supplied energy decreases.

AIM

This thesis explores how we can reduce the energy demand of a building and increase thermal comfort by using passive design strategies in a temperate climate. It will discuss the impact and benefits of each strategy so that conclusions can be drawn about which passive design strategies to use and how to apply them with the most effect.

It highlights the importance of thermal comfort and shows suggested methods on how we can achieve this with less supplied energy. It intends to show the benefits of reconnecting to vernacular architecture principles and reminds us to benefit from the local climate through examples of passive design strategies. In this way, the building can take advantage of existing energy opportunities in the local climate.

It will demonstrate how important it is to study the site so that the architect can make the most appropriate decisions for a specific site, and be aware of the consequences of not following the principles of passive design.

PURPOSE

As the world faces major changes in the way we live due to climate change and the current electricity crisis, there is a need to change the way we live and use energy.

Passive design strategies are not the solution to all problems. But it generates lower energy requirements for a building, which is beneficial both for the climate and economically for people.

Architects and designers have a responsibility as professionals to implement this in buildings to reduce the energy impact a building has during its life cycle. To do this, the benefits of designing buildings with passive design strategies must be understood and highlighted.

THESIS QUESTION

How can passive design strategies be used to ensure thermal comfort with less energy demand in a residential building?

To answer the thesis question, the following sub-questions are asked:

- Which design strategies are suitable in the Swedish climate?
- How do passive design strategies affect the design?
- What are the implementation for a local context?

DELIMITATIONS

- The study will only consider passive design strategies that are relevant for the temperate climate of Kungsbacka, Sweden.
- The economic aspect will be kept at an overall level.
- Energy simulations will only be done in a simplified example building to simulate the general effects of the strategies in the local climate. The most effective strategies will then be implemented in the design proposal.
- The energy demand has been analyzed only for the operational energy, it does not take into account the embodied carbon and the whole life cycle.

METHODS

Literature studies

As a foundation for the project, literature tempt to provide information about subjects such as bioclimatic design, passive house, thermal comfort etc. It is essential for the understanding of the aim. It provides information about the Swedish standards and regulations that are useful to have in relation to the choices that are taken along the way.

Example projects

To understand how passive design strategies have been used in previous projects, a number of example projects are analyzed. The example projects will function as an inspiration for building design and knowledge about previous experiences with passive design strategies. It will also bring information about pros and cons of different passive strategies that will be an additional aspect to consider in relation to the simulations.

IDA ICE simulations

A core part of this thesis are simulations in the program 'IDA Indoor Climate and Energy' (IDA ICE). Relevant default values are used to form a point of departure for the simulations. It will be structured as simulations for each passive design strategy, and at the end, all chosen passive design strategies will be implemented in the same model. This enables not only the evaluation of the design strategies but also the comparison of the simulation results with the default values.

Site analysis

The site chosen for the design proposal in Kungsbacka is located in the south of Sweden. A site analysis is conducted in order to generate information about the chosen site, Söderbro 10, and its surroundings. History, mapping and reflections about the site help to specify the program for the building and form the design of the building.

Design proposal

A residential building will be designed at Söderbro 10 with the implementation of passive design strategies based on the analysis. The design proposal will be a product of the findings from literature and simulations and it will affect the design to strive for a lower energy demand of the building.

THERMAL COMFORT

The definition of thermal comfort is how one perceives the indoor climate. Good thermal comfort is when one is satisfied with how the temperature of the room feels. Factors indoor that affect the thermal comfort are:

- Operative temperature
- Cold surfaces
- Relative humidity
- Air velocity
- Activity and clothing

(Folkhälsomyndigheten, 2018)

Operative indoor temperature

The operative temperature is the average air temperature and the average radiant temperature from surrounding surfaces. The reason for using operative temperature when measuring thermal comfort is that it considers not only the air temperature, but also for example cold surfaces that absorb heat from the body. If the air temperature is normal but the surface around are cold, one can still experience the indoor climate as cold. The Swedish public health authority has set guidelines regarding operative temperature (Folkhälsomyndigheten, 2023).

Operative temp.	Winter	Summer
Minimum	18°C	18°C
Permanently	24°C	26°C
Short term	26°C	28°C

The indoor air temperature should generally be 21°C (BFS 2016:12 BEN 1, 2023). There are many factors in addition to air temperature that affect thermal comfort. These factors can be regulated by for example technical systems, passive design strategies or construction solutions.

Relative humidity

The relative humidity (RF) of the air is another factor that can affect our perception of the indoor climate. The RF should be between 30-70% indoors, too high RFs can cause problems with mites and mold (Socialstyrelsen, 2005). Too low RFs can cause skin problems for some people (Centrum för arbets- och miljömedicin, 2015).

Air velocity

Thermal comfort is also dependent on the air velocity since this can cause discomfort and problems. It should not be above 0,15 m/second. An airtight building construction can prevent unwanted draughts (Folkhälsomyndigheten, 2023).

Activity and clothing

Another factor that affects how we perceive the indoor climate is the level of activity and clothing. One can perceive thermal discomfort if the clothing is inadequate for the room activity.

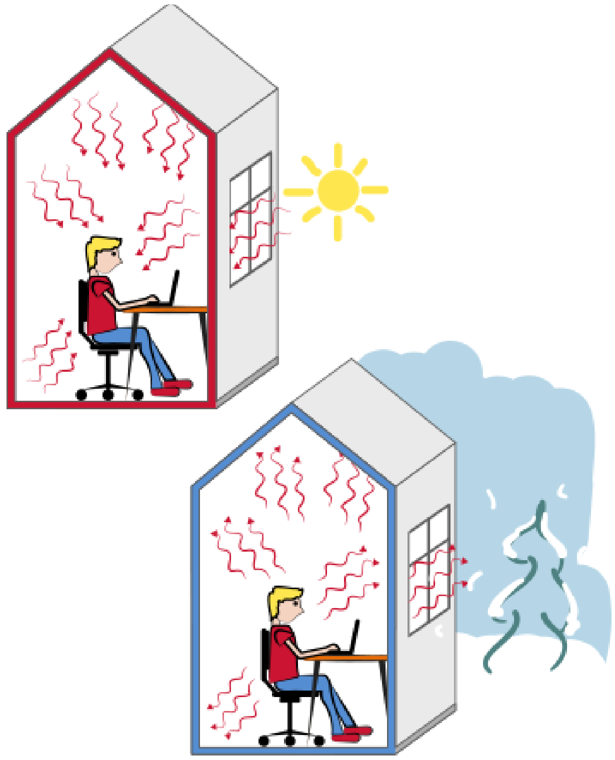


Figure 3: Illustration of how people experience thermal comfort depending on the circumstances around such as air temperature and surrounding surfaces. Illustration: Tictac (Boverket, 2023)

PASSIVE DESIGN

A home, somewhere to protect ourselves from weather and threats has always been a priority for humans. The way of building has evolved a lot through history. Vernacular architecture has always been related to the site with local materials and a design that would benefit from the local climate.

People have always had to adapt to different climates and different circumstances. Rain, wind and sun are elements that affect a building. It can generate water leakage, cold indoor temperature, draughts or overheating.

But the natural elements can be considered and used as an opportunity to create a good indoor climate. What kind of material that were available in the close area along with local circumstances have through history been the key factor.
In Sweden during the 1950's, mechanical systems for heating and cooling buildings were developing. This led to rational building designs that focused on minimizing streets and to sell systems. This made us lose the traditional way of thinking, and the adaptation to the local climate was not the essence anymore (Brainbridge et al., 2011). With the rising interest of passive design in order to lower energy consumption, we need to regain knowledge of the possibilities of passive design, as done in the vernacular architecture.

Radiation

One of the main principles of passive design is radiation. Every object with a value over absolute zero (-273°C) will emit radiation, meaning heat will go from a warmer object to a colder. The sun has shortwave radiation and can therefore heat a room through windows. Object that are heated in a room, instead send out long wave radiation. The long wave radiation has difficulties to go through certain materials such as glass and will therefore be captured inside the room. This is called the greenhouse effect (Brainbridge et al., 2011).

Orientation

This radiation can be beneficial if it is used in the right way. The principle is to let the winter sun into the room to generate heat, but to keep out the summer sun since this can easily lead to overheating. To get the best conditions for solar heating and daylight, the long side of the building with glazing should face the equator. This is because when the sun's altitude is at its highest point in the middle of the day. The summer sun can easily be blocked with overhangs. Sun from east and west in the summer has a lower altitude and leads to glare and overheating. The overhangs in the south block the sun in the summer but let the winter sun in since it has a lower altitude. This is beneficial since it's in the winter that there is need for heating through solar radiation (Brainbridge et al., 2011).

Internal loads

Apart from solar radiation, internal load is an important heat resource. People, appliances and lighting generate energy which warms up the building if the building envelope is insulated enough (Brainbridge et al., 2011).

As a summary, the goal of passive design is to generate the needed heat to achieve good thermal comfort and it should be provided by energy from solar radiation and internal loads. It should also minimize the risk for unpleasant effects such as overheating and glare in the summer, and cold draughty indoor climate in the winter.

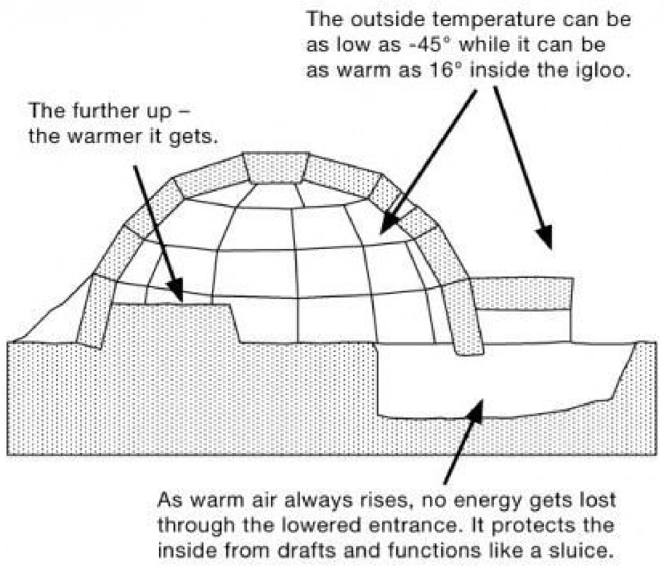


Figure 4: Illustration of how an igloo works, which uses bioclimatic passive design strategies (Pinterest, 2023).

BIOCLIMATIC DESIGN

Bioclimatic design is based on the local climate, conditions and topography. It focuses on awareness of the environment and lets natural organic solutions evolve the building design. The goal is to minimize the energy use and provide good thermal comfort. Mechanical systems are to be excluded, and only used as a support if needed (Almusaed, A, 2011).

Bioclimatic architecture is the main principle of vernacular architecture and has been used with good results throughout generations of knowledge. It uses passive design strategies such as solar radiation, shading and dense mass to create a good indoor climate (Almusaed, A, 2011).

Vegetation such as deciduous trees can be used for natural shading of the building, but it also functions as wind protection. When strong winds hit the building during the heating season, the heating needs are greater. This is because strong winds can increase heat transmissions through the building. In this case, wind protection such as trees and bushes can help block the wind and its effect. This is one way to work with the local surroundings and placement of the building.

The fact that leaves keep moisture when it's hot outside, cooling through evaporation won't have that much effect when it's most needed, instead the shading from the trees is more efficient (Almusaed, A, 2011).

Vernacular architecture is the reason why traditional buildings look different around the world. The concept of bioclimatic design forced one to use materials that were beneficial to create good thermal comfort depending on the local climate. This was also a result of what materials that were to be found in the close area (Almusaed, A, 2011).

Today, we can conclude that materials are not often chosen in accordance with vernacular architecture. Transportation of material around the world and mechanical systems has led to a lack of interest for these basic and effective principles.

PASSIVE HOUSE

Ever since the oil crisis in the 1970s, solutions for energy efficient buildings has been of high interest. (Andrén & Tirén, 2010). The building concept Passive houses aim to ensure a comfortable indoor climate. The goal is to achieve this by only asking for reasonable effort from the occupants and using as little energy as possible (Andrén & Tirén, 2010).

In essence, the Passive house consists of a well-insulated envelope, heated mainly from people, appliances, and solar radiation (Andrén & Tirén, 2010).

The long facade is orientated towards the south and provided with large windows for maximum passive solar radiation which generate heat and provide natural light to the building (Swedish Council for Building Research, 1987). It’s important to protect the building from getting overheated in the summer, as it increases the indoor temperature and creates an unpleasant indoor environment.

To establish energy efficiency, a heat recovery system is crucial to minimize heat losses through the ventilation system. The building envelope must be airtight and allow as little transmissions as possible (Andrén & Tirén, 2010).

One of the main aspects of the passive house concept is that a well designed and energy efficient building envelope can replace a conventional heating system (Andrén & Tirén, 2014). A focus is placed on the building’s energy performance rather than materials (Andrén & Tirén, 2010).

There are a lot of similarities between passive houses and bioclimatic architecture. Both use the same passive design strategies in order to benefit from solar radiation and prevent an unpleasant indoor climate. But what differs is that a passive house is a specific certification. Passive house is one of several classifications under the umbrella term ''low-energy house'', which stands for buildings that need less energy than current building regulations require. This means that the building must live up to certain standards to be called a passive house. This is decided when the building is done and measures of the actual energy use can be performed.

Passive house is used internationally, and the Swedish requirements have been established through FEBY (Forum för energieffektiva byggnader, 2009).

Mini-energy house is another standard from FEBY. Choice of energy source is considered which means that it’s easier to achieve the standards if renewable resources are used.

Zero energy houses can be approved if the building itself produces as much energy as it uses during a year.
And at last, a building can be classified as a plus energy building if it produces more energy than it uses (Andrén & Tirén, 2010).

Requirements for passive houses

The Swedish requirement for passive houses is higher than the standard regulations. The requirements aim to provide good thermal comfort with minimum supplied energy. This is specified via the energy demand for the building and cooling should not be needed in new constructions.

Maximum energy demand for residential buildings and premises according to FEBY:

Zone III	Pmax = 10 W/m² Atemp+garage
Zone II	Pmax = 11 W/m² Atemp+garage
Zone I	Pmax = 12 W/m² Atemp+garage

(Forum för energieffektiva byggnader, 2009).

Building energy consumption

$$E_{bea} = E_{uppv} + E_{kyl} + E_{tvv} + E_{f}$$

Primary energy value

$$EP_{pet} = \frac{\Sigma_{i}^{6} = \left(\frac{E_{uppv,i}}{F_{geo}} + E_{kyl,i} + E_{tvv,i} + E_{f,i}\right) \text{ x } VF_{i}}{A_{temp}}$$

Building energy consumption E_{bea}

The amount of energy that a building use during a normal year is the buildings need of delivered energy.

Building energy E_{f} (kWh/aear)

Energy that is needed to ensure the comfort of the building such as fans for ventilation etc.

Energy for heating E_{uppv} (kWh/aear)

Energy for comfort cooling E_{kyl} (kWh/aear)

Energy domestic hotwater E_{tvv} (kWh/aear)

BUILDING ENERGY PERFORMANCE

The amount of energy that a building uses during a normal year is the building's need for energy. This includes energy for:

- heating
- domestic hot water
- comfort cooling
- building energy (energy that is needed to ensure the comfort of the building such as wfans for ventilation etc.)1.

A normal value for energy demand of a residential building is 30 kWh/m² per year. A difference of 3 kWh/m² is acceptable.

Energy that the building provide from sun energy through solar radiation or solar panels are not to be included in the energy use of the building.

The energy source is not specified in the calculation for energy use of the building, this is considered in the primary energy value.

The primary energy value is a measure of the energy performance of the building. This value is also defining the energy classification of the building. In order to set the primary energy value, the amount of energy that the building uses needs to be defined.

There are instructions on how to calculate the value in Boverket’s regulations and general advice (2016:12) on determining the building’s energy use during normal use and a normal year (BEN).

The primary energy value is calculated with weighting factors for the energy source that is used. For example, district heating has a weighting factor of 0,7 and electricity 1,8.

Then, the value needs to be divided with a geographical weighting factor, and finally this is divided with the buildings Atemp.

The primary energy value encourages climate positive energy sources, since fossil energy sources instead have a high primary energy value. New buildings need to consider energy sources that are better for the climate in order to get certain energy classes and reach the energy requirements.

EXAMPLE PROJECTS

CASE STUDIES

By studying different example projects that use passive design strategies, a better understanding of the subsequent simulations can be gained. The examples chosen are located in Sweden or in places with a similar climate. This provides relevant examples that have the same circumstances and conditions as the design project for this thesis. The energy consumption of the Lindås project, the Glumslöv project and Beckomberga can be compared in kWh/a/m² with the design proposal. Selected values and the choice of passive design strategies in the example project help to choose which passive design strategies would be interesting to explore further through simulations.

*Figure 5: Lindås passive house, (*Dafa Studio, 2023).

THE LINDÅS PROJECT

The Lindås project was the first project in Sweden to use the term "house without a heating system". It was one of the first passive houses in Sweden and functioned as an inspiration for energy efficient buildings.

It was constructed by Egnahemsbolaget and designed by architect Hans Eek. It is located south of Gothenburg and was built in 2001 and consists of two terraced houses with 20 apartments.

The long facades are located towards the south to use solar radiation efficiently while balconies and eaves protect the building from overheating in the summer. The building envelope is well insulated, and the terraced house concept also minimizes outer walls, equal to less envelope transmissions. A skylight is placed in the center of the building to increase daylight and ventilation in the summer.

The building has a heat exchanger with 85% heat recovery, which together with internal gains from people, appliances and light, often can accommodate the energy needed for the building. If more energy is needed, an extra 900W heater will step in.
When planning the project, the energy gains from persons were estimated to 1200 kWh/a, appliances 2900kWh/a. Apart from that, solar radiation will also deliver some energy. Solar panels of 5 m² are installed to each apartment and generate about half of the energy for domestic hot water use.

The cost for the project was not considered much more expensive than other projects at that time. But some expenses for extra insulation and airtightness were added but considered to be acceptable due to the lower heating costs.

Project info	
Outer walls	43 cm insulation, U= 0,10 W/m²K
Roof	50 cm insulation, U= 0,08 W/m²K
Foundation	25 cm insulation, U= 0,09 W/m²K
Windows	Triple-glazed with krypton U= 0,85 W/m²k
Entrance door	U= 0,8 W/m²K

(Andrén & Tirén, 2010).

For the passive houses in Lindås, the energy consumption in 2010 was measured at 55-85 kWh/m². One apartment was measured at a consumption that was 50 kWh/m2 higher, which could be explained by the fact that the damper in the ventilation unit was half open, which meant that the heat recovery did not work (SP Sveriges Tekniska Forskningsinstitut, 2011).

Figure 6: Glumslövs passive house, (Bygg & Teknik, 2015).

THE GLUMSLÖVS PROJECT

The Glumslövs project was built in 2004 and consists of 35 apartments. The goal was to build residents with low rents. In order to do this, the developer, the developer, which was the municipal housing company AB Landskronahem wanted to have low operating costs and therefore decided to build with a FEBY passive house standard. The houses were built with high precision of airtightness and a well-insulated envelope.

To achieve the passive standard, a lot of information meetings were held with all involved to make sure everyone knew the requirements and importance of methods. As a passive house, it should be able to cut out traditional heating systems.

Project info	
Foundation	35 cm insulation, U= 0,1 W/m^{2}K
Outer walls	46 cm insulation, U= 0,1 W/m^{2}K
Roof	55 cm insulation, U= 0,08 W/m^{2}K
Windows	Triple-glazed with argon U= 0,9-0,1 W/m^{2}k

The total electricity consumption of the Glumslöv passive house was measured to be between 60-100 kWh/m2 for the year 2010. In comparison to Lindås, this is a higher energy consumption which can be explained by the fact that the Glumslöv houses did not have any solar panels supplying the buildings with energy (SP Sveriges Tekniska Forskningsinstitut, 2011).

Figure 7: Beckomberga passive house, (Brunnberg & Forshed, 2023).

BECKOMBERGA PASSIVE HOUSE

Beckomberga is located in Stockholm municipality. In 2007, the residential houses with passive standards were built by NCC together with Brunnberg & Forshed architecture firm.

In the first draft, the buildings were not designed to be passive houses, but as the circumstances with environmental problems and rising electricity prices, NCC decided to be a pioneer in Sweden to build big scale residential buildings with passive house certification. The drawings were then adjusted to fit the passive house standard.

When the decision was made to adjust the buildings to passive houses, there were concerns about losing much of the architectural qualities. But in the results, the conclusion was that the buildings didn't need to change as much as thought.

One of the main considerations when building passive houses is that it takes up a bigger footprint on the ground. Since the footprint is regulated by the municipality, this will lead to less area to rent out or sell. Some municipalities allow a bigger footprint, which was the case in Beckomberga. This is an important factor in order to cover extra costs that appear in order to classify the buildings as passive houses.

Another important aspect to weigh in was the life cycle cost of the buildings. Higher costs for construction passive houses will pay back in the long run due to lower drift costs. For the building developer, this is most effective if keeping the building to rent out.

A lower u-value for the windows, as stated in FEBY, was considered important since this prevents cold drafts from the windows. This is usually solved with radiators under the windows, but since passive houses should not need a conventional heating system, this is another argument to lower the u-value for the windows. This is also preferable since it leads to lowered transmissions through windows, as it is one of the weakest links in a building. Excluding elements will allow the windows to go all the way down to the floor, resulting in more daylight.

Since the frame is the weakest part of the window, divisions of the windows were avoided.

The relation between window area and the residential floor area is to be between 15-20%. To gain more daylight to the apartments, studies of angled window jamb were conducted. Studies showed that an angle of 18 was a good option.

Due to the fact that passive houses have a very airtight and thick insulation layer, the effect is that it captures heat very well. This can be a problem if too much solar radiation comes into the building through the windows. Therefore, horizontal shading overhangs were used in the south where the sun's altitude is high, and vertical blinds in the west and east where the sun's altitude is lower.

As the architects redesigned the buildings to achieve the passive house standard, a few things were obvious. It would lead to thicker walls, less window area and the need of sun shading for the windows.

With high precision of airtightness, which was measured to 0,1 L/s under some circumstances, and the requirement for passive houses being 0,3 L/s, they managed to keep the volume of the house as the original.

Solar panels were used to provide energy to the domestic hot water, and it provided the building with 40-50 % of the total need. When installing shafts and roof equipment, they were planned to not disturb the solar panels that were placed on the south side.

The outer walls in Beckomberga consisted of curtain walls and had a total thickness of 400 mm after adding extra insulation to the walls. The inner insulation layer was set to 70 mm instead of 45 mm. This lowers the risks for residents to damage the vapor passion then putting up shelves etc.

Since thermal bridges were a critical point where a lot of energy is being lost, special solutions to break those in balconies. Instead of the slab going out to the balcony, the balcony is its own element and insulation is provided between balcony and slab.

For the foundation, an insulation thickness of 300 mm was used. This was higher than the standards during that time period. The thickness of the roof was set to 500 mm.

The savings connected to passive house standard was estimated to generate a saving of 250 000 kr per year per housing cooperative. Resulting in a saving of 5 000 kr for a 90 m2 apartment. By redrawing the house and certifying it as a passive house, they manage to save about 55 kr per square meter per year (Brunnberg & Forshed, 2009). Beckomberga has an estimated energy performance of 63 kWh/m² per year (Bergqvist, 2015).

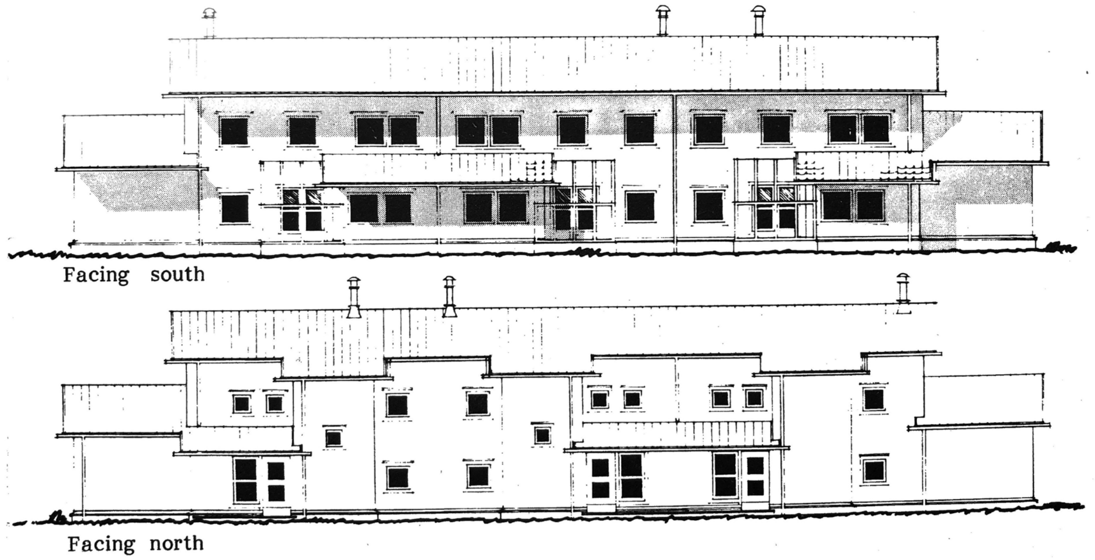


Figure 8: The Karlstad passive solar house (Eek, H. 1987).

THE KARLSTAD PROJECT

In 1984, a building with 16 households was constructed with a goal of using passive solar energy. It was built in Karlstad, in the central part of Sweden.

It was designed by architect Åke Blomsterberg and Hans Eek whom is well known for research in methods to use solar heating and decrease energy demand for buildings. This was one of the projects where they followed up by measuring the effect on the building's energy consumption.

They was studying the effect of the orientation of the building, heavy structure as thermal mass, and sun shading to mention a few.

By their studies, they found out that the optimal orientation to use passive solar heating is to orient big windows to the south. However, they also found out that a deviation with up to +-20° from south did not impact the solar radiation that much. In fact, by a deviation of +-20 one can still capture more than 80% of the solar radiation. Conclusions from this was that it did not matter if the building was slightly deviated from the sun.

In the facades above, it is clear how they have larger windows towards south to maximize solar radiation, and less window area in the north to prevent energy losses.

Another strategy they used was thermal mass. The foundation consisted of concrete with insulation under. According to their simulations, about 15 cm of the concrete layer should be active and able to save energy by storing solar radiation during the day and release it during night when its colder. This was supposed to decrease the energy need to heat the buildings during the heating periods.

When they measured the effect of the heavy construction of thermal mass, they found out that it had little or no effect on the energy consumption. It shows the biggest savings during the autumn and spring. But ot of three measured households, one saved 50 kWh/a, another 0 kWh/a and the third 300 kWh/a. Even though thermal mass has the opportunity to store heat, during the heating period, there is not enough heat available to store either from solar gains or internal gains. The savings that were done were during the summer when there was very little heating demand, resulting in too little effect on the energy consumption.

Sun shading was blocking the sun completely between April 15 and September 15, which is the period when no solar radiation is needed for heating. During the heating season, big windows towards the south maximize the use of solar radiation. The sun shading is horizontal above the windows. In other orientations, the horizontal sun shading is not effective.

During the simulations, they had a window with a height of 1.1 m, and the sun shading was placed 0,3 meter above the window.

Conclusion is that the horizontal shading Should be maximum 1,4 m deep to ensure that the window will not be shaded before 20/3. Until this, it's important to capture as much solar radiation as possible. It should not though be under 1,2 meter to be able to shade the window 20/5 and prevent overheating (Eek, H., & Blomsterberg, Å,1989).

Figure 9: OH BOY hotel in Malmö, Sweden (Google. n.d.).

Figure 10: OH BOY green roof as rain buffer (Network nature, 2023).

OH BOY

Oh boy is a building located in Malmö and was finished in 2017. It consists of residential housing and a hotel, and is famous for its adaptation to bike life.The architect firm is Siegel (Siegel, 2023). The example functions more as a reference for using natural shading and promote biodiversity.

Vegetation is a central part of the project. There is one tree planted in front of each entrance, and plants are climbing along the facade. It is a big contrast to the concrete material.

A big focus in the project is biodiversity, since the amount of vegetation integrated is creating a space for insects in the city.

The building has green roofs, which provide the residents with a green space outside of their window. It also has a function as a rain buffer zone, helping to prevent flooding. There are rain buffer zones at the roof (Oppla, 2023).

Figure 11: SAWA building (Mei, 2023).

SAWA

Sawa is a residential building located in Amsterdam, designed by the architecture firm, MEI-architects. The building features a bioclimatic design that incorporates a range of sustainable features to reduce its environmental impact and improve energy efficiency.

The building's orientation is also optimized to capture prevailing winds. The longest facade of the building is oriented in the north-south direction, which allows for a strong air flow to occur through the building's central courtyard. The building's other facades are designed to be more closed, with smaller openings that help to reduce heat gain from the sun and provide shading to the interior spaces.

Additionally, the building's facade is designed to incorporate adjustable louvers that can be opened or closed to control the amount of natural light and ventilation entering the building. This feature allows residents to customize the amount of natural ventilation in their units, further reducing the need for mechanical cooling systems.

In addition to its passive cooling features, Sawa also incorporates a range of renewable energy systems, including solar panels and a geothermal heat pump. These systems work together to provide the building with clean and sustainable energy, reducing its reliance on traditional energy sources (Mei, 2023).

Figure 12: House K exterior (Arch daily, 2023).

Figure 13: House K's interior showing the chimney of rammed earth (Arch daily, 2023).

HOUSE K

House K is a residential building located in a sloping area in Alpnach, Switzerland. It was designed by Seiler Linhart and built in 2018. Due to the owner’s local wood fabric, it is completely made from wood. The concrete foundation is reinforced with bamboo. The wood, from detail to walls and shading devices, sets the architectural expression of the building.

The core of the building is created out of rammed earth. The earth has been taken from the ground where the building stands, as a result of the earth that had to be removed for the foundation. This central core made from rammed earth functions as a contrast between the light wooden construction, to the dark rough rammed earth. Apart from design perspective, it also functions as a stabilization for the indoor climate. It is connected to a fireplace that heats up the rammed earth core and releases the gained heat during the night. This is an example of how thermal inertia controls the indoor climate and even it out which can contribute to better thermal comfort.

The controllable shading devices above all windows are mechanically controlled and can close or open completely. This generates a good shading and prevents overheating. The angle of the shading can be customized to the need of the orientation and time of the day (González, 2018). House K is an example of a building that connects to the area through material and uses passive design to control the indoor climate.

PASSIVE DESIGN STRATEGIES

As shown in the research and examples, thermal comfort can be influenced by various passive design strategies. It is a traditional way of working with the local climate, as done in vernacular architecture, rather than against it.

Integrating passive design strategies can reduce a building's energy demand, if it is used in the right way. Architects and designers must therefore know how to adapt passive strategies to the local climate.

In order to understand how and which passive design strategies that should be implemented in the design proposal in this thesis, potential passive design strategies are selected from the literature research and examples and are analyzed. The literature study will form the basis and the simulation program IDA ICE will complement with results based on the local climate. This research will help to select strategies that can be useful in the chosen climate in Kungsbacka.

The design strategies will then be implemented in the design proposal, which will be a result of the selected design strategies and the local context. The following design strategies are chosen and will be evaluated based on literature, examples and simulations:

- Insulation
- Energy efficient windows
- Airtightness
- Rotation from south
- fixed shading
- Strategic floorplan
- Thermal inertia
- Natural shading

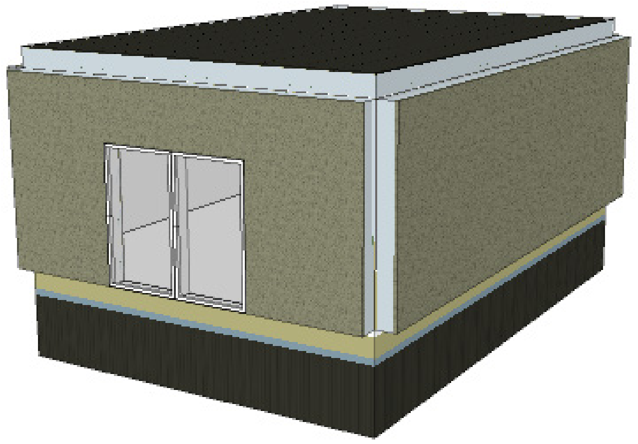


Figure 14: Simplified model (IDA ICE, 2023).

IDA ICE SIMULATIONS

To understand the relationship between thermal comfort and passive design strategies, a simplified model is used for simulations in IDA ICE version 4.8, which is a software used to simulate the indoor climate. The simplified model has a measure of 6x9 m which represent an apartment in the design proposal.

The simplified model and its values will from now on be defined as default values. This reduces the complexity of the simulations, which is beneficial given the timeframe of the thesis, but still shows the principles and effects of the passive design strategies in the local climate.

Each passive design strategy will be simulated and evaluated in the default model to decide whether it is worth using and which value is most effective and beneficial due to other parameters in the design proposal.

The selected passive design strategies and their values will be re-simulated in the default model. This will generate how much energy that can be saved by using the selected passive design strategies compared to the standard model.

The purpose of these simulations is to create an understanding of how each passive design strategy can be used in the design proposal.

Standard model

The standard construction for walls, roof and foundation is from Träguiden (Träguiden, 2023) and represents a normal construction. The passive design strategies will then be added on this basis.

SIMPLIFIED MODEL DEFAULTS

Model info	
Climate file	SWE_GOTEBORG-SAVE_025120(IW2)
Fixed infiltration airflow rate	22,501 l/s
Floor	54 m2
Volume	162 m3
Envelope area	198 m2
Window/envelope	2,70%
Air handling unit	VAV, temp. Control
Lights	5 W
Occupants	1,5
Equipments	6027

mm	Curtain wall	Raw density per kg/m3	Heat conductivity W/mk	Specific heat capacity, kJ/kgK
50	Västkustskiva	80	0,033	1,03
195	Vertical studs/Isulation	25	0,036	1,03
1	Vapor barrier/PE foil	0,4	0,23	1,4
45	Horisontal studs/Insulation	25	0,036	1,03
13	OSB board	660	0,13	2,3
13	Gypsum board	850	0,21	1,05
317	U-value: 0,1174 W/(m2*K)			

mm	Roof (insulated)	Raw density p kg/m3	Heat conductivity W/mk	Specific heat capacity, kJ/kgK
	Roofing felt			
20	Tounge and groove board	630	0,13	2
	Airgap			
1	Windbreaker	0,08	0,2	0,9
220	Roof truss/Insulation	25	0,036	1,03
1	Vapor barrier/PE folie	0,4	0,23	1,4
70	Strapping/Insulation	25	0,036	1,03
13	Gypsum board	850	0,21	1,05
325	U-value: 0,1183 W/(m2*K)			

mm	Foundation	Raw density p kg/m3	Heat conductivity W/mk	Specific heat capacity, kJ/kgK
250	Concrete	2400	1,7	1000
300	Cellular plastic	30	0,037	1500
550	U-value: 0,3312 W/(m2*K)			

Area m^2	Windows	U Glass W/(m^2 K)	Shading factor g	U Frame W/(m^2 K)
5,04	3 pane glazing, clear, 4-12-4-12-4	1,2	0,68	2

Infiltration			Pa	L/s ext. Surf
	Wind driven flow		50	0,6

EFFECT OF PASSIVE DESIGN STRATEGIES

The default model values are compared to the values after implementing the passive design strategies, presented in figure 15. Each category is further explained under Energy categories on the next page.

One can see that it is the local heating unit that consumes most energy to keep the indoor climate above 21°C. It is the category of window and solar, and equipment that deliver most energy. The biggest energy losses are to the envelope and thermal bridges. The two biggest categories also have a lot of potential to be improved by passive design strategies.

The simplified model uses 5 960 kWh/a with the default values, after implementing the passive design strategies, it uses 5 060 kWh/a. This is a decrease of energy demand with 898 kWh/a or 15%. Since the simplified model has an area of 54 m², this would result in an energy demand of 93,7 kWh/m² per year.

Each passive design strategy and the process will be further explained in the following chapter.

Energy default/changed model kWh/a

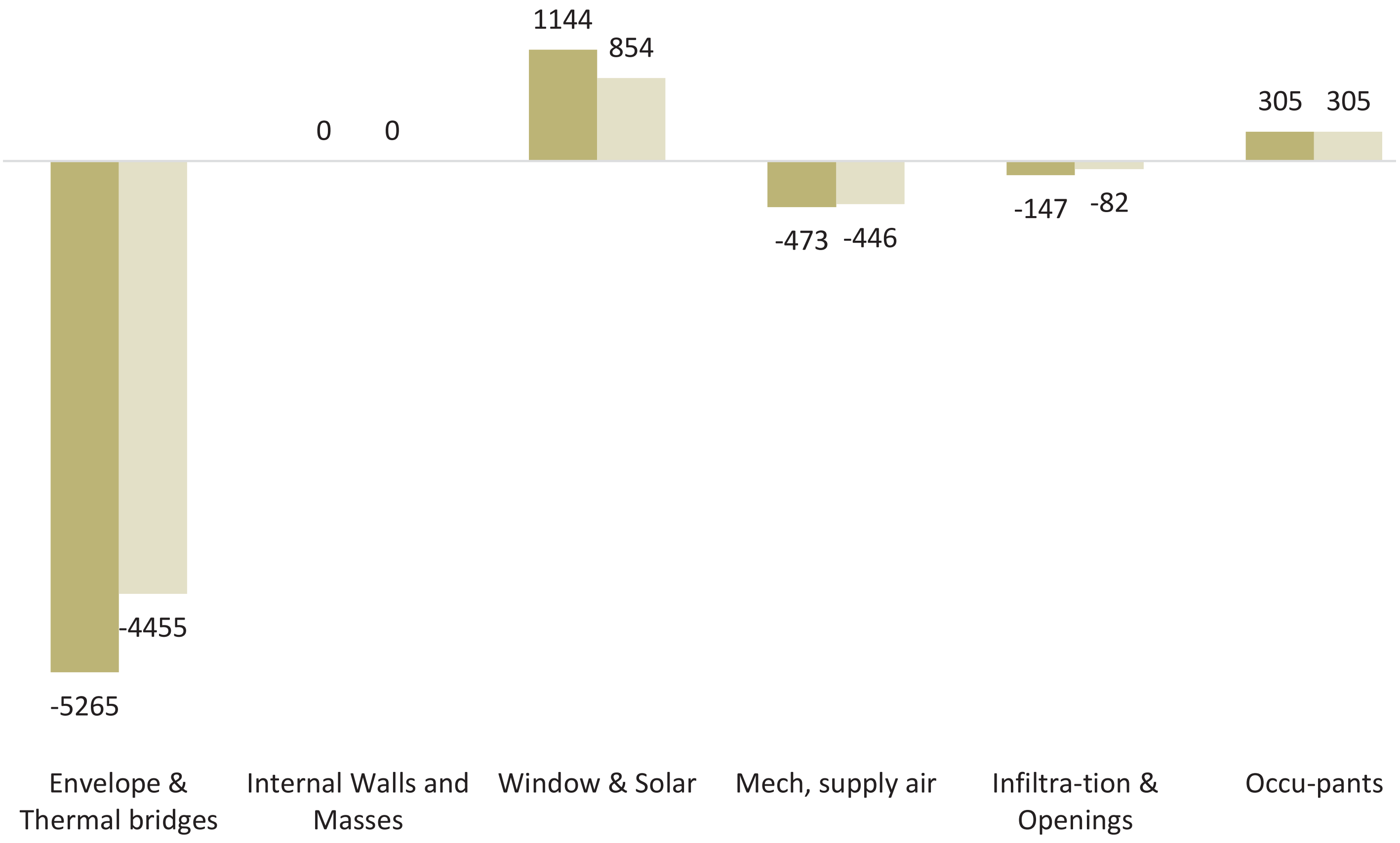


Figure 15: shows the different energy demands for the default model before and after implementation of the chosen passive design strategies.

Energy categories

Envelope and thermal bridges
Heat gained or lost through the envelope and thermal bridges.

Internal walls and masses
Heat that is gained from having internal masses such as floor, walls or ceilings.

External window and solar
This is the net heat that is gained after transmissions. The heat is gained through short and long radiation through the windows and the transmissions are counted for both frame and pane.

Mechanical air supply
Heat from mechanical ventilation

Infiltration and openings
Heat gained or lost through leaks and openings in the envelope

Occupants
Heat gained from people

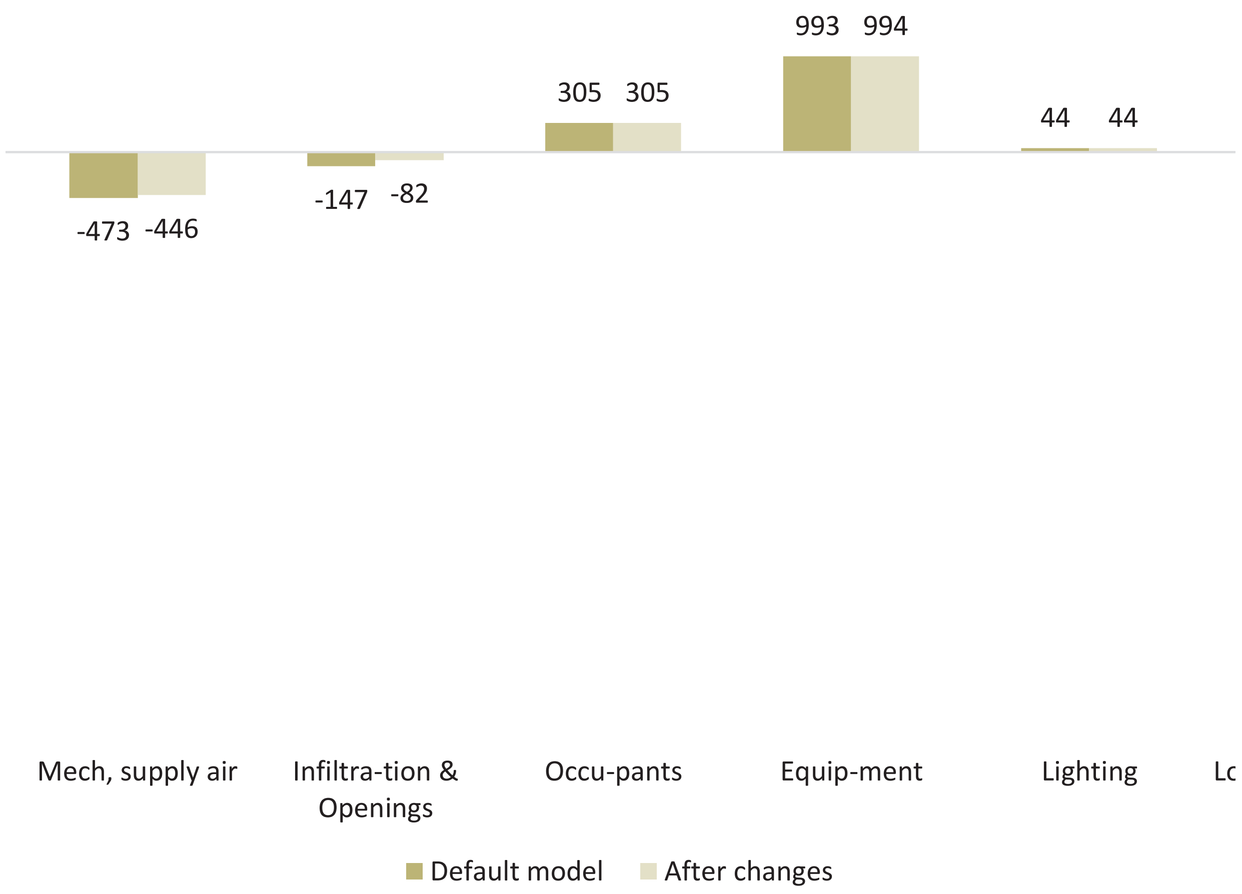
Equipments
Heat from equipments such as freezer or computer

Lighting
Heat gained from artificial lights

Local heating units
Amount heat delivered from heating units

Local cooling units
Amount cooling delivered from cooling units

Net losses
Heat losses from e.g. pipes and ducts.



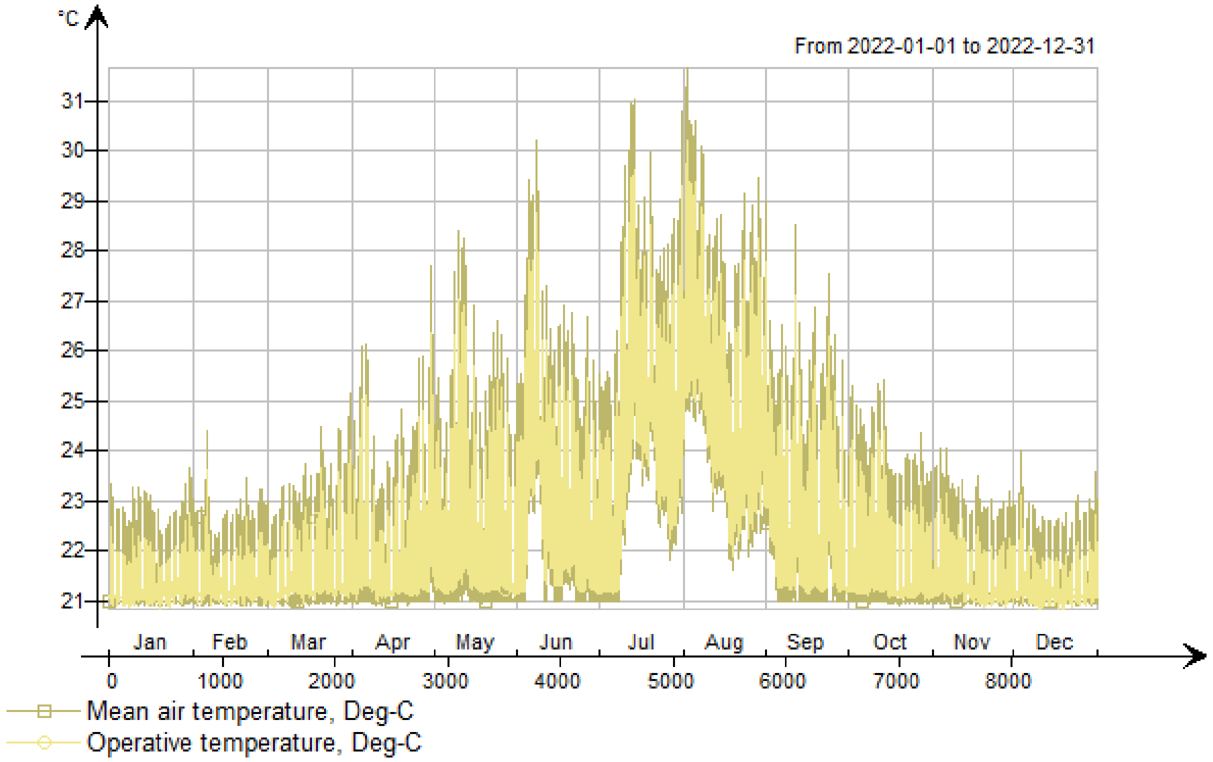


Figure 16: air- and operative temperature before implementing the passive design strategies.

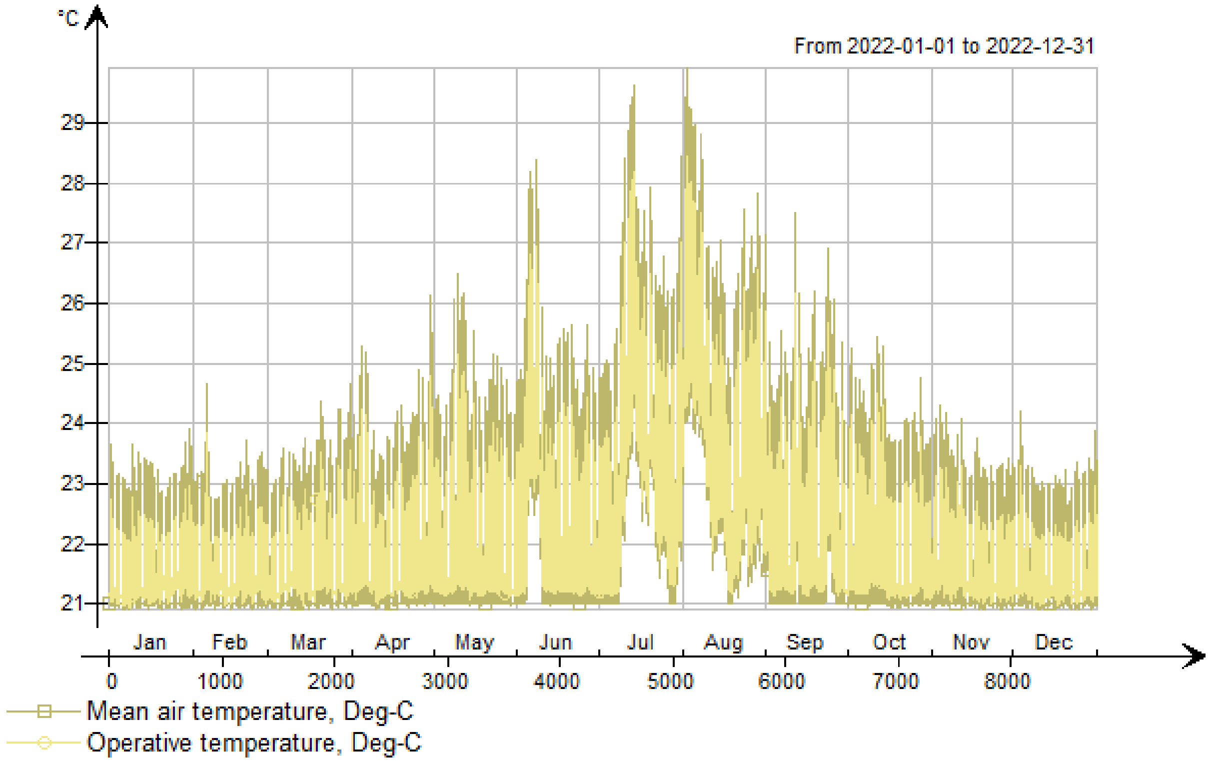


Figure 17: air- and operative temperature after implementing the passive design strategies.

Default building temperature

The mean air- and operative temperature is as high as 32**°C** at its peak, as shown in the graph. It is between May and August that the temperature is highest and most in need of improvement. The temperature is often around 26°C, and in July and August, the temperature does not even drop below 2°C for a period of time. The results can be seen in figure 16.

Temperature after changes

After implementation of the passive design strategies, figure 17, the average air- and operative temperature has dropped by 2°C and is often below 25**°C**. The temperature during the night has also become lower. It is clear that the passive design strategy can help lower the average air and operating temperature and help achieve better thermal comfort.

INSULATION

An energy efficient building is highly related to the thickness of the insulation since this keeps the heat inside the building. It needs to be set in relation to energy savings, regulations and extra economical cost.

A thicker layer of insulation generates a reduced u-value. However, the wall's footprint becomes larger when adding more insulation which leads to less area to rent out or sell.

Therefore, it is essential to find a balance between u-value and insulation thickness. It needs to be evaluated with these consequences in mind. Effect on energy demand, building regulations and extra economical costs.

Simulations show the impact of different insulation thicknesses in relation to heating demand presented in kWh/a.

Wall

Figure 18 shows how much the heating demand is affected when adding 50 mm insulation at each step.

Comparing the energy demand for different wall insulation thicknesses, up to 440 mm still affects the energy demand quite a lot. After that, the effect per step is not as effective.

Considering that every step is equal to less area to rent out or sell, it is a motivation to use 390 mm instead, since there is still a large amount of energy saved and the footprint becomes smaller.

An insulation thickness of 390 mm in the walls seems to be reasonable. The energy demand in the default model will decrease with 199 kWh/a, a saving with 8,5% of energy demand and energy costs. Over the years, the extra cost for material will pay off and start generating savings.

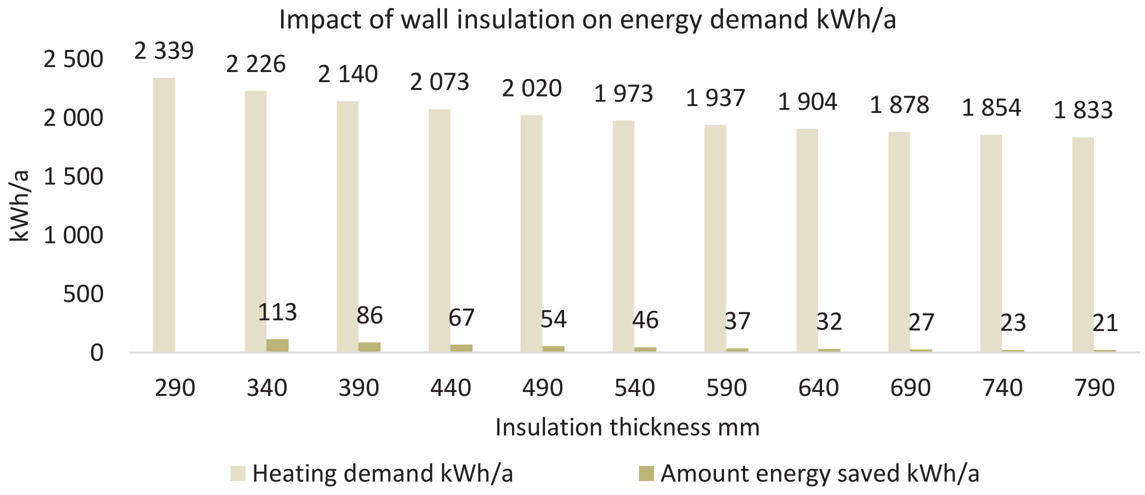


Figure 18: relation between wall insulation thickness and energy demand for the default model.

Roof

The roof insulation is not related to the footprint of the building and will not affect the space available for rent or sale. It will instead impact the building height which is an important factor.

According to the fact that the insulation thickness of the roof doesn't increase the building area, this is one argument for using more insulation in the roof than in the walls.

In figure 19, the insulation thickness is increased with 100 mm for each step. It starts with 290 mm of insulation which is the default value. The first step saves the most energy in relation to the added insulation per step, but the second step is also very effective. The fact that the roof does not affect the building footprint allows us to invest more to the insulation thickness, and another step is motivated.

An insulation thickness of 590 mm can be considered suitable for the roof and will generate a saving of 349 kWh/a. This is a decrease of energy consumption and costs with 9,9%.

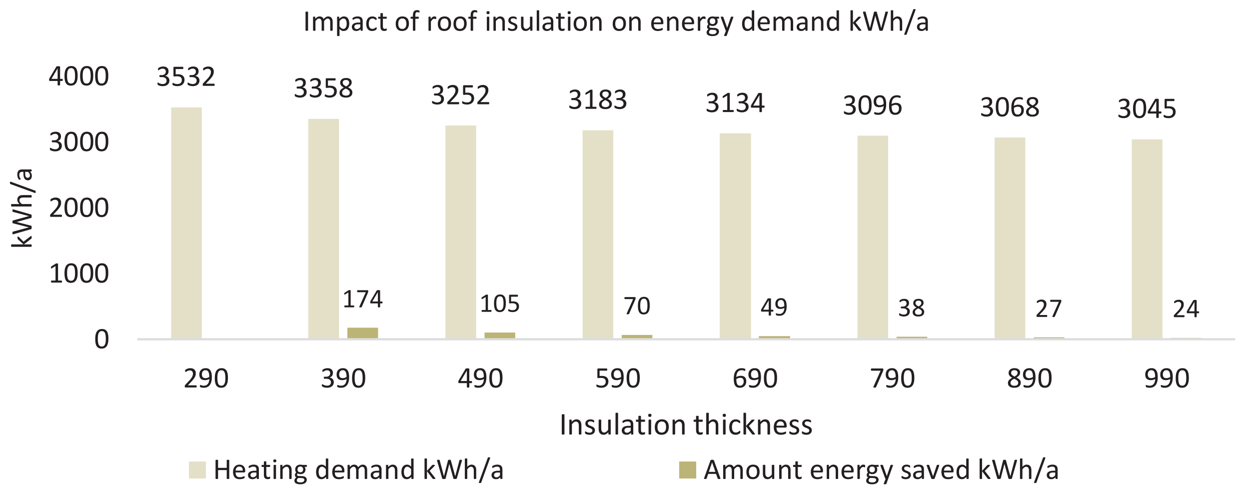


Figure 19: relation between roof insulation thickness and energy demand for the default model.

Foundation

The default insulation of cellular plastic for the foundation is set to 300 mm which is normal for new constructions. This is also shown in figure 20 to be the most effective amount and saves 371 kWh/a, 10,4% of the energy demand and costs. Adding more insulation than 300 mm does not affect as much and confirms that the default value is a proper limit.

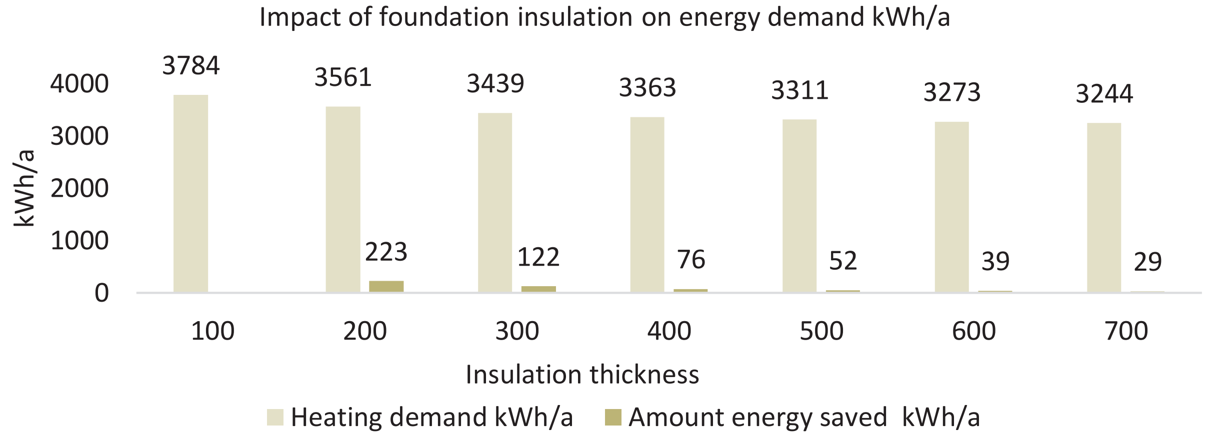


Figure 20: relation between foundation insulation thickness and energy demand for the default model.

ENERGY EFFICIENT WINDOWS

Windows are one of the weakest parts of the building envelope. The figures 21-22 show how a lower u-value affects the heat demand and solar radiation in the default model. The window used is 1200 mm wide and 1600 mm high with a frame thickness of 50 mm. This generates a frame fraction of 0,15. The range is from a u-value of 1,2 down to 0,7. 1,2 is usually the highest u-value in new buildings and 0.7 is considered one of the better values. The u-value indicates how efficiently the window conducts heat. A low U-value means that the window conducts less heat, which generates less energy loss through the windows. The results of the simulations are shown for the warm months of May-August and for the cold months of November-February. Solar radiation, as shown in the diagrams, is the balance between the solar radiation coming in and the energy losses through the windows.

May to August

During the warm months, the heat demand of the building is low, as shown in figure 21. There is not much energy to save from 1,2 and 0,7 in terms of heating, only 20 kWh. Th solar radiation energy entering the building increases by 10 kWh from 1,2 to 0,7, to be seen in figure 22. This is a result of the window not being as good at conducting hea The conclusion is that it does not affect the energy demand or solar radiation that much during these months.

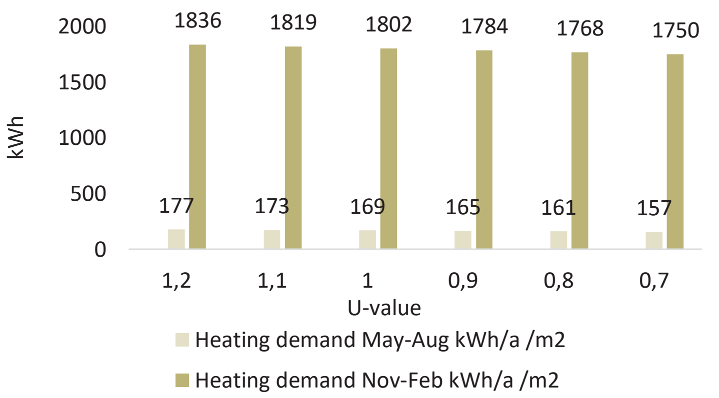


Figure 21: evaluation of the impact on heating demand for different u-values.

November to February

During these cold months, energy losses are clearly reduced and solar radiation increases because the u-value is lower. This shows that it is during winter that a low u-value is important, which is also the heating period. It reduces energy demand by 87 kWh and increases solar radiation by 24 kWh, and the solar energy gain goes from -4 to 24 kWh.

With each step in the reduction of the u-valu the energy demand in winter is significantly reduced. Solar radiation also increases significantly and which helps to reduce the need for added energy in winter. Depending on the economy, in terms of lower energy needs, it is far better to choose a u-value of 0,7 than 1,2.

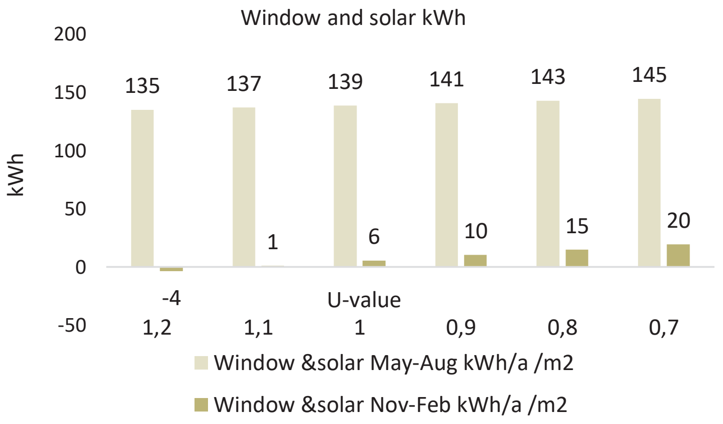


Figure 22: evaluation of the impact on window and solar for different u-values.

ORIENTATION TOWARDS SOUTH

Since solar radiation is a fossil-free energy source that is completely free, it is highly justified to make maximum use of solar radiation during the heating period. The most solar radiation is obtained when the windows are facing south. Although it is important to get solar radiation during the heating period, it is necessary to prevent overheating during the summer.

Figure 23 and 24 shows simulations of the standard model with windows facing south and rotated x° from south. It is clear that the ability to use solar radiation for energy decreases when turning away from the south. Up to 10 or 20°, solar radiation is not much affected, but at 30° there is a significant loss.

This is confirmed in a study by Hans Eek (1989), where he pointed out that the general perception that the building must be oriented directly to the south is not correct. He also concluded that a deviation from the south of up to +-20° does not affect the amount of solar heat entering the building very much.

Windows facing east, west or north have large energy losses during the heating period. This will not be the situation if they are oriented to the south.

The conclusion is that most solar radiation can be captured by windows facing south. Windows facing the other orientations are a major factor in energy losses during winter and should be carefully considered and minimized to reduce energy demand. However, care must be taken to ensure that sufficient daylight enters the building.

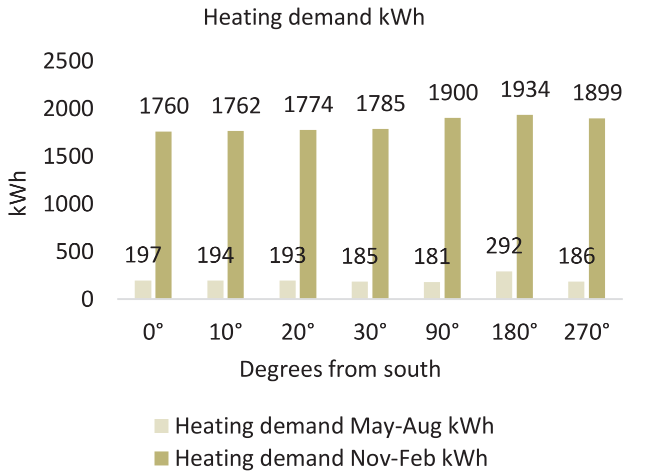


Figure 23: evaluation of the impact of heating demand depending on the deviation from south.

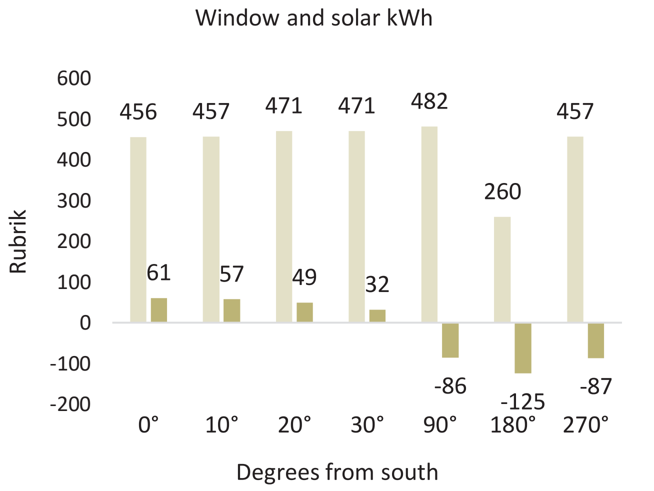


Figure 24: evaluation of the impact of gained solar radiation depending on the deviation from south.

GLAZING TOWARDS SOUTH

To understand how window sizes affect energy demand, three different cases are evaluated through simulations.

In the first case, there are three windows with a size of 10x13, a frame fraction of 0,18 and a total area of 3,9 m². The second case consists of two windows of 12x16 each, a frame fraction of 0,15 and a total area of 3,84 m². The last is a large window, 30x20, with a frame fraction of 0,08 and a total area of 6 m².

Looking at the amount of energy saved, there is a clear correlation between frame fraction and energy saved, where a low frame fraction is strongly related to lower energy demand per m². A low frame fraction also captures a significantly higher amount of solar radiation through the windows per m².

These simulations show the same conclusion as in the Beckomberga Passive House, that dividing the windows would lead to higher energy losses and should therefore be avoided. This is due to the fact that the frame is the weakest link.

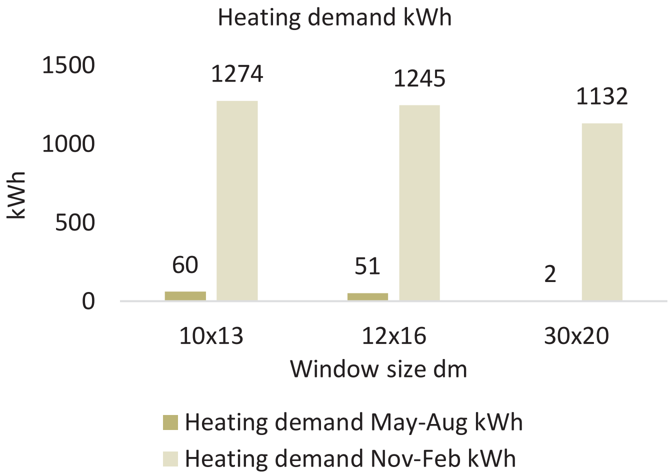


Figure 25: evaluation of the impact of heating demand depending on the window size and frame fraction.

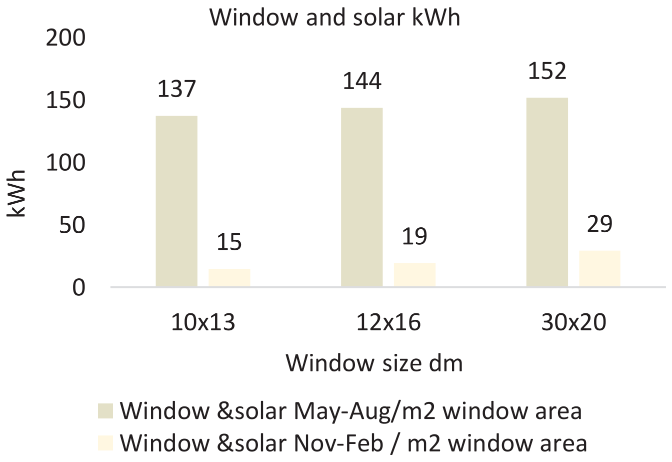


Figure 26: evaluation of the impact of gained solar radiation depending on the window size and frame fraction.

AIRTIGHTNESS

Airtightness is an important factor in minimizing energy losses through the building envelope, but it also prevents moisture from damaging the structure. For both these reasons, it is extremely important that it is installed correctly without holes. A hole in the vapor barrier leads to a concentrated flow of moisture into the structure and generates a high risk of mold.

An airtight construction reduces the energy demand of the building. In the simulations shown in figure 27, airtightness is evaluated from 0,6-0,3 L/(s. m2 ext. area) with an air pressure of 50 Pa. The figures are weighted by one third to represent a building where not all walls are external walls. This gives a more realistic and accurate result that can be used in the residential building for the design proposal.

An airtightness of 0,3 is usually used for new buildings because energy is an important aspect. The 0.3 simulation resulted in a saving of 35,4 kWh/a, or 1,6%.

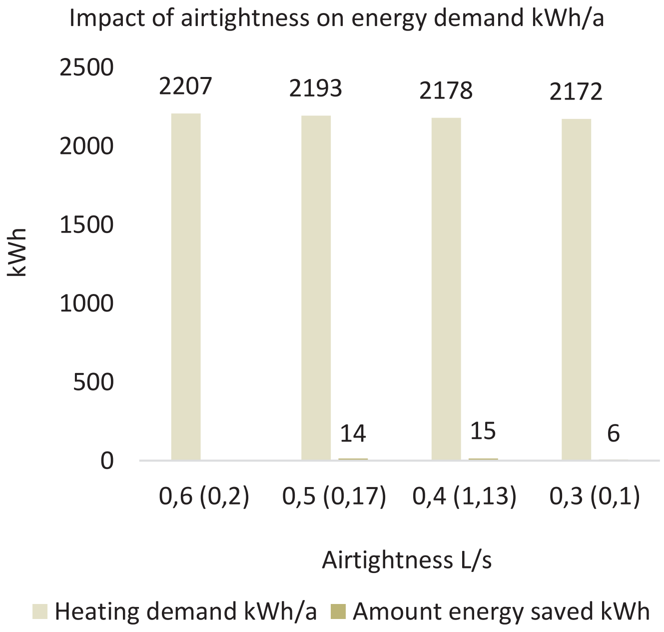


Figure 27: evaluation of the impact of heating demand depending on the airtightness measured in L/s with an air pressure of 50 Pa.

FIXED SHADING

Overhangs above the windows in the south that prevent the summer solar radiation from entering the room, while allowing the low winter sun to enter the room is a well known passive design strategy.

The concept is studied in two cases chosen by its relevance to the design project. The first one is a window or balcony door with a height of 2100 mm and the other a window whith a height of 1300 mm. Sections of the cases are used in order to understand how long the overhand needs to be in order to shut out the summer sun and allow the winter sun to enter.

The relation between parapet height and the height from window to overhang is an important factor since it affects the length of the overhang. The more space between the window and overhang, the longer the overhang needs to be. The principle is shown in the sections. Some set measures are framing the experiment such as set room height, and the balcony is naturally placed in the same height as the upper floor.

The mentioned factors are important to keep in mind when designing with overhangs as a passive design strategy, as it is crucial to its success.

An overhang has a big impact on how much solar radiation enters the window during the summer, when the sun's altitude is high. However, as shown in the diagram, it does not affect the amount of solar radiation during the winter and the heating period which will generate free energy to the building. The affect slows down somewhere eround 1800 mm.

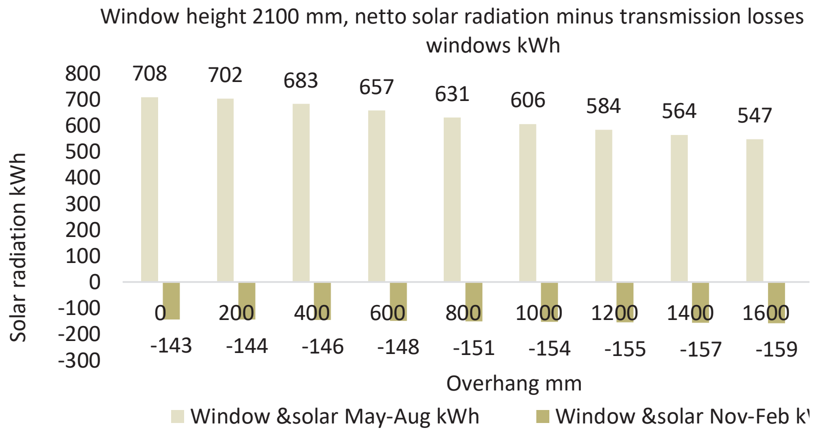


Figure 28: evaluation of the impact of gained solar radiation depending on the dept of the overhang above a window that is 2100 mm high.

Looking at the heating demand, it is so small in summer that it doesn't matter. The same is the case in winter. So it does not significantly affect the heating demand, but it can help to protect against overheating.

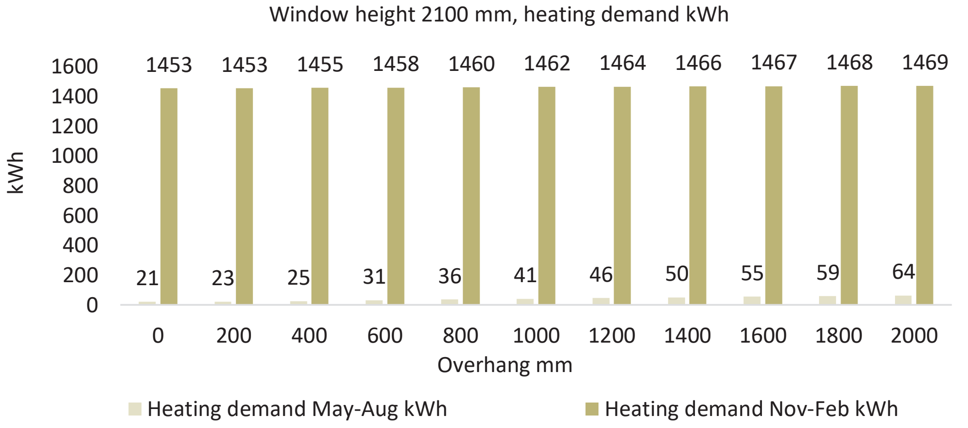


Figure 29: evaluation of the impact of the energy demand depending on the dept of the overhang above a window that is 2100 mm high.

In the example of a window with a height of 1300 mm, having an overhang of about 1200 mm reduces solar radiation significantly in summer, while it hardly affects solar radiation during the winter. The Kalstad project also has a fixed shading of 1,2 m above the window with the same

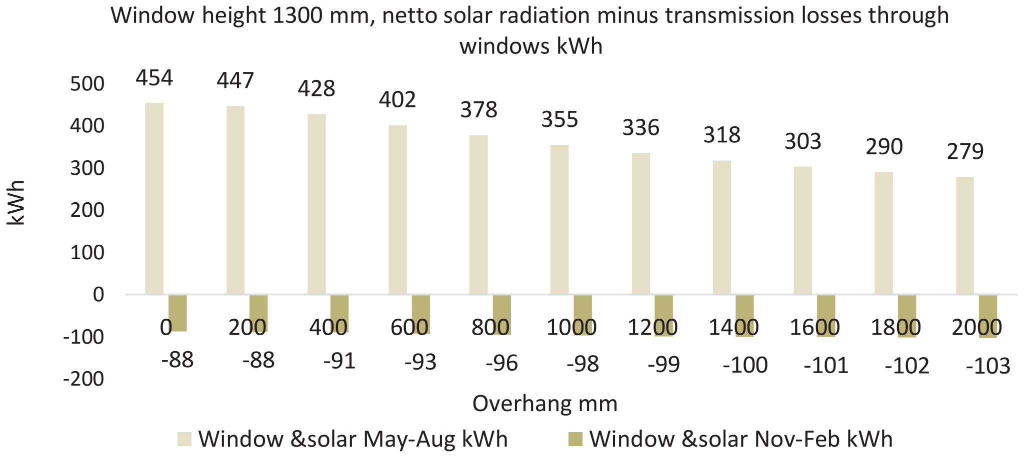


Figure 30: evaluation of the impact of gained solar radiation depending on the dept of the overhang above a window that is 1300 mm high.

It is clear that the heating demand does not increase in winter. In the summer, it increases slightly because there is less solar radiation, but because it is such a small amount of energy, it does not increase or decrease. The important thing is to protect against overheating.

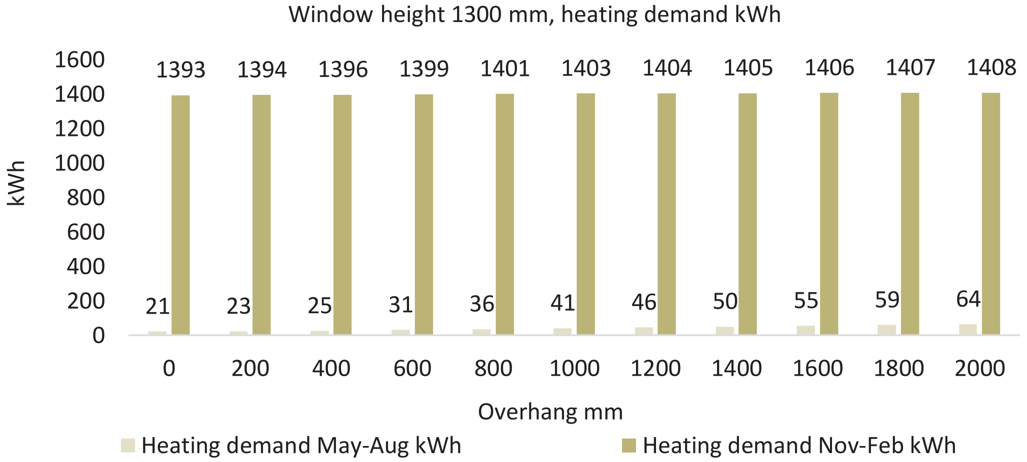


Figure 31: evaluation of the impact of the energy demand depending on the dept of the overhang above a window that is 1300 mm high.

THERMAL INERTIA

The effect of thermal inertia is tried out using a rammed earth floor that is added as the finish floor. By adding material with high thermal inertia, it is considered to be able to even out the indoor climate as it can consume heat and release it when it's needed. It is most effective when able to capture solar radiation, that's why it should not be covered with carpets since that can decrease the effect. This is a method where the surface of the remmed earth floor is being treated to be more durable and withstand everyday life.
Simulations were tried out with different thicknesses of rammed earth added as a finish floor. It is shown in table x.x that the energy demand is not affected much at all. Neither the relative humidity. The maximum operative temperature is lowered with less than one degree, and this is when adding a 300 mm thick layer which will impact the room height too much and becomes very expensive in relation to the effect. The effect that it is supposed to have is not confirmed through the simulations.

Another simulation was performed to investigate the effect of thermal inertia without a concrete foundation. Instead of a 100 mm thick concrete layer, a 22 mm thick wooden plank was used to investigate the difference. The results showed that 67 kWh/a could be saved by using concrete instead of the wooden plank. The results show that the effect would be much greater if the thermal mass was placed on a wooden slab in stead of the concrete foundation.

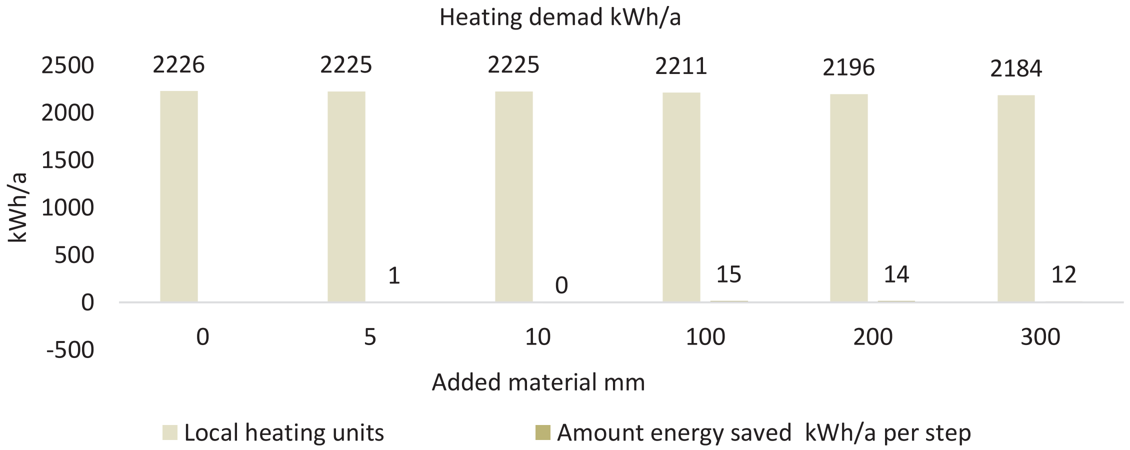


Figure 32: The diagram shows the effect on the heating demand when adding thermal mass in the form of rammed earth above the concrete slab. It turns out that the effect is very small and the layer has to be quite thick to have any effect at all.

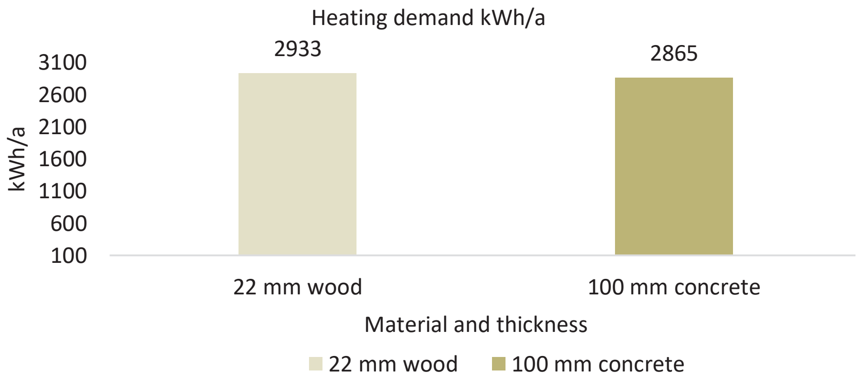
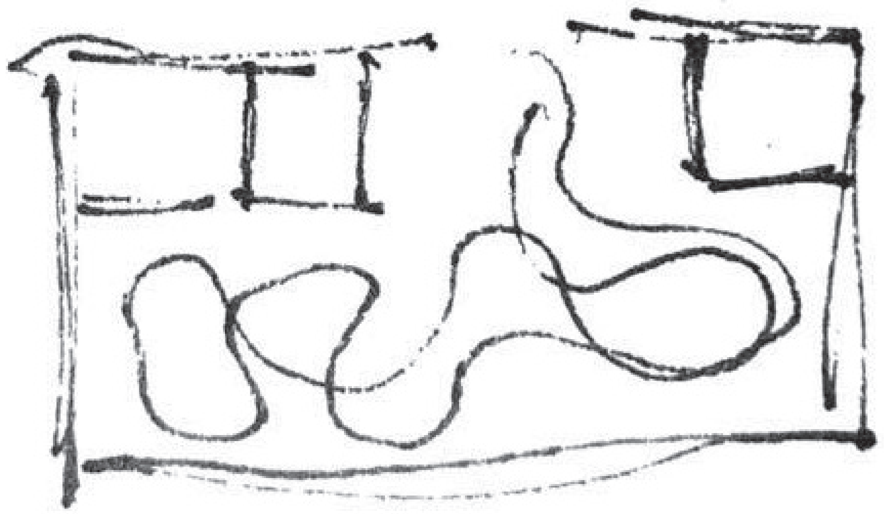


Figure 33: Since the effect was very small when adding thermal mass to the redundant concrete slab, another simulation was made to see the result of adding thermal mass to a wooden slab. This shows that the existing concrete already provides an effect that saves 67 kWh/a.



STRATEGIC FLOORPLAN

According to Hans Eek (1989), there are some basic rules about the floorplan to follow.

The enveloping surface should be as little as possible in relation to the floor area in order to minimize the energy use. It is also preferable to minimize angles and out-stuck building elements to reduce thermal bridges that lead to increased energy losses.

Regarding the placements of functions, the south orientated part of the building is suitable for common rooms such as the living room and kitchen. This is because you need bigger windows in these areas, and it's most justified to have big windows to the south regarding energy losses.
Another factor he mentions is the synergy of having several apartments in one building volume. By doing this, envelope transmissions can be reduced as the amount of outer walls decreases.

NATURAL SHADING

Studies show that greenery planted next to buildings and green plants along the facades can help reduce the energy demand of a building more or less.

For example, trees planted in front of the facade to the south or west can help shade the building when the sun has a lower altitude. It can also reduce the amount of cold winds that reach the building envelope and cools the building.
Evaporation from vegetation on buildings seems to have less effect according to several studies. Shading is highlighted as the most effective strategy when using vegetation for natural cooling (González M, 2018).

Natural shading was harder to simulate in IDA ICE. But conclusions can be drawn that it has an effect on the energy demand, more or less. It is also promoted for biodiversity and biophilia, and it can also be seen in the building examples.

SUMMARY

- Regarding the thickness of the wall insulation, the effect on energy use must be compared with the economic costs for extra material and the footprint of the building. A thickness of 390 mm has been chosen.
- The insulation thickness of the roof affects the economy, building height and energy consumption: the chosen thickness of the insulation in the roof is 590 mm.
- The chosen default value of 300 mm of insulation for the foundation seems to be the best according to the simulation as this is where the effect is greatest.
- The u-value of windows is an important factor in retaining solar heat from radiation during the heating period, as it also reduces energy demand. In summer, it is even more important to shade the windows to prevent overheating if you have a lower u-value because the windows are less good at conducting heat and the transfer of heat losses is reduced.
- A south-facing orientation with large windows has the best conditions for capturing solar radiation during the heating period. Simulations and literature show that it makes little difference to the effect up to a deviation of +- 20 from the south. In the east, west and north, transmission losses are greater than solar heat gains.
- Frame fraction is an important factor in minimizing energy losses. The frame fraction (amount of frame) should be as small as possible. This is because the frame is the weakest link. Therefore, divisions should be avoided and one large window is better than several small windows.
- The building should be as airtight as possible to minimize uncontrolled energy loss through the building envelope. It is important to install it with high accuracy because holes in the vapor barrier lead to energy loss and moisture problems.
- Solar radiation in the summer can be significantly reduced by using horizontal shades in the south. The depth of the shading element should be adjusted to block out the summer sun and let the sun in during the heating period.
- Thermal inertia was simulated to see how it affected heat demand as it can store heat and release it when the indoor temperature drops. The simulations show that it has to be a very thick layer to have any effect at all.
- An open floor plan is a way to ease the heating of the whole apartment. The area and angles of the envelope should be minimized to reduce energy losses. Since common areas need more daylight, they are preferably located in the south where large windows are suitable.
- Natural shading from trees and vegetation can prevent solar radiation from entering the building from the east and west because the height of the sun is low and horizontal shading above the window has no impact here.
- Solar panels can advantageously be used to provide the building with solar energy, which is often used to heat domestic hot water. Roof installations should be clustered on the north side so as not to interfere with the solar panels.

SITE & CONTEXT


Figure 34: The design proposal will be located where the garage is today, as shown in the image above. It will be a residential building with public functions on the ground floor, with integrated passive design strategies to reduce energy demand.

SÖDERBRO 10

To understand the selected site better, the analysis serves as a basis to know what is important and relevant for the site. This will help to understand different design choices, material choices and what is important to consider in this particular location.

Since every site is different, with different orientation, surrounding buildings, flows of people, etc., one needs to take this into account to know what passive design strategies are possible to implement in a particular site.

The analyses presented in this chapter are a brief introduction of Söderbro 10 and Kungsbacka, the history of the site to get a better connection to the surrounding buildings and circumstances, a description of the classification of the surrounding buildings, the ongoing work on a new zoning plan to make it possible to build new residential buildings on the site, mapping of flows in relation to the site, SWOT analysis to identify strengths, weaknesses, opportunities and threats within the site and its surroundings, and finally an analysis of the material in the area.

Söderbro 10 is a block in the old city center of Kungsbacka, Sweden. There are about 85 000 inhabitants in the municipality, and it is expected to increase with 13 000 within 10 years and 42 000 within 30 years (Kungsbacka kommun, 2023).

The climate of Kungsbacka is described as Cfb, marine west coast, warm summers and belongs to the temperate climate according to Köppen climate classification (Weather and climate, 2023). In the area around Kungsbacka, the average temperature for one year is about 9,9°C. The temperature records is -26°C as the coldest and 34,5°C as the warmest (SMHI, (2023).

Söderbro 10 were chosen for its complexity, as it has a lot of character with various historical buildings and complexity as the river Söderån flows through it. These aspects make the site complex but with that comes a opportunities.

The site also has a connection to the author, as she has walked by here a lot, wondered about the buildings and the site. The trigger to choose this site were a feeling of much more potential than the buildings on the site today live up to.

This thesis is about integrating passive design strategies into a residential project, but likewise, a proposal for architecture that are adapted to the site.

Green surroundings

Figure 35: View from the east towards the tannery with Söderån in front.

Figure 36:The local planting around Söderbro 10.

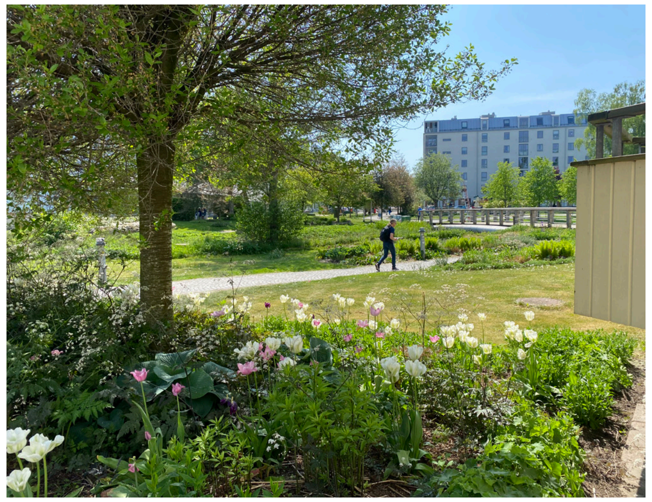


Figure 37: View of the greenery and park south of Söderbro 10.

Figure 38:View of the pedestrian bridge spanning the river Söderån.

Figure 39: View from the pedestrian bridge with a view of Söderån flowing north.

New detail plan

A new detail plan for the block Söderbro 10 is currently being prepared. The new detail plan will change the current property boundaries and include Söderbro 10 and Söderbro 11.

Figure 40: Map showing the boarders of Söderbro 10 (Kungsbacka, 2023).

Söderbro 10

Söderbro 10 consists of the area bounded by the orange area in the image on the right. It includes the garage and several other buildings. Söderån is not included in the property.

Figure 41: Map showing the old boarders of Söderbro 10 (Kungsbacka webbkarta, 2023).

Söderbro 11

Söderbro 11 is bounded by the orange-colored area to the right. It consists of the grocery store Hemköp and an area to the north where they have their loading dock and deliveries today.

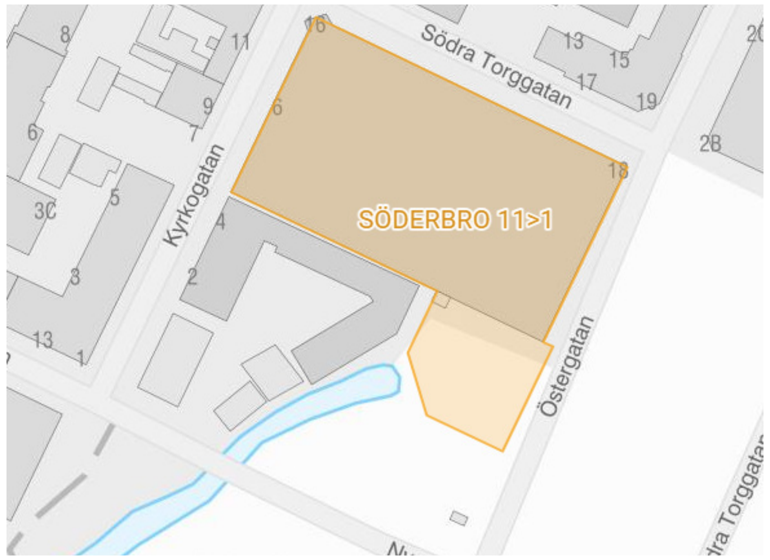


Figure 42: Map showing the old boarders of Söderbro 11 (Kungsbacka webbkarta, 2023).

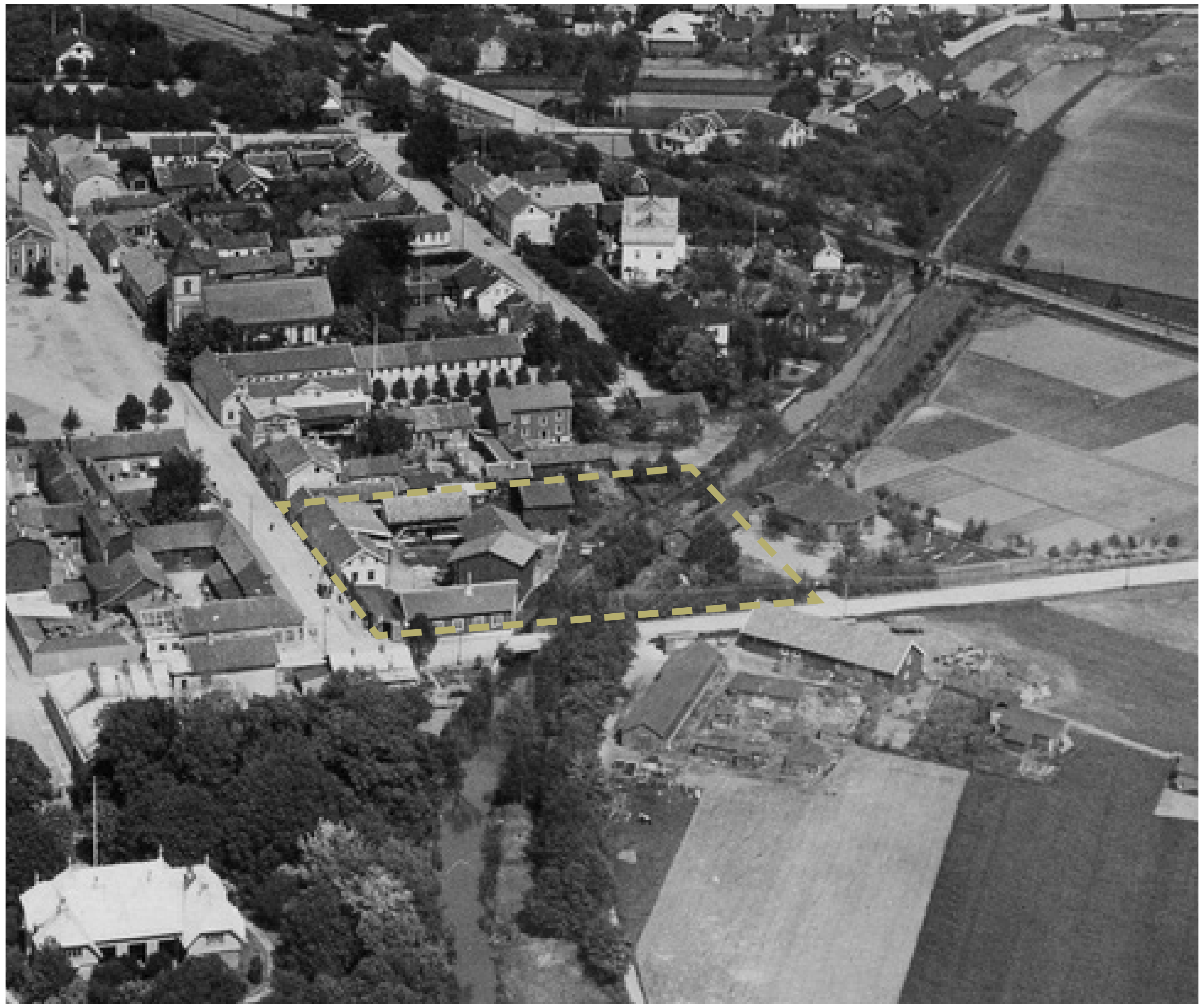


Figure 44: View of Kungsbacka, approximately 1910. Picture from Hallands konstmuseum.

HISTORY

Söderbro 10, is a property in the old city center of Kungsbacka, marked in yellow in the picture above. The city plan of Kungsbacka consists of a strict grid, dated back to the reconstruction after the devastating fire that destroyed the city center in 1846. The poor soil quality is one of the reasons why it the city was built with low wooden houses.

Kungsbacka has been a hub for commerce since the 1300s, and the square has played a crucial role. Commercial farms were common, and citizens earned a living through various crafts and agriculture. It used to be a commersial farm connected to each house it the city, and Söderbro 10 is one of three properties that has parts of its commercial farm left. Söderbro 10, located to the south east of the square, was a commercial farm that specialized in the tanning industry. It had three tannery buildings in the center of the site which only one of them is still there today.

The commercial farms were organized with its living house to the street and the other buildings were placed to ease the daily work (Visit Kungsbacka, n.d.).

Figure 42: One of the old tannery buildings, photo from the book Handel och småstadsliv i gamla Kungsbacka Larsson, S. (1996).

Figure 43: The tannery building that is left today.

Figure 45: The site Söderbro 10 in Kungsbacka, (Sweden Google. n.d.).

EXISTING BUILDINGS

Several buildings at the site date back to the era of the commercial farm, while others were constructed later. Among these structures, there are some of particular historical or cultural significance that must be preserved.

In collaboration with Kulturmiljö Halland, the County Administrative Board has conducted a thorough assessment of buildings in order to identify all culturally significant structures within the county (Acanthus Arkitektur & kulturvård AB, 2017). The structures featured in this inventory have been categorized into three different classes: A, B, and C and suggested markes for the buildings in the new detail plan:

Class A (national interest)
The first classification signifies that a building should be preserved and restored as closely as possible to its original state. This pertains to the building's form, materials, and style, down to the smallest detail. Any modifications or additions must also adhere to this standard. It is recommended that the building be designated as a q-mark in the detailed plan and protected under PBL 8:13-14 sections and 4:16 section (prohibiting alterations, maintenance requirements, and demolition).

Class B (regional interest)
The second classification also represents a very high cultural and historical value, and any modifications should be adapted to the building's character regarding its form, materials, and style, although not necessarily to the same level of detail as Class A. It is recommended that the building be designated as a q-mark in the detailed plan and protected under PBL 8:13-14 sections and 4:16 section (prohibiting alterations, maintenance requirements, and demolition).

Class C (local interest)
This classification signifies that the building holds a more everyday character with local historical and cultural value. Sometimes, the building may have been partially altered but still holds its characteristic and time-specific features. It may be protected to some extent through q-marking under PBL 8:14 and 8:17 sections (maintenance requirements and careful handling).

1. Norra Halland, Class C
The current premises of the newspaper Norra Halland since 1921. The building dates back to 1850 and is the residential building of the former commercial farm.

2&3. Garage (no class)
A garage building stands on the site of a former agricultural building. The garage was built around 1960.

4. Tannery, Class B
The structure dates back to sometime between 1846-1899 and functioned as a tannery during the period of 1860s to 1920.

5. The printing house, Class C
It was built in 1955 in a functionalist style and was used as a printing house for Norra Halland. The newspapers were printed by hand and the equipment remains untouched today. It is considered a unique printing environment of great value.

6. The farmhouse wing, Class B
The courtyard wing is thought to have been built after the fire of 1846, but may date slightly later. Probably animals were kept on the ground floor. Later, several functions have existed in the house but are more or less empty today.

7. Loading dock (no class)
Loading dock to grocery store.

Figure 46-52 (Acanthus Arkitektur & kulturvård AB, 2017).

FLOWS

Many people pass the site every day. Just a short distance south of Söderbro 10 is Aranäsgymnasiet, a local gymnasium whereby several hundred people walk to from the station every day. Also, Söderstaden, with its apartment complexes and new ones being built right now, strengthens the flow to the station and many people pass Söderbro 10 daily.

Because there is exposure to both pedestrians and traffic on the road adjacent, the building has good conditions for exposure and visibility. This provides a basis for running public functions here such as a restaurant or a cafe.

MAPPING OF FUNCTIONS

Key features that contribute to the main pedestrian flow are identified on the map. Shopping center, train and bus station, Söderstaden and Aranäs gymnasium are not shown on the map but the text shows the direction.

Since Söderån flows through the site, it creates a living environment that can be used for recreation by the residents who can see the water and greenery, and also for the public premises such as the restaurant right next to the river. This creates good conditions for an outdoor seating area that can connect the building with the river.

Main car road

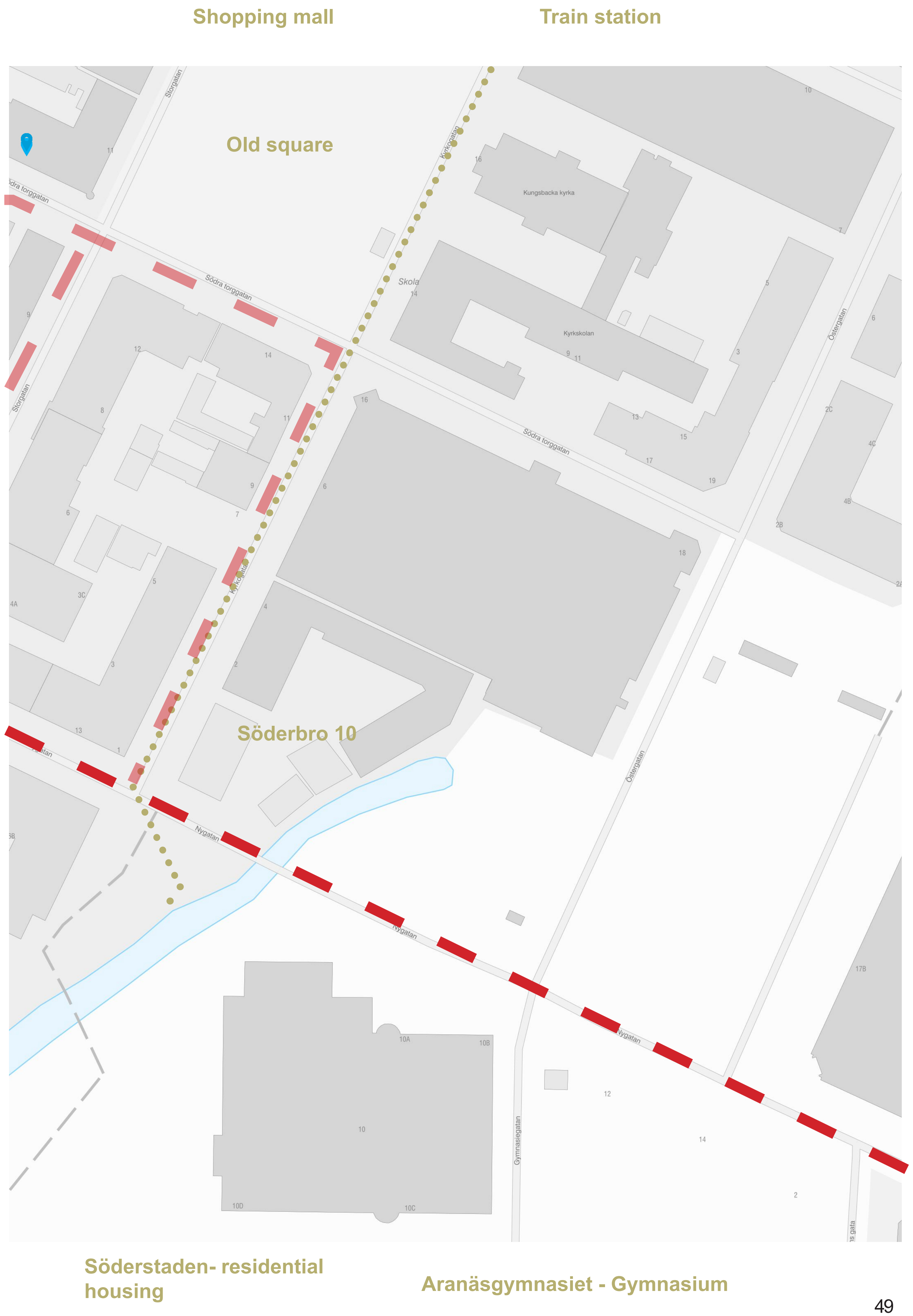
▬ ▬ ▬

Car road

▬ ▬ ▬

Pedestian strong flow

• • • • • • • • • • • • • • •



STRENGTHS

Strong flow of pedestrians passing by, providing good opportunities for public functions.

Söderås river contributes to a biophilic atmosphere

Open space in front of south facade

WEAKNESSES

Main car road in front of south facade

Building blocking the evening sun

Buildings towards north and west that block daylight

Deviated 26° from south

OPPORTUNITIES

Public functions, such as a café or restaurant

Söderån can be an integrated feature within or adjacent to the building

Connect to historical aspects

Place long facade towards south

THREATS

Flooding

Weak soil

SWOT ANALASYS

Strenghts, weaknesses,opportunities and threats are identified in the SWOT analysis above. The analysis is a way to clarify what influences the design and how to adapt the building to the specific circumstances of the site.

The fact that a lot of people pass by the building provides the opportunity for a base of public functions. this differentiates the building from one that is on the outskirts of the city where there is no flow of people. The building will also be seen by many people every day and will be the focus of attention, which creates the conditions for it to become a well-recognized building in the city.

Söderån creates many synergies for the area, such as an outdoor biophilic environment that can strengthen the biodiversity of the area. It will be visible from inside the building and the water will complement the greenery both visually and as an important water supply. There are also risks associated with the river, such as the flood risk it brings, which should be controlled with awareness and possible water protection around the building. Söderån can also create soil instability, which is also affected by poor ground conditions at the site.

The area in front of the building to the south is open and there is an open green area. This allows the sun to reach the building in the south unhindered and creates good conditions for the sun to heat the building during the winter. It also enables a long view of the green area from the building, which is a highly valued quality.

The fact that the block of söderbro 10 has a solid history characterized by the commercial farms and the craft tradition of tanning means that there is a strong soul on the site and opportunities to connect to this. Marerial has been characterized by the tradition of the time and there are both wood and plaster as facade materials on the buildings around.

To the south of the site is a road that is one of the most used in the inner city and serves as a main route through the inner city. This causes some noise, although the speed is low. However, it contributes to a good exposure for the building which strengthens the basis for public buildings.

To the west of the site are buildings that are three stories high. This means that the evening sun is limited. But it also does some good as it helps to block out the strong evening sun in the summer which often results in overheating indoors. Daylight is also blocked by the building to the north.

The site naturally follows the street bordering the site which is deviated 26° from south. This reduces the amount of solar radiation and can be compensated for by angling the building.

The previously mentioned conditions of the site will be guiding and decision-making for the site and design.

MATERIALS

The materials for facade cladding and roofing in the area are widespread. However, there is a clear effort to keep the character rather traditional. As the material palette differs from house to house, the choice of cladding for the design proposal is more open. Taking into account the context and history of the site, inspiration can be drawn from the traditional.

wooden facade and plaster are common in the vicinity of the site. Various colors decorate the buildings, which are traditional bright and earthy colors.

DESIGN PROPOSAL

Figure 1: Perspective from the southwest. The building is shaded by trees and ivy to the west. Balconies and roof eaves shade the building in summer and prevent overheating. Along the promenade you enter the restaurant.

SÖDERBRO 10

The purpose of the design proposal is to show how integrating passive design strategies can affect a building on a specific site. To do this, different passive design strategies suitable for the climate of Söderbro 10 have been analyzed and actively chosen to be integrated in the design proposal.

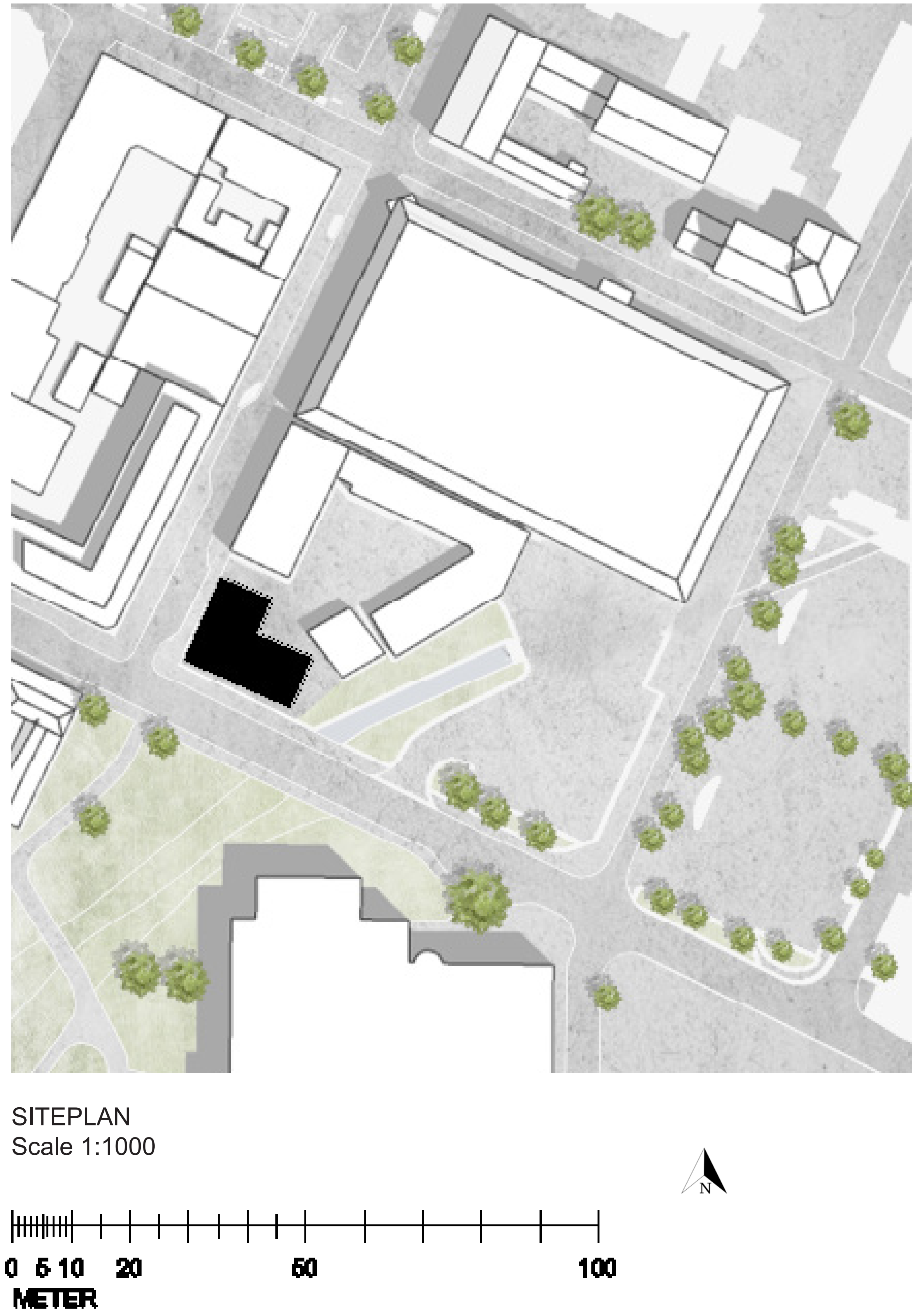
The following passive design strategies have been integrated:

- Insulation
- Energy efficient windows
- Airtightness
- Orientation and glazing towards south
- Fixed shading
- Strategic floorplan
- Natural shading

Thermal inertia was excluded as it was found to have little or no impact on the energy consumption of the building, that is to say, on the energy efficiency of the building.

Insulation

Insulation was identified in the literature as an important passive strategy to retain heat inside the building. This was confirmed in the simulations. Based on the default value of 290 mm insulation, the first 3 - 4 steps of added insulation of 50 mm at a time in the wall had the greatest effect. After that, the effect decreased. However, given that the wall thickness affects the footprint of the building, and indirectly the area that can be sold or rented, an insulation thickness of 390 mm was chosen. This significantly improved energy efficiency while preserving the size of the building's footprint.



SITEPLAN
Scale 1:1000

Figure 1: Perspective from the southeast showing the outdoor seating area for the restaurant. Here customers have a view of Söderån and can enjoy breakfast or lunch in the sun. The tannery encloses the area and together with the building it protects the area from cold winds.

Energy efficient windows

The U-value of the windows was found to have a large impact on the energy demand of the building, it is also one of the weakest links in the building. The effect of reduced energy consumption was found to be linear between the chosen u-values of 1,2 and 0,7. Therefore, a u-value of 0.7 is chosen as it is a reasonable value to aim for considering the energy saving effects and in relation to the windows being a necessity.

Airtightness

Airtightness is an important factor in minimizing heat loss through leaks in the building envelope. A value of 0.3 l/s was chosen and is a reasonable value according to analysis of previous projects.

Orientation and glazing towards south

To capture as much solar radiation as possible during the heating period, literature and simulations show that a long side of the building with large windows should be oriented towards the south. The design proposal and site allows for a long side facing south, but with a natural deviation from south of 26°, due to the natural angle of the road that touches the site. To compensate for this, the building was angled 3° to the south. This may have a major impact as the analyses and literature showed that a deviation of +-20° from the south did not have a significant impact. On Söderbro 10, it is therefore well argued to angle the building slightly and deviate from the alignment with the street. In addition, it is also towards the south that the building has the largest window areas.

When examining the impact of the number of windows and window size on energy consumption, the frame fraction was found to have a significant impact. Hence, thinner window frames of 50 mm have been chosen. It also turned out that one larger window is significantly better than several small ones because it minimizes the frame fraction. The design proposal therefore uses larger windows rather than several smaller ones.

Fixed shading

To reduce the air- and operating indoor temperature, horizontal fixed shading was used above the windows to the south. In the south, it was natural to use the roof overhang and balconies as shading. The balconies were placed 380 mm from the top of the window to the bottom of the balcony as this was the natural way to align the balcony with the floor of the apartment above. The depth of the balcony was determined through simulations and sectional studies, it also varies depending on the size of the window below. This creates a dynamic in the balcony belt that extends around the south and a bit into the west and east. In the west and east, it has no shading function as the sun in these weather decks is too low. The design rather supports the possibility of viewing in more directions on the balcony. It will be possible to enjoy the morning sun in one apartment and the evening sun in the other. The sun shield became an important part of the proposal and proves to be possible to create a playful expression of the facade while fulfilling its purpose. As the need for horizontal solar shading only exists in the south, Söderbro 10 was well suited to argue for balconies for all the apartments.

Strategic floorplan

The common areas of the apartments, such as the living room and kitchen, are oriented to the south due to the appropriate combination of large windows. Bedrooms and bathrooms are placed in other directions as they tend to need smaller windows. The apartments have an open plan layout to facilitate the distribution of heat.

The scale has been minimized by designing a residential building with several apartments sharing walls with each other. The facade is also designed without unnecessary angles to minimize thermal bridges.

Natural shading

To shade the building to the west and east, natural shade can be used. The advantage of natural shading is that it loses its leaves during the winter. This allows the winter sun to enter the building and heat the room, while

Figure 1: The courtyard on the north side of the building is a gathering place and a semi-private space for the residents. It is from here that one enters the apartments. By having the entrance on this side, rather than the south or west side, there is a clear division of private and public.

in summer the leaves prevent overheating by blocking the sun. In the proposal, ivy climbs on the east and west facades, which will provide shade for the building, and on very hot days it can also serve to cool the building through evaporation.

Since the building is located in a corner of the plot, extending the shape of the building has allowed for an additional apartment. It would otherwise be an unused plot, so it was decided to add it to the otherwise simple rectangle shape. The apartment located in this extension has different conditions and cannot meet all passive design strategies in the same way as the building to the south.

Reflections on passive design strategies for Söderbro 10

The site was quite suitable for integrating the passive design strategies, some of them with slight modifications. This shows that it does not have to be black or white, but you can solve problems to promote the effect. Since this building is fortunate to be south-facing and there are no buildings blocking the sun in the south, it can use solar radiation effectively to heat the building in winter.

Similarly, when designing buildings in a strict urban pattern, it could be that the building is not exposed to the south at all. Then the only way to minimize energy demand is to minimize transmission losses by having smaller windows and a well insulated and airtight building envelope. So the conclusion is that Söderbro 10 is well suited for all the chosen passive design strategies, which would not be the case in any location in the center of Kungsbacka.

APARTMENT APARTMENT APARTMENT
APARTMENT APARTMENT APARTMENT
RESTAURANT RENTABLE SPACE

PROGRAM

The program is based on the growing population of Kungsbacka and on a location with good pedestrian flows. Therefore, the building will have public functions on the ground floor and apartments on the two upper floors. The apartments can either be condominiums for sale or for rent. The latter option would be beneficial if the developer rents it out, as they can recoup their inventions for passive design strategies thanks to low operating costs.

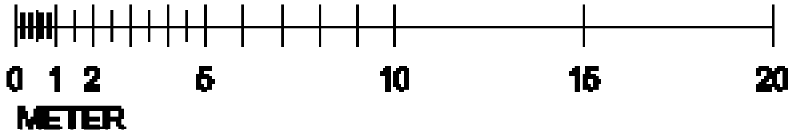
As the housing market is expensive and there is a housing shortage in Sweden, the building contains smaller apartments that are cheaper to rent or buy.

There are public functions on the first floor and then six two-room apartment and two one-room apartments. Hopefully this, together with the passive design strategies, will generate cheaper apartments on the market.

FACADE TOWARDS WEST 1:200

FACADE TOWARDS EAST 1:200

Scale 1:200

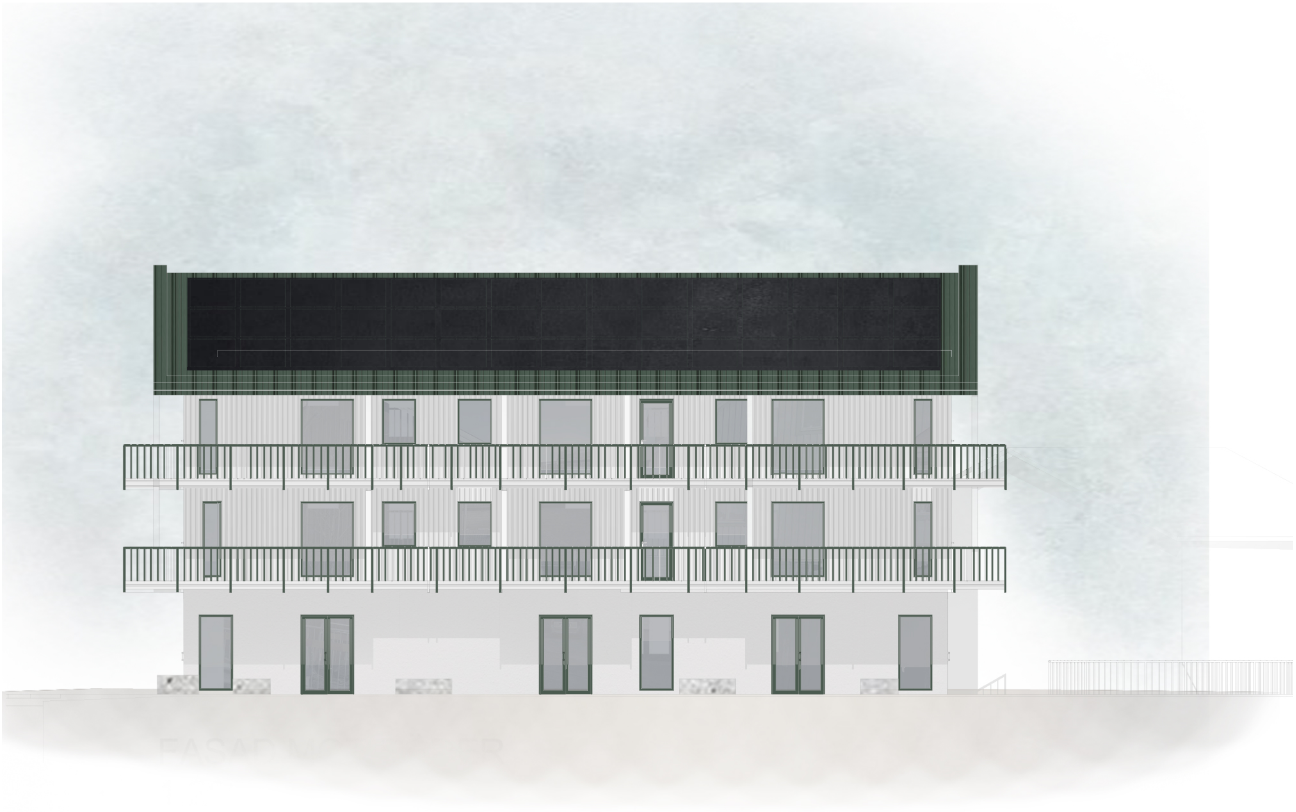


Facade towards west

There are fewer windows in the west, based on the results of the research and simulations, as this reduces the amount of transmission losses through the windows. It is also more difficult to avoid overheating in the west, as horizontal shading cannot be used. Instead, ivy leaves decorate the facade and provide the building with some shade and evaporative cooling. It also contributes to the character of the building, as the greenery allows the building to stand out.

Facade towards east

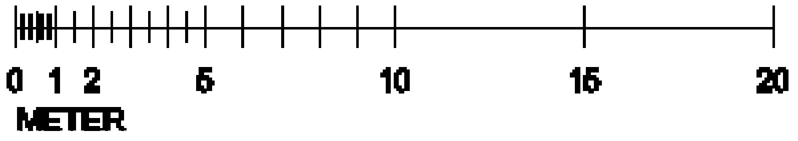
As with the eastern facade, horizontal shading above the windows cannot be used because of the low sun. Instead, ivy leaves are also used here. Fixed vertical shading elements were not used since it could block the view.



FACADE TOWARDS SOUTH 1:200

FACADE TOWARDS NORTH 1:200

Scale 1:200



Facade towards south

The south facing facade is important when it comes to capturing solar radiation to heat the building with free solar energy. This is why the building has large south facing windows. There are also balconies which, together with the roof overhang, block the sun during the summer to prevent overheating.

Facade towards north

The northern facade has no relevance for capturing solar radiation but is instead only a source of large energy losses. Therefore, there should be fewer windows on the northern facade. However, it is important to ensure that it is not limited to the extent that there is a lack of daylight in the building. This can be ensured by daylight simulation for the individual project.

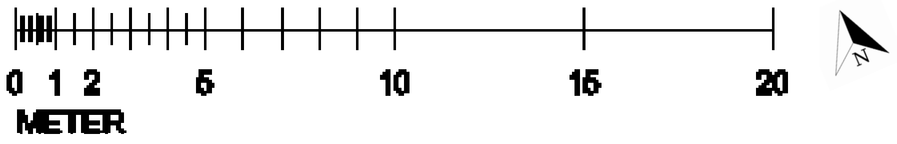
ENTRANCÉ FLOOR 1:200

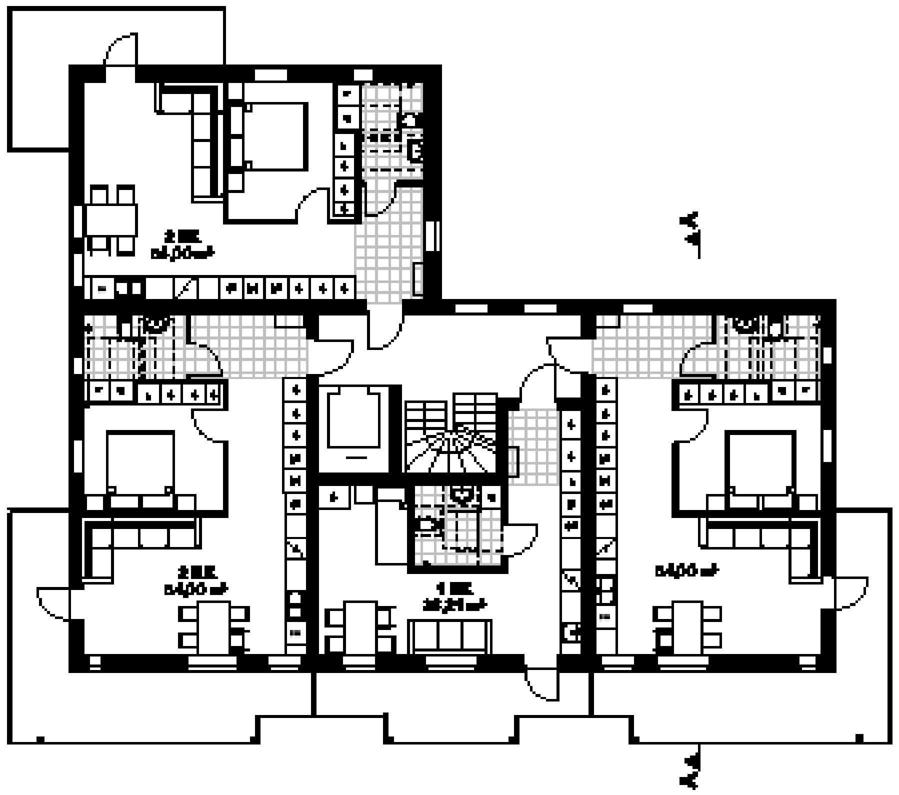
ENTRANCE FLOOR

The ground floor houses a restaurant with seating facing south and west, overlooking Söderån. The outdoor terrace extends out towards the river Söderån and creates an outdoor space to enjoy a meal. The outdoor dining area borders the tannery, which together with the new building creates an enclosing feeling between old and new. There is also a premises for rent that could be used as a shop.

The entrances to the restaurant and premises are accessed from the street side, which is the public part of the building. In the courtyard is the entrance to the stairwell leading up to the apartments. The courtyard becomes the entrance and a space for the residents.

Scale 1:200





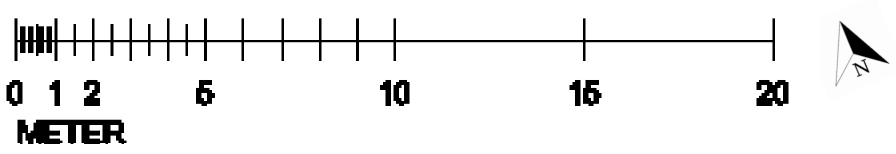
STANDARD FLOOR 1:200

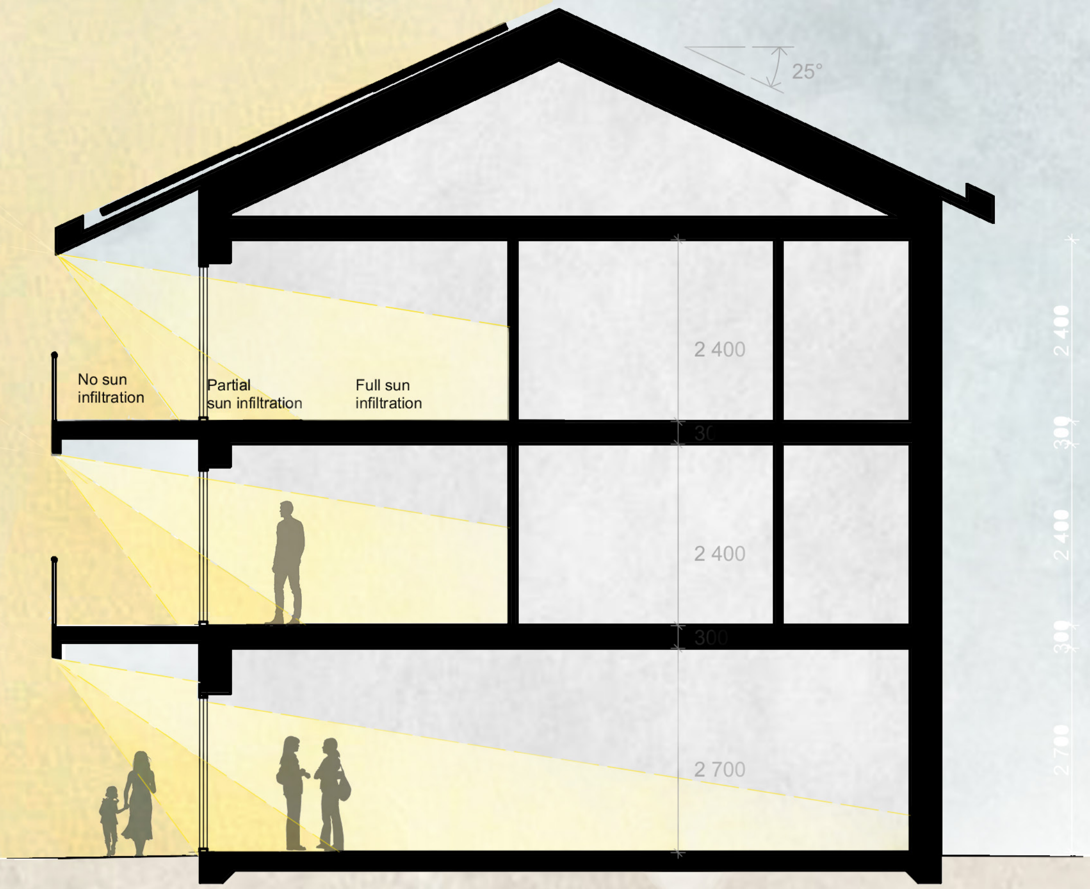
RESIDENTIAL FLOORPLAN

The layout of the second and third floor is identical and consists of two two-room apartments and one one-room apartment on each floor. The depth varies due to the size of the windows below. This creates natural deeper sequences on the balconies that are more suitable for furnishing.

The floor plan is open to facilitate heat distribution and create open and bright apartments. Four apartments can be accessed from the stairwell.

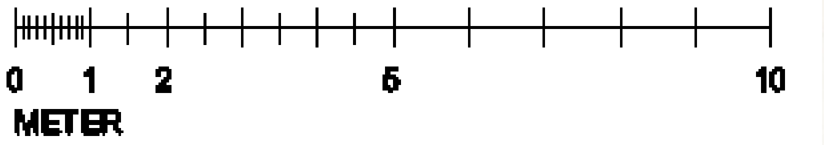
Scale 1:200





SECTION A-A 1:100

Scale 1:100



SECTION

Section A-A shows how the sun enters the building at different times of the year. Balconies and the roof overhang protect and block solar radiation during the summer, preventing overheating and lowering the operational temperature inside the building. The overhang for a window that is 2100 mm high is shown in simulations and sectional analysis to be appropriate at a depth of 1900 mm. A window that is 1200 mm high, on the other hand, requires an overhang of 1200 mm.

The first step from the left in the section marked in yellow shows the summer sun during summer solstice 21 June with a sun altitude of 53.47. The middle step shows the sun between 15 April (altitude 40,31) and (15 Sep altitude 33,99). During this period there is no need for heating and therefore the sun can be blocked. In the section it is partially shaded. During the heating period, the sun is not blocked at all, which means that solar radiation can be optimally utilized.

DISCUSSION

In my design proposal for Söderbro 10, the passive design strategies resulted in a 15% reduction in energy consumption. This was based on the passive design strategies selected from the literature research and the example projects, and on the simulation performed in a simplified model in IDA ICE. The simulations were performed in a simplified model that strived to resemble the local climate and conditions, and to be based on a common building standard in Sweden. In addition to this construction, all added passive design strategies are a plus that reduces the operating energy of the building.

The simulations could have been carried out with more variations in order to get a better picture of how to get the most effective implementation of the passive design strategies, for example, it could have been investigated how it affects the energy demand by having different insulation thicknesses in walls facing different directions. This leads to a further question that would benefit from more attention, how different design strategies affect the economy, the rationality of construction and the time of the construction phase.

These measures affect the operational energy of the building, it does not take into account the embodied carbon and the whole life cycle. This is another aspect that would have been essential to investigate in order to get an holistic view of the consequences of the design proposal.

The variety of analyses, the economics and the life cycle of the energy consumption of the building would have been important steps to take this work further, and to investigate how the passive design strategies could be optimized or developed to achieve even higher energy savings. The work has been limited in this way due to the time aspect and the amount of investigation that was possible during this time. Hence, further development of the project could certainly have led to even higher energy savings and deeper reflection on its pros and cons. However, the work has given a clear picture that it is quite possible to save on operational energy consumption and that it is possible to use common building elements such as roof projections and balconies, as long as they are placed consciously.

The implementation of the passive design strategies on Söderbro 10 has provided a good understanding of how they are affected by the local context. For example, the site has quite good conditions for capturing solar radiation as it is oriented 26° from south. The building is angled with 3°, which provides even better conditions and is a clear example of how the passive design strategies affect the design of a specific site. If the site had been shaded by other buildings to the south, passive solar energy would not have been useful for the buildings. A conclusion from this is that which passive design strategies are suitable for a certain site is very individual, but you can work with them according to the conditions you have and minimize the energy consumption.

A difficulty in performing simulations of calculated energy demand is that all parameters have to be estimated and set correctly. This entails the risk that the calculations do not match the reality once the building has been put into operation. This is the reason why it is important to make follow-ups of the actual energy consumption when the building is completed to ensure the actual impact of the passive design strategies. In this work, the estimation of the energy consumption and the settings in IDA ICE is something that is a difficult balance and affects the results. A great effort has been put into this, but it is first when actual measurements are taken that an accurate result is available.

Thermal inertia was one of the passive design strategies investigated and it was found in the simulations carried out to have very little impact and was excluded from the design proposal. This was considered to be due to the fact that there is not enough solar radiation generating heat to absorb during the heating period. This was also the case in the Karlstad project. In House K, thermal inertia is an important aspect, but here it is used in combination with a chimney which means a large amount of added energy that can be stored and thus may be of greater relevance. As a complement, another simulation was performed where the purpose was to investigate how much the concrete base plate did, it turned out that without the base plate, 67 kWh/a was lost. This indicates that the effect of implementing thermal mass on a wooden floor has a much greater impact.

CONCLUSION

- Passive design strategies needs to be adapted to the local climate and surrounding area
- Big windows orientated towards south are the best to capture enough solar radiation during the heating period
- A deviation from south up to +-20° does not affect the amount of solar radiation that much
- Vertical overhangs in the sout are very important to prevent overheating in the summer
- The optimal length of the vertical overhangs depends on the local altitude of the sun. It also depends on size of the window, parapet height and distance from window to overhang
- Horisontal overhangs only works towards the south, since the sun has a higher altitude. In east and west, overheating is also someting to prevent but shading must be in front of the windows
- Thermal inertia has shown by studies by hans Eek and simulations in ida ice to have little or no impact on energy demand
- There are different ways of working with lowering the energy demand, but they share some principles. Since the vernacular architecture, bioclimatic design has been used. This is strongly connected to the local surroundings and climate. Passive house is using principles fron bioclimatic architecture but is a vad to certify a building and a proof that it uses less energy.
- Bioclimatic design is more related to choice of material, by using local materials. Passive houses are only focusing on the energy demand.
- The impact on energy demand because of vegetation is hard to simulate an there are different opinions on how much it accualy affects
- The affect of the insulation thickness can clearly be seen in the simulations, and it are in relation to the example with beckomberga passive houses
- Windows are the weakest part of the buildings and a lot can be done to prevent heat losses, but as the u-value gets lower it becomes even more important to shade the window during the summer to prevent overheating.
- Frame fraction is an important factor and less but bigger windows with no divisions have shown to be the most energy saving stratgy.

REFLECTIONS

While working on this master's thesis, I have faced a major challenge as my prior knowledge of the subject was not enough to be able to familiarize myself with the topic. I have learned that there are many aspects to consider when it comes to passive design strategies and my work has really deepened my knowledge. The most important thing I take away from the work is the ability to communicate with architects and other disciplines regarding a building's energy needs and to be able to influence the design of buildings that are characterized by passive design strategies.

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