CHALMERS

Users impact on energy consumption in a low energy building

Master of Science Thesis in the Master's Programme: Structural engineering and building technology

ANDERS FREMLING

Department of Civil and Environmental Engineering
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CHALMERS UNIVERSITY OF TECHNOLOGY
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Abstract

When calculating the energy consumption for a low energy house the tenant’s behaviour is hard to predict and is not well defined in the calculation methods. Therefore the result can be misleading when the users behaviour don´t respond to the behaviour that was expected by the person calculating the energy consumption.

This master thesis explains how the energy consumption can differ in terms of airing, hot water use and how different building solutions affect the total energy consumption in a multifamily house. This will lead to a better understanding of how calculations are made for low energy houses and how the results are going to be interpreted.

In water calculations there are different calculation methods, one for conventional houses (Sveby: see chapter 3.1) and one for low energy houses (Feby: see chapter 3.2). The studied property is designed with Feby 09 which is now replaced with Feby 12. These three are compared with measured data from a number of different properties and none of them match perfect with the measured data. An alternative standard of 25 kWh/m^2(BOA) are suggested instead.

Opinions on how much hot water individual measuring and billing saves is discussed in the report. What emerges is yet to individual metering should be installed in new construction. The purpose is to be able to track where the energy is consumed.

Energy losses due to airing are more complicated in calculations. The reason why people vent differs in the calculations for Sveby and Feby. This means that there is an interest to investigate which parameters that causes airing.

To achieve an indoor climate were the user vents as little as possible, even during summer time, it is important with proper solar shading. If there is a lack of shading, the indoor temperature will rise as much so there is a constant need for airing during summer which probably results in increased airing habits even in the colder seasons under the year. Lack of shading also leads to large variations during the day. The user can prevent this in two ways. Either by open the windows a lot during a short time or open with a small gap during a long time. This thesis show that even small gaps can lead to large energy losses and also small gaps should be avoided as far as possible.

Key words: User behavior, energy, IDA ICE, airing habits, water consumption,

Sammanfattning

Vid beräkning av energiförbrukning av ett lågenergihus är brukarens vanor svåra att förutse och beteendet är inte definierade på ett tydligt sätt. Därför kan resultaten för energiberäkningen vara missvisande när det antagna beteendet inte motsvarar det verkliga beteendet.

Denna masteruppsats förklarar hur energiförbrukningen kan variera när det kommer till vädring, varmvattenförbrukning och olika byggnadstekniska lösningar i ett flerfamiljshus. Detta kommer att leda till en större förståelse för hur beräkningar utförs i ett lågenergihus och hur resultaten skall tolkas.

Vid beräkning av varmvattenförbrukning finns det olika beräkningsmodeller att följa, en för konventionella byggnader (Sveby se kapitel 3.1) och en för lågenergihus (Feby se kapitel 3.2). Den studerade fastigheten är projekterad efter Feby 09 som numera är ersatt med Feby 12. Dessa tre beräkningssätt är jämförda med uppmätta förbrukningar i ett antal fastigheter och brister är identifierade i samtliga beräkningssätt. Ett alternativt schablonvärde på 25 kWh/m^2(BOA) föreslås istället.

Åsikter om hur mycket varmvatten individuell mätning och debitering sparar diskuteras i rapporten. Vad som framkommer är ändå att individuell mätning bör installeras vid nybyggnation. Detta främst för att kunna spåra vart energin förbrukas.

Vädring har en något mer osäker beräkningsgång. Anledningen till varför de boende vädrar skiljer sig åt i de olika beräkningarna för Sveby och Feby vilket innebär att det finns intresse att undersöka vilka aspekter som föranleder vädring.

För att uppnå ett inomhusklimat där brukaren vädrar i så liten utsträckning som möjligt, även sommartid, är det viktigt med genomarbetad solavskärmning. Vid brist på solavskärmning kommer inomhustemperaturen att stiga så pass mycket att ett konstant vädringsbehov finns under sommartid vilket kan medföra ökade vädringsvanor även till de kallare delarna av året. Brist på solavskärmning leder även till stora dygnsvariationer, detta kan brukaren undvika på två sätt. Antingen genom att ställa upp fönstern mycket under kort tid eller med en liten glipa under lång tid. Arbetet påvisar då att även små glipor leder till stora energiförluster och ska undvikas i så stor utsträckning som möjligt.

Nyckelord: Brukarbeteende, energiförbrukning, IDA ICE, vädringsvanor, varmvattenkonsumtion

Contents

Preface

This thesis is the last semester at Chalmers and at the master program Structural Engineering and Building Technology. Most of the work has been spent at WSP with my supervisor Hans Wetterlund. I would like to thank Hans and the rest of my colleagues at WSP for all the help and support. At my time at Chalmers, Angela Sasic Kalagasidis has been a great support.

The work has been an interesting and stimulating process, not only during this thesis but all of my time at Chalmers. Thanks to family and friends that have been supporting during these five years.

Göteborg May 2013

Anders Fremling

Abbreviations

A_{temp}	The total area heated over 10 ° C also mentioned a heated area. [m^2]
BOA	Living area (Boarea in Swedish) [m^2]
DHW	Domestic hot water
DVUT	Dimensioned outdoor temperature, the lowest outdoor temperature used in calculations. In Göteborg the DUT is -10.9°C for a medium heavy building (Erlandsson, 2009). (Dimensionerande vinterutomhustemperatur in Swedish)
Feby	Forum for Energy Efficient Buildings, the group that is setting the demands for passive- and low energy houses in Sweden ("Forum för Energieffektiva Byggnader" in Swedish)
g-value	How much solar energy that is led through the window. [%]
HLF	Heat loss factor – a method to calculate the power demand in a passive house.
HVAC	Heating ventilation and air conditioning
Million program	During the 60s and 70s, one million new homes were supposed to be built in Sweden. They are mainly located in the suburbs in the larger cities and the quality of these houses often poor.
SHF	Sun heat factor – a way to measure risk for overheating.
Sveby	A development program that is run by the building and housing industry ("Standardisera och verifiera energiprestanda för byggnader" in Swedish)
T-value	How much daylight that is led through the window [%]
PPD	Predicted percentage dissatisfied [%], a way to measure indoor climate
PMV	Predicted mean vote [°C], a way to measure indoor climate

1 Introduction

In the opening chapter the background, purpose, limitations and questions will be presented to get an overview of this master thesis.

1.1 Background

Heating of buildings and heat for domestic hot water is today a big part of the total energy consumption in Sweden and in the world. To minimize the energy used in buildings, many different types of low energy house concepts are introduced the last years. Mini energy, plus energy and passive houses are some of the concepts that can be found on the market today.

When calculating the energy consumption for a low energy house the tenant's behaviour is hard to predict and is not well defined in the calculation methods. In a low energy house the energy consumed by the user becomes a significant part of the total energy use, due to the low total consumption. Total energy use can therefore differ a lot from what was calculated. The expected value for user related energy use is normally around 24 – 29 kWh/m^2, this is normally around half of the total heating demand for a low energy building. Variations can though vary from 0 to over 100 kWh/m^2 between the apartments. Therefore, the calculated energy consumption can be misleading when the users behaviour do not respond to the behaviour that was expected by the person calculating the energy consumption. The people or company running the building will then expect an explanation why the calculated energy consumption does not respond to the measured result.

This master thesis will explain how the energy consumption can differ in terms of airing, hot water use and how different building solutions affect the total energy consumption in a multifamily house. This will lead to a better understanding of how calculations are made for low energy houses and how the results are going to be interpreted.

1.2 Purpose

The aim with this thesis is to be able to explain in good way why and how much the energy consumption can differ from what was calculated in a low energy house. In further calculations the thesis will be a support for consultants to be able to estimate how the tenant affects the total energy consumption, both in terms of domestic hot water use and airing habits.

Furthermore, the thesis is going to explain which technical and architectural solutions that affect the indoor climate. Different types of indoor climates will require a certain airing habit of the user to adjust the indoor temperature and will lead to varied energy consumptions for different users.

Questions that are going to be answered in this thesis are the following:

Are the calculation methods there are used today representative for how the measured results look like?

Is it possible to adjust the predicted hot water consumption based on the type of building being built?

What effect has different types of airing at the energy consumption of the building?

Can we predict how much and how often the tenant will open their doors and windows for airing, in the studied building?

1.3 Method

Literature studies and investigations have been made to find out how airing, hot water use and building solutions are taken into consideration when calculating the heat losses and how the habits look like for different types of tenants. Moreover, it is investigated how these three factors affect the total energy consumption.

To be able to get reliable data when it comes to water consumption, the big housing companies in Göteborg are contacted to get data for buildings where hot water is measured for each apartment. Data is collected and evaluated in order to compare the calculated values with and see how the calculation methods respond to real consumptions.

The calculations, when it comes to airing, are going to be made in IDA ICE due to its benefits with zone division and airing simulations in energy calculations. All simulations will be performed on a passive multifamily house, owned by Eksta Bostad AB, located in Kungsbacka. Results from the simulations are going to be compared with each other to see how different technical solutions affect the building in terms of overheating and need for airing. The conclusions from IDA ICE are then compared with literature studies and further simulations to see how the energy consumption is affected by airing habits and different technical solutions.

The calculation tool that is used in this thesis is IDA ICE from Equa. The user of IDA ICE can influence most parts of the building, technical solutions, outer conditions, climate zones and so on. From these inputs it is possible to create a 3D model to simulate and find out energy consumption, indoor climate, temperatures in all parts of the building.

IDA ICE is a useful tool when it comes to simulations of indoor climate. The possibility to create different climate zones with different loads and conditions makes the program precise and easy to handle. To find out how the indoor climate in a certain place, a “person” is set somewhere in the room and after simulation IDA gives the result in PPD (predicted percentage dissatisfied), PMV (predicted mean vote) and operative temperature for that specific place as well as the average temperature in the room. It is possible to easy move around within the room to see how the indoor climate changes for different parts and thereby see where the difficulties can appear.

When calculating the energy consumption for a building IDA ICE is a good program to see how much energy that is needed in each part of the building. By dividing the building into zones, the same as for the indoor climate calculations, it is easy to see where the power is needed.

Results from the simulations are presented in diagrams made in Matlab which is a program for mathematical calculations. The data used is transferred from Excel sheets created in IDA ICE into Matlab and presented in a diagram called boxplot.

Simulations to determine the shading for the building and thereby the risk for overheating were performed in program ParaSol. The results were transferred to an Excel sheet to see what have to be done to prevent overheating in terms of external and internal shading.

1.4 Limitations

Calculated energy demand and measured energy can differ for a number of reasons. Air tightness, thermal bridges and technical systems are some of the aspects that can have a lower quality than what was calculated with. These parameters will not be taking into consideration in this thesis. The thesis will only focus at the user behavior and its affect at the energy consumption that is reported to Swedish National Board of Housing, Building and Planning. The consumption included is heating of air and water, building electricity for fans, elevators, light in staircases etc. Electricity used by the tenants, the household electricity, is not included in the demands from Swedish National Board of Housing, Building and Planning and therefore not included in this thesis.

Hot water usage is studied in a number of different buildings. In these studies, focus will be on the average usage and not as much why some people use more and some less water. The indoor climate and airing is focused on one multifamily building to be able to evaluate in a good way.

The thesis will only study one multifamily house and how this type reacts at different conditions when it comes to energy consumption. Three aspects, airing, hot water usage and different building solutions, will be taken into consideration. The tenant could affect other aspects but these are not taken into account.

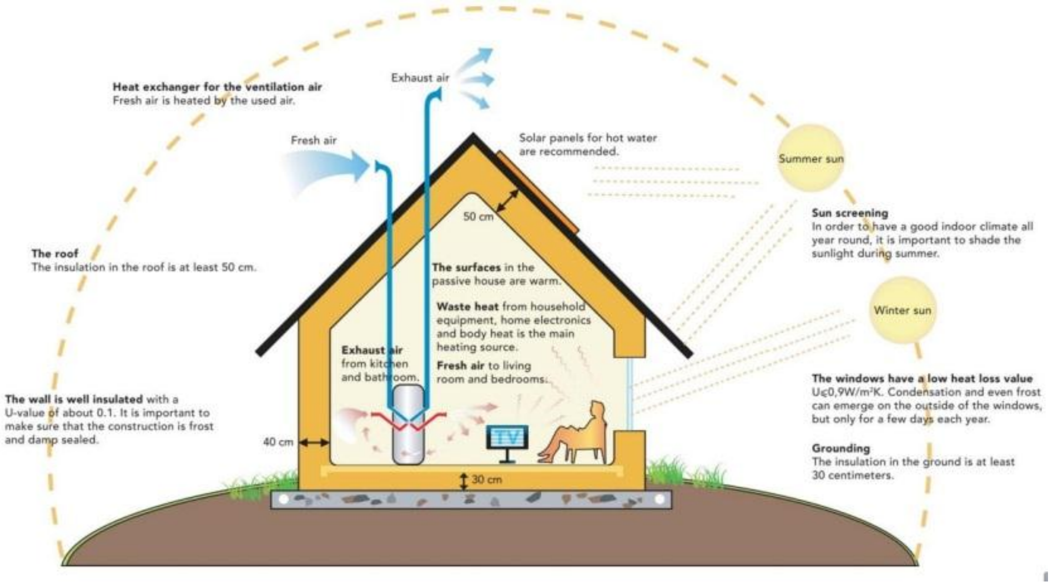
The building that is studied is located in Kungsbacka, 30 km south of Göteborg, but all simulations are going to be based on the Göteborg climate file since this is what IDA ICE is provides. Deviations in calculations are seen as negligible due to this action.

2 Variations of energy use in passive house projects

To be able to explain the problems with calculations of low energy buildings, two existing passive house projects are presented. In these two projects, the energy consumption differs a lot within the apartments or from what was calculated and is therefore interesting for this thesis. The reference object at Gnejsvägen 65 is presented. The chapter though starts with an overall presentation of the passive house concept.

2.1 The passive house concept

Passive house concept was first introduced in Germany in the 1990; s. The thought was to create a house with no radiator system with low energy demand and high quality of the indoor climate (Passivhuscentrum, 2012). This should be made by creating an air tight house with more insulation then a conventional building and with air bourn heat with heat exchanger. The standard principle of a passive house is shown in Figur 2.1 below.



Figur 2.1: Passive house principle (Goksöyr & Tärnås, 2009)

2.2 Variations between the apartments at the passive houses in Lindås

In 2001, the town houses in Lindås was the first project to be built with passive house standard in Sweden. After a year in use the energy consumption, including the household electricity, was measured and the result was that the apartment consuming the most energy consumed over twice as much than the one with the lowest consumption. As can be seen in Figure 2.2 the lowest consumption was only 45 kWh/m^2 year and the apartment with the largest consumption 97 kWh/m^{2}year. Even if the two apartments were built just next to each other with the same techniques and were supposed to consume the same amount of energy, the difference were clear (Danielski, 2012). Even if the mean consumption for all apartments respond well to what has been calculated, the difference within the 20 apartments are interesting (Bengtsson, 2008).

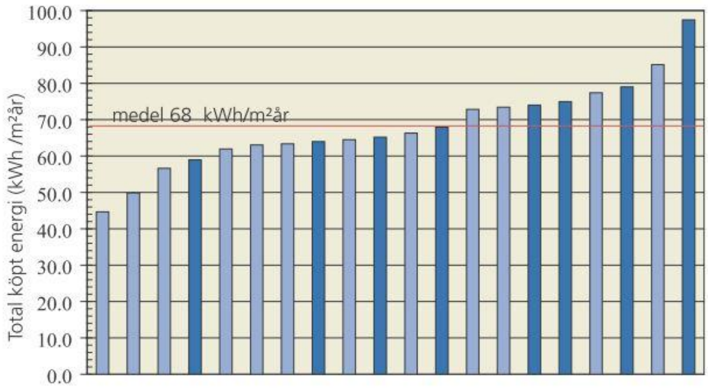


Figure 2.2: Energy consumption for 20 town houses in Lindås (Wall & Jansson)

Figure 2.2 shows how the energy consumption can differ from apartment to apartment even if the total energy consumption is in line with what was calculated. Probably nothing is wrong with the construction of the buildings due to the results. It´s unreasonable that the difference in energy consumption within the buildings can occur due to construction mistakes and it makes it interesting to look into what parameters that have effect on the energy consumption.

2.3 Variations of total energy use at the passive houses at Höjden, Lerum

A similar project to the houses in Lindås due to building technics are the passive houses, built in 2008, at Höjden in Lerum outside Göteborg. Both projects are town houses with three respective four buildings within the area.

The difference is that the houses at Höjden, for each year since the building was introduced, consume more energy for each year. The calculated value for specific energy was 35 kWh/m^2 year, but this number was not even close when measuring the energy consumed in the building. Year 2011, the houses at Höjden consumed almost 100 kWh/m^2 year and the first year 58 kWh/m^2 year (Lindström & Fremling, 2011). The energy consumption has increased each year and the question is why this happens.

2.4 Study case: passive house at Gnejsvägen 65 in Kungsbacka

Kolla parkstad is a new district in Kungsbacka, 30 km south of Göteborg, with different types of buildings. Single family houses, town houses and multifamily houses are going to be built together with a new kindergarten, a school, sports area and shops to create a new attractive district.

Figure 2.3: Kungsbacka, 30 km south of Göteborg

The building that is studied is owned by the local housing company Eksta Bostad AB and located in the area Kolla Parkstad. Construction of the building has started and it is going to be built as a passive house and must fulfill all the demands in Feby 09. Solar collectors will be installed on the roof of the building.

At the area were Kolla Parkstad is built there were a large field before the project started. Therefore infrastructure is terms of new roads and old roads are redrawn. A situation plan over the area can be seen in Figure 2.4.

Figure 2.4: Situation plan over Kolla Parkstad before and after building

It is a multifamily house in five stories with a total heated area of 2 185 m^2 and a total living area of 1 774 m^2. There are three types of apartments in the building; one 1,5 room 51 m^2, twenty-seven 2 room 61 m^2 and one 3 room 76 m^2 and all apartments are going to be for rent**.** In November 2013 the buildings is going to be ready for the tenants to move in.

A plan view over the fourth floor can be seen in Figure 2.5 below. The plan below shows the most common plan, a 2 room apartment and as shown each apartment has an airlock that is supposed to lower the heat loss when opening the front door. The balcony on each floor works as shading for the apartment under to prevent overheating. At the top floor no balcony was shading the apartments in the original drawings. Eksta realized the problem and risk for overheating and mounted an awning at the same place as the balconies at the lower floors.

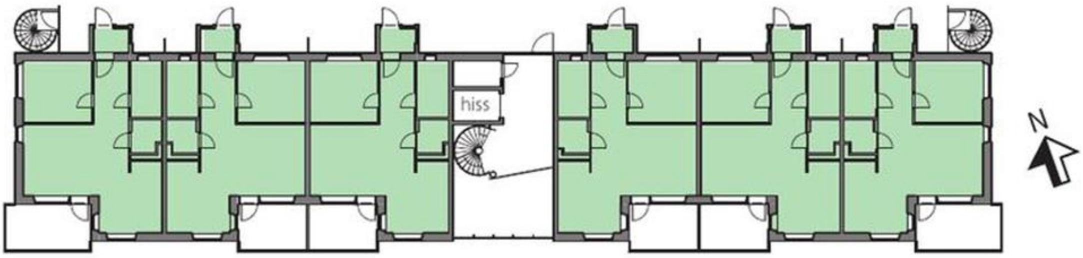


Figure 2.5: Plan view over fourth floor

2.4.1 Construction

The structural system at Gnejsvägen 65 is made by a concrete slab and concrete indoor walls that separates the apartments. In the façade steel columns is used and the walls and roof is light weight constructions. The balconies are made by prefabricated concrete as well as the outdoor stair case that is held up by concrete columns.

To be able to fulfill the passive house demands the building must be insulated in a proper way and have good air tightness. The designed air tightness at Gnejsvägen 65 is 0.2 l/m^{2}s at 50 Pa pressure difference, compared to the passive house demand at 0.3 l/m^{2}s.

The wall construction follows the recommendations for how a passive house is going to be built. It is a light weight construction with 375 mm mineral wool as insulation material and the wall has a U-value of 0.094 W/m^{2}K. The total thickness of the wall construction is 451 mm.

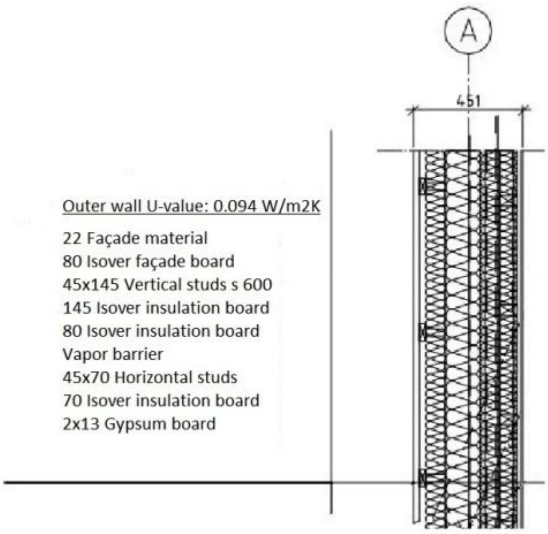


Figure 2.6: Section over wall at Gnejsvägen 65

All doors and windows used have the same U-value as the passive house demand in Feby 09, which is 0.9 W/m^{2}K.

In the passive house principle, the roof construction should be insulated with at least 500 mm insulation material. The insulation thickness at Gnejsvägen 65 varies between 280 – 900 mm, as can be seen in the drawing. Also here the insulation material is mineral wool. A mean U-value for the roof with underlying attic is calculated to 0.079 W/m^{2}K.

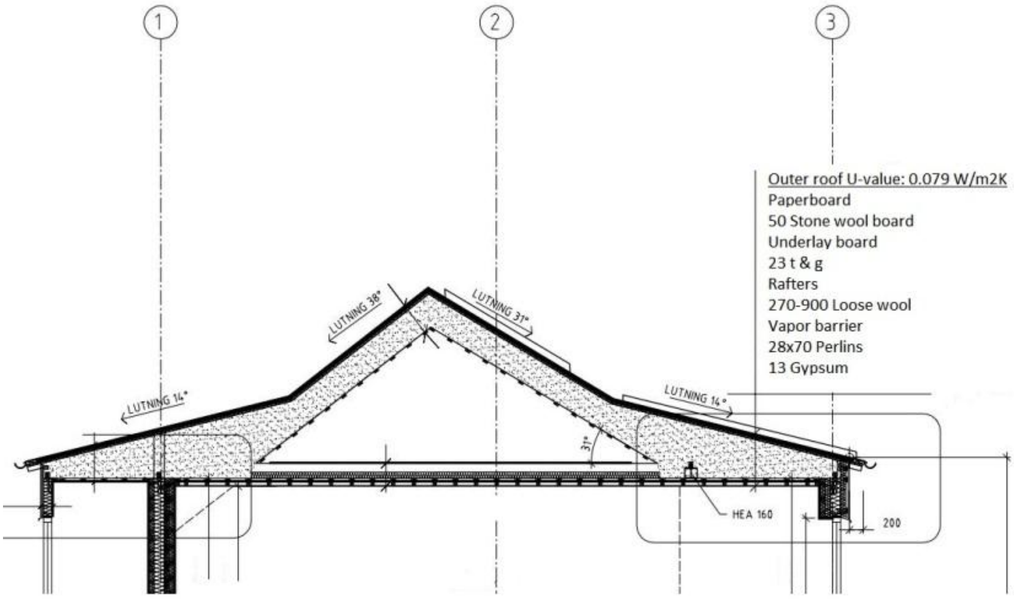


Figure 2.7: Section over roof construction at Gnejsvägen 65

2.4.2 Energy use

One of the aspects that make Gnejsvägen 65 interesting to investigate is the total heating demand. According to the calculations made for Gnejsvägen 65, the total heating demand is 38.6 kWh/m^2(A_{temp})year. These are divided into five different parts: ventilation (6.8 kWh/m^2(A_{temp})), transmission losses (16.4 kWh/m^2(A_{temp})), heat for domestic hot water 18.8 kWh/m^2(A_{temp})) minus the energy produced by the solar panels (5.3 kWh/m^2(A_{temp})). On top of this, the heat loss due to airing must be added which is calculated to 1.9 kWh/m^2(A_{temp})year. This means that over 50 % of the total heat needed is connected to the behavior of the tenant, airing and domestic hot water use, and can therefore vary a lot between the apartments within the building.

2.5 Water data collected

A number of housing companies has been contacted to get data of water use from apartments in properties of different types. The data collected is compared to different types of calculation methods and analyzed to be able to see how the calculation methods match real consumption. Information about the different properties that is in the study is given in chapter 8 and the results are presented in chapter 11.

3 Calculation methods and demands in the design phase

To get an overview of what calculation methods are used concerning user related energy consumption, domestic hot water use and airing, Sveby and Feby are presented. These two reports are the guidelines for calculations of conventional houses (Sveby) and a low energy houses (Feby). Furthermore, demands for indoor climate, due to Feby, in a passive house are presented.

3.1 Sveby

Sveby is a development program that is run by the building- and housing industry (“Standardisera och verifiera energiprestanda för byggnader” in Swedish) (Levin, 2012). The programs purpose is to present guidelines when calculating energy usage in buildings, both office buildings and dwellings. In the reports from Sveby standardized input of hot water use, internal loads from persons and appliances, solar shading, airing, ventilation, electricity use and more can be found to facilitate the energy calculations.

In Svebys reports the design regulations from Swedish Board of Housing is interpreted by the industry. This is to make all consultants to calculate in the same way and therefore make the regulations easier to follow.

3.2 Feby 09 and Feby 12

Forum for Energy Efficient Buildings, abbreviated Feby, is the group that sets the demands for passive- and low energy houses in Sweden (“Forum för Energieffektiva Byggnader” in Swedish) (Sveriges Centrum för Nollenergihus, 2012). A group of experienced consultants from the building industry as well as researchers are selected, by the Swedish department of energy, to set the demands for the passive house standards in Sweden. The demands are developed from the original German demands for a passive house and fitted into Swedish conditions.

Feby 09 is introduced because the studied building at Gnejsvägen 65 is designed from Feby 09 and not Feby 12. This was the first passive house manual and is now replaced with Feby 12.

3.2.1 Overall demands for a passive house according Feby 12

The regulations for passive houses in Sweden are made by Swedish department of energy/Feby and there are a number of demands in different fields that the house must fulfill. In Feby 12 the old demand for heat power demand is replaced with a heat loss factor (HLF):

$$HLF_{DVUT} = H_T \cdot \frac{21 - DVUT}{A_{temp}} \quad \left[\frac{W}{m^2{}_{A\,temp}}\right] \qquad equ\ (4.1)$$

$$H_T = U_{mean} \cdot A_{envelope} + \rho \cdot c_p \cdot q_{leak} + \rho \cdot c_p \cdot d \cdot q_{vent} \cdot (1 - v) \left[\frac{W}{K}\right]$$

$$equ(4.2)$$

$U_{mean} = Mean\ U - value\ for\ the\ buidling\ [W/m^2K]$

$\rho = Desity\ [kg/m^3]$

$c_p = \ Heat\ capacity\ [kJ/kgK]$

$q_{leak} q_{vent} = Leak\ and\ ventilation\ flow\ [m^3/s]$

$d = \ Operation\ time\ [s]$

$v = \ Efficiency\ of\ heat\ exchanger\ [\%]$

$DVUT - Dimensioned\ outdoor\ temperature\ [°C]$

HLF must be less than 15 $W/m^2(A_{temp})$ for buildings over 400 m^2 and 17 $W/m^2(A_{temp})$ (for zone 3 south Sweden) for buildings less than 400 m^2 (Sveriges Centrum för Nollenergihus, 2012). This demand is replacing the old power demand at 10 W/m^2 in Feby 09 (Erlandsson, 2009). Because of the problem with what internal loads that should be chosen in the building this is replaced with a heat loss factor instead.

Total energy used must be below 50 $kWh/m^2(A_{temp})$, or 55 $kWh/m^2(A_{temp})$ for buildings under 400 m^2, for non-electrical heated buildings. The demand is 25 $kWh/m^2(A_{temp})$, or 27 $kWh/m^2(A_{temp})$ for buildings under 400 m^2, for electrical heated buildings. Noise from the ventilation system must fulfill noise lever B in the bedroom and the air leakage must be less than 0.3 l/m^2s at 50 Pa under or over pressure. This demands is for larger buildings but for smaller buildings with a shape factor over 1.7 the demand is 0.5 $l/s,m^2(A_{temp})$ (Sveriges Centrum för Nollenergihus, 2012).

$$Shape\ factor = \frac{A_{envelope\ area}}{A_{temp}} \qquad equ\ (4.3)$$

There is a demand for the U-value of the windows at 0.8 W/m^2K, demands for material, fans and measuring can also be found in Feby 12. Beyond the demands there are also plenty of advices that are recommended to follow when building a passive house.

3.2.2 Indoor climate demands in passive houses

In Feby 09 one of the advices was that the indoor temperature should not exceed 26°C for more than 10% of the time within the period April – September in the most vulnerable part of the building (Erlandsson, 2009). When calculating or simulating the indoor temperature there was no specific guidelines for airing habits for the user. It is therefore hard to apply this advice. If assuming that the user vents a lot the result will be much different than if the users rarely open their windows.

Feby 12 has developed the 10 % advice with a demand that the indoor temperature must be presented for the period April – September or the sun heat factor (SHF) should be less than 0.036. Calculation of SHF is presented in equ (4.4) below. The g-value is depending on type of glass and what type of shading that is installed.

$$SHF = g_{system} * \frac{A_{glass}}{A_{floor}} \qquad equ\ (4.4)$$

It is also mentioned in both Feby 09 and 12 that the operative temperature should be checked for bigger glazed parts at DVUT. Calculations are made to make sure that the thermal climate is good enough near by the glazed parts (Erlandsson, 2009) (Sveriges Centrum för Nollenergihus, 2012). Feby though does not say anything about what is meant by “good enough”. This can be compared to the demands for the Swedish certification system Miljöbyggnad were the same type of winter scenario has a simple calculation method, similar to the sun heat factor, to calculate the transmission factor (TF) for a room:

$$TF = U_{glass} \frac{A_{windows}}{A_{floor}} \qquad equ\ (4.5)$$

TF should not be less than 0.4 to fulfill certification class bronze and less than 0.3 for silver (Warfvinge, 2012).

In Feby 09 the only demand in indoor climate was that the temperature of the supply air could not be higher than 52°C (Erlandsson, 2009). This demand is deleted in the latest version of Feby.

Other advices there are not connected to the passive house regulations are advices from Socialstyrelsen. These say that the highest operative temperature during summertime should not exceed 28°C to prevent nuisance for the tenants (Ceder, 2005).

Heating in a passive house differs from a conventional house. The most common way to heat a building is by having radiators placed under each window. The radiators are placed here to prevent downdraught from the windows. In a passive house though, the water based system often is replaced with air bourn heating. This can be done due to the efficient windows with low U-value that minimizes the downdraughts. The benefit with air bourn heating is that the passive house uses a heat exchanger to transfer the heat from the exhaust air to the supply air and thereby saving a lot of energy and lowering the demand of effect. At Gnejsvägen 65 water based radiator system is used together with a supply/exhaust ventilation system with and heat exchanger.

4 Airing in calculations during design phase

Energy losses due to airing can be calculated in different ways and what parameters that affect the airing habits and why people vent depend on a number of aspects. This chapter will explain the different calculation methods, the most common parameters why people vent and what effect it has at the user and on the building.

4.1 Airing calculations in Sveby

When calculating the total energy consumption for a building, airing are taken into consideration in some different ways. The most common solution is that 4 kWh/m^{2}year is added to the energy needed and this number is supposed to take airing into consideration. Due to Sveby it´s also allowed to add 0.5 l/m^{2}s extra for multifamily houses or 0.3 l/m^{2}s for single family houses to the air leakage at 50 Pa pressure difference. The last alternative is to use 2.3 l/s extra constant ventilation flow for apartments or 4 l/s extra for single family houses (Levin, 2012). All these options are allowed due to Sveby and will probably give almost the same result. Although the result will not be the exactly the same and the question is how much this will differ.

In Svebys “Brukarindata bostäder” an equation to calculate the extra air exchanges, due to airing, is presented. The equations come from Birgitta Nordquists report “Ventilation and Window Opening in Schools - Experiments and Analysis” and are defined as (Nordquist, 2002):

$$q_{in} + \mathrm{q_{supply}} = \mathrm{q_{out}} + \mathrm{q_{exhaust}} \qquad equ\ (4.6)$$

$$q_{in} = W\sqrt{\frac{2*\Delta\delta g}{\delta_i}}*\frac{2}{3}h_{NL}^{\frac{3}{2}}*C_d \qquad equ\ (4.7)$$

$$q_{out} = W\sqrt{\frac{2*\Delta\delta g}{\delta_i}}*\frac{2}{3}(H-h_{NL})^{\frac{3}{2}}*C_d \qquad equ\ (4.8)$$

$$\begin{aligned} W &- width\ [m] \\ H &- hight\ of\ the\ window\ [m] \\ \delta &- density\ of\ the\ air\ [kg/m^3] \\ g &- gravity\ [m/s^2] \\ h_{NL} &- neutral\ layer\ [m] \\ C_d &- contraction\ factor\ [-] \end{aligned}$$

4.2 Airing calculations in Feby 12

In Feby 12 the airing is considered as a factor of how good the regulation of the heating system works. The energy loss due to airing is seen as an effect of high indoor temperatures that the user vents out. If the regulation system is adjusted by the indoor temperature the time with over temperature is considered less than for a system with outdoor regulation. Thereby the airing is considered to be more frequent for a system with outdoor regulation then for a system with indoor regulation. These numbers are mentioned as efficiency factors for the heating system in Feby 12 to take regulation and airing losses into consideration.

- Not integrated heat control, 0.8

- Floor heating, 0.88

- Only outdoor temperature control, 0.82

- Indoor temperature controlled, mechanical regulator, 0.89

- Indoor temperature controlled, electronic regulator, 0.93

4.3 Parameters that affects airing

To explain what parameters that affect the airing habits of the user some of the aspects are presented in this chapter. As can be seen in Figure 4.1 the difference between the users is big when it comes to airing. The energy loss due to airing also differs a lot for different users, between 3 – 40 kWh/m^2 (Meby, 2002).

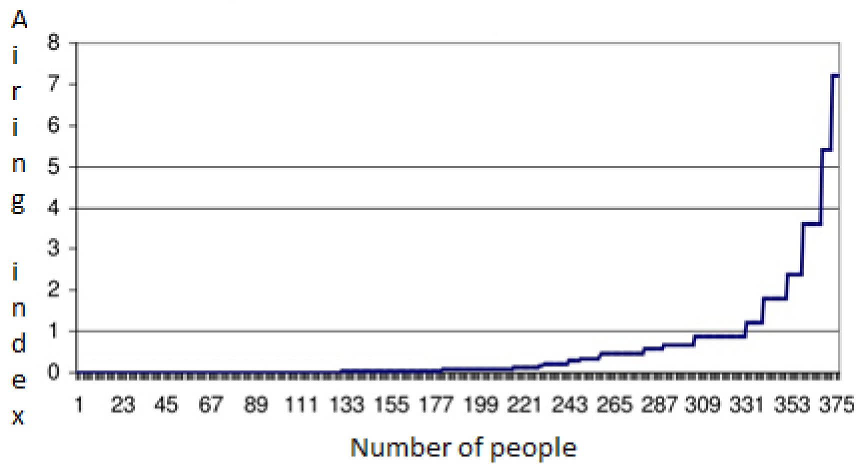


Figure 4.1: Airing index for 393 apartments (Meby, 2002)

4.3.1 Fresh air

The most common reason to vent is that the air is perceived as not fresh enough. 80 - 85 % of those who open their windows did it because of this reason in an interview study that Meby did 2002 (Meby, 2002).

4.3.2 Indoor climate

High indoor temperature is the second most common aspect why people air. In the same Meby report 20 - 30 % of the questioned said that they opened their windows because the temperature was too high (Meby, 2002). This aspect is the most discussed in this thesis.

Different types of building solutions affect the perceived indoor climate. People living in newer and better insulated buildings prefer a higher indoor temperature and vents less than people in older buildings with not as good insulation level (Santín, 2010).

To prevent overheating and when working with passive houses one important aspect is proper shading for the windows directed toward south. As can be seen in the principle Figure 2.2 the winter sun is supposed to heat the building while the summer sun is not preferable though it overheats the building. Therefore shading that lets in the winter sun and shade summer sun is important. An angle of 45° between the bottom of the window and the fixed screen is a proper angle to let in the winter sun and to prevent over heating during summer (Eek, 2013).

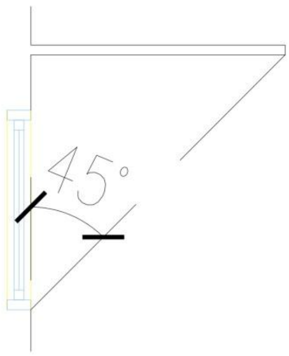


Figure 4.2: Example of proper shading

4.3.3 Smoker or non-smoker

In Mebys report about airing habits one of the parameters that affect the airing habits is if the user is a smoker or not. The difference is measured in airing index that is explained in chapter 4.4.1.1. A non-smoker has an average airing index of 0.47 and for smokers the number is 1.1 instead. Smokers also have 0.45°C lower indoor temperature than non-smokers (Meby, 2002).

4.3.4 Older/children

In the PhD “Actual energy consumption in dwellings - The effect of energy performance regulations and occupant behaviour” by Santin, a number of aspects where investigated to see what types of persons that vents the most. Questions were asked if the household had any children or elderly, what type of education the users had and the income level of the users. One of the conclusions was that age is important when it comes to airing habits. Older persons and families with kids vents less than others (Santín, 2010). For education level and income level it was hard to see any specific pattern of airing habits.

4.4 Effects of airing

In the following subchapter, the effects of airing will be presented. This is made in order to explain what affects airing can have, not only for the buildings energy consumption but also at the user.

4.4.1.1 **Energy**

In an interview study made by MEBY, where around 400 apartments were questioned, the airing habits of the tenants were investigated and presented. Each asked person had to fill in a form to answer questions about how often and how much they normally opened their doors and windows. Example of question where:

How often do you vent during the heating season?

Were "daily" gives a factor 1 and "once a week" a factor 0.14. A number of questions were asked and the factor from each question was multiplied to get the final product. The answers from the form were graded from 0 to 7.2 for each apartment where 0 is no airing and 7.2 in airing index was maximum airing. The average energy loss due to airing was then 3 kWh/m^{2}year. The apartment with the highest energy losses due to airing had a loss of around 40 kWh/m^{2}year (Meby, 2002).

The way to calculate the energy losses due to airing was presented as:

$$q_a = a_i * k * V_s \qquad \left[\frac{l}{s\ apartment}\right] \qquad equ\ (3.1)$$

$$a_i - Airing\ idex\ (mean\ value\ 0.54)$$
$$k - Correction\ factor\ for\ conversion\ to\ air\ flow\ (k\ =\ 8.4)$$
$$V_s - Factor\ due\ to\ ventilation\ system\ (0.5\ for\ exhaust\ 1\ for\ others)$$

4.4.1.2 **Noise**

Noise has a big effect at people, often more than what we think. People that often are exposed to noise runs a larger risk of having sleeping problems, concentration problems (Socialstyrelsen, 2008) and even heart diseases (Socialstyrelsen, u.d.).

Therefore, it is for great importance to ensure that the building does not have a need for constant open windows to keep the indoor temperature stable. In a larger city the noise lever outside is rarely less than 45 dB (Granå, 2013). This fact can cause problems for the users when the need for airing is large. The surroundings of the building must therefore be investigated to see if there are any noise sources in the nearby area and how they can affect the users.

4.4.1.3 **Air quality**

In areas were the outdoor air is contaminated by high concentrations of gases, particles and volatile organic compound, airing can be a problem for the users. This can for example occur in central parts of a city or nearby a larger road. Persons that are exposed to contaminated air runs a larger risk of having cough but also mush more serious diseases as heart attack and lung cancer (Bellander, 2007).

Children are especially susceptible for contaminated air. Children that are growing up in areas with a low air quality have more problems with their air ways and have a risk of decreased lung function when getting older (Bellander, 2007).

4.4.1.4 **Security**

For those apartments that are located at the ground floor the risk of breaking in can be a problem. When the tenant leaves the apartment there can be desirable to leave windows open not to get over heating. In this case the risk of breaking in increases and it is not sure that the insurance apply in these cases.

5 Hot water in calculations during design phase

The amount of energy consumed for hot water is dependent on a number of different aspects. Types of taps, hot water circulation and of course the habits of the people living in the building affect the consumption. In this chapter the different types of calculation methods and recommendations will be explained as well as how different aspects affect the hot water consumption.

5.1 Hot water calculations according to Sveby

In Sveby, the recommended energy needed to provide a building with hot water is set to 25 kWh/m^2(A_{temp})year for multifamily houses and 20 kWh/m^2(A_{temp})year for single family houses. This number is based on measurements from stakeholders in the housing industry. An example of those is a measurement made by housing company JM where 1500 apartments, built between 1997 and 2003, where investigated. The result of this study showed that the average hot water was 25 kWh/m^2(A_{temp})year (Levin, 2012). Another was a study were the water consumption was measured in four apartments and four single family houses. The result here was that the people living in the apartments consumed 18 m^3/person,year and the people living in single family houses was 12 m^3/person,year. Due to these measurements and many more Sveby also says that a normal consumption for a person living in a multifamily house is 18 m^3/person,year and 14 m^3/person,year for a single family house (Levin, 2012).

The reduction for individual measuring and billing was in earlier recommendations from Sveby 20 % of the total hot water use. In the latest version, Sveby says that the latest studies showed that individual measuring and billing not affects the hot water consumption to this extent. So the latest version of Sveby says that:

”Nya mätningar från bl.a. SABO och HSB har senare visat på att besparingen uteblivit. Därför avstår Sveby i dagsläget från några rekommendationer mer än att ett avdrag på 0 - 20 % kan användas och att vidare utredning krävs.”

“New measurements from e.g. SABO and HSB later showed that the saving has not materialized. Therefore, SVEBY refrains in the current situation from any recommendations more than a reduction of 0 – 20 % may be used and that further investigation is required.”

It is obviously hard to interpret what Sveby means with this statement.

When it comes to modern mixer taps with a function that reduces the maximum flow and the maximum temperature and other efficient equipment, nothing is mentioned more than it affects the consumption. No reduction can be made by using these types of taps.

5.2 Hot water calculations according to Feby 12 and Feby 09

In the latest version of Feby the hot water calculations are changed a lot compared to Feby 09. In Feby 12 the hot water is set to 25 kWh/m^2(A_{temp})year, the same as for Sveby. They though differ in terms of reductions that can be made. In Feby 12 reduction can be made with 20 % if the building is using individual measuring and billing. No reduction can be made due to modern mixer taps because it is considered as a standard installation in new built houses.

When calculating the water use in a passive house, due to Feby 09, the estimated number of people in each building is multiplied by a set volume of water that each person is expected to use. A person is expected, according to Feby 09, to consume 18 m^3/ year of hot water regardless if it is a multifamily house or a single family house (Erlandsson, 2009). The number of people living in a building is expected to be living area/41 (Erlandsson, 2009). The total energy needed is then calculated as:

$$E_{dhw=}\frac{V_{dhw}*55}{A_{temp}} \qquad equ\ (4.4)$$

$$E_{dhw} = Energy\ for\ domestic\ hot\ water\ [\frac{kWh}{m^2(A_{temp})}]$$

$$V_{dhw} = Volume\ of\ domestic\ hot\ water\ [m^3]$$

$$55 = Energy\ needed\ to\ heat\ the\ incoming\ water\ from\ 8\ to\ 55°C\ [\frac{kWh}{m^3}]$$

$$A_{temp} = Heated\ area\ [m^2]$$

The consumption can be reduced by 20 % if the building is using individual measuring and billing for the tenants. If the building has installed efficient mixer taps with a function that reduces the maximum flow and the maximum temperature, combined with a shower head with a thermostat, the consumption can also be reduced by 20 %. If these two are used together the reduction can then be 36 % (Erlandsson, 2009). So the total expected consumption for a person, if individual measuring and modern mixer taps are installed, is then 11.5 m^3/person,year.

At Gnejsvägen 65 the water consumption is though only reduced with 20 % instead of 36 % that could be done due to the individual measuring and modern mixer taps. This ends up in a total hot water consumption of 18.8 kWh/m^2(A_{temp}).

5.3 Parameters that affects the water consumption

A number of aspects can affect the hot water consumption. In this chapter some of them will be explained to demonstrate the difficulties in hot water calculations. Things like efficient toilets will not be mentioned though it just affects the cold water use.

5.3.1 Individual measuring and billing

By measuring the water use for each apartment and billing the tenant instead of including the water use in the rent, water can be saved. By using individual measuring and billing between 15-30 % of the hot water use can be saved, due to the economic interest of the tenant (Troedson, 2008). This number was presented by Troedson at Boverket in 2008. But in Svebys latest report how to calculate the hot water use no reduction for individual measuring and billing are mentioned (Levin, 2012).

In Stockholm a number of the big housing companies have evaluated properties with individual measuring and billing. The conclusion was that no clear water savings were done and the cost for installing the equipment needed is not economical (Åslund, 2012).

5.3.2 Taps

Modern mixer taps, with a function that reduces the maximum flow and the maximum temperature, has an impact on the consumption. The reduction of energy needed for hot water can be up to 40 % compared to older types of taps (Energimyndigheten, 2011).

By choosing efficient shower heads, the water consumption can also be reduced. Older types of shower heads spend double as much water as modern efficient type. Let's say that two people live together and shower 15 min each per day then the energy saving, because of modern shower heads, can be up to 2500 kWh per year (Energimyndigheten, 2011).

5.3.3 Number of people

When calculating the water use for an apartment, one main parameter is the number of people living there. According to Sveby, the number of people living in an apartment is shown in the table Table 5.1: Number of people per apartmentbelow but Sveby does not take number of people into consideration. When calculating due to Sveby it is only the A_{temp} that decides the water use. Feby though take number of people into consideration and the way to calculate is living area/41. When looking at Svebys and Febys way to calculate number of people the average number is 1.92 for Sveby and 1.64 for Feby when looking at the 1200 apartments from KBAB, see chapter 8.2.

	Kitchenettes	Bedroom apartment					
Apartment size	1	1	2	3	4	5	6+
Number of people	1,42	1,42	1,63	2,18	2,79	3,51	3,51

Table 5.1: Number of people per apartment (Levin, 2012)

In different areas of a town, people have more or less space per person depending on a number of aspects. A study made, in Göteborg, shows that in the north district Angered the average square meter per person is 25. This can be compared to the central district Lorensberg where the average person has 65 square meter of space.

In total, the northern east parts of Göteborg each person has around 27 m^2 of living area compared to the central parts where the average person has around 55 m^2 (Faktum, 2011). Due to this study the location of the building has impact over the total water use but needs to be investigated more.

5.3.4 Information

People know that they should reduce their water consumption as much as possible. But to actual remind people, information is important. By giving the user information, consumption can be reduced (Karlberg, 2011). The efficiency of the information increases if it is placed near the source, in this case the taps (Karlberg, 2011).

5.3.5 Habits

The parameter that affects the consumption the most is probably the habits of the people living in the building. Shower habits, if a person prefer to wash the dishes over running water, washing habits and so on will affect the total consumption largely. As can be seen further in the report the apartment with the highest consumption consumes more than 35 times more hot water than the apartment with the lowest consumption. The highest consumption is from a 54 m^2 (3.5 m^3/m^2) apartment and the lowest from an 81 m^2 (0.07 m^3/m^2) apartment with the same technical equipment so nothing changes except the habits of the tenants. The diagram below shows the hot water consumption per square meter for each apartment in Gårda.

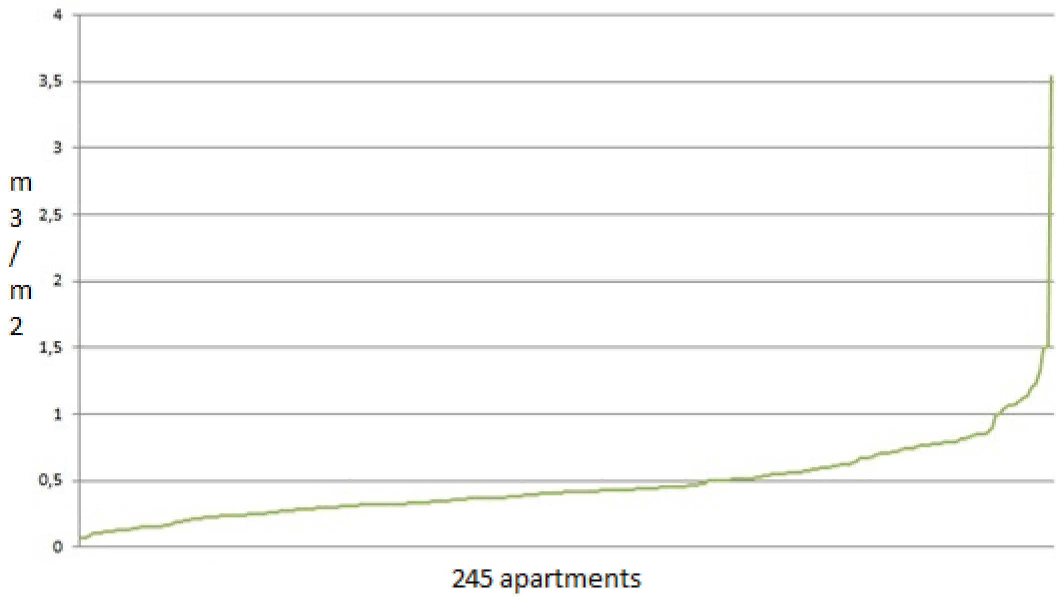


Figure 5.1 - Water consumption per square meter for 245 apartments in Gårda

6 Simulations of case study at Gnejsvägen 65

To find out what type of behavior that can be expected at Gnejsvägen 65, simulations are made. These are made to see how the temperature changes and what behavior that can be expected due to the indoor temperature. The program that is used, IDA ICE, is presented in chapter 1.3. Results will be presented in boxplot diagrams made in Matlab, presented in chapter 1.3, and duration diagrams made in IDA ICE.

6.1 Simulations preformed at the entire building

Simulations in IDA ICE are made to investigate how the indoor climate in the passive house at Gnejsvägen 65 in Kolla parkstad.

The building is divided into zones as in the plan below. At each floor there are 6 apartments with around 7 zones per apartment. There is also the staircase with around 4 zones at each floor. This makes it around 46 zones at each floor.

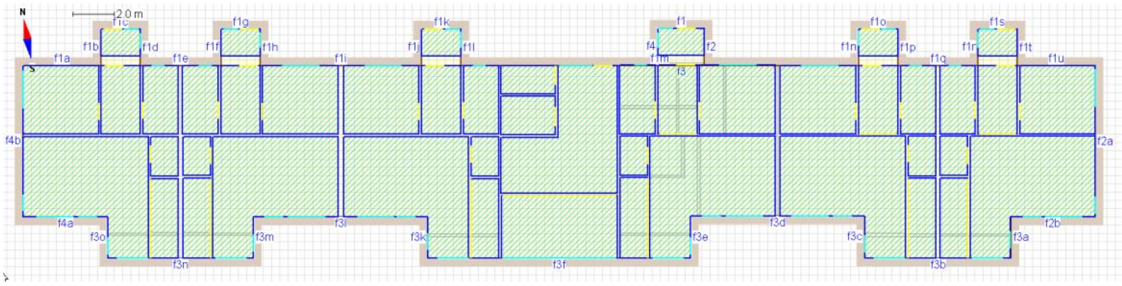


Figure 6.1: Zoning for 4th floor

When simulating how the indoor climate is in the building the apartments with the predicted poorest indoor climate are chosen. The apartments on the top floor is then studied due to its shading were less in the original drawings than on the lower floors. At floors 0-3 the balconies are shading the apartment below, but on the top floor no balconies are build and no extra shading existed in the original drawings. Therefore, it is interesting to see how this affects the indoor climate.

Figure 6.2: Gnejsvägen 65 seen from north

Figure 6.3: Gnejsvägen 65 seen from south

To see what affects the indoor climate, several simulations are made with small changes in the building. The changes and theory between why they will affect the indoor climate will be described in this chapter.

6.1.1 Balcony for shading at top floor

At all floors, except of the top floor, the balcony at the higher floor is shading the large window towards south, the glazed balcony door and the south/west smaller window. The angle created between the balcony and larger window is 49° which is good shading.

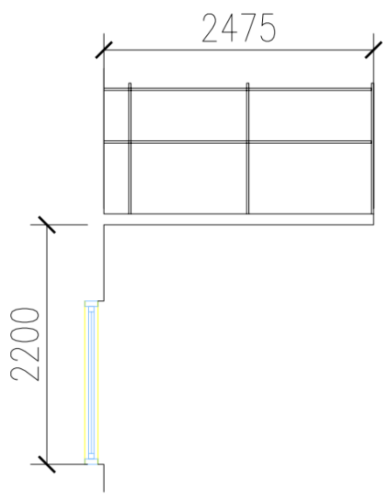


Figure 6.4: Shading at balconies

The apartments at the top floor had as mentioned no external shading in the original drawings. Risk for overheating in these apartments was therefore high. Balconies or similar shading as for the lower floors was therefore installed by Eksta. The simulations will though be with and without shading to see how big impact it has at this place.

6.1.2 Shading for all south windows

At the remaining windows toward south, no external shading is installed in the original drawings. Shading is therefore installed in the simulations to see how this affects the indoor climate.

Figure 6.5: South directed windows without shading

The screen that is inserted is 1500 mm deep and located at 2400 mm, 400 mm over the window. With this location the angle created between the screen and the window is 42.5°.

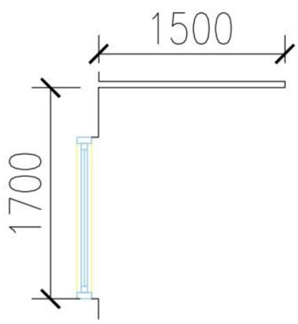


Figure 6.6: Proposal of shading

6.1.3 Higher U-value at walls, windows and roof

Well insulated walls, windows and roof are a must for a passive house. This of course holds the heat in the building during winter, but also keeps the heat in the building at summer when overheating is a problem. To see how the insulation affects the indoor climate during summer simulations are made with a U-value of 0.23 W/m^2K for the walls, 1.2 W/m^2K for all windows and 0.09 W/m^2K for the roof.

6.1.4 Different airing schedules

To see how the airing habits of the tenants affects the indoor climate different airing schedules are created. These can be a way to prevent overheating in the apartments.

1. 10 % open in bedroom and living room both day and night.
2. 50 % open in bedroom and living room 30 minutes in the morning and 30 minutes in the afternoon.
3. 50 % open in living room, 25 % open in bedroom 2 hours every afternoon, if the room temperature is over 25 °C.
4. 50 % open in bedroom and living room 30 minutes in the morning and 1 hour in the afternoon, 10 % open 17-9, all if the room temperature is over 25 °C.

6.1.5 No glazing in staircase

The largest glaze part of the building is towards south in the staircase and therefore overheating can be expected in here. To see how big impact this overheating has in the rest of the building the glazed part will be replaced with a normal external wall.

6.2 Simulations performed at selected apartments

To investigate further what parameters that can affect the indoor temperature in an apartment simulations are made. These are made with weather file for Göteborg April – September. The difference between these and the previous is that only the apartments at ground, 3rd and 4th floor is kept in the model. This is made due to the time needed to perform the simulations in the earlier model.

In this case two apartments are studied. The one on the top floor at south west direction, due to the lack of shading and therefore risk of overheating. The other one is the south west apartment at ground floor. This one is chosen due to the lack of airing possibilities during daytime when no one is home. In the other floors, an assumption can be made that one or two windows can be left open when no one is home but at ground floor this cannot be done due to the risk of someone breaking in.

Focus in these simulations will be at different airing habits and the difference between the top floor apartment and the ground floor apartment.

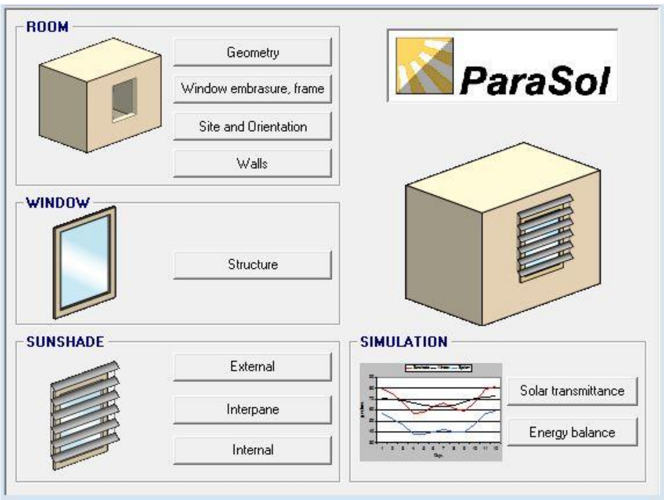
6.3 Sun heat factor calculation

To make sure that Gnejsvägen 65 has a comfortable indoor climate during summer time sun heat factor simulations and calculations are made. The sun heat factor is a method to calculate the shading of the building and thereby the risk for overheating.

The simulations to determine the g-value for the system, the glass and the internal/external shading, are performed in ParaSol which is a simulation tool created by researchers at Lund University.

When using ParaSol all parameters that affects the g-value for the system is determined. Type of glass including g-value, U-value and T-value is filled in together with how large the frame is related to the size of the total window.

Geometry of the room, U-value of the walls and how the room is orientated can also be filled. These are most used when making an energy balance for the room which also can be made in ParaSol.



Figur 6.7: Start page in ParaSol

Then the solar shading can be chosen in many different ways. Internal, external or/and interpane shading can be chosen and within these a number of different blinds. It is also possible to create your own blinds or screens.

The simulations are made for three different cases: a south north apartment at floor 0 - 3, a corner apartment at floor 0 - 3 and a corner apartment at 4th floor. Results of the simulations are made to see if all rooms fulfil the demand for Feby 12 that says that the sun heat factor cannot be higher than 0.036 for the most exposed room. This is not something that the building must fulfil to achieve a passive house standard, because it is designed from Feby 09, but it is still interesting to see how the passive house demands are developed.

7 Effect of long and short term airing

Different airing habits lead to varied energy consumptions. But to investigate how much heat an open window lets out, simulations in IDA ICE are performed with a single zone with no internal loads. The zone is 4 x 4 x 2.6 m with a window at 1.5 x 1.2 m toward south. In the zone, the ventilation flow is 0.35 l/m^{2}s and is regulated by a supply/exhaust system with heat exchanger with 80 % efficiency and 21 °C supply temperature.

The test building is insulated in the same way as the property at Gnejsvägen. U-value of the walls is 0.1 W/m^{2}K, the flat roof 0.08 W/m^{2}K and the air tightness is also the same as at Gnejsvägen (0.2 l/m^{2}s at 50 Pa).

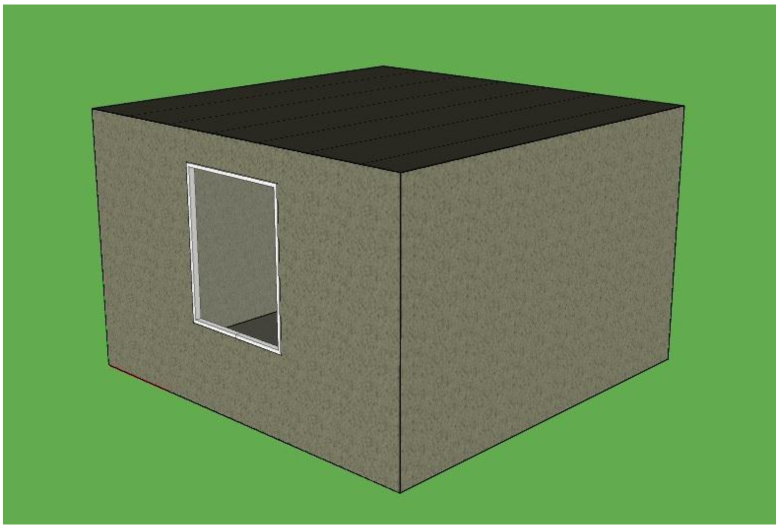


Figure 7.1: Test building 4x4x2.6 m

Simulations are made at two different outdoor cases, one winter case which means no solar radiation (0 % clearness number) and – 10 °C constant outdoor temperature. The other case is a spring case with constant 10 °C and 50 % clearness number in IDA ICE. The indoor temperature is kept between 21 and 25 °C with an ideal heater.

The window is opened varied much and at different time spans to investigate how the energy losses changes if the window is let opened longer time with a small gap or shorter time with a bigger gap. Simulation time is one week and the scenarios investigated are:

Always closed
1 % open
2 % open
5 % open
10 % open
25 % open during 1 h, closed rest
25 % open during 1 h, 2 % open rest
5 % open during 4 h
2 % open at two windows each, half the size of the original one
10 % open at two windows each, half the size of the original one

8 Measured domestic hot water use

To be able to investigate how the recommended data from Sveby and Feby responds to real measurements a number of housing companies has been contacted to get water use from apartments in properties of different types. The results from the two first companies, Hyresbostäder i Norrköping and KBAB, were sent from Daniel Nilsson at SP and the three other properties was handed over direct from the housing companies Poseidon and Familjebostäder.

8.1 Ringdansen in Norrköping

In the area Ringdansen in Norrköping, eastern Sweden, the hot water use is measured by the owner Hyresbostäder i Norrköping. The area was built in the 60: s and was a part of the Million program and had 1750 apartments when it was built.

In the end of the 1990: s a decision was called to remake the area to become an ecological, economic, social and cultural sustainable district. After the renovation the number of apartments was lowered to around 900. Individual measuring and billing as well as modern mixer taps was installed to reduce the water use in the building (Nilsson & Ek, 2011).

8.2 KBAB in Karlstad

The local housing company KBAB in Karlstad, middle of Sweden, has renovated a large part of their property portfolio and installed equipment for individual measuring and billing for each apartment. The hot water use is measured in totally around 1200 apartments each year in 21 different properties. Types of properties differ, everything from the Million program to new built low energy houses. But most of the properties have been renovated under the 2000s and at the same time modern mixer taps was installed as well as most bathtubs was removed and showers was installed instead (Nilsson & Ek, 2011).

8.3 Gårda in Göteborg

In Gårda, the central parts of Göteborg, housing company Poseidon have a number of properties. The ones studied are built in 2004 divided in four different houses with total 248 apartments. In all four houses individual measuring and billing of water is installed as well as modern mixer taps that regulates the maximum flow and the maximum temperature.

The houses in Gårda thus have both criteria’s that takes to reduce the water use in calculations by 36 %, due to Feby 09, and by 20 % in Feby 12. Of the total 248 apartments 245 was in the study and the other three did not have reliable results due to broken measuring equipment. The results from the study are from 2012.

8.4 Backa in Göteborg

Another property owned by Poseidon, and studied, is a low energy house in Backa, Göteborg. The 15 apartments are mainly three room apartments with total living area of 80 m^2. In all apartments modern mixer taps that regulate the maximum flow and the maximum temperature are installed and individual measuring and billing of the hot water is used. The study is made during 2012.

8.5 Hamnhuset in Göteborg

Hamnhuset is a house built in 2008 located in Sannegården, Göteborg harbor. In total, the building consists of 115 apartments and a garage with 89 parking lots. That gives Hamnhusets a living area of 7868 m^2 and a heated area of 11616 m^2. The house is own by the housing company Familjebostäder. The measuring is made from October 2011 to September 2012.

Figure 8.1 – Hamnhuset (white.se/projekt/34-hamnhuset/bildspel)

Each apartment has individual measuring and billing of the hot water use and modern mixer taps are installed. Other interesting equipment is the solar collectors that are placed on the roof towards south to produce hot water.

When Hamnhuset was designed the thought was that it was going to be a passive house. Hamnhuset though did not manage to fulfill all demands for a passive house (the windows in Hamnhuset have a U-value of 1.1 W/m^2K and the demand is 0.9 W/m^2K) but it is still very energy efficient house. The owner Familjebostäder still markets Hamnhuset as a passive house.

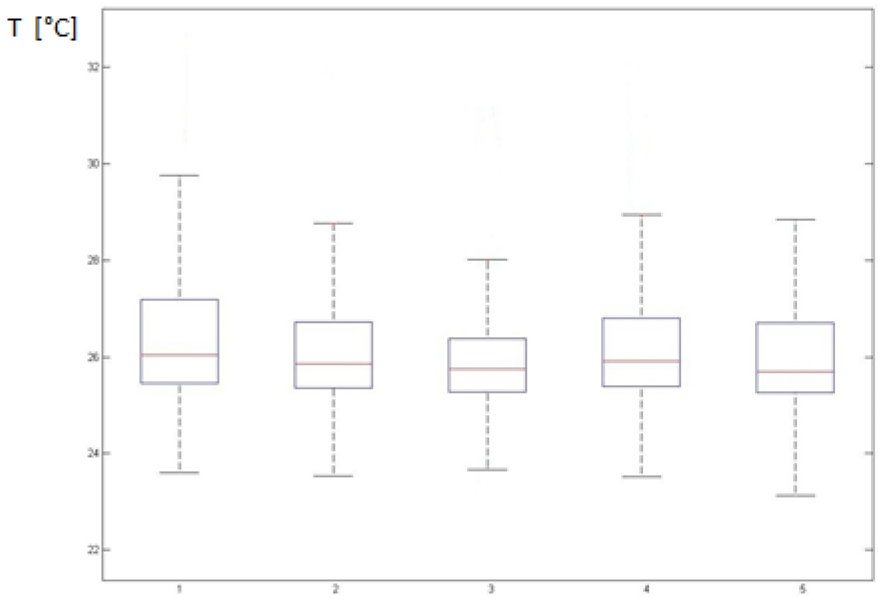
9 Results from study case simulations at Gnejsvägen 65

Three types of simulations have been performed in this thesis. All three will be presented in this chapter. First, the results from the simulations done with the entire building is presented and followed by the simulations at selected apartments. The chapter ends with the results from the sun heat factor simulations.

9.1 Simulations performed at the entire building

The result from the original file, with no shading at top floor, is shown below in the first boxplot. The following boxes are with the original file from the start but with some small changes to see how the temperatures differ between the two. All results are taken from the top floor apartment in south west direction. The simulations are made with weather file from Göteborg April – September.

Results from the simulations are shown in the box diagram below. Boxplot diagram shows the median which is the red line in the middle of the box. The edges of the box represent the 75th and the 25th percentile. Top and bottom line is the most extreme values of the selection.



1. Original drawings
2. Balcony shading
3. Balcony shading and external shading at the south directed window
4. External shading at the south directed window
5. Higher U-values in the building

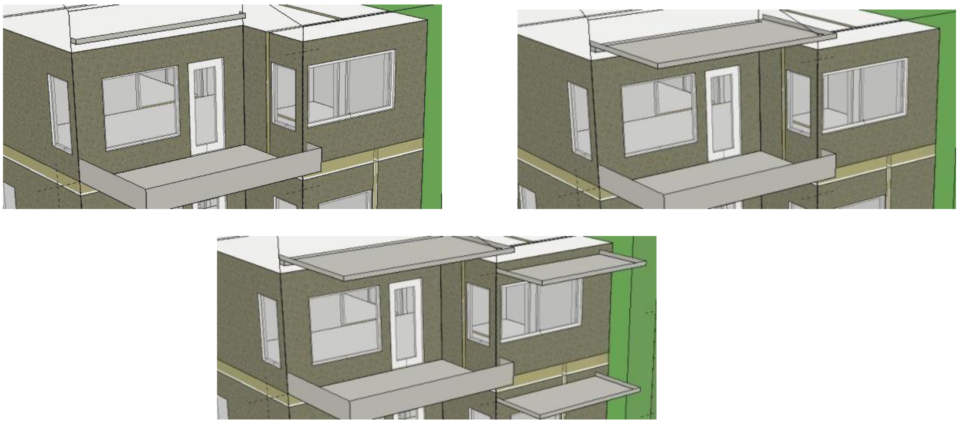
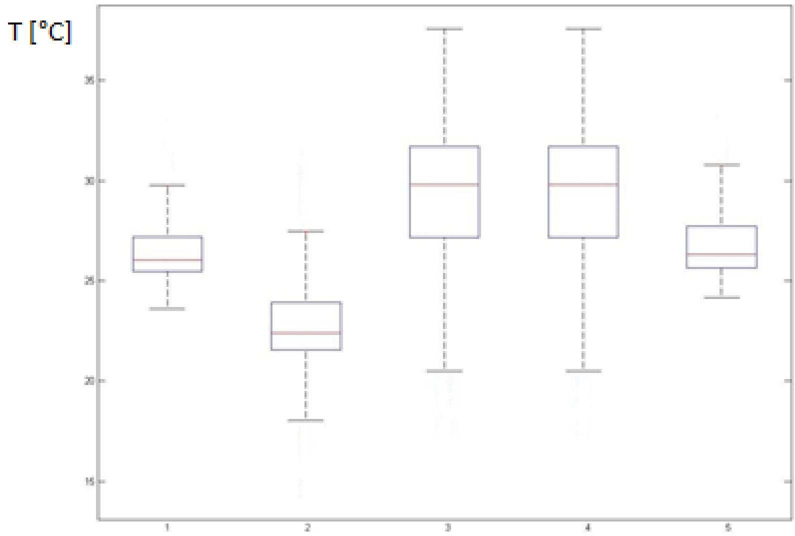


Figure 9.1: The IDA ICE model with different types of shading

As can be seen in the diagram, the effect of proper shading lowers the maximum temperatures in the apartment with around 2°C. Both shading as a balcony and shading at the other south directed window has large influence at the indoor temperature. The minimum temperature is not affected as much for any of the cases. Simulation with higher U-values in the building lowers the minimum temperatures with around 0.5°C but the other four is in the same range.



1. Original file (weekdays 10 % open 18 – 09 and 25 % open 16 – 18, weekends 10 % open day and night and 25 % open 16 – 18, all if the room temperature is over 25°C)
2. 10 % open in bedroom and living room both day and night.
3. 50 % open in bedroom and living room 30 minutes in the morning and 30 minutes in the afternoon.
4. 50 % open in living room, 25 % open in bedroom 2 hours every afternoon, if the room temperature is over 25 °C.
5. 50 % open in bedroom and living room 30 minutes in the morning and 1 hour in the afternoon, 10 % open 17-9, all if the room temperature is over 25 °C.

As can be seen in the box diagrams the tenants must have open windows most time of the summer to create a comfortable indoor temperature. A solution with shading at top floor balcony and south windows will also decrease the indoor temperature. The temperature will still be too high but a solution with blinds can be an alternative to solve the problem.

Interesting is also that the only airing schedule that gives an indoor temperature which is not to high is the one with 10 % open both day and night. The other more normal schedules are not enough and the temperature becomes too high.

The last simulation done is without any glazed parts in the stair case. The studied apartment is not affected by the stair case since it is apartments between the apartment and the stair case. But it could be seen in simulations that the apartments that are located next to the stair case are in need of good insulation. This is to prevent energy losses in the winter when the temperature is accepted to be lower in the stair case than in the apartments. It is also to prevent overheating in summer when the temperature is accepted to be higher in the stair case than in the apartments.

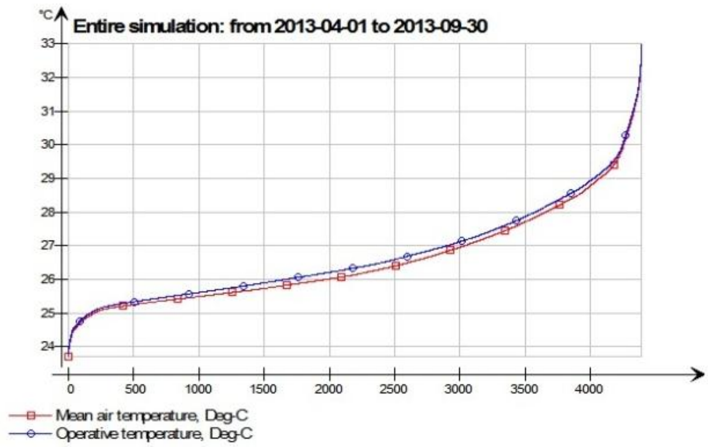


Figure 9.2: Temperature duration diagram for top floor corner apartment

9.2 Results from simulations performed on selected apartments

The results from this study will not be as exact as the ones made before due to the lack of energy exchange between the apartments. Comparisons are made between the original simulations and the simplified model and the differences are very small. Focus in these simulations is different airing habits and how they differ for an apartment with shading and one without shading.

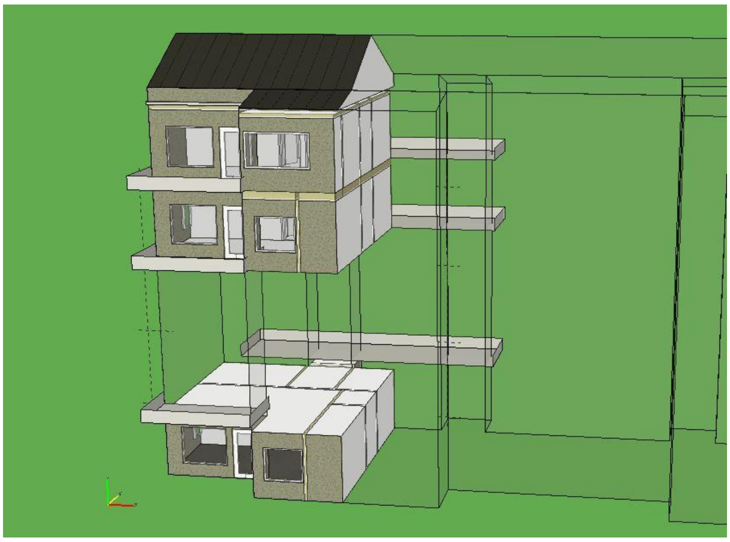


Figure 9.3: Model when three apartments are kept

Results are presented in duration diagrams which all can be found in Appendix I. The results show that the airing has a large impact on the indoor temperature and the comfort of the user. The difference between the two apartments is also clear. The windows are opened at 25°C in most simulations and as can be seen in the diagrams the windows must be open much more in the top floor then in ground floor apartment to even out the curve at 25°. An example of this is shown below in Figure 9.4.

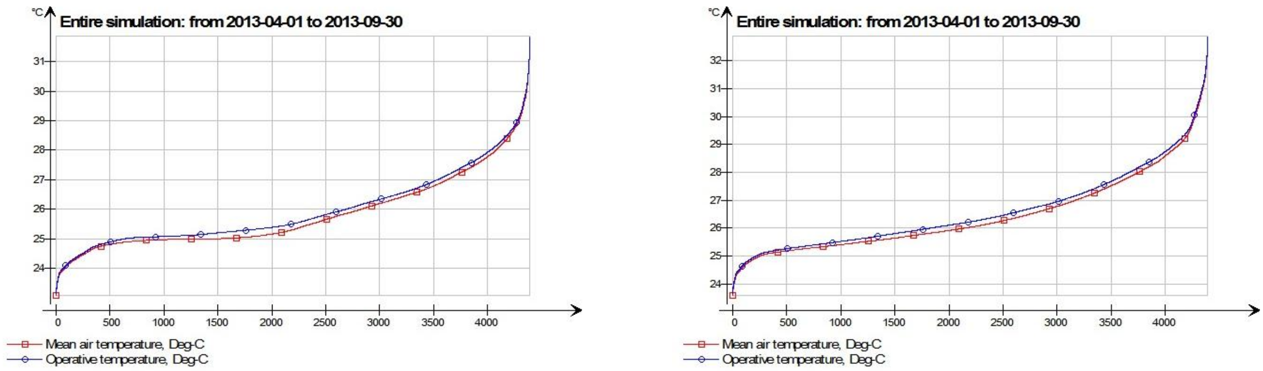


Figure 9.4: Temperature duration diagram over ground floor apartment (left) and top floor apartment (right)

9.3 Results from sun heat factor simulations

Calculations and simulations performed to determine the sun heat factor are made in ParaSol and presented in tables with suggestions for extra installations. The results are divided into four types of apartments: regular south-north directed apartment at floor 0 – 3, corner apartment at 0 – 3th floor, top floor regular apartment and top floor corner apartment. The windows are presented as 1 – 5 and what type of window that refers to what number is shown in Figure 9.5.

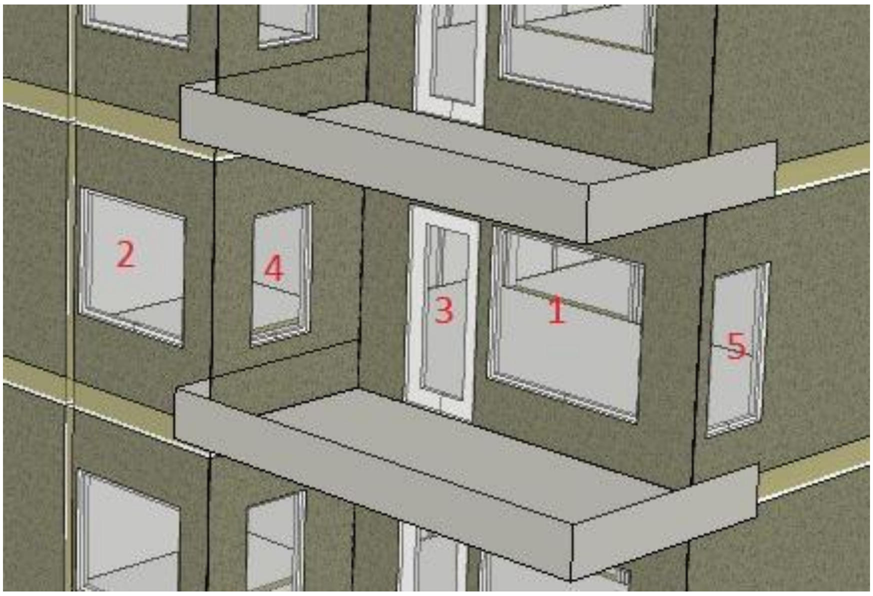


Figure 9.5: Window numbers

Different types of shading are used to see how this affects the sun heat factor. The external shading that is presented is the same type as mentioned in chapter 6.1.1 and 6.1.2. Two other types of shading are tested; one internal blind and one interpane blind, both are in a neutral dark color.

First type of apartment presented is the regular south-north apartment at floor 0 – 3. As can be seen in the Table 9.1 the only adjustment that is needed is to add an internal blind at window 2, due to its lack of external shading.

Regular apartment 0-3 floor

		Glass area	Solar shading g-value due to ParaSol	plus internal blinds	only internal blinds
1	1,8*1,5	2,38	0,18		
2	1,4*1,2	1,2	0,22	0,23	0,38
3	2,1*1,0	1,26	0,19		
4	1,3*0,8	0,84	0,19		

	No shading	internal blinds at window 2
SHF=	0,039	0,034

Table 9.1: Regular apartment sun heat factor

Results from the corner apartments at 0 – 3th floor is presented in Table 9.2 below. As can be seen the sun heat factor can be reached in two ways. Either by adding internal blinds at all windows and with extra external shading at window 2 or by using an interpane blind at window 2 and 5. Possibility to add external shading at window 5 is not investigated because it is located in west or east. Shading here would not lower the g-value as much because the sun is low in these places.

Corner apartment floor 0-3

	Window size	Glass area	Solar shading g-value due to ParaSol	plus internal blinds	only internal blinds	no shading
1	1,8*1,5	2,38	0,18	0,14		
2	1,4*1,2	1,2	0,22	0,15	0,33	0,38
3	2,1*1,0	1,26	0,19	0,14		
4	1,3*0,8	0,84	0,19	0,14		
5	0,8*1,5	0,78			0,34	0,4

	No shading	with internal blind at all windows	external shading at 2	plus internal blind at 2,3,4,5
SHF=	0,049	0,040	0,043	0,036

Corner apartment floor 0-3

	Window size	Glass area	Solar shading g-value due to ParaSol	plus interpane blinds	only interpane blinds	no shading
1	1,8*1,5	2,38	0,18	0,05		
2	1,4*1,2	1,2	0,22	0,06	0,1	0,38
3	2,1*1,0	1,26	0,19	0,05		
4	1,3*0,8	0,84	0,19	0,05		
5	0,8*1,5	0,78			0,11	0,4

	No shading	with interpane blind at window 2,5
SHF=	0,049	0,032

Table 9.2: Corner apartment sun heat factor

The changes for the top floor apartments when comparing with the lower floors is that the size of window 2 is increased from 1.4 x 1.2 m to 2.2 x 1.2 m and the fixed external shading is replaced with an awning. Simulations are still performed without any shading to see how this awning affects the result.

As can be seen in Table 9.3, for the top floor south north apartment, the extra shading needed is internal blinds at window 1, 2 and 3 to fulfill the Feby 12 demand at 0.036. The sun heat factor can also be reached by installing an interpane blind at window 2. If the awning was not installed the apartments would have been far from this number.

Top floor regular apartment

		Glass area	Solar shading g-value due to ParaSol	plus internal blinds	only internal blinds	no shading
1	1,8*1,5	2,38	0,18	0,14	0,23	0,38
2	2,2*1,2	2	0,22	0,15	0,23	0,38
3	2,1*1,0	1,26	0,19	0,14	0,23	0,38
4	1,3*0,8	0,84	0,19	0,14	0,24	0,4

	No shading	external shading at 1,3,4 and internal blinds at window 1,2,3	internal blinds at all windows
SHF=	0,076	0,035	0,046

Top floor regular apartment

		Glass area	Solar shading g-value due to ParaSol	plus interpane blinds	only interpane blinds	no shading
1	1,8*1,5	2,38	0,18	0,05	0,1	0,38
2	2,2*1,2	2	0,22	0,06	0,1	0,38
3	2,1*1,0	1,26	0,19	0,05	0,1	0,38
4	1,3*0,8	0,84	0,19	0,05	0,1	0,4

	No shading	external shading at 1,3,4 and internal blinds at window 2
SHF=	0,076	0,032

Table 9.3: Tor floor apartment sun heat factor

The most exposed apartment is the top floor corner apartment. As can be seen the results the sun heat factor can be reached in two ways. Either by installing internal blinds at all windows and by mounting external shading at window 2. The other option is to install interpane shading at window 2 and 5.

Top floor corner apartment

		Glass area	Solar shading g-value due to ParaSol	plus internal blinds	only internal blinds	no shading
1	**1,8*1,5**	2,38	0,18	0,14	0,23	0,38
2	**2,2*1,2**	2	0,22	0,15	0,23	0,38
3	**2,1*1,0**	1,26	0,19	0,14	0,23	0,38
4	**1,3*0,8**	0,84	0,19	0,14	0,24	0,4
5	**0,8*1,5**	0,78			0,24	0,4

	No shading	external shading at 1,3,4 and internal blinds at all windows	internal blinds at all windows
SHF=	0,086	0,039	0,052

external shading at 1,2,3,4 and internal blinds at all windows
0,034

Top floor corner apartment

		Glass area	Solar shading g-value due to ParaSol	plus interpane blinds	only interpane blinds	no shading
1	**1,8*1,5**	2,38	0,18	0,05	0,1	0,38
2	**2,2*1,2**	2	0,22	0,06	0,1	0,38
3	**2,1*1,0**	1,26	0,19	0,05	0,1	0,38
4	**1,3*0,8**	0,84	0,19	0,05	0,1	0,4
5	**0,8*1,5**	0,78			0,11	0,4

	No shading	external shading at 1,3,4 and interpane blinds at window 2,5
SHF=	0,086	0,034

Table 9.4: Top floor corner apartment sun heat factor

10 Results from long and short term airing

Results from the simulations with one zone are presented below. Table 10.1 shows how airing during a short time affects the energy consumption and also when the window is opened just with a small gap during a longer time. The simulations were performed with two weather conditions, one with -10 °C and no sun and the other with 10 °C and 0.5 in clearness number.

1 week	Winter -10°C			Spring 10 °C	
	Total **kWh**	% increaste		Total **kWh**	% increaste
0 % open	87			29	
1 % open	129	48%		37	28%
2 % open	168	93%		45	55%
5 % open	282	224%		69	138%
10 % open	334	284%		107	269%
25 % open 1 h, else closed	118	36%		37	28%
25 % open 1 h, else 2 %	196	125%		52	79%
5 % open during 4 h	120	38%		36	24%
2 % draft	144	66%		43	48%
10 % draft	327	276%		87	200%

Table 10.1: Energy consumption depending on airing

As can be seen from the results in Table 10.1 the airing affects energy consumption even when opening a window with only a small gap. The case with one percent open window increases the energy consumption with the same amount of energy, for the spring case, as the case with 25 percent open during one hour.

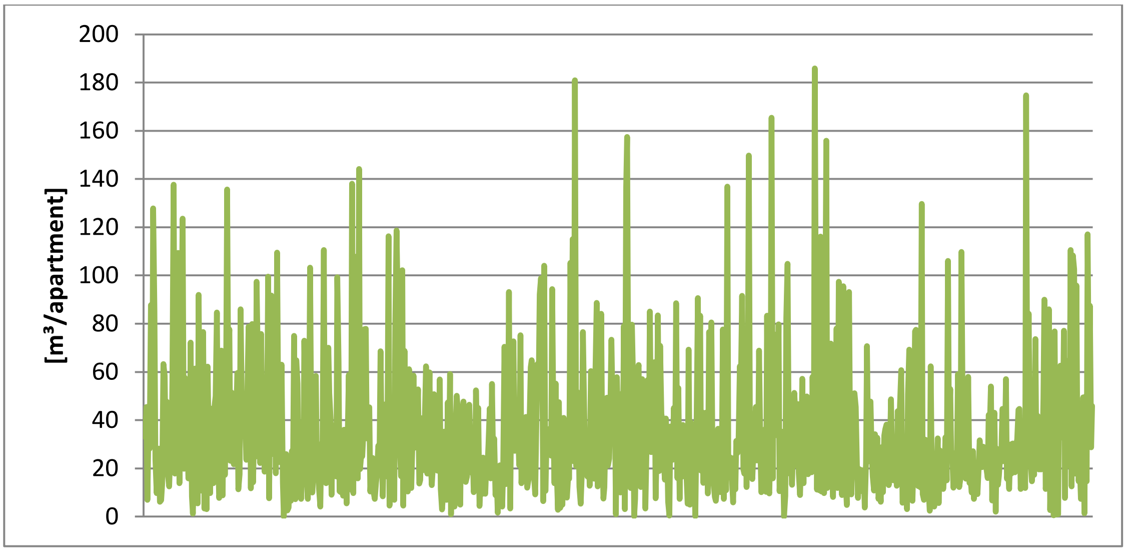
The interesting part with these simulations is not the numbers in the energy consumption but the difference between airing for shorter and longer timespans. A result that cannot be explained is why the energy consumption is lower for the cases where two windows are installed instead of one. The thought was to see how much more energy that was consumed but the total energy loss got less than for one window.

11 Results of measured domestic hot water

The results from all the collected data will be presented and compared in this chapter. To be able to compare the measurements with Sveby and Feby the results are translated into comparable numbers. The results from the measurements can also be found in Appendix III presented in $m^3_{(dhw)}/m^2_{(BOA)}$.

11.1 Ringdansen in Norrköping

The total number of apartments that was measured in Ringdansen was 836 between 36 – 149 m^2. In the diagram below the hot water use for each apartment is shown and the average value is 36.2 m^3/apartment or a total hot water consumption of 30 300 m^3. This diagram does not take area, number of rooms or anything else into consideration, it´s just the hot water use per apartment.



Figur 11.1: Hot water consumption for all apartments at Ringdansen

Compared to the expected values the measured hot water use is between Svebys and Febys values. The calculated hot water use, due to Sveby, was made as:

$$\frac{25*BOA*1.15}{55} \qquad equ\ (7.1)$$

The 25 is the given 25 kWh/m^2(A_{temp}),year from Sveby multiplied with the living area and 1.15 to convert living area into heated area (Wånggren, 2008). Then this number is divided with 55 kWh/m^3 though this is the amount of energy that is needed to heat the water to the right temperature. The hot water use that was expected, due to Sveby, was 40 m^3/apartment or a total consumption of 33 300 m^3.

Feby 12 is using almost the same calculation method as Sveby. The difference is that in Feby 12 a reduction can be made due to individual measuring and billing with 20 %. Expected total consumption due to Feby 12 is then 26 700 m^3 or 32 m^3/apartment.

Feby 09 uses another method to calculate the hot water use. Here the living area is divided with 41 to get how many persons that lives in the apartment and multiplied with 18 m^3, which is the expected hot water use for one person.

Reduction can be made with 20 % if the building uses individual measuring and billing. Another 20 % reduction can be made if modern mixer taps are used, which they are in this building. The total reduction is then is 36 % of the starting 18 m^3/person, which means 11.5 m^3/person. So the final expected value, due to Feby, is 21.5 m^3/apartment or a total of 17 900 m^3 domestic hot water.

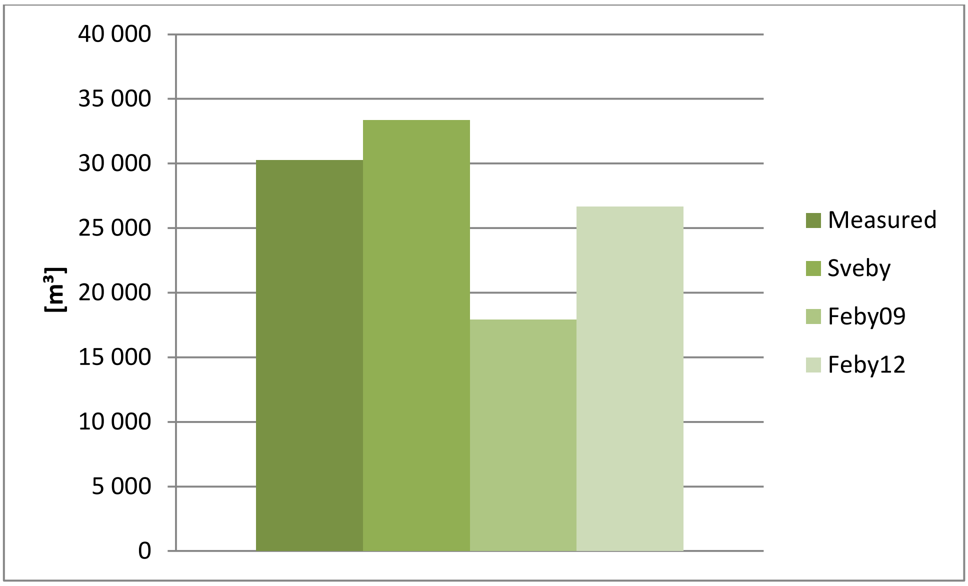


Figure 11.2: Total hot water consumption compared to calculation methods at Ringdansen

11.2 KBAB in Karlstad

In KBAB: s properties the studies were made in over 1 200 apartments and the hot water use for each apartment are shown in the diagram below.

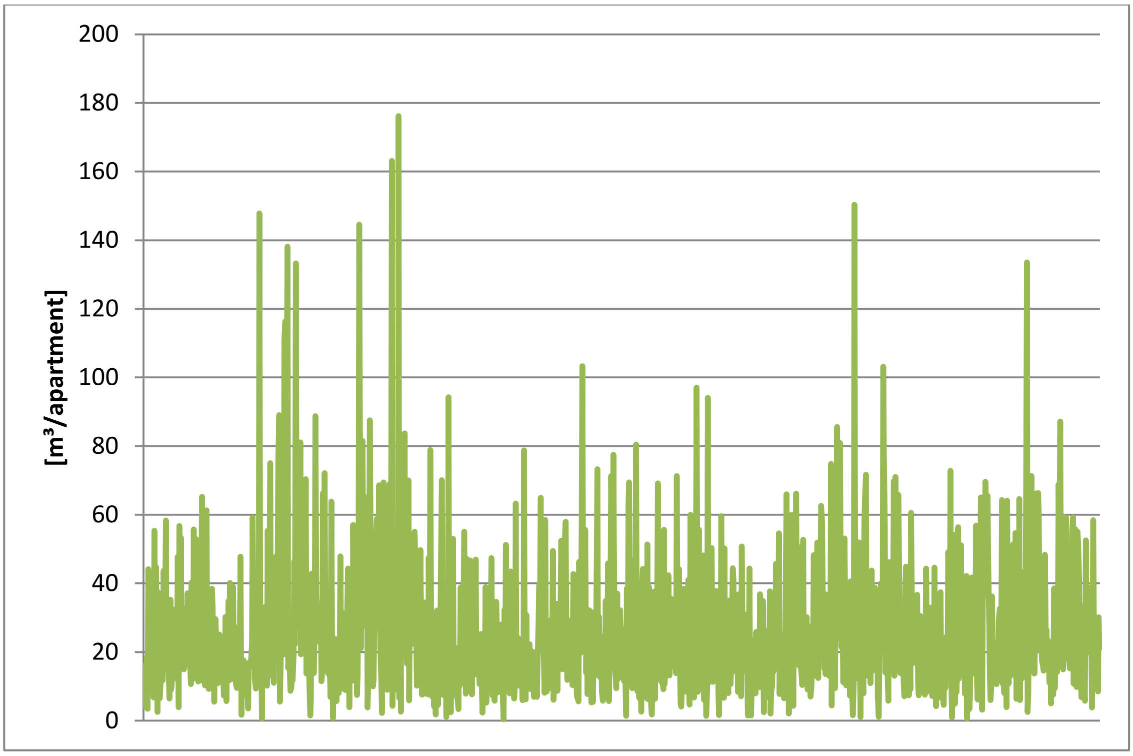


Figure 11.3: Hot water use for each apartment at KBAB

To get a clearer view over the consumption, the diagram below shows the energy needed due to hot water use for each of the 21 properties. The property with the lowest hot water consumption is Seglet, with 42 apartments in the sizes 51 – 69 m^3, which is consuming 14.4 $kWh/m^2(A_{temp})$. The highest consumption is Mörsaren with an consumption of 25 $kWh/m^2(A_{temp})$. The sizes of the apartments in Mörsaren are between 26 - 84 m^3 and consist in total of 62 apartments.

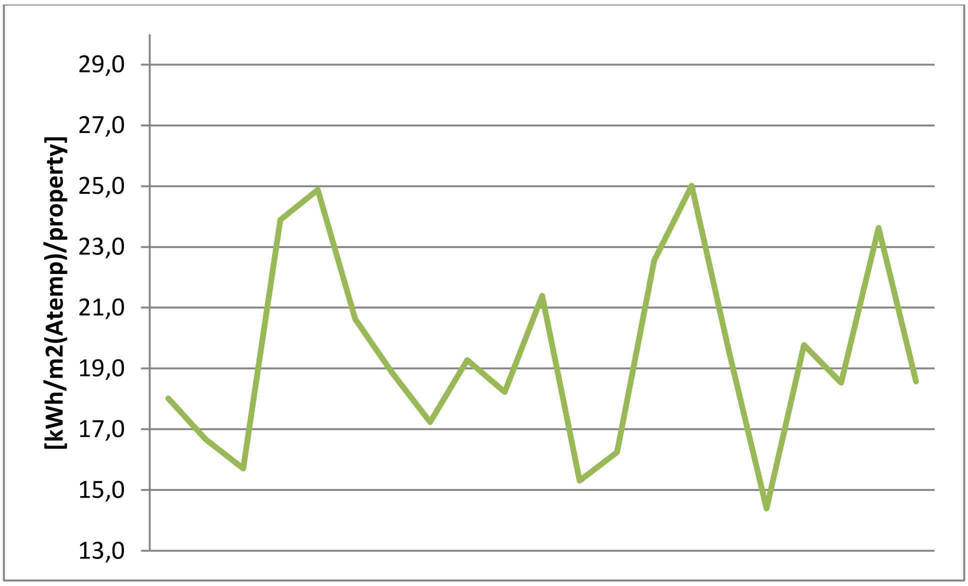
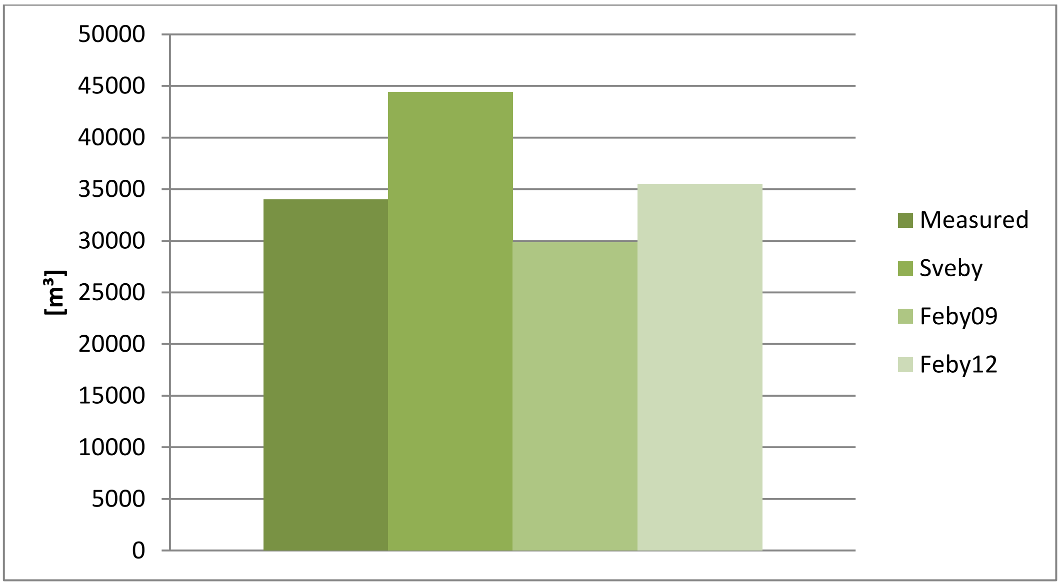


Figure 11.4: Energy due to hot water use in 21 properties

The total hot water use for all 1 200 apartments is 34 000 m^3 and compared to that was expected the result is lower than what was expected due to Sveby (44 388 m^3). In Feby 12: s calculations the expected consumption were 35 500 m^3 due to its reduction for individual measuring and billing.

Feby 09: s calculations were a bit harder to compare with. Reductions are made for all properties due to individual measuring and billing, but for modern mixer taps another 20 % reduction can be made. Not knowing what kind of taps that are installed, an assumption are made that no modern mixer taps are installed in the properties. This assumption will probably give a higher expected value then if it was known what types of taps that each property had.



Figur 11.5: Total hot water consumption compared to calculation methods at KBAB

11.3 Gårda in Göteborg

The measuring from Gårda consists of 245 apartments divided in four properties in the sizes 16 – 130 m^2. In the diagram below the hot water use for each apartment are presented.

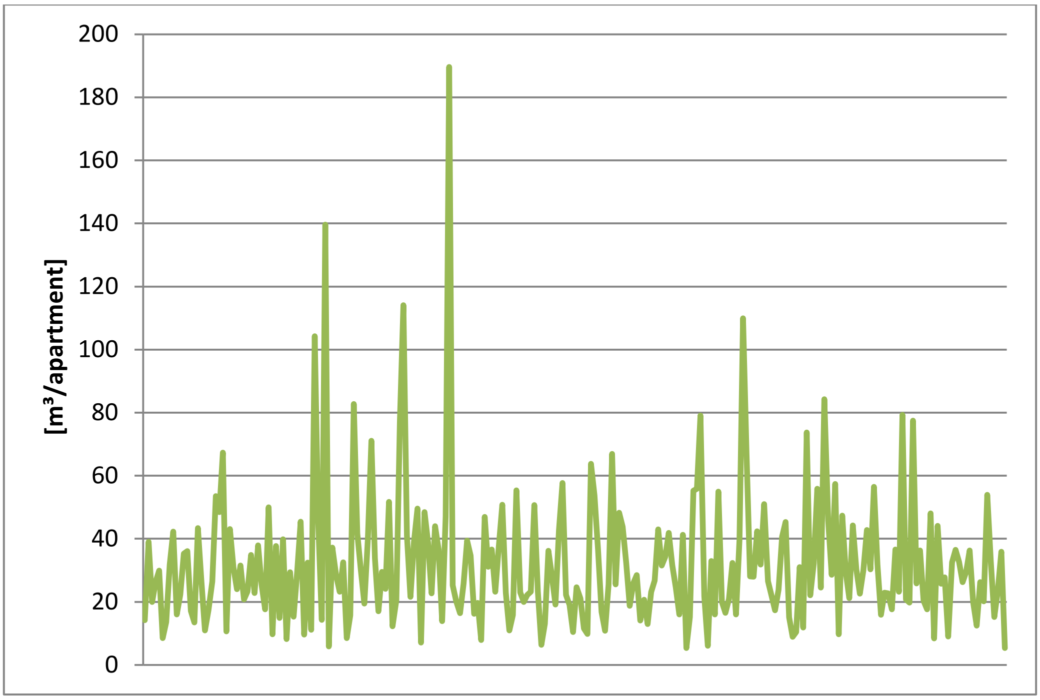


Figure 11.6 – Hot water use for each apartment in Gårda

When calculating the hot water use, the same type of calculation method was used as for Ringdansen. The total calculated water use due to Sveby is then 8 800 m^3 with an average use of 36.1 m^3/apartment (0.523 m^3/m^2(BOA)).

In Febys calculations the number per person living in each apartment was calculated. Then this number was reduced in this case with 36 % due to modern mixer taps and individual measuring and billing. So the total calculated hot water use is 4 756 m^3 with an average use of 19.4 m^3/apartment. This is around half of the consumption that is calculated by Sveby.

The result from Poseidon is a total hot water use of 7 900 m^3 with an average use of 32.3 m^3/apartment. When comparing with Sveby, the measured hot water use is 12 % lower than the expected value. Comparing with Feby though the measured value is 52 % higher than the calculated value.

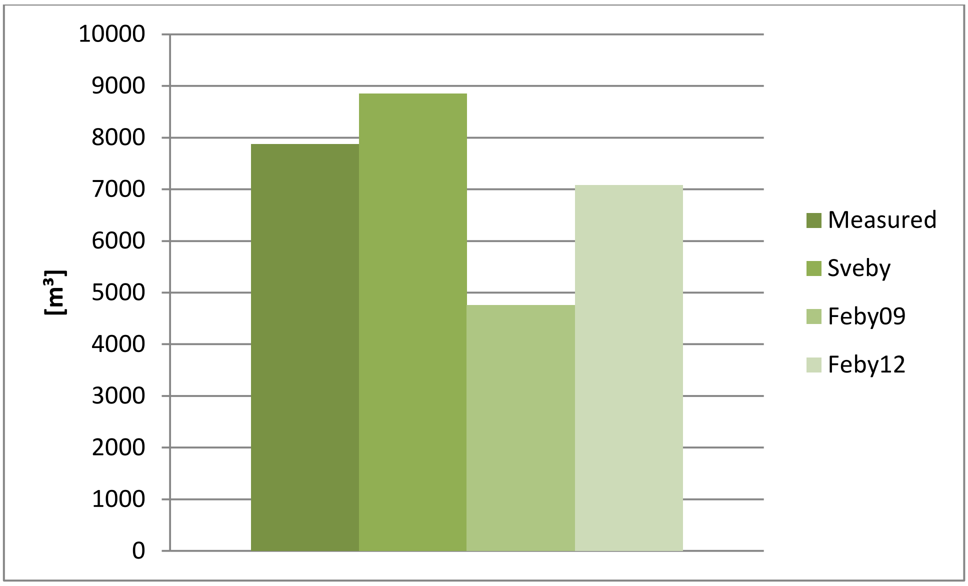


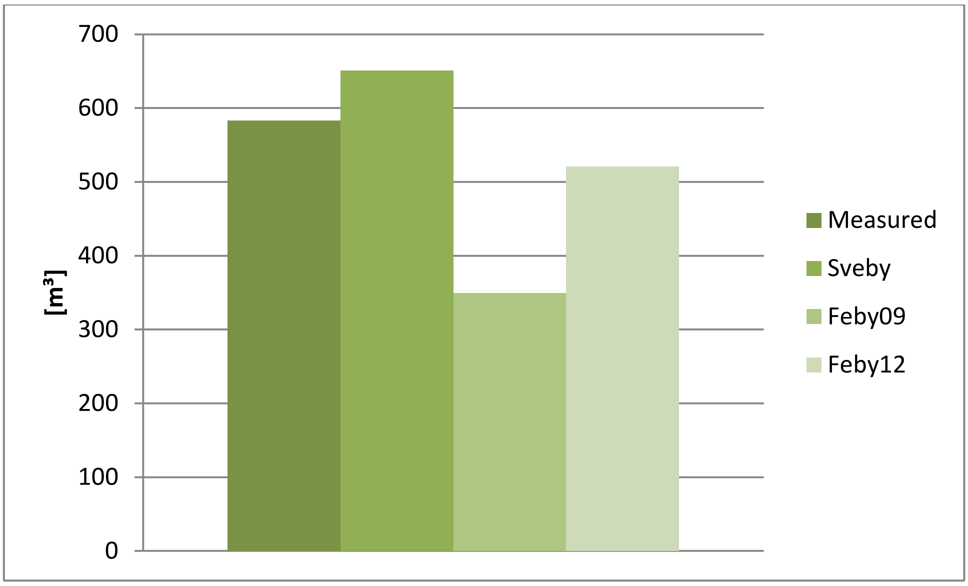
Figure 11.7: Total hot water consumption compared to calculation methods in Gårda

11.4 Backa in Göteborg

In the diagram below the hot water use for each apartment is presented. The average consumption for all 15 apartments is 36.4 m^3/apartment (0.469 m^3/m^2(BOA)).

Figur 11.8: Hot water use for each apartment in Backa

The total hot water use is compared with expected values from Sveby and Feby below. Calculations for Sveby are made in the same way as for previous buildings. In Svebys calculations the expected value is 650 m^3 and due to Feby 350 m^3. The low value due to Feby depends on the reduction for modern mixer taps and individual measuring and billing. The measured consumption was in between Sveby and Feby 12, at 583 m^3.



Figur 11.9: Total hot water consumption compared to calculation methods at Backa

11.5 Hamnhuset in Göteborg

Hamnhusets hot water use was calculated due to Feby since it was supposed to be a passive house. The 115 apartments are in total 7 868 m^2 and the A_{temp} 11 616 m^2. The apartment's sizes are between 41 – 116 m^2 and the total hot water use for each apartment is shown in the diagram below.

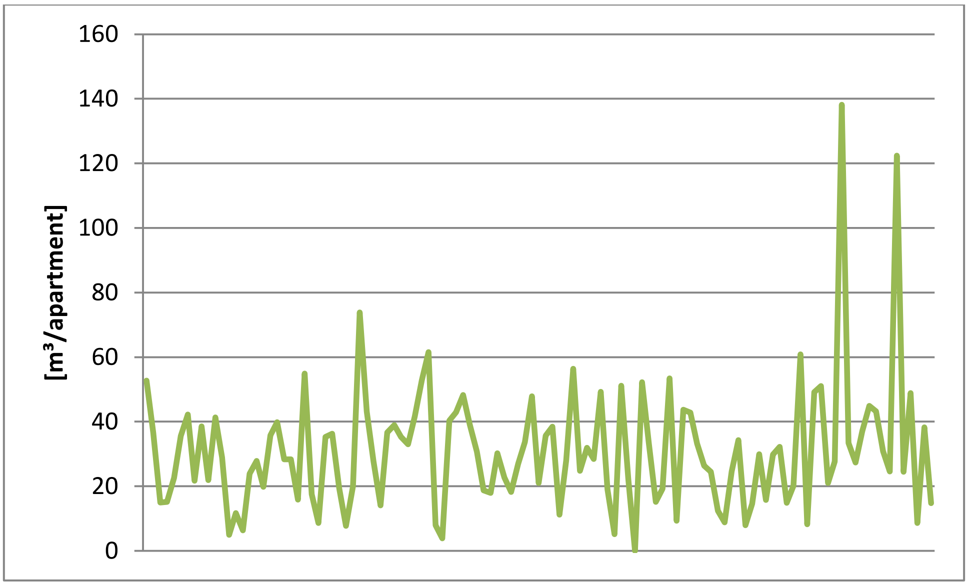


Figure 11.10 – Hot water use for each apartment in Hamnhuset

Calculations for Sveby become more exact for Hamnhuset than for the other properties. This is due to the A_{temp} is known in this case but not for the other properties. The translated hot water use due to Sveby and Feby is calculated to 5 300 m^3 and 2 200 m^3 respectively and to measured use is 3 600 m^3. Calculations for Sveby were made in the same way as for Poseidons property in Gårda, except for the factor between living area and heated area. For Feby the calculations are made in the same way as for Poseidon i.e. both individual measuring and modern mixer taps are installed in the building.

The hot water use per apartment for Hamnhuset is measured to 31.1 m^3 (0.454 m^3/m^2(BOA)) and due to Svebys calculations the measured value is 47 % lower than the expected. Due to Feby 09 the measured value is 61 % higher than what was expected.

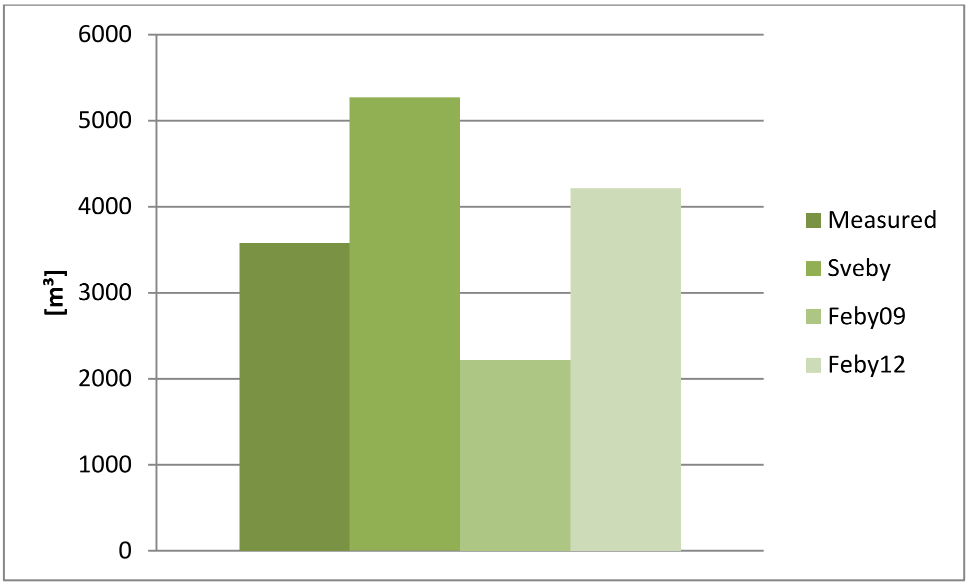


Figure 11.11: Total hot water consumption compared to calculation methods at Hamnhuset

12 Analysis

The following chapter will analyze the results that have been presented in previous chapters. Analyzes for water usage and airing are divided into one subchapter each.

12.1 Domestic hot water use

In the measurements done in different properties a pattern can be seen. In all studies there were some apartments that used between 125 – 200 m^3 hot water each year. There was also always some apartment that almost didn't use any hot water at all. The explanation of this low or high consumption can of course vary between the apartments. But the fact is that even if the consumption pattern is average over a large number of apartments there is always a large standard deviation within the properties.

12.1.1 Sveby compared to Feby

As seen in the measurements in chapter 8, the expected consumptions differ a lot between Sveby, Feby 09 and Feby 12. There are some parameters that differ between the methods and these will be presented and analyzed.

In Sveby, the area that decides the consumption is the A_{temp}. In Feby 09 it is the number of people that decides and thereby indirect the area. But for Feby 09 instead of the heated area it is the living area that decides. Also the number of people living in an apartment differs from Sveby to Feby 09 even though this has nothing to do with the hot water consumption for Sveby. The expected number of people due to Feby 09 is in all cases in the study lower than for Sveby. The expected consumption for one single person also differs. In Sveby a person living in a single house consumes 14 m^3/year and a person in an apartment 18 m^3/year. Due to Feby 09, the consumption is always 18 m^3/year no matter if the person lives in an apartment or in a single family house.

Another aspect that differs a lot between the methods is that, in Feby 12, reduction can be made due to individual measuring and billing. In Sveby no reductions can be made and in Feby 09 reductions can be made due to individual measuring and billing and to modern mixer taps. If the building uses these two, the expected consumption, due to Feby 09, per person is 11.5 m^3 instead of 18 m^3 when no reduction is made.

To make a 20 % reduction, as in Feby 09, for modern mixer taps today can be discussed. In Feby 12 it is written that nowadays the standard is expected to be modern mixer taps with maximum flow and this way of thinking is more reasonable.

In the study at Hamnhuset Svebys expected consumption (25 kWh/m^2,year) was more than double as much as Feby 09: s (10,5 kWh/m^2,year) and 20 % more than for Feby 12 (20 kWh/m^2,year). The result was probably because the A_{temp} was known in this specific building. In the other the living area was multiplied with 1.15 to translate living area into heated area. This number is probably, in average, to low. But Feby 09 is the only of the three that uses living area instead of heated area in the calculations.

The fact that Feby 09 uses living area instead of heated area is probably the only positive aspect for the calculation method. At buildings similar to Hamnhuset were the heated area is much larger than the living area there is no idea of using heated area instead of living area. The area that is not living area in heated area is stair case, technical rooms or similar and the water use of these areas is probably close to none.

All measured values was studied and a purpose of 25 kWh/m^2(BOA),year was added to the diagrams. This number comes from an iterative process were different methods are used to calculate the hot water consumption from the studied properties. One negative aspect compared to Sveby: s calculation method is that Sveby always has a safety margin when looking at the studied properties. On the other hand is the 25 kWh/m^2(BOA) a much better match in almost all studied properties than all Sveby and Feby calculations. This number (25 kWh/m^2(BOA)) is what this report propose to calculate with in further hot water calculations.

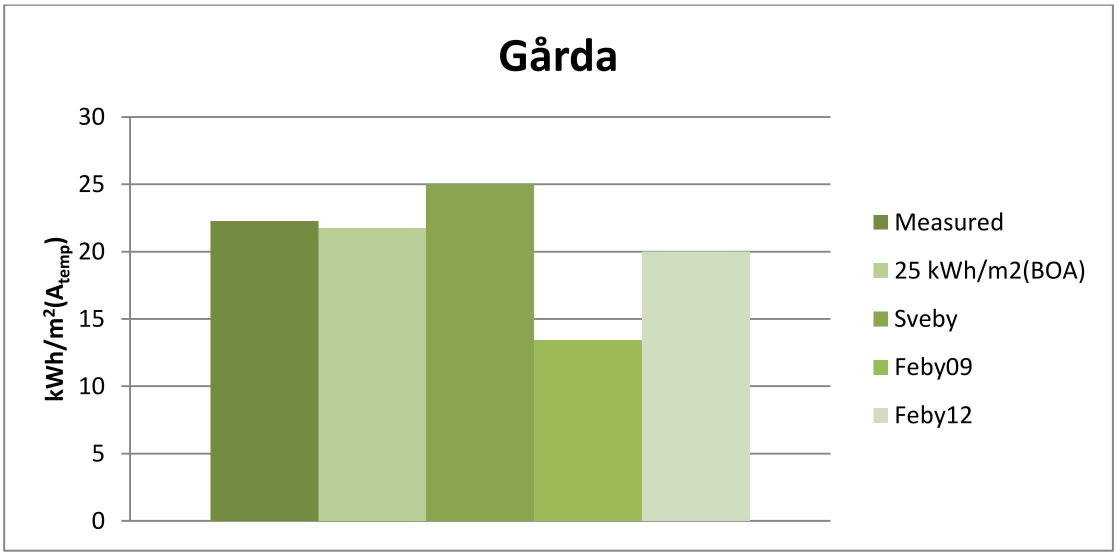


Figure 12.1: Energy needed due to hot water use in Gårda

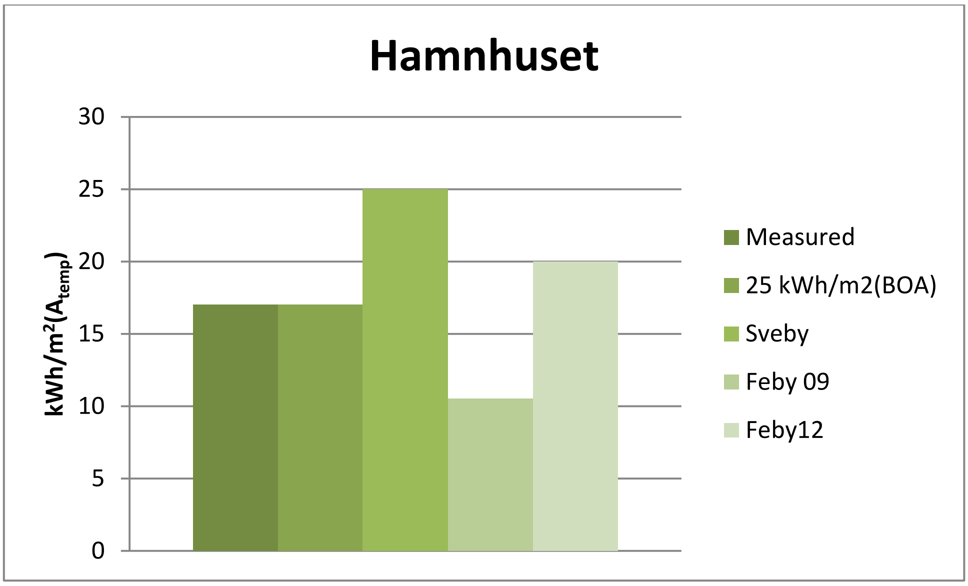


Figure 12.2: Energy needed due to hot water use in Hamnhuset

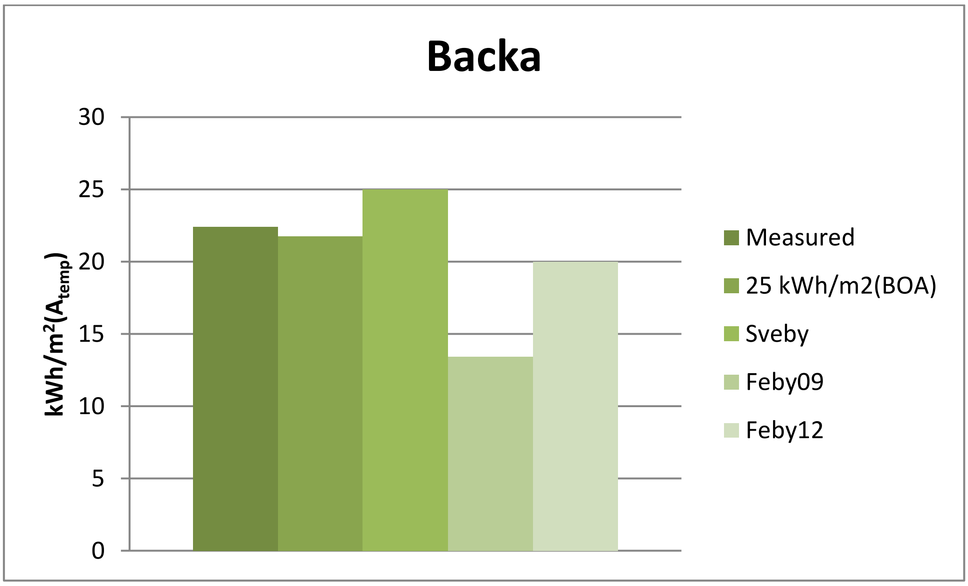


Figure 12.3: Energy needed due to hot water use in Backa

12.2 Airing

In Feby 12 the energy added, due to regulation and airing losses, is dependent on what kind of control system that is used for the heating system in the building. It is expressed in Feby 12 that the airing losses is an effect of overheating in the building that the user vents out. In the Meby report were people are asked why they vent, around 80 % says that they open their windows to let in fresh air and only around 25 % because the temperature is too high.

In Sveby the energy added is constant at 4 kWh/m^2,year for all types of building based in part on the Meby report. It is hard to say if it is Sveby: s or Feby: s method that consistent best with reality. But of what can be seen in the Meby report most people vent to get in fresh air. An alternative would be to have a lower energy factor added to those buildings that can guaranty a better air quality than an average building.

12.2.1 Shading

As could be seen in the results shading has a large impact on the indoor temperature and also the required airing habits to create a good indoor climate.

At those windows toward south that is not shaded by the balconies, glass with a lower g-value was discussed to be used. With this method the total energy gain due to solar will decrease and therefore compensate the lack of solar protection. But the thought with passive house technics is to let in the heat during winter and protect from overheating during summer. With windows with low g-value and no shading none of these two will be fulfilled and are therefore not an efficient alternative. In a passive house the focus should instead be at having proper fixed external shading together with a higher g-value.

Simulations in ParaSol show that all apartments are in need of having some shading installation to fulfill the demands in Feby 12. This is not necessary for this building thus it is designed from Feby 09. It is still interesting to see how the passive house demands are developed. A prejudice that people often have about passive houses is that they often get over heated. With the new demands for sun heat factor the problem with buildings getting over heated will probably be reduced a lot and improve the reputation of the passive house concept.

Eksta has realized the problems that could be with overheating and has installed awning at the top floor that the tenant regulates. This is necessary step to avoid over heating at the top floor, but some external shading at the other south directed window would also be desirable. At least it would be good if installing interpane blinds at those windows that do not have any external shading. ParaSol simulations show that almost all apartments need some kind of shading to fulfill Feby 12. Eksta probably do not need to make any bigger installations due to this. If looking at the most common apartment the only shading needed is an internal blind at one of the windows. It can be assumed that the tenant installs some kind of blind or curtain for the windows and therefore this is not much to worry about.

As can be seen in chapter 6.3, ParaSol simulations, the difference is large in case of using interpane or internal blinds. The ambition must though be to avoid blinds as much as possible. If not the user must adjust the blinds at those times when the sun is shining which will lead to that the view will be a blind instead of looking out on the surrounding.

It should also be mentioned that the demand in Feby 12 is though. The demand at 0.036 is the same as for the Swedish certification system Miljöbyggnad highest grade Gold, but Miljöbyggnad grade Bronze is at 0.048 which also must be seen as acceptable. If comparing the calculated values with 0.048 the changes needed to fulfill would not be as extensive.

12.2.2 Airing habits

Simulations showed that the indoor temperature increases a lot during day time when probably no one is home. The user can chose to vent out the over temperature in two different ways: Either the user chooses to open the windows fully when coming home or some of the windows is kept open with a smaller gap the whole day to prevent the peak when coming home.

In the simulations with different airing habits the internal loads are kept at the same level in all simulations. This is made to be able to compare the different results. The airing would probably be affected by the internal loads in reality, but the investigation is still interesting to see how the indoor temperature changes with different airing habits.

In the simulations with one zone, to investigate the effect of airing, an ideal heater is used. Therefore the indoor temperature is kept at a good level even if the outdoor temperature is low. In reality the effect of the heating system would probably not be enough and the temperature would sink and the user would close the window. The ideal heater in the simulations though keeps the indoor temperature constant at 21 °C.

13 Discussion and conclusions

In this chapter the results and analysis will be discussed and the conclusions of the work will be presented. The chapter is divided into two subchapters, hot water use and airing habits.

13.1 Hot water habits

In all buildings studied the standard deviation are large. The apartments consuming the most consume between 125 – 200 m^3 per apartment. If looking at a property like the one studied in Backa with only 16 apartments this one is much more sensitive to an apartment that consumes around 150 m^3. If the apartment with the highest hot water consumption in Backa (77 m^3 hot water) is replaced with a consumption of 150 m^3, the total energy consumption will be 3 kWh/m^2(A_{temp}) higher for the entire property. This shows how sensitive properties with a lower number of apartments can be for only one apartment consuming large volumes of hot water.

When calculating the water use in a passive house, due to Feby 09, the number of people is multiplied by a set volume of water that each person in expected to use. The number of people living in an apartment is expected to be BOA/41. This means that all apartments under 41 m^2, the expected number of people living there is less than one and will over all give a low amount of people living in an apartment. This will off course affect the result in the water calculations to a lower expected water use. The impression is that this number is working better for single family houses with larger areas but not for apartments with a smaller area.

There are more parameters that are assumed in Feby 09 that underestimate the real hot water consumption. Thereby the building gets lower calculated energy consumption than what can be expected, according to this study. What can be determined is that Feby 09: s calculations do not agree with real consumption. In total it is positive that the calculation method from Feby 09 is replaced with a new one in Feby 12, according to this study.

To come up with an alternative way to calculate, the studies shows that 25 kWh/m^2(BOA),year is overall a better way to estimate the hot water use than both Sveby and Feby 12. This number does not take any modern mixer taps or individual measuring and billing into consideration. But what can be seen in literature, and even in Sveby, individual measuring does not have that large impact on the consumption habits. It is still positive to keep installing individual measuring in new built properties. This because of the fact that it is much easier to discover were the energy is consumed with a system like this and thereby easier to evaluate the property in a good way.

The impact of modern mixer taps is not studied enough in this thesis to determine how large impact this has on the total hot water use and needs to be investigated more to decide how large reduction that can be made. But as mentioned in Feby 12, the standard in newly produced buildings should be, and almost always are, to use efficient taps.

When an experienced consultant calculates the energy demand for hot water, the Feby 09 calculations will appear as non-reasonable low. The Sveby method can be seen as calculations at the safe side which can be seen as positive compared to Feby 09 but still far from perfect.

13.2 Airing habits

During summer when the solar radiation is high the tenant must air a lot to avoid too high indoor temperatures. This airing behavior can be a habit that the tenant applies also during the cooler periods of the year when the temperature is lower and no airing is needed. This will of course lead to higher energy consumption. The goal must be to avoid airing a much as possible, even summertime to avoid increased airing habits that can be applied during the colder seasons. In Feby 12 the demand of sun heat factor will decrease the overheating and is a big improvement for passive houses compared to Feby 09.

Variations over the days also have an impact on the user. If not using proper shading the variation will be big and the windows will be opened during the day and night. The user must otherwise close the window when the indoor temperature is back at a comfortable level again. But the risk is that the window is kept open to even out the temperature level over the day and thereby loosing energy.

Both of these scenarios will be a risk that the user has small openings on their windows for a long time. As could be seen in the one zone simulations, energy loss is higher if only a small gap is opened for a long time then what it is for a short big opening.

As can be seen in the results from the IDA ICE simulations, airing works better when proper shading is used. At the top floor, when no shading is installed, airing has not as big effect as at the ground floor. At the ground floor with good shading, the temperature curve levels off at 25°C when the windows are opened. The top floor apartments cannot get a good indoor thermal comfort with this level of airing, the windows must be opened much more.

In the studied case at Gnejsvägen, the need for a lot of airing could have been a problem. As can be seen in chapter 2.4 the situation plan is changed. The building is located so the northern façade, the bedroom, was facing Askvägen that was the main road to a residential area with around 700 people living. This road could probably have been busy even during night time which could lead to noise problems if the window is kept opened. The road is though led in a new way after the area is built. Askvägen will be removed and the only road nearby will be Gnejsvägen to the south of the building. In this case the airing will not be as problematic as it could be if the road was kept at the previous place. It is therefore important to not only evaluate the building but also the area were it is going to be built.

When it comes to energy, the different airing habits of the user have a great impact. If the original drawings were kept, the top floor apartments would have been over heated and this would lead to a lot of airing for the tenants.

As seen in the results from the simulations, energy consumption differs a lot for the different airing schedules. So if a building is made in a way that requires a large need for airing the energy consumption will increase as well. How much the energy use increases is however hard to say. The thesis is focused on airing habits and from that point of view the conclusion is that the possibility of airing is important to vent out over temperature but airing should be minimized as much as possible with a proper shading system.

14 Further research

This thesis has focused on indoor temperature and the connection between temperature and airing habits for the user. It would be interesting to investigate another important aspect why people air and that is the air quality or air freshness. In the Meby study, 80 – 85 % of those who aired did it because the air was perceived as not fresh enough (Meby, 2002). To investigate what aspects that are the most influencing to achieve fresh indoor air would help a lot to minimize the unnecessary airing.

The focus of this thesis is at Gnejsvägen 65 and all simulations are made at this specific building. A wider research for both low energy and conventional houses would be interesting to see the difference not only in building solutions but also in an architectural aspect.

For domestic hot water use the impact of individual measuring and billing as well as different types of mixer taps should be investigated more. The 20 % reduction that is made for individual measuring in Feby 12 and 0 – 20 % reduction in Sveby must be investigated to decide a recommended value for both.

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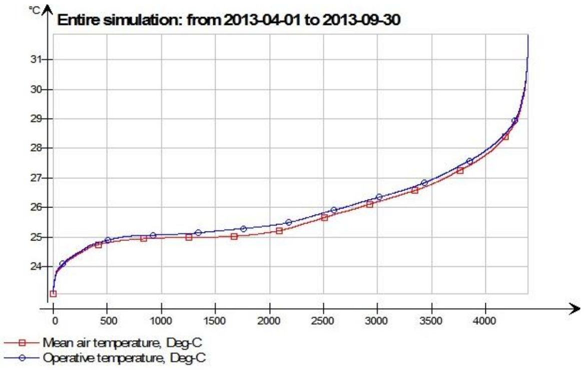
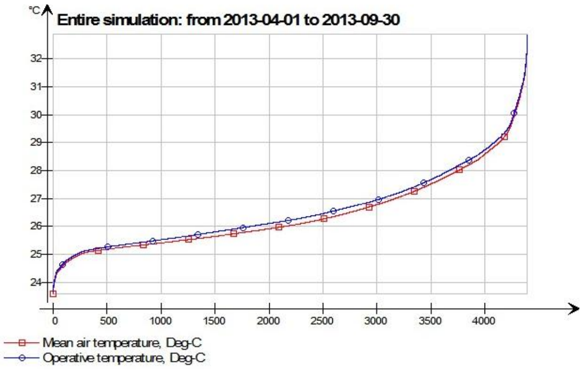
(Nordquist, 2002)

Appendix I

The first diagrams presented are the original cases with normal airing habits. These will then be modified and presented in diagrams below.

Ground floor Top floor

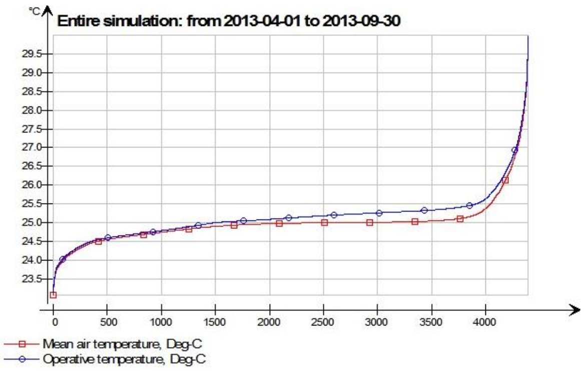


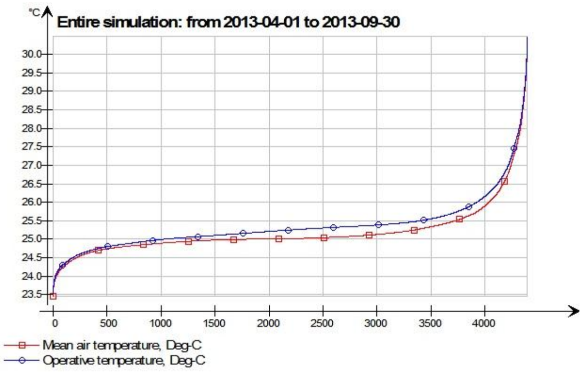


Results

First simulation is made with one window in the bedroom and one window in the living room open 50 % between 8-9 and 16-18 every day, and 15 % open rest of the day and night. The windows are opened if the temperature is over 25°C. The balcony door is also opened 25 % 9-21 if the temperature is over 25°C.

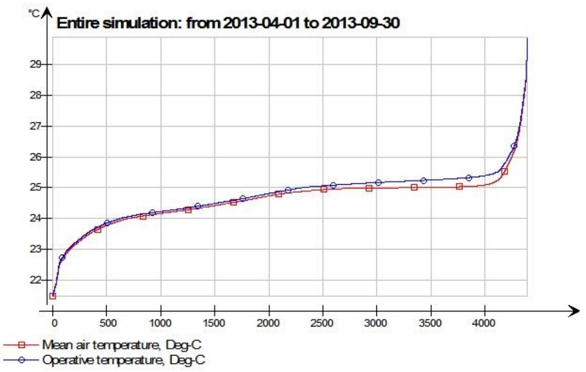
Ground floor Top floor



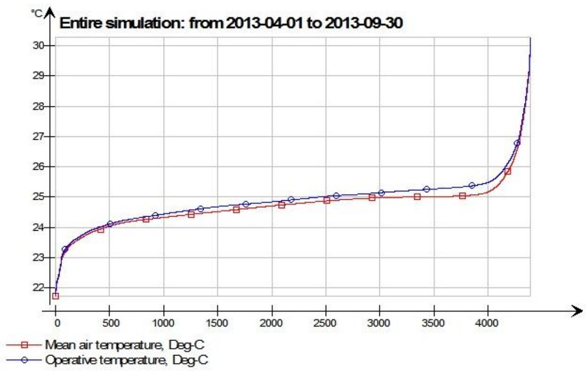


In this simulation the window in the bedroom is opened 50 % 8-9 and 16-18 and 15 % rest of the time, no matter what the indoor temperature is. The window in the living room is opened the same times but only if the temperature is over 25°C. The balcony door is also open with 25 % if the temperature is over 25°C.

Ground floor Top floor

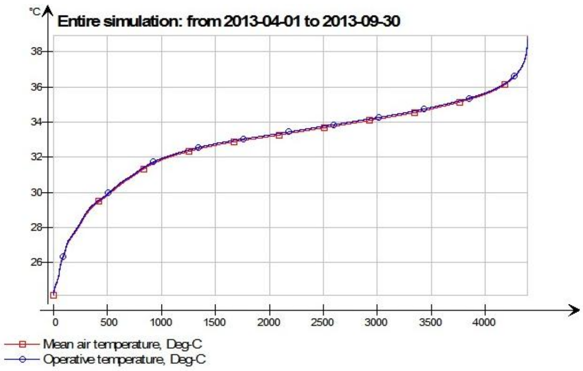


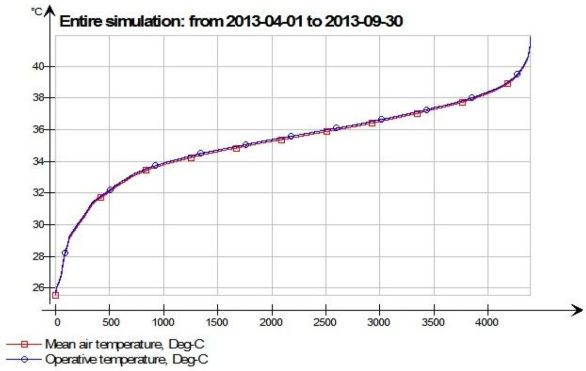
laster



One simulation is made when no airing is done. This is made to have something to compare with in the other simulations and see how much the airing affects the indoor temperature.

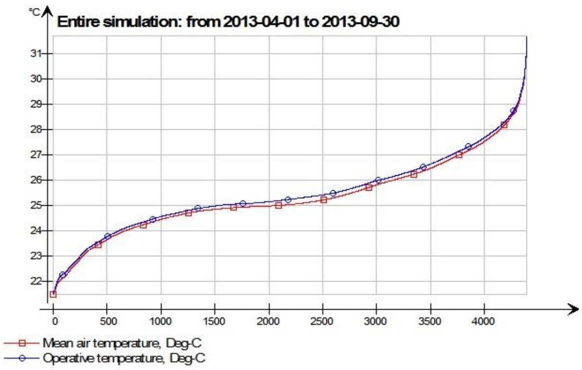
Ground floor Top floor

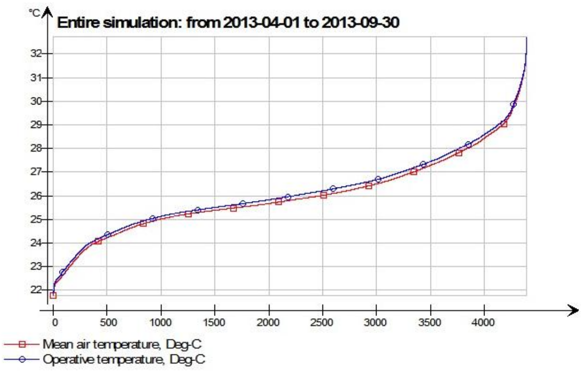




Extra airing window in living room is added to make it possible to air at the ground floor when no one is home. The window is always 10 % open both day and night.

Ground floor Top floor

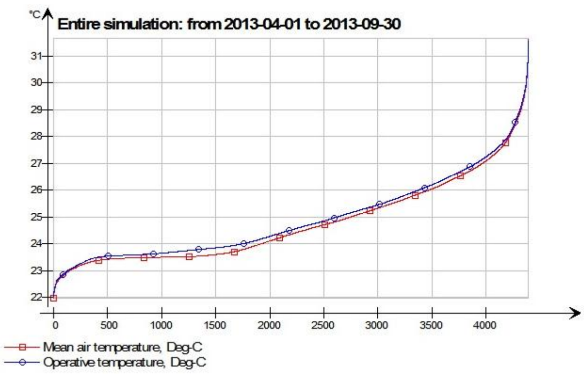


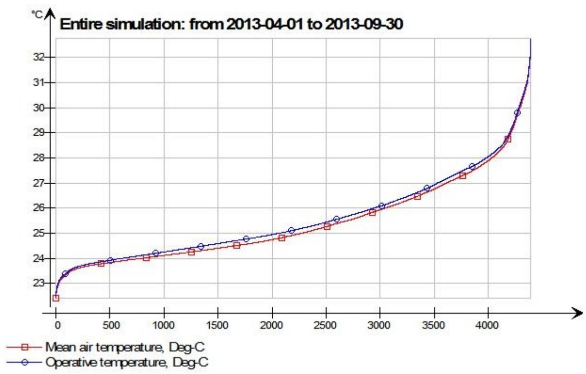


To see how the indoor temperature differs when the temperature level were people open their windows simulations are done. One case where windows are opened at 23.5°C and one at 26.5°C are made.

23.5°C

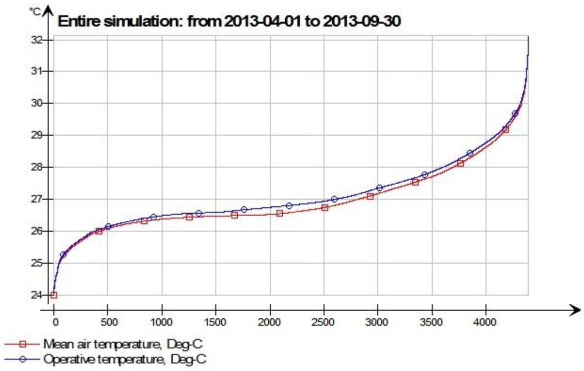
Ground floor Top floor

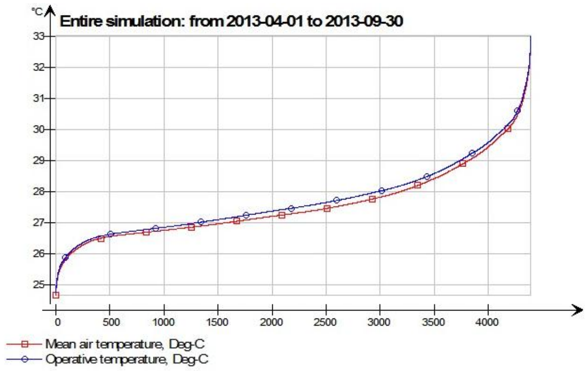




26.5°C

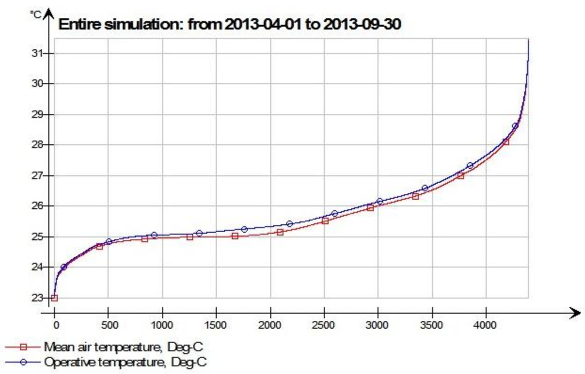
Ground floor
Top floor

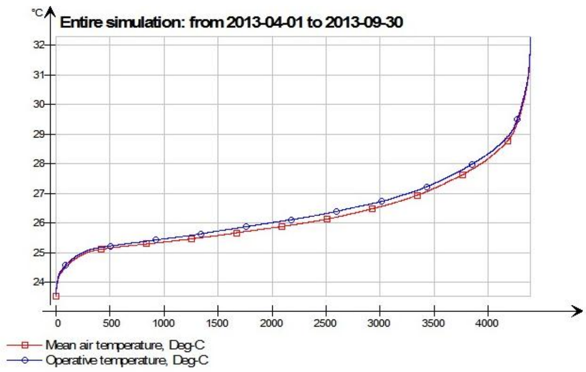




Solar shading is added at those south-facing windows were no shading. This is made to prevent overheating.

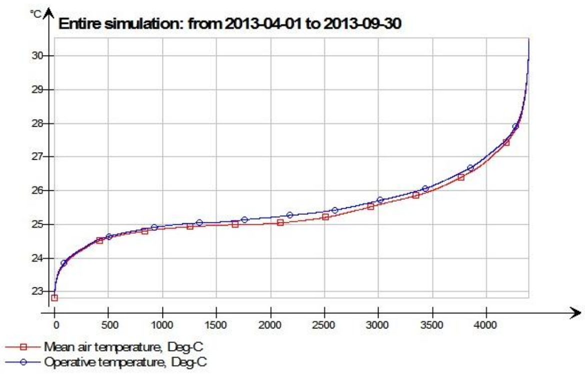
Ground floor
Top floor

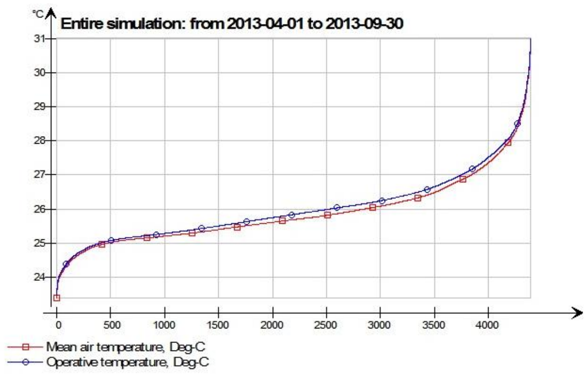




Solar shading is added at those south-facing windows were no shading. This is made to prevent overheating. Windows with a lower g-value (0.3) is also installed.

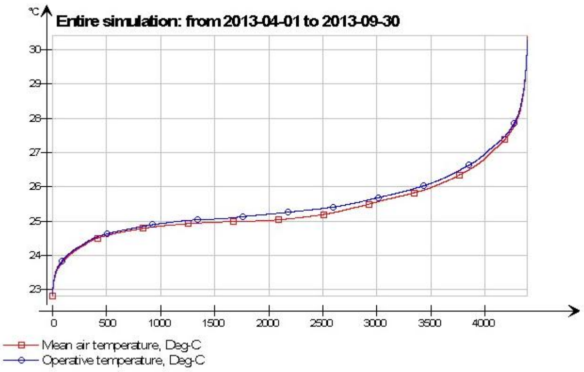
Ground floor
Top floor



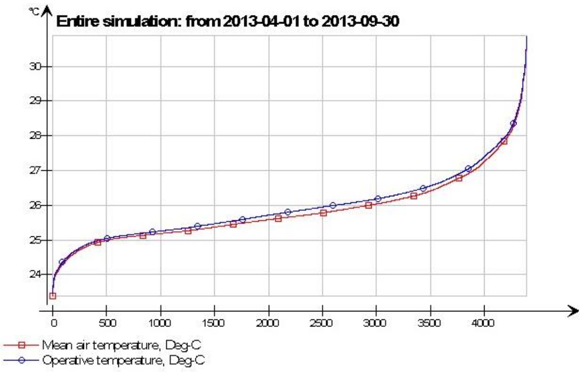


Solar shading is added at those south-facing windows were no shading. This is made to prevent overheating. Windows with a lower g-value (0.3) is also installed as well as internal blinds that roll down when the solar radiation is high.

Ground floor



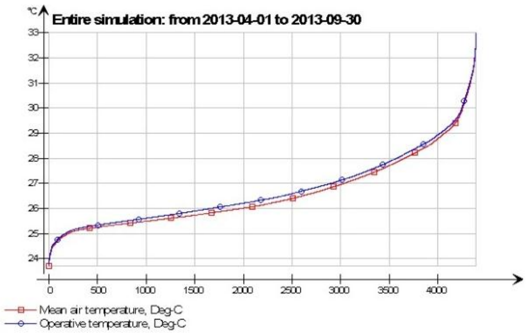
Top floor



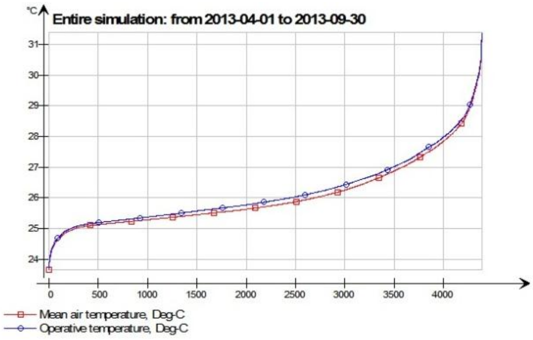
Appendix II

In the diagrams the results for both mean air temperature and operative temperature are shown. The operative temperature refers to the middle of the room 0.8 m up. In the second diagram the numbers presented is:

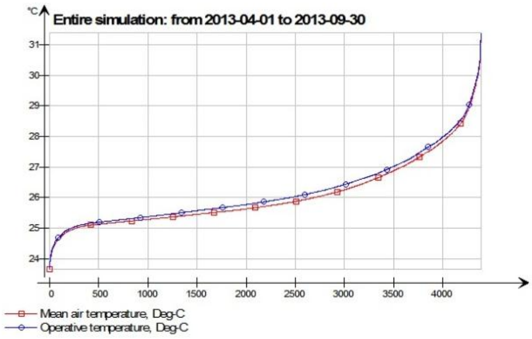
Original drawing



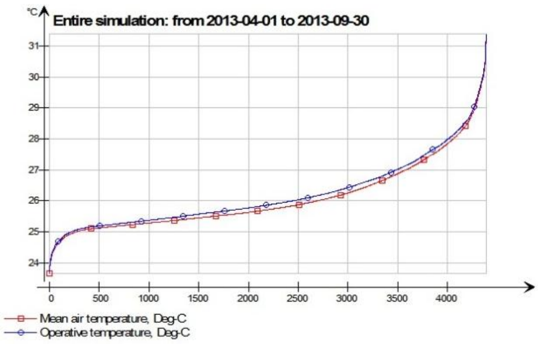
Balcony for shading at top floor



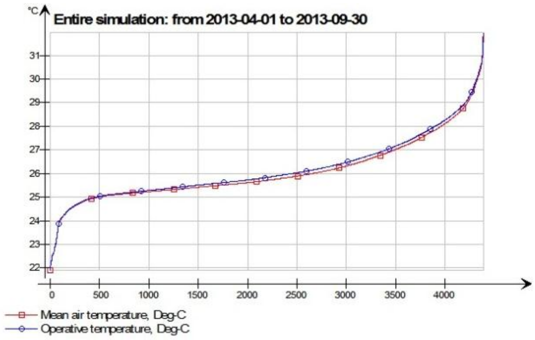
Balcony for shading at top floor and shading for all south windows



Shading for south directed windows

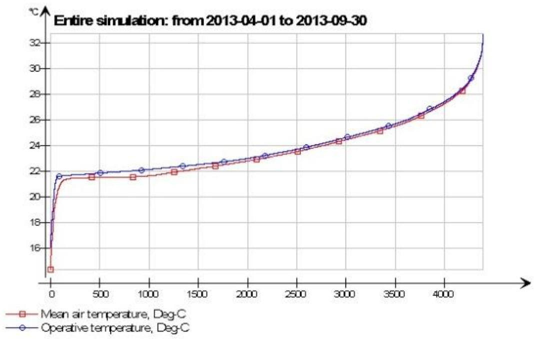


Higher U-value at walls, windows and roof

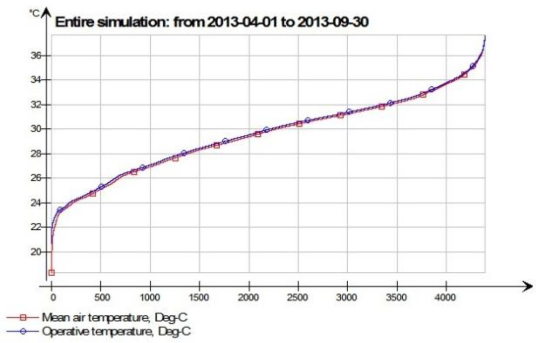


Airing schedules

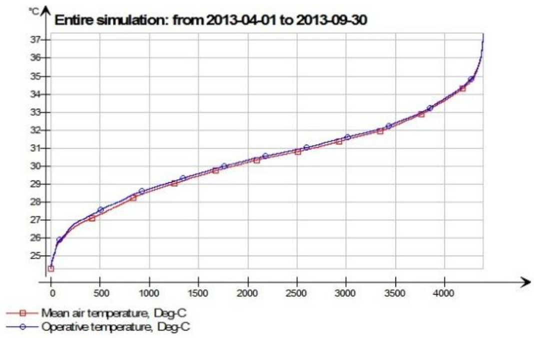
1. 10 % open in bedroom and living room both day and night.



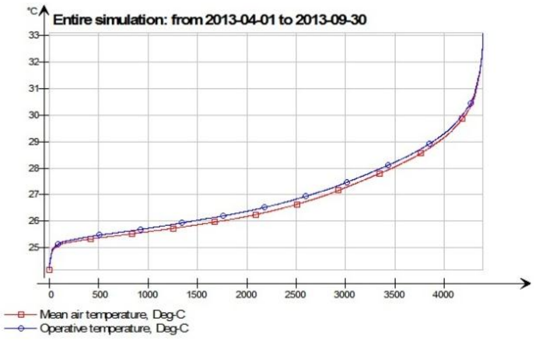
2. 50 % open in bedroom and living room 30 minutes in the morning and 30 minutes in the afternoon.



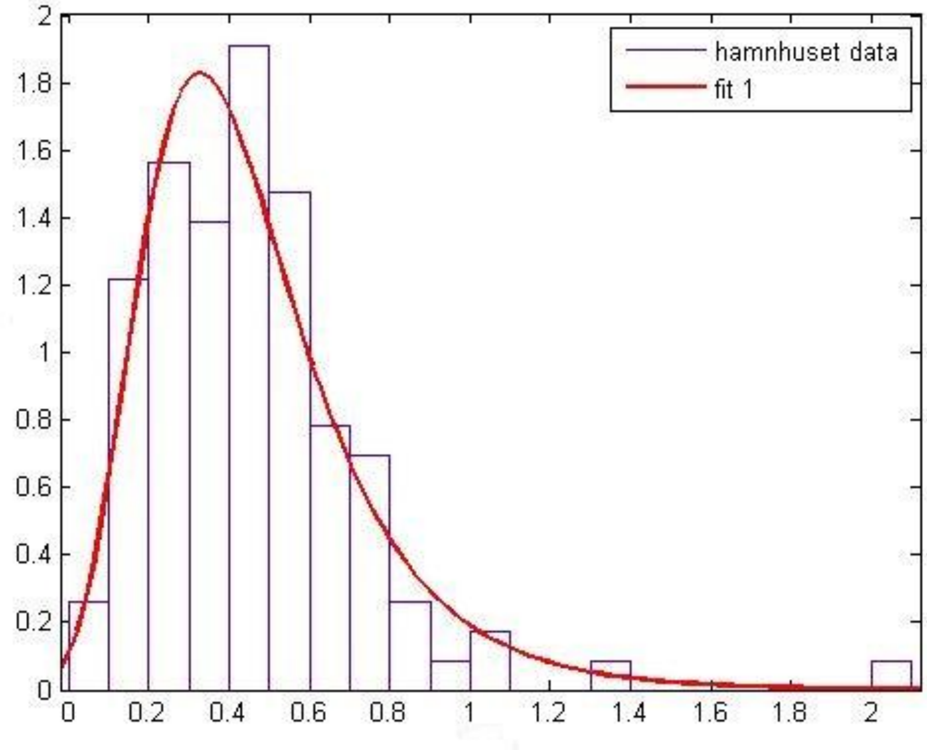
3. 50 % open in living room, 25 % open in bedroom 2 hours every afternoon, if the room temperature is over 25 °C.

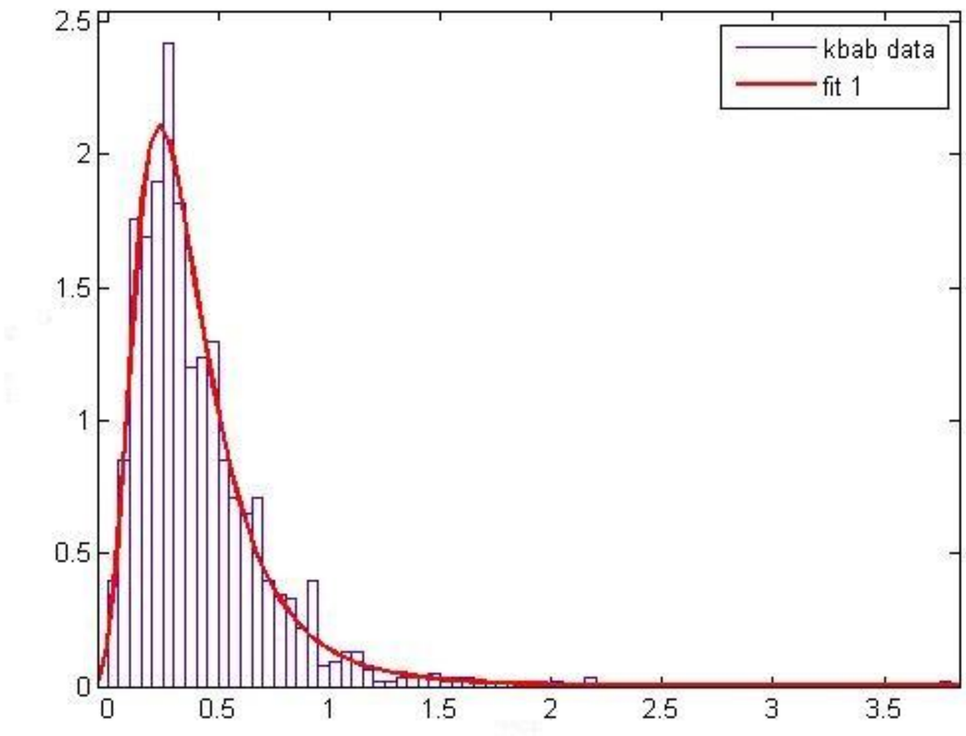


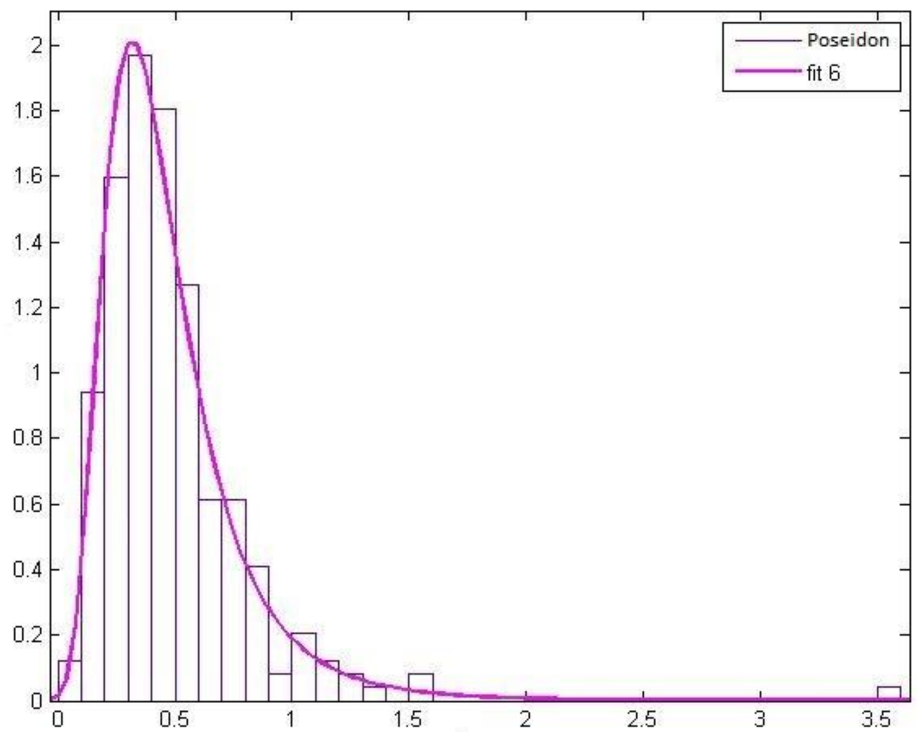
4. 50 % open in bedroom and living room 30 minutes in the morning and 1 hour in the afternoon, 10 % open 17-9, all if the room temperature is over 25 °C.



Appendix III






Poseidon
fit 6
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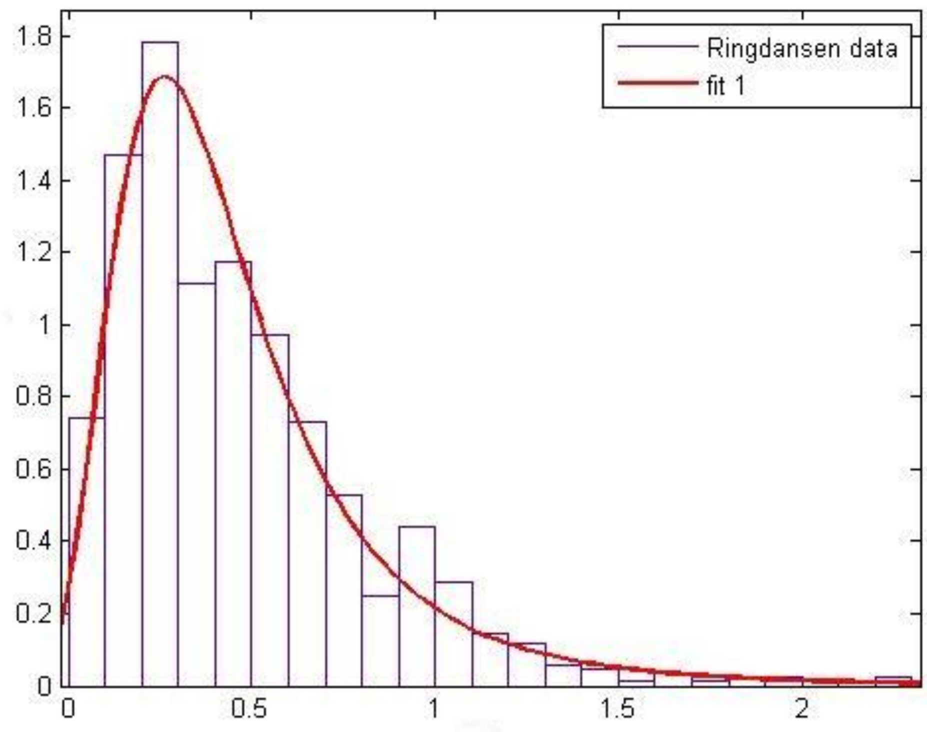
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
0.5
1
1.5
2
2.5
3
3.5


Ringdansen data
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0.6
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1
1.2
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1.6
1.8
0
0.5
1
1.5
2