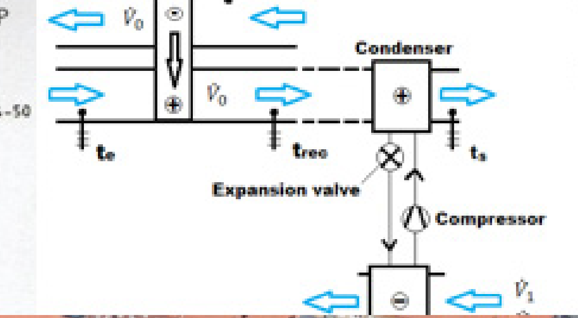
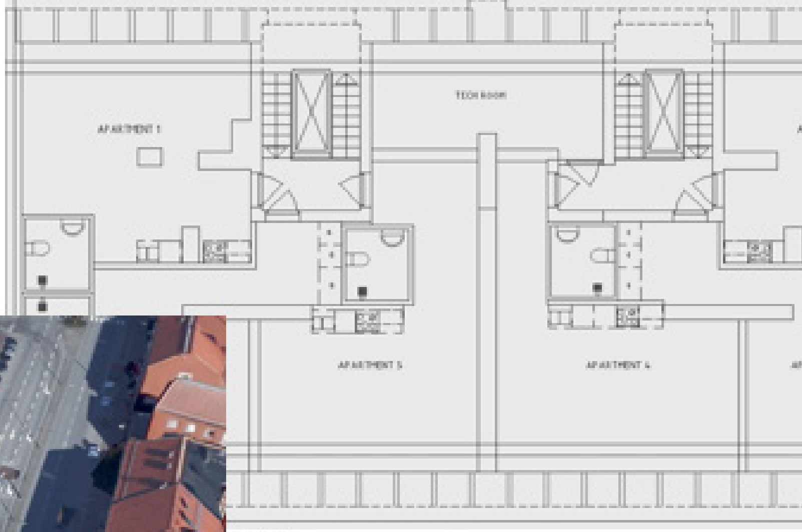
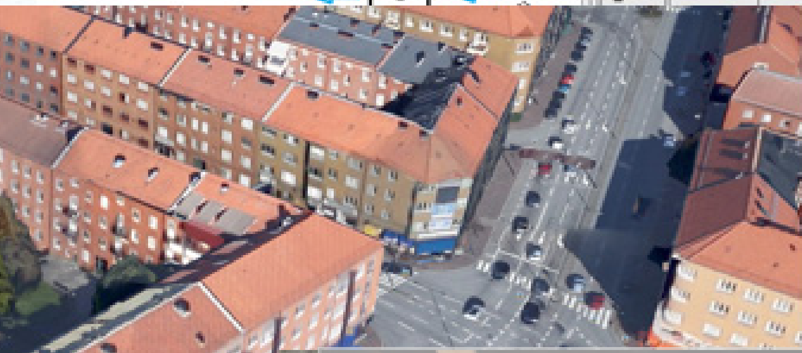




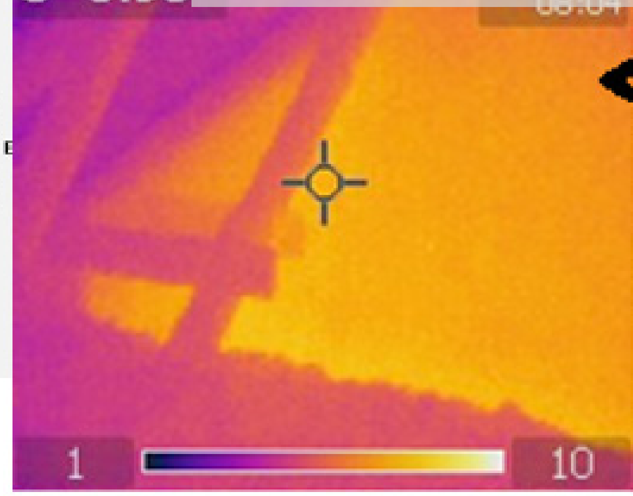


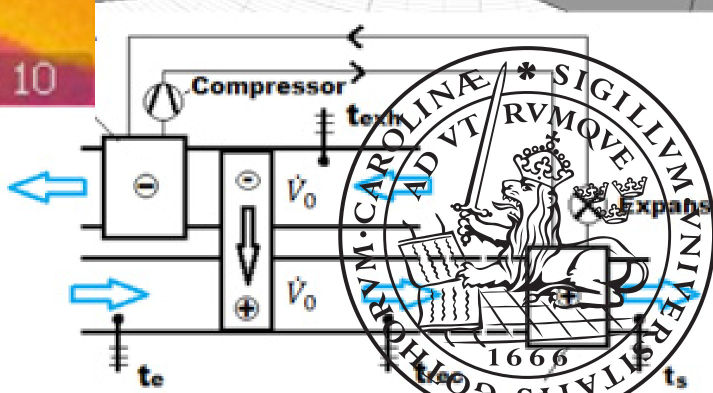
CONVERTING AN ATTIC SPACE INTO A PASSIVE HOUSE LEVEL LIVING AREA IN MALMÖ

A conversion study with focus on approach, costs and ventilation

Mauricio A. Cortes Carrasco

Master Thesis in Energy-efficient and Environmental Buildings
Faculty of Engineering | Lund University





Lund University

Lund University, with eight faculties and a number of research centers and specialized institutes, is the largest establishment for research and higher education in Scandinavia. The main part of the University is situated in the small city of Lund which has about 112 000 inhabitants. A number of departments for research and education are, however, located in Malmö and Helsingborg. Lund University was founded in 1666 and has today a total staff of 6 000 employees and 47 000 students attending 280 degree programs and 2 300 subject courses offered by 63 departments.

Master Program in Energy-efficient and Environmental Building Design

This international program provides knowledge, skills and competencies within the area of energy-efficient and environmental building design in cold climates. The goal is to train highly skilled professionals, who will significantly contribute to and influence the design, building or renovation of energy-efficient buildings, taking into consideration the architecture and environment, the inhabitants' behavior and needs, their health and comfort as well as the overall economy.

The degree project is the final part of the master program leading to a Master of Science (120 credits) in Energy-efficient and Environmental Buildings.

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Supervisor: Mats Dahlblom

Keywords: Passive house, solar, energy, heat pump, cost, production, construction, approach, investor and ventilation.

Thesis: EEBD–14/09

Abstract

The housing shortage today might be alleviated if more empty attic spaces were to be converted into living areas. In this thesis, the idea of converting an attic into a living space is studied with three objectives.

The first objective is about the steps needed to make a conversion real. The attic space is intended to reach a passive house energy performance. Condition assessment and inventory of the attic were made. This assessment and inventory analysis will present an idea on how to approach the design. The design strategy includes moisture safety, thermal performance, and air tightness.

The first objective also includes the steps needed from an investor's point of view. The investor in this study is a housing society or a conversion company. The housing society should at an early stage hire a conversion company with experience in low energy buildings. The main reason for this is delegation of responsibility. Should anything happen or if the construction is faulty, then there is no need for economical setback for the members of the housing society. This was concluded after the interviews with companies experienced in attic conversions.

The second objective, costs, is further discussed with the interviewed companies. A high selling price is of outmost importance. The companies concluded that the selling price has to be above 25 000 SEK /m^2. Some even suggested above 30 000 SEK /m^2. An average cost for the proposed constructions was not shared by the companies due to secrecy involving competition of businesses. A calculation of production cost was done with the design realized. The estimated production cost are just in-between the mentioned selling prices provided by the companies. A payback calculation of the design provides information that no short term investor would find the proposition attractive enough to invest upon. Instead a long term investor would probably be tempted for such an attic venture, as the venture is profitable only after many years.

The third objective is about possibility of heating the attic without radiators through the supply air. In addition, a subjective approach taken in this study is not to have an evaporator on the roof or the outside of the building. Subjective in a sense that people might find the outside unit of equipment to be distasteful. Instead the study will show if there is a possibility to regenerate energy with a heat exchanger and also having the condenser piece of an air source heat pump in either the air handling unit or in the buildings exhaust air.

Acknowledgement

First I would like to thank my supervisor and mentor Dennis Johansson for greatly helping me in this endeavour. I also would like to thank my family, cohabitant and friends for their support and patience during this work. Appreciation is also very noted and not forgotten to companies for their shared knowledge and valuable time. A special extended gratitude to Wikells for sponsoring this study with their flagship Sektionsdata. Furthermore, last but not least a very special thanks to the educators and staff of LTH and Lund university, who made this study possible.

Malmö June 2014
Mauricio A. Cortes Carrasco

Acronyms and abbreviations

AHU	Air handling unit
BBR	Boverkets byggregler, regulations from the Swedish national board of housing, building and planning
BI	Sveriges byggindustrier, Swedish building industries
DVUT	Design winter outdoor temperature
DB	DesignBuilder
DHW	Domestic hot water
El	Electricity in Swedish
FEBY12	Specification of requirements for zero-, passive- and mini-energy houses
HVAC	Heating ventilation air-conditioning
Luft	Air in Swedish
PH	Passive house
RH	Relative humidity
ROT	Deduction for repairs, conversion and additional constructions
SBC	Sveriges bostadsrätt centrum, Swedish housing society centrum
SCB	Statistiska centralbyrån, Swedish statistisk bureu
SCN	Sveriges centrum för nollenergihus, Swedish center for low energy houses
SEK	Swedish currency, Kronor
SMHI	Sveriges meteorologiska och hydrologiska institut, Swedens meteorological and hydorlogical institute
VS	Värme och sanitet, heating and sanitation

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1 Introduction

What would you do with an empty attic?

1.1 Background

When a city grows in population the demand for living spaces increases and new solutions are needed. Conversion of empty attic spaces into living areas could be one of the possible solutions.

The housing shortage is real and has negative impacts on several aspects one of them being employers finding it difficult to attract work force to the cities. Several countermeasures are taking place today and one example is the creation of a commission by the chamber of commerce named "bokriskommittén" (Hem och Hyra, 2013). Their main objective is to present concrete proposals to reform and improve the Swedish housing market. Their view is that far too little is being built today and shortages of rentals press the co-operative prices high, often leaving young people outside the market (Bokriskommittén, 2014).

Today one of the solutions to the housing shortage is to build small homes called "Attefallshus" or "Komplementhus". These houses do not require permission if they are built according to regulations and are of maximum 25 m^2 (SVT, 2014). An additional solution to address housing shortages is the conversion of empty attic spaces. The government passed a regulation in April 2014 that makes it easier to construct homes for students and young people. The government passed proposition "2013/2014:CU" permitting attic constructions of homes to be of maximum 35 m^2 each and the elevator extension is not obligatory for the attics anymore. The new regulation starts pertaining from July 1st 2014 (Riksdagen, 2014).

One of the main reasons for converting an attic is economical. The empty space after a conversion is a long lived source of income. A co-operative will thus have added members sharing costs, meaning that the buildings operational fees will be reduced for everyone. Another positive effect of converting the attic is the improvement of energy performance for the whole building. Try and picture a scenario where a giant cap or hat is being placed above the structure, reducing the heating cost (Bostadsrätterna, 2014.).

Energy efficiency is a prerequisite in order to reach the Swedish environmental goals. There are several ways to lower the energy use, like technologies that perform equally well but use less electricity or heating. Reduction in energy use could also lower emissions of carbon dioxide, methane, nitrous oxide, nitric oxide, sulphur dioxide, volatile organic compounds and particles (Naturvårdsverket, 2014).

Swedish prognosis about energy use in the housing sector done for the year 2020 and 2030 shows a decrease in bought energy. This decrease is believed to occur even though there is an increase of future living areas. One reason is the energy price being relatively high to work as an incentive for energy efficient heating solutions (Energimyndigheten, 2012).

According to Janson (2008) a way to reach the climate goals set by the Swedish government is to build more passive houses. Andrén et al. (2012), concurs in the matter and adds that the price of energy probably will increase in the future, making energy efficient homes a part of the solution. These homes require less bought energy.

Unfortunately studies show that competence of building proprietors is generally low (Andrén et al., 2012). This thesis aims to clarify what steps and considerations to take in order to convert for an energy efficient attic using a case study. Hopefully this study will increase the capability of future building proprietors, wanting to convert for an energy efficient attic living area.

1.2 Case study and objectives

The housing society G10 owns a building with an empty attic space. The case study is the attic of a building located in Malmö, Sweden. The building itself was constructed in 1937 and has an energy performance of 224 kWh/(m^2·year). After a fire, the storage space in the attic was moved to the basement. The attic is today only insulated with fiber glass blowing insulation and contains some building service installations.

Before constructing anything in the attic, an approval needs to be granted from the city planning office. A detailed plan from 1931 was obtained from this office, stating that no more floors are allowed for this building, see figure 1.

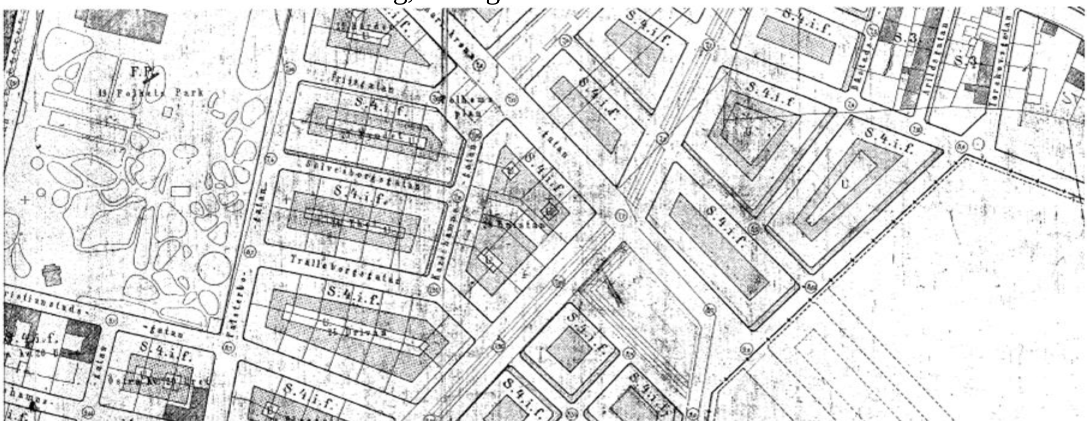


Figure 1: Detailed plan from 1931.

The plan can however be modified due to the new regulation stated in the background of this thesis regarding small apartments. There are three objectives identified for this study: the first is development based, the second is cost estimation and the third is technical solution, see figure 2.

The development based objective is about the actual steps and considerations to take in order to make the conversion possible. How should the investor approach the attic conversion, and what steps are needed for an energy efficient performance of the new design?

The second objective is about cost estimation. How much does it cost to refurbish an attic?

The technical objective is about heating the attic through the supply air. The option of having a heat pump on the roof will not be considered. The main reason for this is personal or subjective and some might agree that many outdoor unit of an air source heat pump are distasteful, lacking integration properties with the architecture. The objective will thus focus on having the evaporator on the inside instead, by either having the evaporator in the air handling unit or in the extract air of the main building.

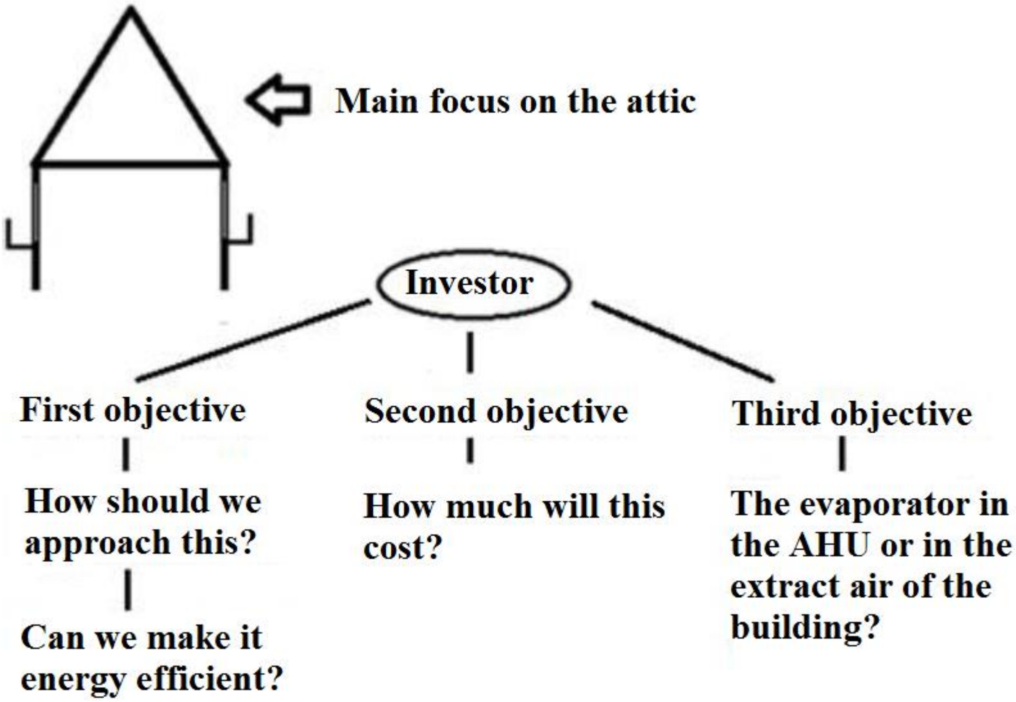


Figure 2: The investor's objectives.

1.3 Research questions

There are four research questions aiming the outcome of this project. Each topic will be solved with a method, following with the results.

Question A: How should an investor approach conversion of an attic to a penthouse?

Question B: How can the intended penthouse reach passive house energy performance?

Question C: How much does it cost to convert an attic to a penthouse?

Question D: Heating the penthouse through the supply air, with the evaporator in the AHU or in the extract air from the building?

1.4 Limitations

Following are the limitations of this study.

- No load bearing calculations have been done.
- No noise or sound calculations have been done.
- No in depth calculations have been done of the thermal images.
- Fire and roof safety has not been considered.
- Daylight has not been considered.
- Performance and improvements has not been done for the existing building.
- Socio- economic aspects are considered but not taken into account.
- Payback time will only be calculated for the study case design, and there are no considerations made for future renovation cost. The payback time is solely calculated as if the investor would mortgage the profits and with 1 or 2 % annual increase in income.
- No English translation of Sektionsdata has been done.
- The option of having a heat pump on the roof is not considered.
- The moisture productions and moisture addition from the ventilation is not considered.
- Icing due to low temperatures is not studied for the ventilation system.
- No specific air handling units or air source heat pumps are chosen.

The limitations of the study are subjects to consider in any conversion project.

2 Literature review

This literature review is divided in four parts, each corresponding to the four research questions at hand:

- 2.1 - Investor approach (question A)
- 2.2 - PH performance (question B)
- 2.3 - Cost (question C)
- 2.4 - Ventilation (question D)

2.1 How the investor should approach an attic conversion

The investor needs to be identified first. The housing society has to evaluate if they have the economy and time to spend on a conversion project, or if they should sell the empty attic to a conversion company. A recommendation for the housing society is to sell the empty attic to a conversion company to avoid the risks as an investor.

In either case the co-operative needs to take some steps towards an attic conversion. If the co-operative intends to be the investor, they proceed to vote towards a pre-study (pre-investigation). If the attic is sold to a conversion company, the company becomes a member of the housing society (Bostadsrätterna, 2014.).

According to Swedish Bostadsrätts Centrum (SBC, 2012), the housing society needs to first agree upon a pre-study. The pre-study contains the following prerequisites in order to form a decision base:

- Detail plan
- Building permits
- Building consultation
- Existing attic
- Basement storage
- Disturbance for the accommodators
- Noise-demands
- Economic consequences
- The building process

The next step is to take a decision again, this time for an approval or a decline, on converting the attic according to the pre-study results. If a resistive decision occurs, a court order might settle a decision for the housing society. After an approval is granted, a building permit document needs to be produced (SBC, 2012). The building permit is given by the local authorities and might take time to receive. In order to speed up the process an advance ruling/notice is given by the authorities (Boverket, 2014). After the building permit is produced and approved, a tender document for the entrepreneurs is written. (SBC, 2012)

The housing society bylaws might need an update and the economic plan needs to be changed. It takes about 18 months to renovate an attic, and before selling the new apartments a tenure-agreement and a technical description needs to be prepared. Any form of self-renovation is strictly advised against, one reason being that the housing society takes over the responsibility when the project is finished (SBC, 2012).

The building proprietor (client) is by definition “the one that for his/her own account executes or let others execute construction, demolition or ground works” (Mittbygge, 2014). The building proprietor in this case is either the housing society or the conversion company. A building proprietor needs to be well informed about laws and regulations. The building proprietor has principal responsibility in his/her project, and should lead the project through all the requisites set for a building project. The building proprietor will have assistance from different specialist and from the quality manager that was chosen for his/her project (Mittbygge, 2014).

When a building proprietor (client) orders a building for his or her own account, the person or company enters the “building process”, a term used in the Swedish building industry. The building proprietor has a central function and a principal responsibility when it comes to the building process. Studies show that competence of building proprietors has been generally low (Andrén et al., 2012).

The building process follows in general certain premises and structures as shown in figure 3:

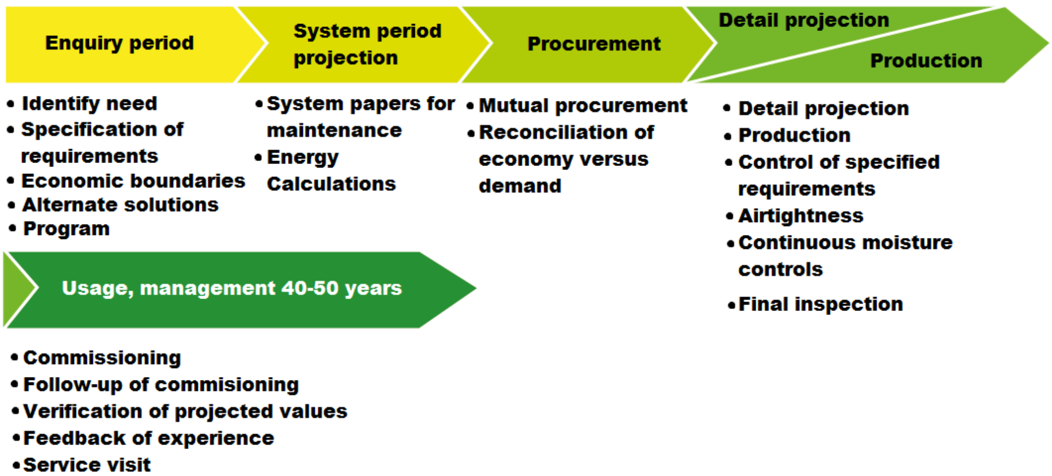


Figure 3: The process of a building project (Andrén et al., 2012).

In the building process there is a client that identifies the need of a building. According to the intended use of the building the client then produces a premises program. The program envisions what the building is intended for and what rooms it will contain. From this the architect forms a building plan and functions. When the client and architect agrees on the project, the structural engineer comes into play, as well as the other project based producers like HVAC engineers, electrical engineers etc. depending on the project. This phase contains compromises from all parts in order to proceed with the project production. These compromises could be construction dependent or of economic reasons with purpose of complying with set goals (Andrén et al., 2012).

The ambition and intention of the building proprietor may get lost during the way in a conversion project with a lot of participants. Figure 4 shows a conventional way of organizing a construction project. It is thereby desirable to shorten the organizational line, from the building proprietors to the builders in order to get a good overview and outcome of the project (Andrén et al., 2012).

Directives and tendering procedures can be problematic during the building process. A procurement of contractors with total responsibility for the construction project is consequently not unusual. The contractor will later procure services such as ground works, electricity, building service installations etc. A problem with this type of procurement is the information flow between concerned parties in the building process, e.g. from the building proprietor and downwards in the organizational line. Another problem that can affect the quality, energy performance and other, is the pricing strain being so low that it affects the vision of the building proprietor. The subcontractor is not always invited to meetings with the building proprietor and contractor. This becomes a communication deficit as sometimes the subcontractor does not share the visions and goals of the project. Another hindrance crippling the outcome can be legislative (Andrén et al., 2012).

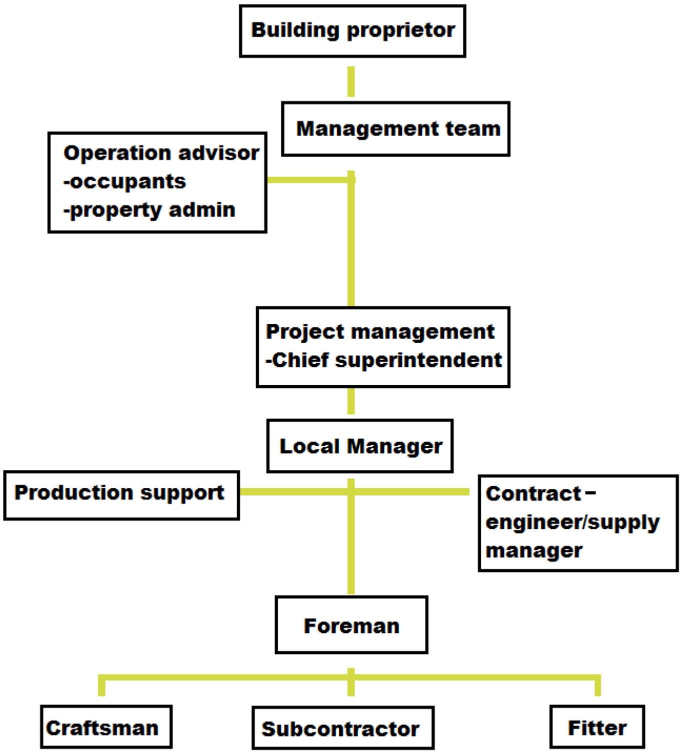


Figure 4: Organization chart of a conventional construction project (Andrén et al., 2012).

To succeed in a project with high quality goals, the developer should engage in other forms of building processes like trust contracts or partnering with open information. In these types of ventures, the parties agree on the financial premises and prerequisites. The economic gains that take place in the project due to smart solutions, logistics and production, befall on all participants accordingly (Andrén et al., 2012).

The city of Malmö has their own guidelines for conversions of attic spaces into living areas, and consists of detail plans, aesthetics, garden planning, parking, availability, fire safety, storage, roof safety and noise. These are all points to consider in the approach of a conversion (Malmö stad, 2007).

2.2 How the attic reaches a Passive House energy performance

When building passive houses, the low allowance of heat loss requires the design to be very energy efficient. To achieve a good building envelope it is vital to consider a list of goals in the design (Abel et al., 2007). These are the design goals:

1. Suitable thermal insulation
2. Reduction of thermal bridges
3. Adequate airtightness
4. Moisture safety

According to Janson (2008) a way to reach the climate goals set by the Swedish government is to build more passive houses. In order to do so there needs to be a positive feedback from demonstration projects to further feed the production demand and investments. In the planning process everyone needs to be involved to secure a successful project. There needs to exist excess time in order to deal with unforeseen obstacles and issues in the production process, especially if the involved parties are not familiar with passive houses before. The author also depicts the importance of the right type of leadership educated in the matters of passive houses (Janson, 2008).

So first there needs to be an education among people involved in building passive houses. And to clarify what a passive house is, FEBY12 was created as a requirement tool to assist in the construction of passive houses. The report contains steps and advices to be taken in order to fulfil classifications of the mentioned criteria's. These classifications are: "Projected", "Certified" and "Verified". The "Projected" class is when the calculations are satisfying the demands for the building. The "Certified" class is when the building has been examined by an organisation that has been granted permission to audit by "Sveriges Centrum för Nollenergihus, SCN. The "Verified" class is when the demands are met through measurements (FEBY12, 2012).

Ten tips are provided by Andrén et al. (2012) on how to build a passive house in Sweden. These are:

1. Clear object description and goal formulation.
2. Choose co-operation partners with care.
3. Create early the feeling of us (team).
4. Protect quality.
5. To create a passive house is to create a total solution.
6. Airtightness is central, designate an accountable person.
7. Avoid any forms of thermal bridges.
8. Be cautious of moisture problems or issues, designate an accountable person.
9. Set high comfort demands.
10. Follow up on economy and function.

2.2.1 FEBY12 energy requirements

These are the FEBY12 requirements translated from the document for residential buildings. For buildings with refined[1] systems (for heating and hot water), the following requirement is set for the energy delivered to the building as $E_{Delivered}$:

[1] Buildings that have either electric heating systems (including heat pumps) or pure non- electrically heated systems.

[kWh/(m^{2}A$_{temp}$,year)]	**Climate zone III**
Max non electrically heated	**50**
Max electrically heated	**25**

A_{temp} is by definition the collective area within the climate shell of all the floors in the building that is intended to be heated above 10 °C. It also includes inner walls and cavities.

Climate zone III is by definition one of the three Swedish climate zones. Including countys: Västra Götaland, Jönköping, Kronoberg, Kalmar, Östergötland, Södermanland, Örebro, Västmanland, Stockholm, Uppsala, Skåne, Halland,Blekinge and Gotland. Other climate zones have other requirements regarding energy use.

Note that the definition for electrically heated building in these criteria differ from Boverkets Byggregler (BBR) and refer to buildings with all types of electrically heated systems (including heat pumps) for heating and hot water regardless of installed electrical output. For systems with mixed forms of energy, the requirements are made on balanced energy $E_{weighted}$.

Additional non electrically heated buildings less than 400 m^{2}A$_{temp}$:

$E_{Delivered}$ 50 + 5 [kWh/(m^{2}A$_{temp}$,year)]

Additional for electrically heated buildings less than 400 m^{2}A$_{temp}$:

$E_{Delivered}$ 25 + 2 [kWh/(m^{2}A$_{temp}$,year)]

For buildings with non- refined systems (mixed energy forms) for heating and hot water, the requirements for maximum delivered balanced energy is instead, $E_{weighted}$ and where balanced energy also relates to electricity to the building's operation.

$E_{weighted}=2.5 \cdot E_{elecricity}+0.8 \cdot E_{district\ heating}+0.4 \cdot E_{cooling}+E_{other}$
[kWh/(m^{2}A$_{temp}$,year)]

[kWh/(m^{2}A$_{temp}$,year)]	**Climate zone III**
Max $E_{weighted}$	**63**

Additional for buildings less than 400 m^{2}A$_{temp}$ Max $E_{weighted}$ + 5
[kWh/(m^{2}A$_{temp}$,year)]

2.2.2 BBR19 energy requirements

Residential buildings should be designed so that the buildings specific energy use installed electrical power for heating, and average heat transfer coefficient (U_m) for the building parts that enclose the building (A_{om}), should not exceed the following limits.

Non-electrically heated residential building

[kWh/(m^2A_{temp},year)]	**Climate zone III**	
Buildings specific energy use	**90**	
Average heat transfer coefficient	**0,40**	[W/(m^2K)]

Electrically heated residential building

[kWh/(m^2A_{temp},year)]	**Climate zone III**	
Buildings specific energy use	**55**	
Installed maximum electrical power for heating [kW]	**4,5**	
+ Addition when A_{temp} is bigger than 130 m^2	**0,025(A_{temp}-130)**	
Average heat transfer coefficient	**0,40**	[W/(m^2K)]

The building specific energy use is allowed to be reduced by energy provided from solar cells or solar thermal installations placed in the direct vicinity. Also, specific circumstances may allow for a disregard of the requirements. These could be geological or other hindrances.

$\mathbf{A_{om}}$ is by definition the collective outer area of the climate shell (m^2), this area is connected to heated indoor air.

2.3 Cost of conversion

Cost is one of the most significant features when constructing a building. There is a discussion today about additional costs when it comes to either building conventional buildings or passive house buildings. Building a passive house does imply a higher cost than a conventional building and could be around 2 to 9 % more expensive (Andrén et al., 2012). There seems to be a general discord when it comes to the additional cost of low energy performance buildings. In a critical review from the Swedish centre for zero energy houses, SCN, the building agency (Boverket) states that their demands (conventional building demands) are set to be the most cost efficient. The appendix of the review links to some videos where the cost additions are set to nearly zero, this is done to counter the claim done by the building demand committee, stating that additional cost are 10 to 15 % (SCN1, 2012).

Another cost related study of energy efficient buildings from SCN shows a percentage addition for different type of buildings, see table 1. This is done depending on how energy efficient the building will be. Another difficulty presented in the report is when many projects are won by lower bidding, and not by set goals and visions (SCN2, 2012), as needed for a good conversion outcome (Andrén et al., 2012).

Table 1: Added cost depending on the type building intended (SCN2, 2012).

From BBR zone 3	To	Added cost
90*	55-65* (25 % better)	0-5 %
90*	50*(passive house)	3-10 %
90*	0*(zero energy house)	10-15 %

* kWh/(m^2·year)

A building constructed with passive house energy performance would probably give low operational costs. The investor that focuses on low operational cost does not solely consider initial cost but perhaps the cost for the whole lifecycle of the building. The other type of investor probably wants to buy at a low price, put the investment to work and then sell it for the highest possible price focusing on the initial cost and not so much on the operational cost (Andrén et al., 2012).

The government passed the proposition to allow for 35 m^2 apartments to be built on attic spaces and there is no longer a requirement to extend elevators to the attics (Riksdagen, 2014). A report from Larsson et al. (2009) studies elevators extended to an attic, they mention a total cost for a budget elevator to be 475000 SEK. The study also contains cost estimation of their attic and they acknowledge the importance of pre-investigations. This is done to lower the economic impact of ventures for the building. Examples of such future ventures could be façade renovations that will need scaffolding, containers and work sheds. These are same type of elements needed for an attic conversion and thus, co-ordination of ventures is strongly recommended.

According to Isacson (2006) the cost of renovating an attic in Stockholm in 2005 is about 25000 SEK/m^2 and the brokers selling price is about 15000 SEK/m^2 for the same year. He also highlights that if a company is buying and constructing the new selling price accumulates to 40000 SEK/m^2 (25000+15000=40000) in order to make the venture feasible. This means that we need to find a selling price and a construction cost in Malmö, to make the same comparison.
According to statistics of Sweden the cost of newly built spaces for the three major cities in Sweden is seen in figure 5. Here it is almost possible to see what Isacson refers to for Stockholm in 2005 (~29000 SEK/m^2), the cost is slightly higher for newly constructed buildings. Figure shows the mean value of the selling prices in the bigger cities in Sweden. Parallels can be drawn with selling price of 16000 SEK/m^2 as identified by Isacson (2006) for Stockholm for the year 2005. An accumulation of these figures for a newly built building in Stockholm in 2005 would be 45000 SEK/m^2 (29000+16000=45000).

Following Isacsons calculation, the figures 5 and 6 from the Swedish statistical central bureau, SCB should give a cost accumulation near the real value. Note that there are only values until 2012. If the cost in figure 5 were dissected, it would give the production and construction cost as illustrated in figure 7.

After production and construction cost are estimated, the Payback time for a venture could be important for an investor. The Payback time also known as payoff time of an investment is not commonly used for profit measurement. In fact if the investment never achieves payback, then most likely the investment option is not feasible. On the opposite side, if a payback period is short it might signal that the venture is profitable but not necessarily.

A crucial statement for feasibility is if there is an alternate investment option that would give a higher return in which the company would lose upon not making a venture in (Greve, 2007).

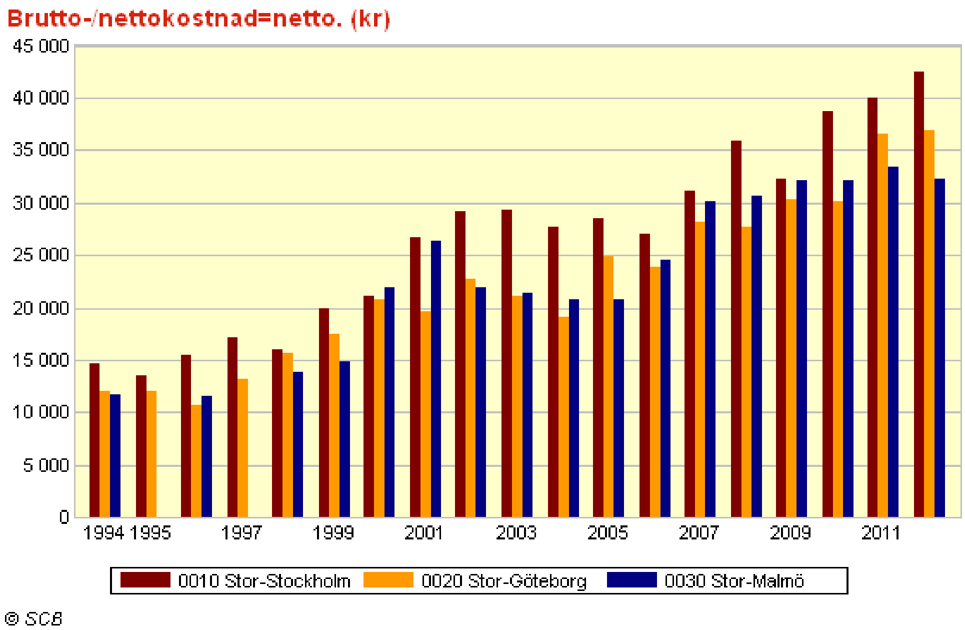


Figure 5: Net building cost for multifamily buildings in three cities (SCB, 2014).

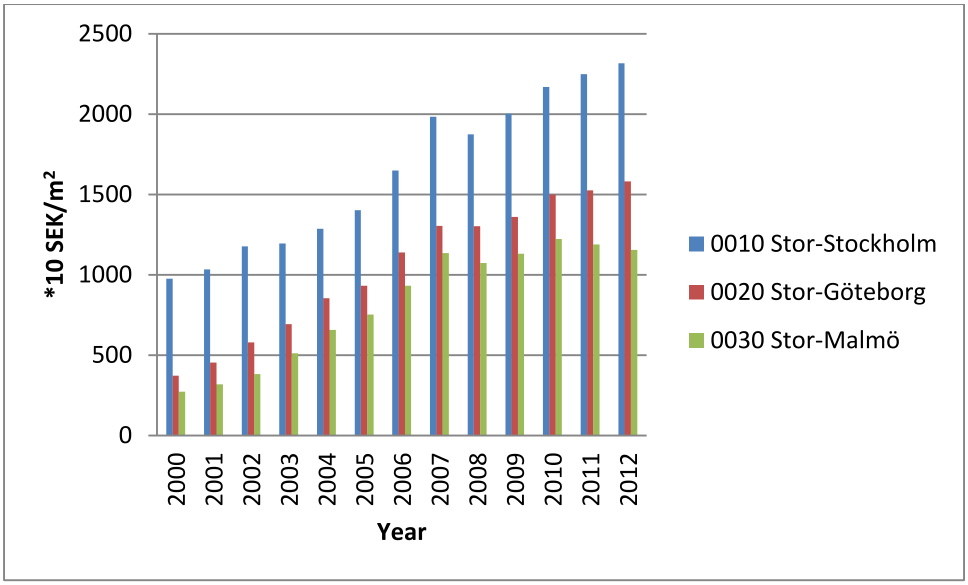


Figure 6: Mean value selling price per square meter according to Swedish statistics in Stockholm, Gothenburg and Malmö (SCB, 2014).

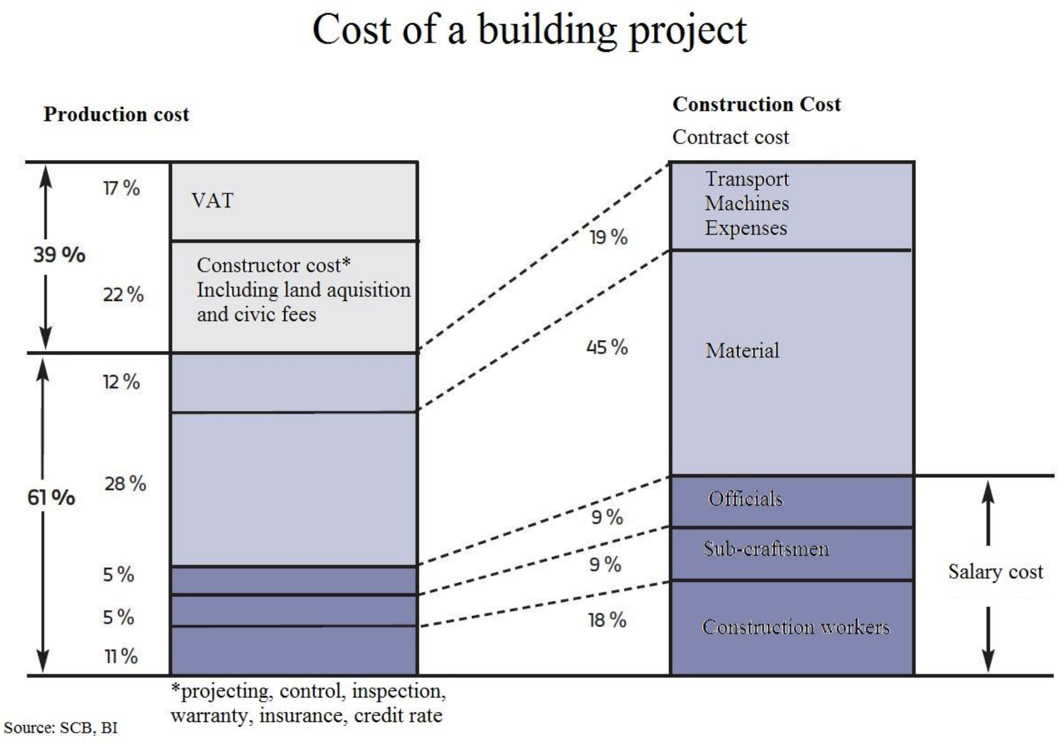


Figure 7: Costs in a construction project (BI, 2013).

2.5 The type of ventilation and the use of heat pump

The purpose of ventilation is to have clean indoor air and to balance the limits of carbon dioxide, heat surplus, odors, moisture, and other substances. In a passive house, the ventilation system is a crucial part since the heat is provided mostly by air (Andrén et al., 2012). These types of buildings are very airtight and for that reason there exists special demands on the ventilation. The heat exchange in this case is also crucial. Tempered supply air should be distributed centrally with insulated ducts and extracted with some sort of heat recuperation (Andrén et al., 2012).
An easy way to recover heat from exhaust air is to recirculate it and mix it with the supply air which was a common solution until the end of the seventies. However, this method is hardly done in Sweden today and it is becoming less popular in other European countries too due to hygienic reasons (Abel et al., 2007).

Heat exchangers are today a normal way to recover heat in Sweden. This heat comprises of latent vapor content and the sensible air temperature, known as the enthalpy of the air *h* in kJ/kg. If there is no moisture production in the building and the supply air is not humidified, the enthalpy will be roughly proportional to the return air (Abel et al., 2007).

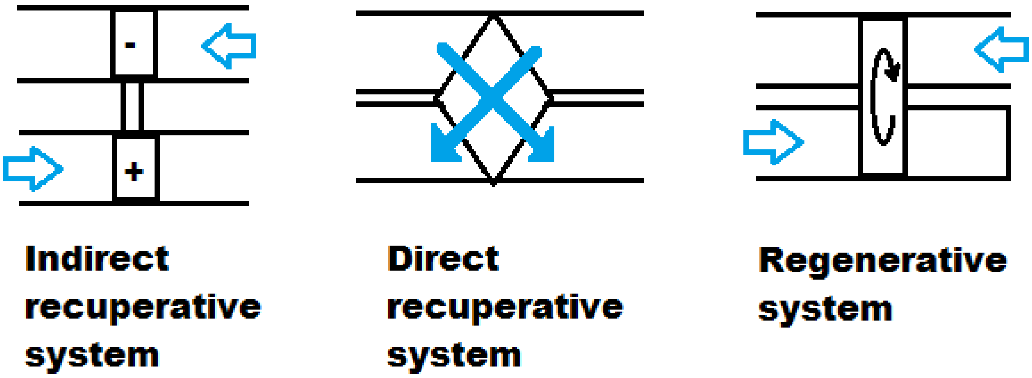


Figure 8: Three heat exchanger systems (Abel et al., 2007).

An indirect recuperative heat exchanger system, consist of coils in the supply and extract air with an intermediate circulating liquid circuit. A direct recuperative system is a heat exchanger positioned between the supply and extract air system. The supply and extract air flows through a common piece of equipment. A regenerative system consists of a rotary heat exchanger between the supply and extract air. See figure 8 for different systems (Abel et al., 2007).

The technical objective is to heat up the attic through the supply air. This means that no radiators, floor heating or other heating systems will be used. Andrén et al. (2012) writes that when the heating need is as low as 10-12 W/m^2 then there is no motive for technical or economical need in fitting a traditional distribution system for heating. The little heating need could thus be distributed by a heating coil in the supply air (Andrén et al., 2012).

According to a coil vendor there are less electrical coils sold today, compared to a few years ago. A reason explaining this could be the rising energy prices.

An air source heat pump can provide efficient heating or cooling for a home. When properly installed, an air source heat pump can deliver one-and-a-half to three times more heat energy to a home than the electrical energy it consumes. A heat pump moves the heat rather than converting it like a combustion heating system do (Energy, 2014).

A heat pump's refrigeration system consists of two coils made of copper tubing which are surrounded by aluminium fins to aid heat transfer. The system also contains a compressor and a thermostatic expansion valve. One coil (the condenser) condenses the refrigerant releasing heat. The other coil is the evaporator, absorbing heat and with a compressor it compresses the refrigerant, see figure 9 (Energy, 2014).

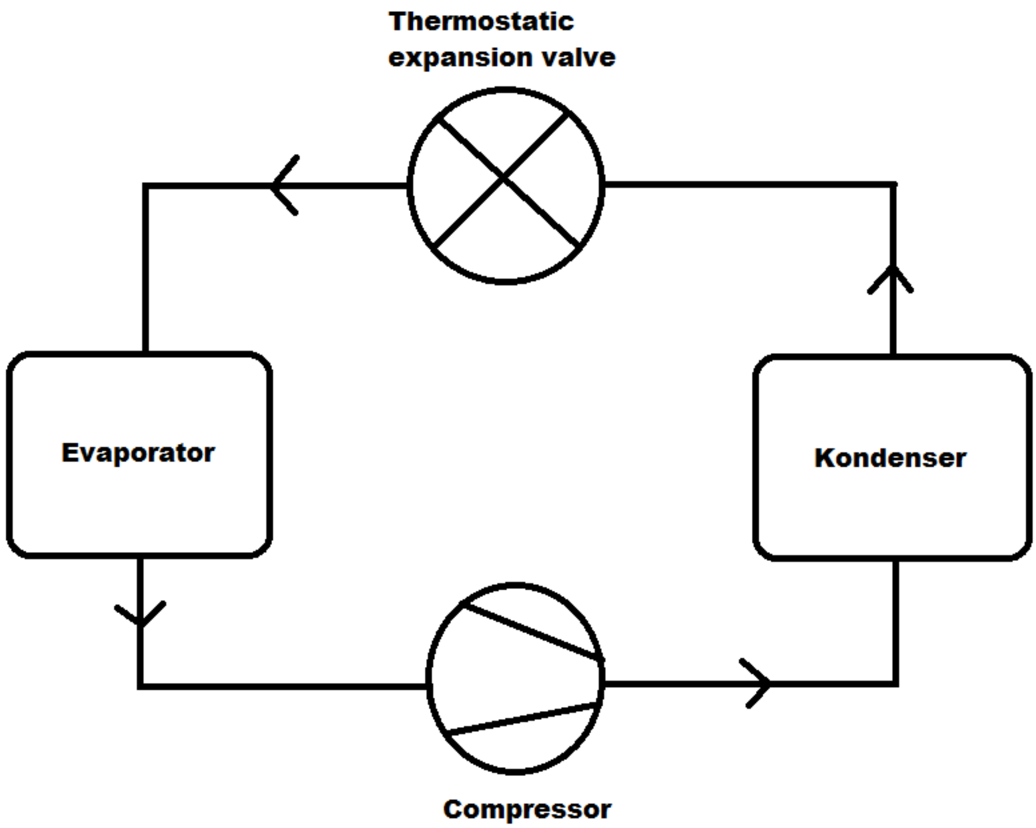


Figure 9: Heat pump system.

3 Methodology

Different methods were chosen to correspond with the four research questions. The first step was to look at the attic and its present condition. This was later used for design strategic reasons for the new apartments in the attic.

The main questions addressed in this section are:

- The attic's existing condition and its inventory. This is a crucial first step and will facilitate the understanding of the three objectives.
- - Investor approach (question A)
- - PH energy performance (question B)
- - Cost (question C)
- - Ventilation (question D)

3.1 General inventory of the attic

This section is the pre-investigation of the case study and the objective here is to have a clear vision of the existing building and the attic, before any conversion is projected. This will facilitate a design strategy for the new apartments in the attic. To do this the orientation, climate and the site of the study case are looked at.

A visit was done to the city planning and drawing archive to retrieve plans and drawings of the attic and the building. The next step was to visit the vacant attic space for inventory and site analysis, with a regular- and an infrared camera. The thermo graphics where done early in the morning to minimize eventual solar impacts on the façade and roof. Every discipline is of interest in the inventory check-up. No in depth calculations was done of the thermal images.

The orientation-, climate- and site analysis was done with the computer programs Google Earth, WUFI and Ecotect. Google Earth was used for the orientation and site analysis, WUFI for its climate data and Ecotect was used to simulate the building for a shadow analysis and annual solar radiation. A psychometric chart was used for the exhaust air, in order to see how much energy the air contains.

3.2 The investor approach of an attic conversion

Interviews were held with companies in Malmö related to either present or recent conversions of attic space projects. Following questions were in focus:
How should the investor approach an attic conversion?
How much does it cost to refurbish?
The interviews with the conversion companies were done over phone.

3.3 Passive house energy performance implementation

This section is closely related to the outcome of the pre-investigation. The strategic steps toward an energy efficient design were used here. Six apartments were designed in the empty attic space, with an area of 35 m² each. The apartments were designed with the goal of reaching a passive house energy performance. Moisture safety and thermal bridges are of outmost importance, computer programs were used to foresee and improve the proposed design behaviour regarding these important subjects. The 35 m² apartments were drawn accordingly in the program AutoCAD. The moisture safety criteria and the behavior are produced in the program WUFI. The thermal bridge criteria and its behavior are done in the program HEAT2. The energy assessment was done using the program DesignBuilder and also by a steady state calculation in Excel.

3.3.1 WUFI (moisture assessment)

This program was used for assessment of the moisture conditions and performance of the attic envelope. A section of the intended wall and roof was put into the program for the study.

3.3.2 HEAT2 (thermal assessment)

This program was used to see how the thermal transport is in sections of the walls and roof. With this program possible thermal bridges were illustrated in 2d.

3.3.3 DesignBuilder (energy assessment)

A 3d model was created in DesignBuilder to assess the energy use of the six apartments with two persons living in each apartment. The inputs were set in hierarchy from the building level down to block and zone levels. The input information was done for the building envelope, users, HVAC and climatic conditions.

3.3.4 Excel steady state calculation (heating power assessment)

The steady state calculation follows the FEBY12 recommended method to assess the power needed. This was done to heat up the apartments at dimensioning winter outdoor temperature, DVUT. The steady state Excel sheet was created by LTH and can be used for assessing the energy and power requirement of a building, without consideration of the heat gains. For this study the steady state is only used for the power assessment, since DesignBuilder is used for the energy assessment. The first input is the heated indoor area known as A_{temp}, for this study it is 210 m^2. To calculate the transmission losses through the building envelope we need the values for $UA_{effective}$. The U-value for the windows is chosen to be 0.8 $W/(m^2 \cdot K)$, a common value from manufacturers for passive house windows. The floor is adiabatic, the roof and walls U-values are however calculated using λ-values, thicknesses, densities and specific heat capacities for each material, see appendix E. When the U-values and areas A are known then a factor of 1.1 is multiplied to compensate for thermal bridges as in equation 1a.

$$UA_{effective} = \sum U \cdot A \cdot 1.1 \quad [W/K] \quad \text{(Equation 1a)}$$

The next step is to calculate the ventilation losses both intentional and unintentional. Equation 1b is used with $\eta = 75\%$ efficiency for the heat exchanger.

$Q_{vent}=\rho_{air}\cdot c_p\cdot q_{vent}(1-\eta)+\rho_{air}\cdot c_p\cdot q_{leakage}$	[m^3/s]	(Equation 1b)
$q_{vent}=q_{demand}\cdot A_{temp}$	[m^3/s]	
$q_{leakage}=(0.05\cdot A_{temp}\cdot \text{Indoor height})/3600$	[m^3/s]	
Indoor height=2.5	[m]	
$\rho_{air}=1.2$	[kg/m^3]	
$c_p=1000$	[J/(kg·K)]	

A page in the Excel file shows different locations in Sweden and also different days to choose from depending on the building. A heavy building withstands more days than a light building, and according to FEBY12 one might choose 3 days as an initial value for a light building, assuming the attic is a light structure for this study. The nearest location to Malmö is Lund and for 3 days the DVUT value is -10.1 °C.

The results in the Excel sheet is presented with or without heat exchange in the ventilation air. The power need P is calculated as the sum of the transmission- and ventilation losses divided by the difference in the indoor air temperature and DVUT, see equation 1c.

$P=(UA_{effective}+Q_{vent})/\Delta T$	[W]	(Equation 1c)
ΔT=indoor air temperature-DVUT=21-(-10.1)	[°C]	

3.4 The cost to refurbish

The program Sektionsdata was used to calculate the cost of the proposed conversion. Together with supporting arguments a conclusion should be available to provide cost estimation according to the boundary of SEK/m^2.

3.4.1 Cost calculation

The design suggested for the conversion was used together with the program Sektionsdata to calculate cost/m^2 of the refurbished area. There are four sections of data in the program, ROT, VS, EL and LUFT, which respectively correspond to conversion (ROT), sanitary (VS), electricity (EL) and air (LUFT). The inputs together with the calculations are presented in Appendix C1, C2, C3, C4 and C5.

3.4.2 Payback of investment

The annual rent for newly produced apartments in Malmö in 2013 is averaged at 1544 SEK/m^2 and an average fee for tenants in a housing society is 645 SEK/m^2 (SCB, 2014). The calculation for payback time was simplified with the annual rent minus the fees, 1544-645=899 SEK/m^2. The investment (loan) was calculated for different discount interest rates. The income of 899 SEK/m^2 was accumulated for each year, with a rate of 1 % and another one at 2 %. The rate could be explained by a yearly increase in rents.

The payback calculation was limited to only renting out apartments. The calculation did not include cost for future renovations of the attic and its systems. The calculation was done numerically in Excel with a net present value method for each year, see equation 2. The NVPs were for income and expenditures, income being the rent minus the fees and expenditure being a yearly rate of the investment. The income in this calculation was first deducted with the yearly expenditure and if there was a surplus it was mortgaged directly, see appendix G and F.

$$NPV_i=\frac{C_i}{(1+r_{di})^n} \qquad \text{(Equation 2)}$$

NPV_i=Net present value of expenditure occuring after n years

C_i=Expenditures in today's values

r_{di}=Discount interest rate

The payback was achieved when the investment (loan) including the paid interest equalled the accumulated mortgages. Only the PH investment was calculated for.

3.5 Ventilation type

The objective is to heat up the attic without radiators through the supply air. In order to do so; an air source heat pump was figuratively connected to the supply air. The condenser is the part placed in the duct of the supply air while the evaporator is placed in either exhaust of the same air handling unit AHU, figure 10 or the buildings exhaust duct, figure 11. The AHU was studied first to know what temperatures occur in the process. The system was calculated at dimensioning winter outdoor temperature DVUT, for the location in which the attic is located, -10.1 degrees. The indoor temperatures were assumed to be 22 degrees for both the attic and buildings exhaust air.

The air handling unit needs to heat up the incoming outside air at DVUT. The first phase is when the outside air passes the heat exchanger. The study will focus on a rotary heat exchanger for this system.

The first phase was to calculate the temperatures of the ingoing and outgoing air of the AHU, before the condenser coil. The next phase was to heat the air enough to counter the heat loss of the attic. The heating after the heat exchanger occurs when the air passes the condenser coil.

The air passing the rotary heat exchanger was calculated with temperature efficiency η_T=0.75, using equation 3. The supply air temperature t_s was calculated with a modified equation 4.

η_T is the temperature efficiency and used to calculate t_{rec} with equation 3:

$$t_{rec}=t_e+\eta_T(t_{exh}-t_e) \qquad [°C] \qquad \text{(Equation 3)}$$

t_{rec}	Air temperature after heat recovery	[°C]
t_e	Outdoor (external) temperature	[°C]
t_{exh}	Exhaust air temperature	[°C]
t_s	Supply air temperature	[°C]

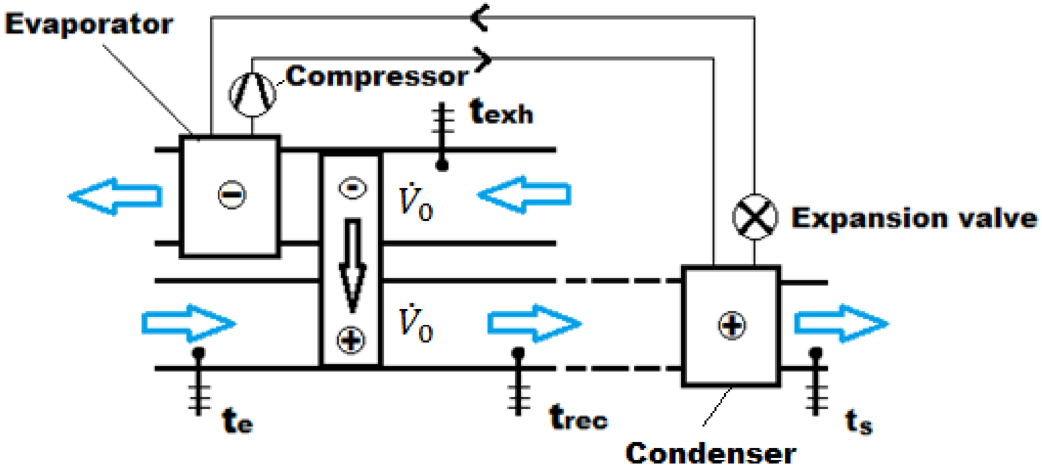


Figure 10: The AHU with an integrated air source heat pump.

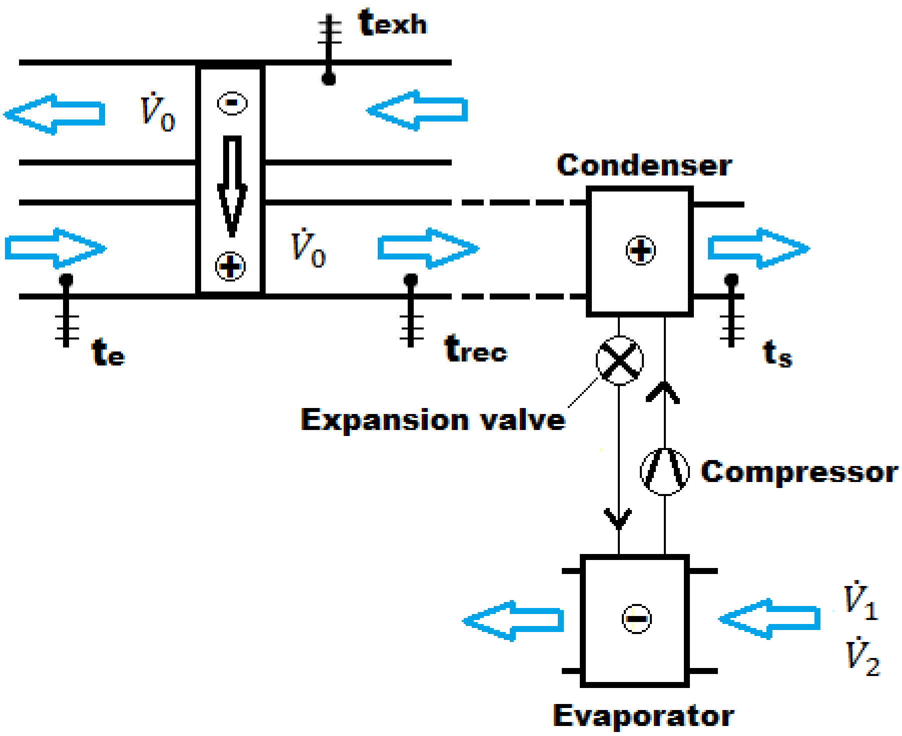


Figure 11: The AHU with an air source heat pump connected to the exhaust air duct of the building.

The heat loss rate VFT_{DVUT} was determined by a list of locations in Sweden, the location nearest the study case is in Lund, where the heat loss rate VFT_{DVUT}=15.0 W/m²

The heat loss rate together with the heated area A_{Temp} is the allowed heat loss for the attic

A_{Temp}= 6 apartments times 35 m²/apartment = 210 [m²]
A_{Temp} Tempered indoor area set to 21 [°C]
A_{temp} is by definition the collective area within the climate shell of all the floors in the building that is intended to be heated above 10 °C. It also includes inner walls and cavities.

Figure 10 shows the AHU that is integrated with an air source heat pump. The flow for this AHU is $\dot{V}_0$ and is calculated with 2 persons in each apartment, with the requirement of 0.35 l/ (s·m^2) plus 7 l/person. Two persons per apartment differ somewhat from Svebys data value of 1.42 that FEBY12 uses. The reason that the calculation is performed with two persons is that if the apartments are used by 2 persons then the air should suffice accordingly to the requirements. The internal loads were assumed to be 3 °C with one 1 °C addition for the exhaust air set at 22 °C, Hence a set point of 18 °C was used. The set point only covers the ventilation loss not the heat loss.

Figure 11 shows the AHU with the same air flow $\dot{V}_0$ with an air source heat pump connected to the exhaust air of the building. Here there are two flow options for the exhaust air evaporator, the first option $\dot{V}_1$ is to let the whole unsorted air pass the evaporator that exhaust the building today. This means 707 l/s for the whole building and averages at 19 °C. The other option $\dot{V}_2$ is to sort the air to meet the heating need only, perhaps avoiding the kitchen air to avoid clogging the condenser in the system. Avoiding the kitchen air gives $\dot{V}_2$=313 l/s. The energy in the different exhaust flows for the air source heat pumps were done with equation 4 and with a psychometric chart, see appendix D1.

$$\dot{Q}=\dot{V}\cdot\rho\cdot(h_2-h_1)\approx\dot{V}\cdot\rho\cdot c_p(t_2-t_1)=\dot{V}\cdot 1.2\cdot(t_2-t_1) \qquad \text{(Equation 4)}$$

h_2 is enthalpy of air at 22 °C [kJ/kg]
h_1 is enthalpy of air at given temperature for the heat pump [kJ/kg]

No specific air handling units or air source heat pumps were chosen for this study. This, because of the time restrain of the thesis. There are many companies to look at and this study aims to see if it is theoretically possible to do this technical objective.

4 Results

In this chapter the results are presented corresponding to the previous methodology chapter in the following order.

- Orientation and climate analysis
- Site and inventory analysis
- Investor approach (question A)
- PH energy performance (question B)
- Cost (question C)
- Ventilation (question D)

4.1 Orientation and climate analysis

The building is situated in a dense city area of Malmö. The average temperature is eight degrees Celsius and the relative humidity average is about 70-90 % (SMHI, 2014). The building is on a one-way street with a perpendicular street in front of the main entrance. Both these streets have low traffic. Heavy commuting exists north and east of the block as seen in figure 12.

Figure 12: The building in a green circle (Google earth).

4.1.1 Wind and rain analysis –WUFI

Predominant winds are mainly from south west having a parallel direction with the street on which the building is located, see figure 13. The predominant winds are also where the driving rain occurs most of the time.

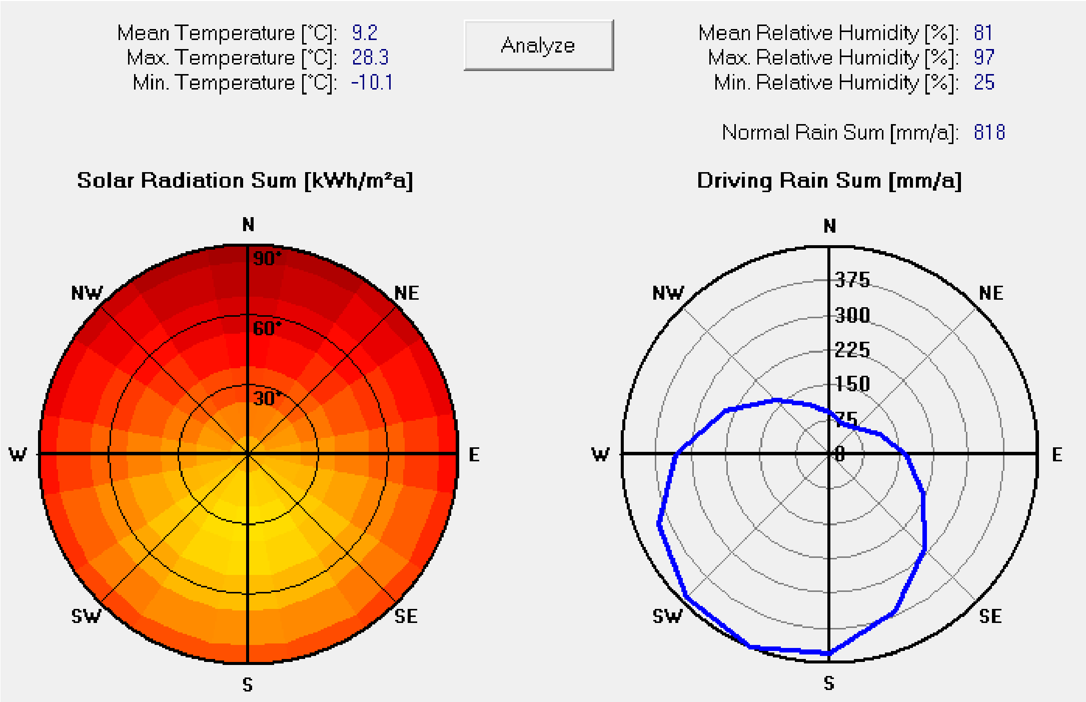


Figure 13: Climatic data of Lund a city close to Malmö (WUFI-interface).

4.1.2 Shadow analysis - Ecotect

The first of January is a day with a very low sun angle. If there are no clouds that day the surrounding buildings will cast the most accumulative shadows on the roof, see figure 14. Note that winter solstice will have the lowest sun angle in December 22nd, but this comparison is meant to show the surrounding buildings impact only.

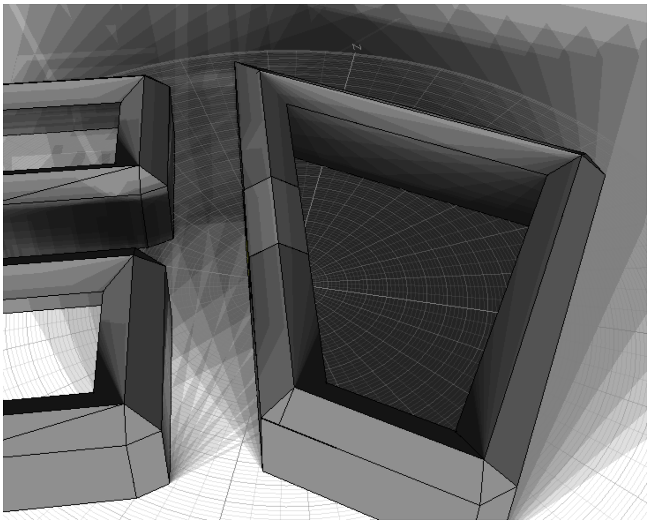


Figure 14: Shadow analysis on January 1st (Ecotect).

4.1.3 Annual solar irradiation - Ecotect

For annual solar irradiation the west roof is most optimal, see figure 15. The simulation was done in Ecotect and the annual solar radiation is shown in table 1.

Table 1: Annual solar irradiation on the building surfaces (Ecotect).

West wall= 468	kWh/(m^2·year)
East wall=339	kWh/(m^2·year)
West roof=906	kWh/(m^2·year)
East roof= 750	kWh/(m^2·year)

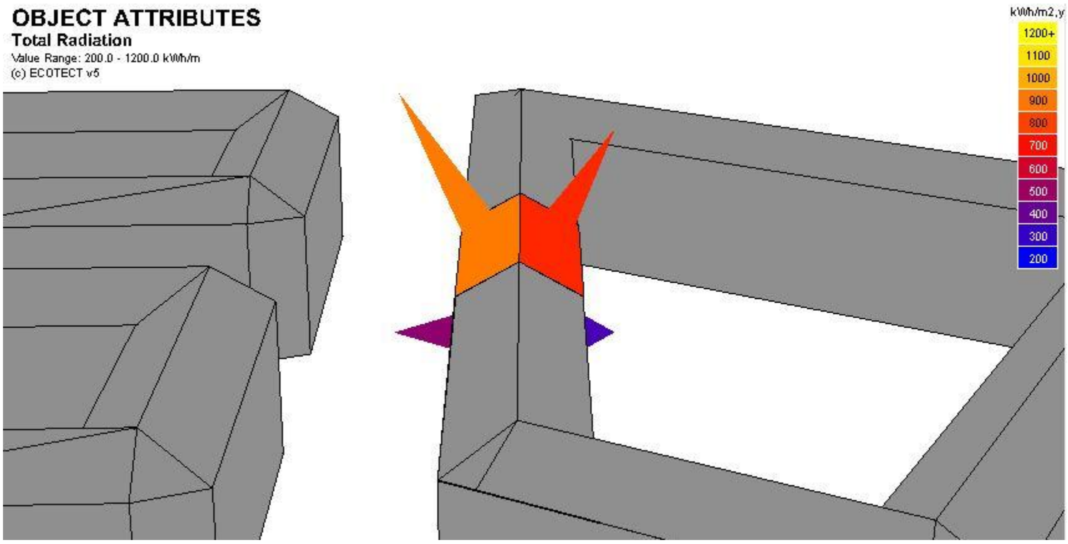


Figure 15: Solar annual irradiation on the building surfaces (Ecotect).

4.2 Site analysis

The attic space consists of 25 timber roof trusses with a distance between centers of about one meter. There is evidence of historic fire exposure with sot and newer construction details to fortify and strengthen the roof. Today the attic serves as insulation space with 600 mm fiber glass blowing insulation and HVAC installations see figure 16.

Figure 16: The attic at a height of three meters above floor level.

In the attic there are two separate stairways that are insulated on the top leaving the staircase walls fairly unprotected, see figure 18. The old chimneys have been removed from the outside of the roof but remain inside the attic for structural purposes. These structures are part of the existing thermal bridges and must be considered for the new design.

4.2.1 Existing thermal bridges

Before entering the attic through the metal door a clanking sound was noticeable from inside the staircase. This is due to pressure fluctuations in the building, for example when someone is using the entrance. The small gap in the door is not airtight and allows for air to move through which create this sound.

With an infrared camera it becomes obvious that a thermal bridge or air leakage is present, see figure 17.

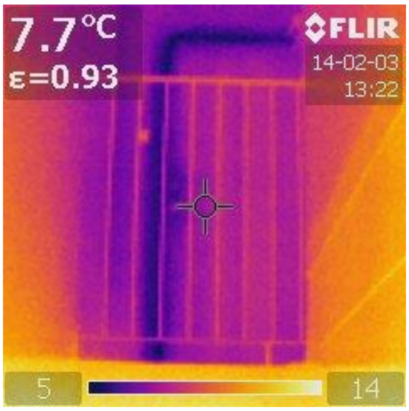


Figure 17: One of two metal doors that enter the attic.

The infrared pictures inside the staircase were taken prior to the ones inside the attic. Figure 18 was taken mid-day February 12th 2014 inside the staircase leading up to the attic. The other IR-images inside the attic are taken early in the morning a week later due to potential solar irradiation on the roof misrepresenting the images. That early winter morning it was was 4 °C outside.

Figure 18 is showing one of the sides of the staircase adding to the assumption of poor insulation between the staircase and the cold attic space. Figure 19 shows both staircases in the attic. Even here the thermal bridges are noticeable from the pictures.

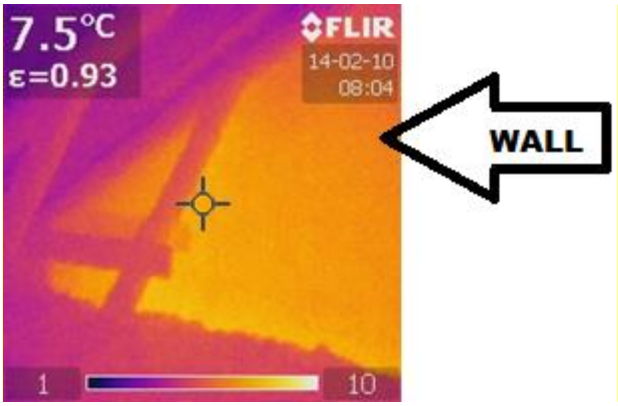


Figure 18: Surface of the staircase.

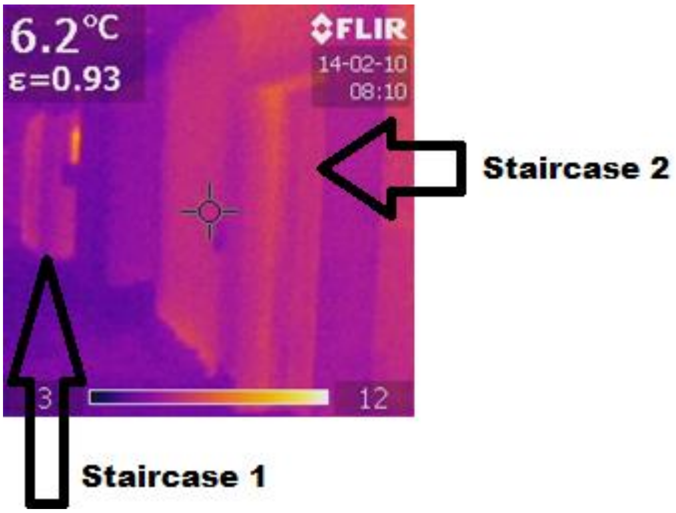


Figure 19: Both staircases entering the attic.

A vent pipe that penetrates the roof is shown in figure 20. The exhaust air ducts in the attic are also visible through thermal imaging, see figure 21. These ducts have 50 mm insulation and chicken net around. The cleanout doors are poorly insulated.

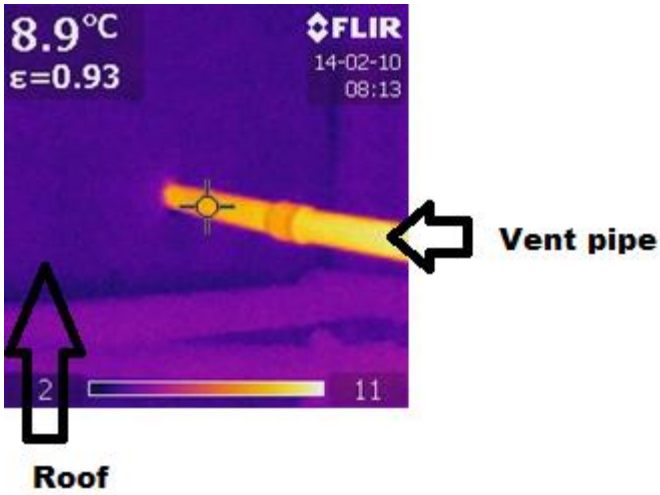


*Figure 20***:** *A plastic vent pipe.*

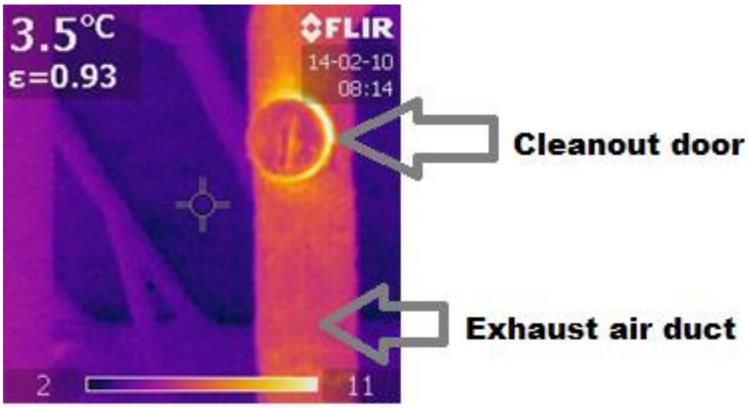


Figure 21: An exhaust air duct and its cleanout door.

4.2.2 Ventilation

Two main extract air ducts passes through the attic to the rooftop where the air is exited through fans. Fan one (1) is for the residential and service areas, see table 3.

Table 3: Airflow and the average temperature by Fan 1.

Floor	Flow/ (l/s)	Temperature/ °C	
Basement	177	15	
Level 1	150	21	
Level 2	100	21	
Level 3	100	21	
Level 4	180	18	
Sum	707	19	Average

The second fan (2) extracts 310 liters per second from the garage area, see figure 22. For ventilation plans see Appendix B.

Figure 22: Fan 1 furthest away, nearest is fan 2.

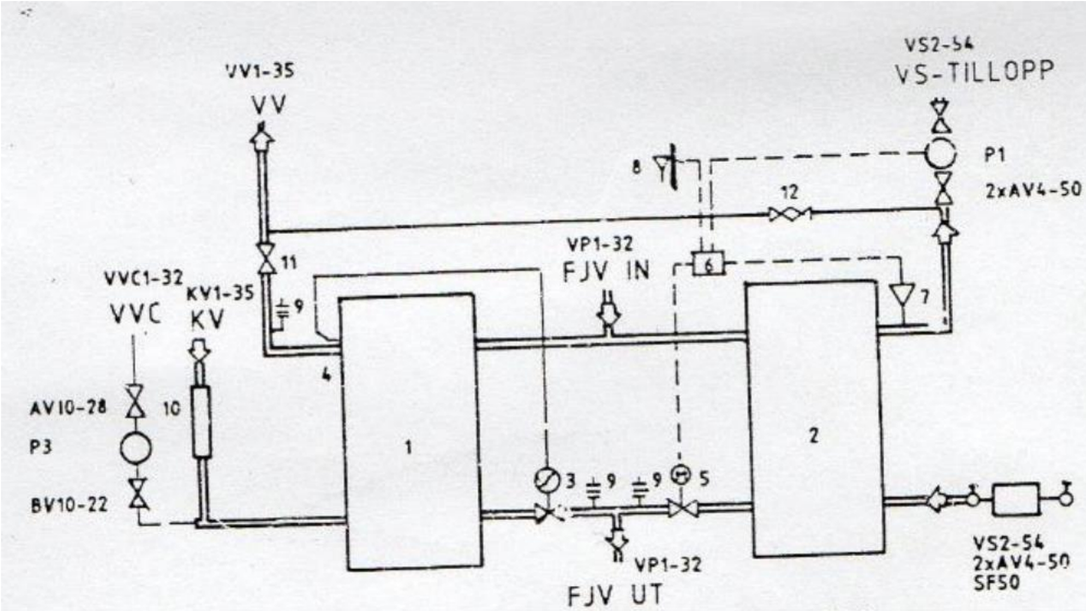
4.2.3 Sanitary

There is no water supply to the attic but several stack vents connected to waste water discharge stacks, see figure 3. These could be used for the extended system for the attic apartments.

Figure 23: *To the left is the plastic stack vent. To the right is an air admittance valve next to a ventilation duct inside the attic.*

4.2.4 Heating and cooling

The district heating is the main source for warming the domestic hot water (DHW) and for heating (VS) up the building and the garage, see figure 24. No active cooling exists in the building and no heating installations exist in the attic today. FJV in figure 24 is district heating.



1. Heat exchanger (DHW)
2. Heat exchanger (Heating)
3. Control valve (DHW)
4. Sensor (DHW)
5. Control valve (Heating)
6. Controller
7. Sensor
8. Sensor external
9. Thermometer
10. Valve-pipe unit, with check and safety
11. Shut-off valve
12. Replenishment with shut-off and check

Figure 24: Heat exchangers for the building.

4.2.5 Electricity

With the exception of the control box for the fans and lights in the attic there is no other electricity feeder in the attic, see figure 25.

Figure 25: Control box for fan number one.

4.3 Approach of the investor

According to the interviews with the building companies, there was little interest to build on attic spaces because of low economic gains. However, the central parts of Malmö were identified as viable options. The companies buy out the empty attic space and refurbish them, then sell it off to the highest bidder. The interviewed companies didn´t recommend other types of ventures unless the housing society has knowledge (experts) in the area of conversion and wants to take responsibility of the project. Additionally, they also recommended doing the venture at the same time as other conversion project i.e. when changing façade, windows or roof works, to lower the costs.

4.4 Passive house energy performance

In this chapter the results is presented of the proposed apartments in the attic. The aim is to achieve an attic conversion with passive house energy performance.

4.4.1 Projecting the PH energy performing attic

A visit was done to the urban planning office to see what they suggest in order to build apartments in the attic. According to them the windows are crucial and they would suggest that the windows should be open able, and placed so that a child could escape trough in case of fire (max 1.2 m from the floor). The urban planning office also referred to their published guidelines called "riktlinjer för inredning av vind till bostad" a reference also used for this study. The guidelines are used in this study as a base for projecting the attic apartments, together with the requirements for a passive house energy performance found in FEBY12.

4.4.1.1 Floor plan of intended apartments in the attic

The new layout for the attic has been divided as seen in figure 26. There are six apartments, each 35 m² with a small kitchen unit and a bathroom. The lavatories are placed near the kitchen areas to lower the installation costs for piping. The height over the bathrooms are suitable to provide storage space if needed and ventilation should be planned accordingly. The technical room is placed centrally to minimize transportation length of thermal air or sanitation to respective parts. No doors are presented for the bathrooms as the idea will be presented for the investor who then should determine the type of door. The option in a small apartment should be either sliding doors or regular well placed doors.

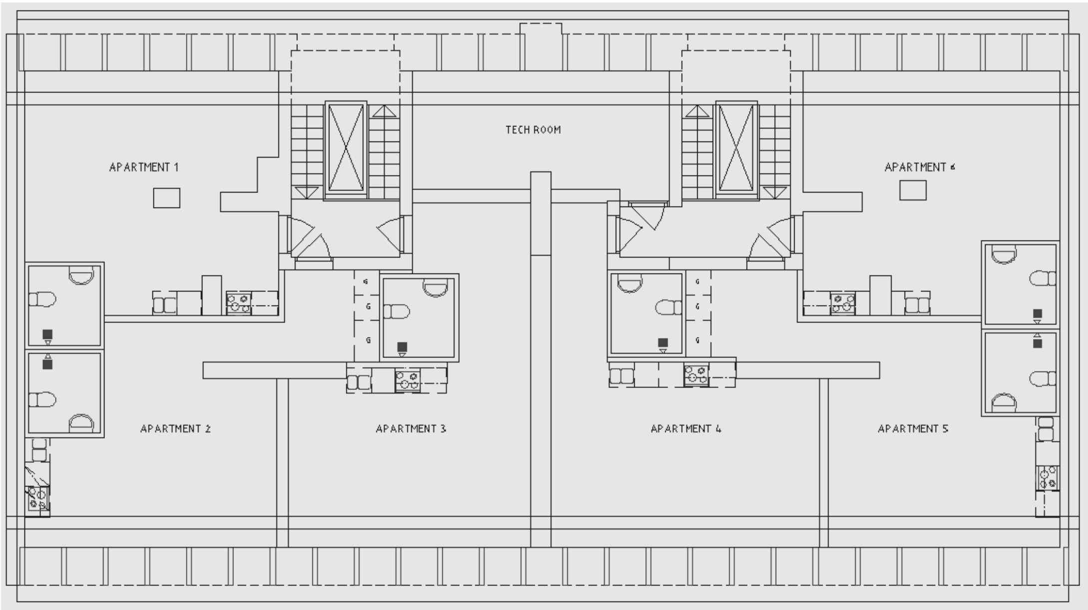


Figure 26: The new attic floor plan (AutoCAD).

4.4.1.2 Attic windows

The next step is the attic windows, and according to the city council, Malmö Stad (2007) there needs to be a link between the architecture of the building and the attic windows. For placement of the windows, see figure 27 and figure 28. (Excluding roofing of the attic windows)

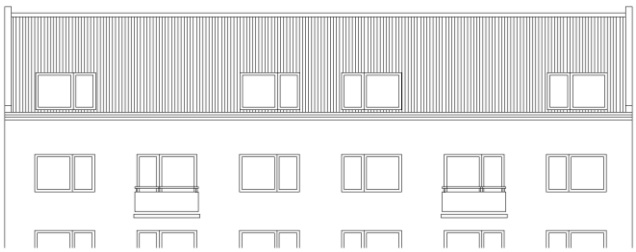


Figure 27: Front side of the building, towards the street with attic windows (AutoCAD).

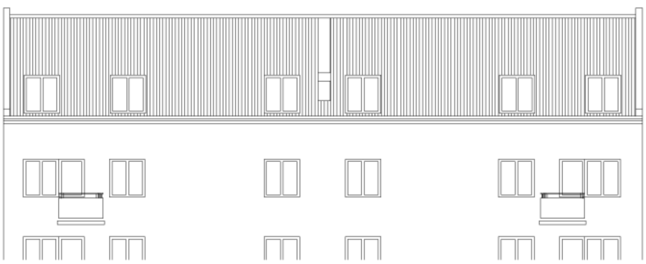


Figure 28: Back side of the building, towards the back yard with attic windows (AutoCAD).

The daylight from these attic windows is shown in figure 29. Note that the daylight focus is not included in this study. The innermost areas do not have sufficient daylight. If this was the focus an advice could be to have more windows on top of the roof. This option is however in direct violation of the city planning architecture, as described in Malmö Stad (2007).

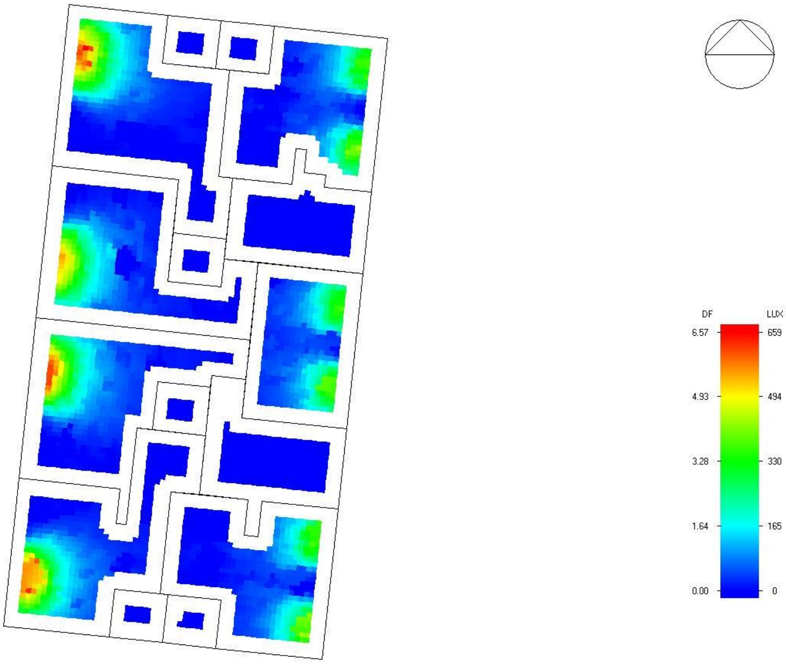


Figure 29: Daylight through the windows (DesignBuilder).

The attic windows roofing part have a midpoint slope of 30 degrees as seen in figure 30.

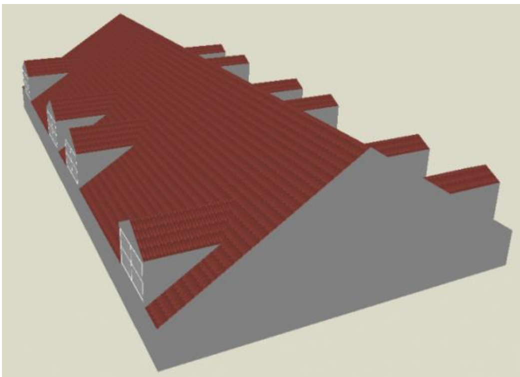


Figure 30: Dormer windows with sloped roofing (DesignBuilder).

4.4.1.3 Walls

The new walls will be constructed in line with the roof trusses. This is done in order to limit the thermal bridges. Neighbouring walls are adiabatic in calculations and in reality the walls are not insulated towards neighbouring attics. The present conditions of the neighbouring attics toward the attic in the study are not known and therefore the walls are presented with 200 mm fiber glass blowing insulation. This is done to depict the importance of thermal transports and reusing the fiber glass blowing insulation. The outer wall in this case is a climate shell. The inner wall is considered an airtight wall and a section view of the new wall is seen in figure 31.

First, the wall is presented in a section view and includes the design behaviour of the thermal bridges as well as moisture safety.

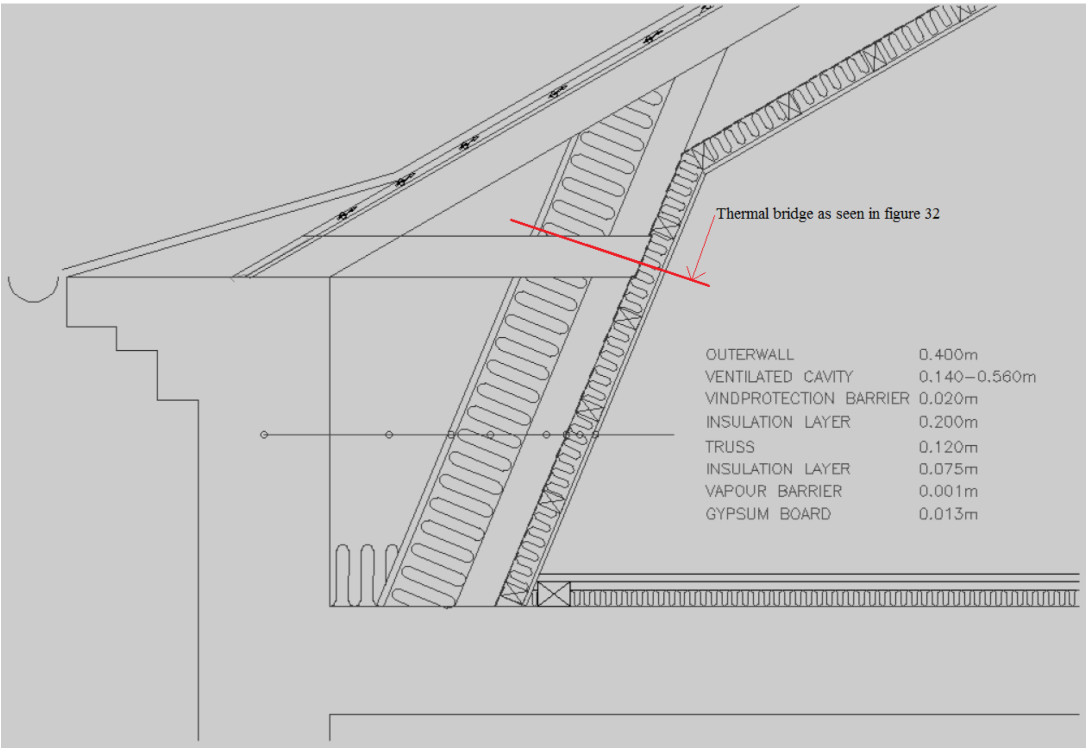


Figure 31: Section view of the wall construction (AutoCAD).

The thermal bridge in the truss happens when a horizontal wood beam penetrates the wall, see figure 32. The thermal bridge is not showing signs of significant values.

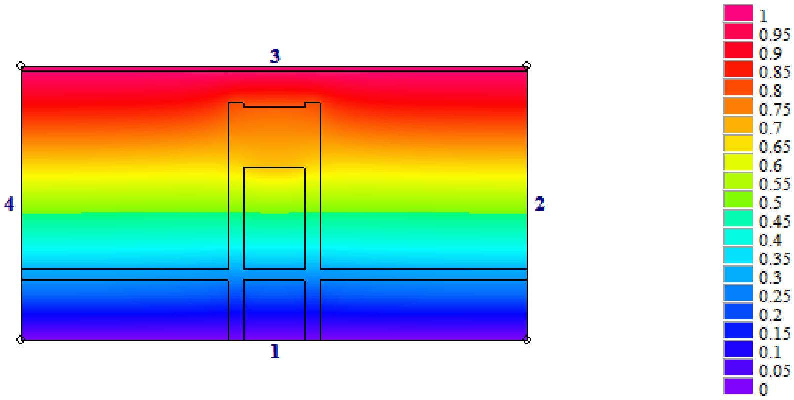


Figure 32: Horizontal thermal bridge in the wall (HEAT2).

The thermal bridge in this case was avoided as much as possible by breaking the inner most layer of wooden studs, and not having them directly connected to the inside of the attic. This is also seen in figure 31.

The moisture content and relative humidity is calculated over a three year period starting from January 1st, 2014. The wall construction shows a promising decrease trend as seen in figure 33 to figure 36. The wind protection barriers moisture content is seen in figure 33, and figure 34 shows its relative humidity. Figure 35 shows the mineral wool insulations moisture content and figure 36 shows the relative humidity midways through the wall.

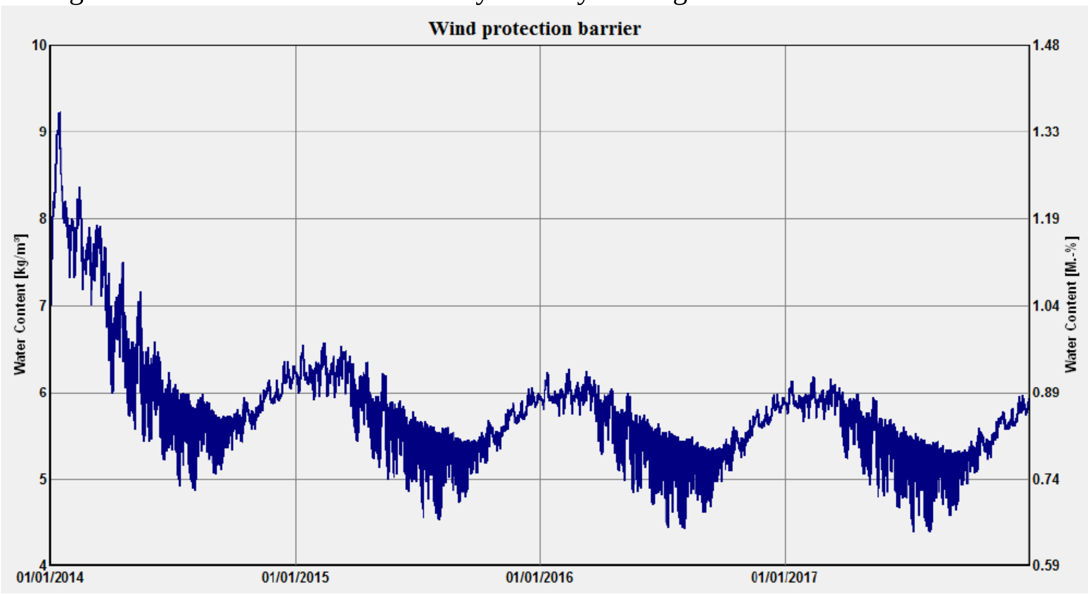


Figure 33: Moisture content in the walls wind protection barrier (WUFI).

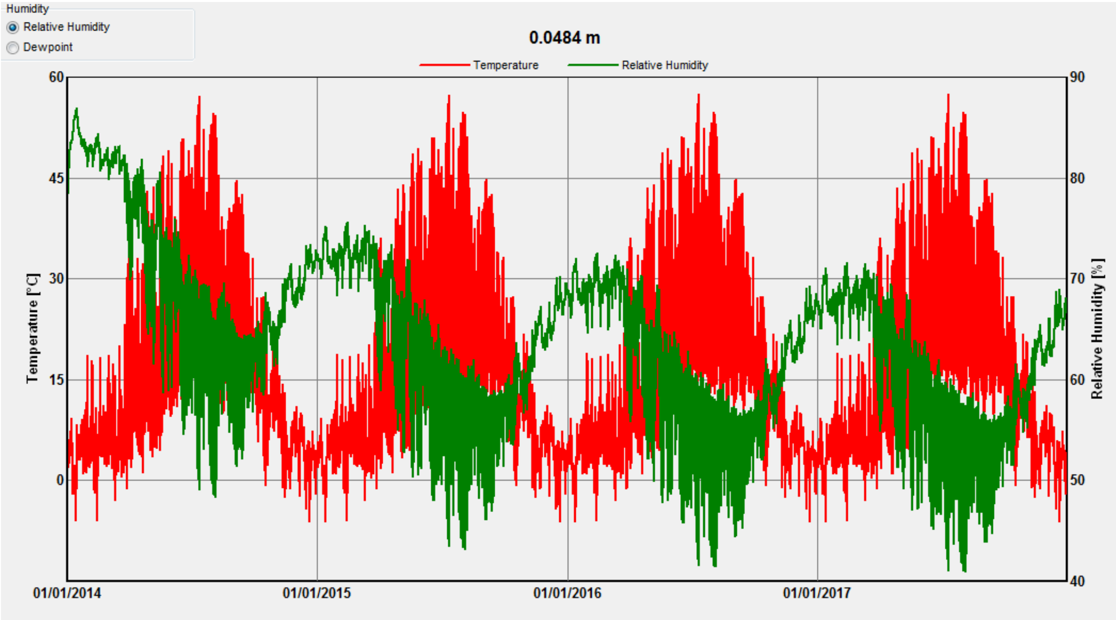


Figure 34: Relative humidity in the walls wind protection barrier (WUFI).

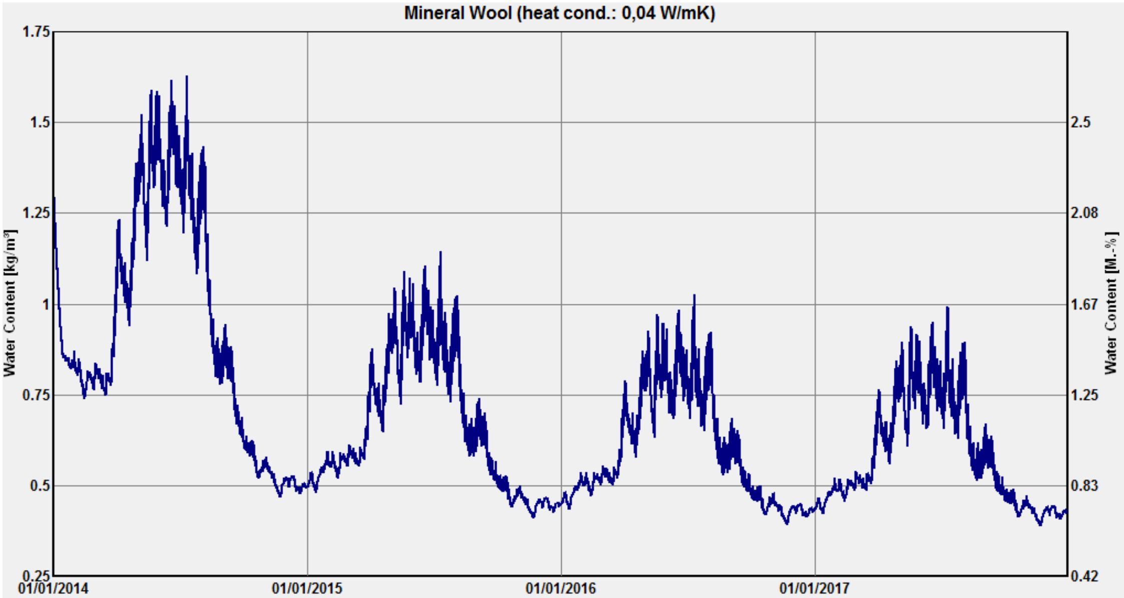


Figure 35: Moisture content in the walls mineral wool insulation (WUFI).

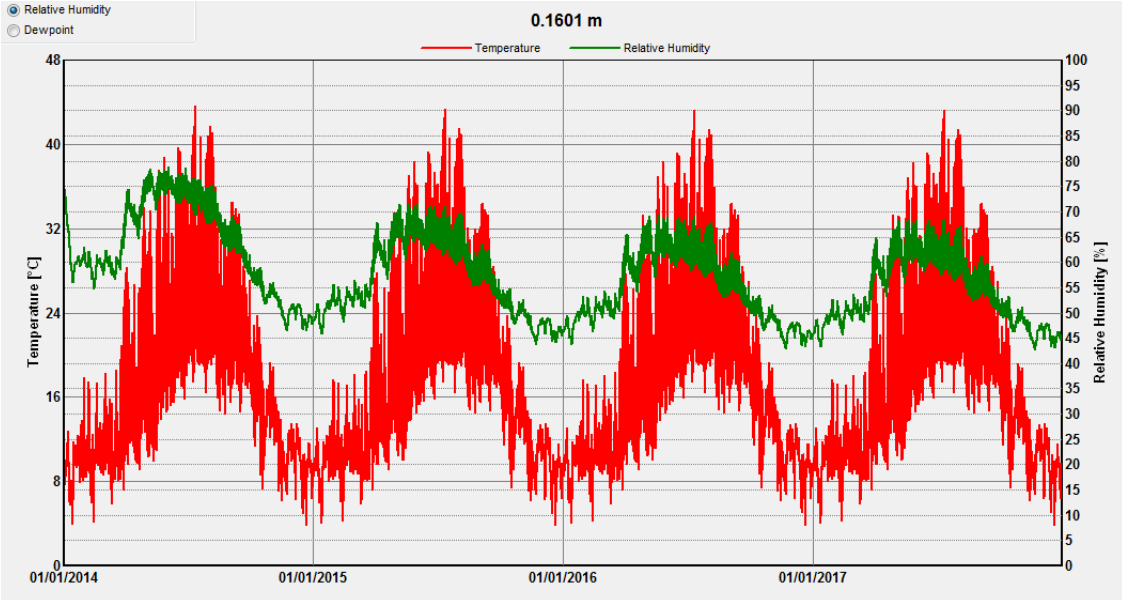


Figure 36: Relative humidity in the walls mineral wool insulation (WUFI).

4.4.1.4 Roof

The roof construction is similar to the wall, with the exception that the truss is extended with a masonite I beam, in parallel. The parallel placement is to simplify the reinsulation of the cavity. Horizontal studs break of the thermal bridging on the inside. A thermal bridge in this case is created and hardly avoidable by the truss.

First, the section view of the roof is presented in figure 37. The design behaviour of the thermal bridges and moisture safety of the roof will also be presented here.

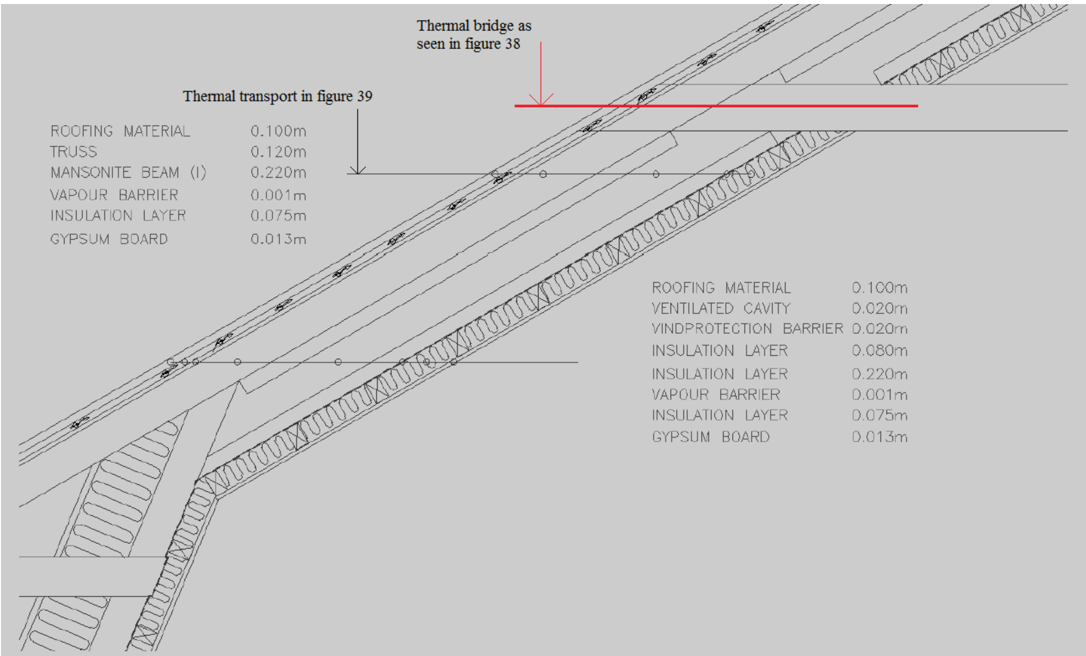


Figure 37: Section view of the roof construction (AutoCAD).

The truss penetrating the roof is the part that creates the peak thermal bridging in the construction, see figure 38. This is notable and unavoidable due to construction integrity reasons. The temperature is 30 % lower on the inside near the penetration point. This means that there is a risk for condensation and a notable moisture risk.

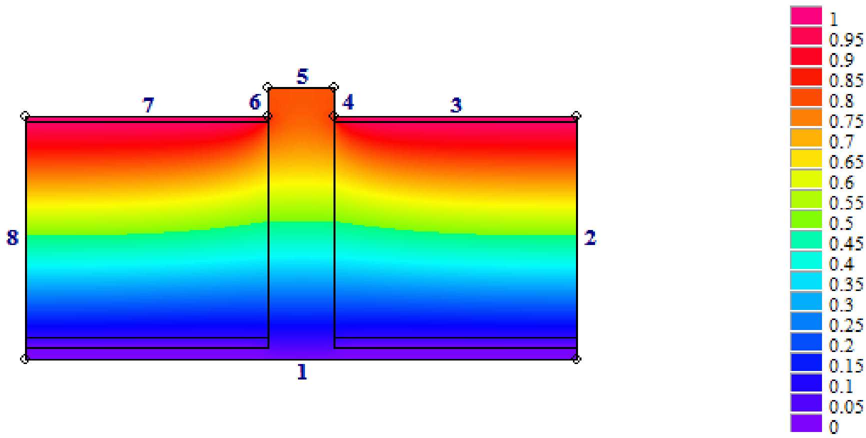


Figure 38: Thermal bridge by a roof truss in the roof (HEAT2).

The other part of the roof is fairly good in thermal performance as seen in figure . The figure shows a Masonite I beam in a section view, where a small fluctuation is noticeable in thermal performance.

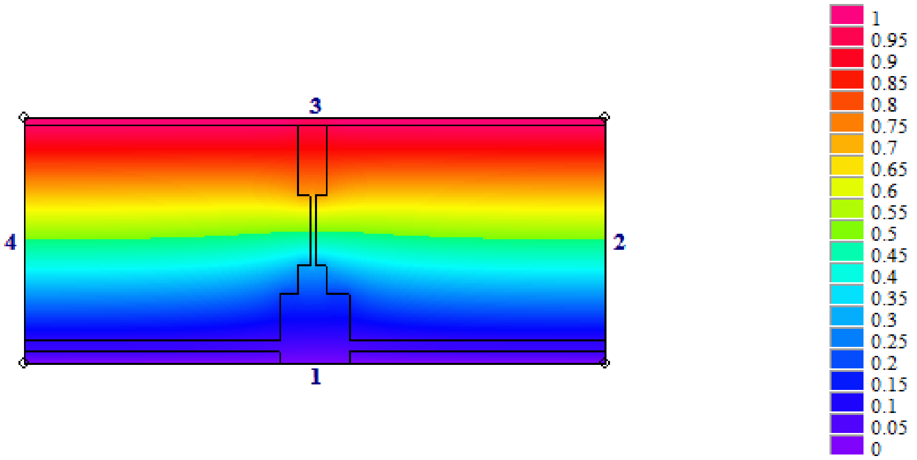


Figure 39: Masonite I beam in a section view (HEAT2).

In WUFI the moisture content of the roof and relative humidity is showing a decreasing trend over a three year period, see figure 40 to figure 43. Figure 40 shows the wind protection barriers moisture content and figure 41 the relative humidity. Figure 42 shows the mineral wool insulations moisture content and figure 43 the relative humidity midways through the roof.

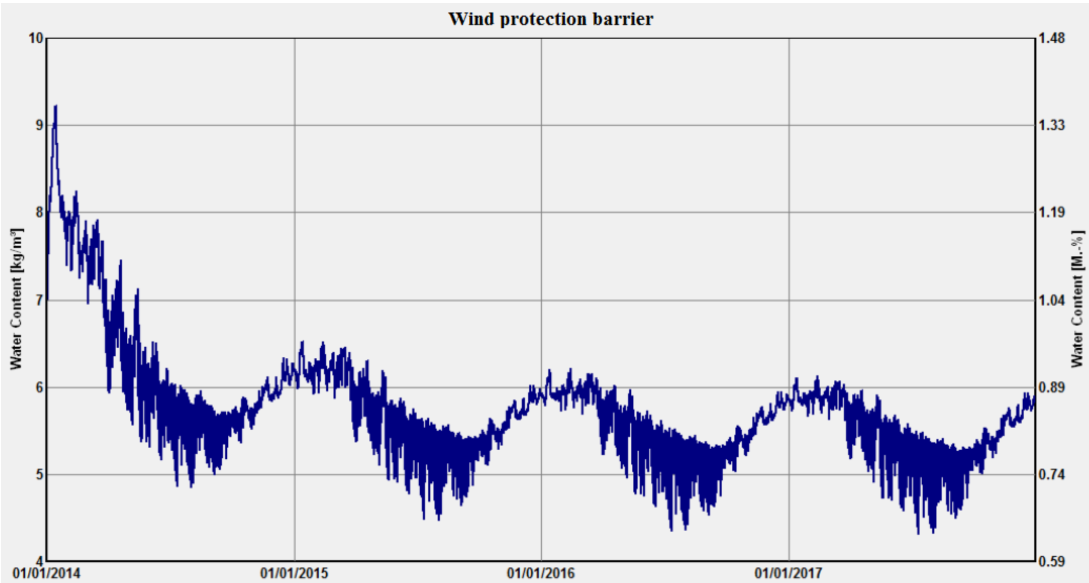


Figure 40: Moisture content in the roofs wind protection barrier (WUFI).

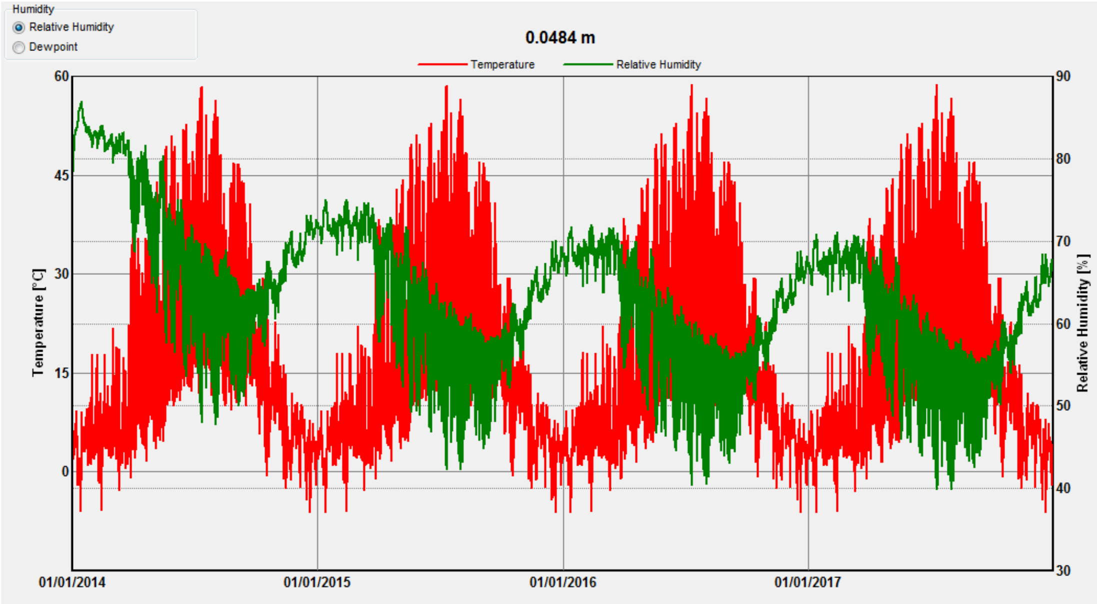


Figure 41: Relative humidity in the roofs wind protection barrier (WUFI).

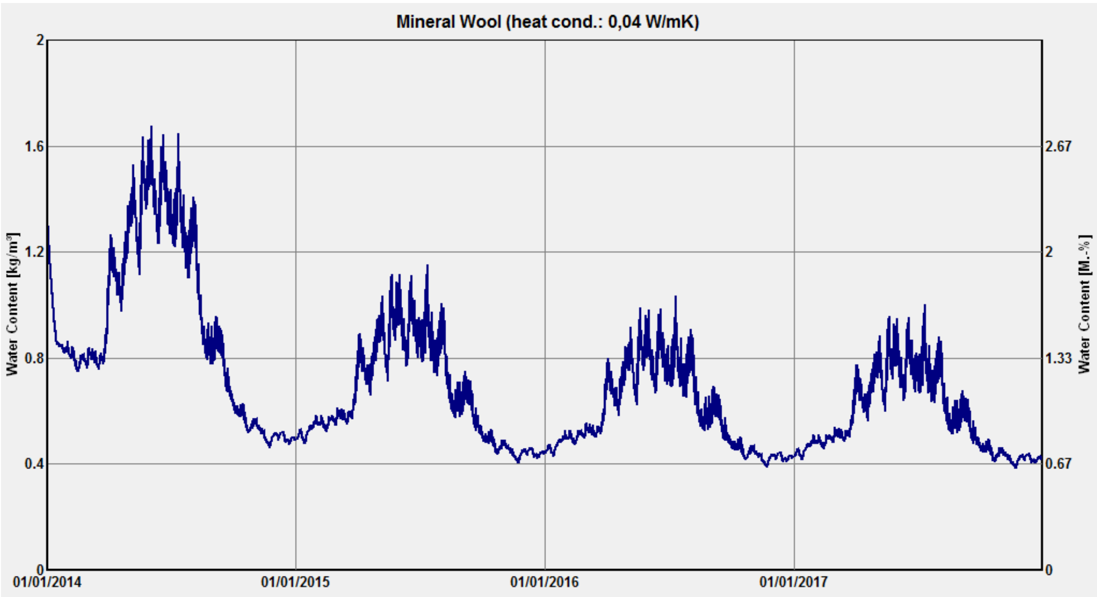


Figure 42: Moisture content in the roofs mineral wool insulation (WUFI).

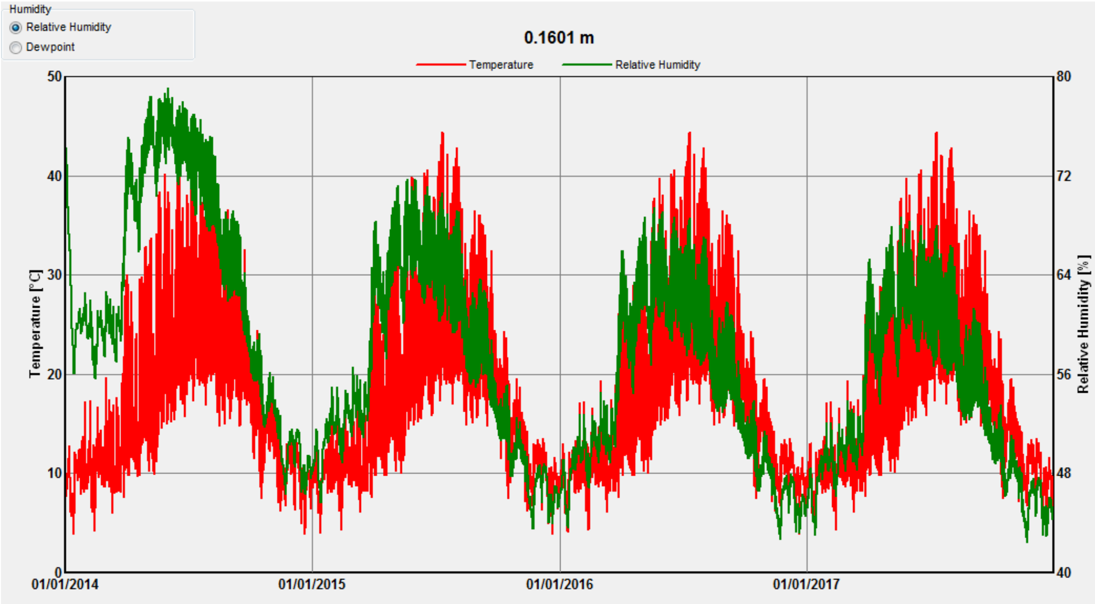


Figure 43: Relative humidity in the roofs mineral wool insulation (WUFI).

4.4.2 Energy results

The buildings specific energy use, differ depending on FEBY12 and BBR19. This section presents the calculated results from DesignBuilder and the Excel steady state calculation.

4.4.2.1 DesignBuilder calculation

The annual energy results from the program DesignBuilder are presented in table 4.

Table 4 : Annual energy need (DesignBuilder)

Heating	8132	kWh
Cooling	185	kWh
Fans	1006	kWh
Domestic hot water	2085	kWh
Total	11408	kWh

Specific energy use

The minimum coefficient of performance required for the heat pump when using it for heating and domestic hot water is calculated in the following. The required COP has been calculated without cooling.

$$E_{delivered} = \left({}^{(8132+2085)}\!/_{COP} + 1006 \right)/210 = 25\ \mathrm{kWh}/(\mathrm{m}^2{}_{A_{temp}} \cdot \mathrm{year})$$

$$COP = \left({}^{(8132+2085)}\!/_{(25 \cdot 210 - 1006)} \right) = 2.4$$

This means that the energy need for heating and DHW is just divided by a factor of 2.4. The specific energy use for FEBY12 is 25 $\mathrm{kWh}/(\mathrm{m}^2{}_{A_{temp}} \cdot \mathrm{year})$ and the calculation gives 25 using a COP of 2.4, passing the criteria. The specific energy use for BBR19 is 55 $\mathrm{kWh}/(\mathrm{m}^2{}_{A_{temp}} \cdot \mathrm{year})$ and the calculation gives 25 using a COP of 2.4, passing the criteria. However the criterion for BBR19 also includes installed electrical power and average heat transfer coefficient. See energy requirements under literature study in section 2.2.1.

The passive house design will surely pass the average heat transfer coefficient requirement of 0.4 $\mathrm{W}/(\mathrm{m}^2 \cdot \mathrm{K})$. The installed electrical power for heating will however still need more values as shown in the Excel steady state calculation.

4.4.2.2 Heat loss rate a steady state calculation in Excel

As described in the method, the steady state calculation can be used to assess the energy and power required to heat up a building. The Author of the Excel file is Henrik Davidsson from LTH.

In this study the steady state calculation is done in Excel for heating including ventilation air, no fans or domestic hot water are taken into account, neither is internal or external heat gains. The calculation is done in order to fulfil the heat loss rate, VFT_{DVUT} requirement of 15 W/m^2.

The calculation using equation 1a for transmission losses results in 59.4 W/K. The calculation using equation 1b for ventilation losses results in 97 W/K. The resulting power need for heating is calculated with equation 1c and results in 4862 W without heat recovery. The power need for heating with heat recovery in the ventilation air results in 2805 W.

To see if the VFT_{DVUT} requirement of 15 W/m^2 is met, the power results are divided with A_{temp}, 210 m^2. First the power need without heat recovery is 4862 W/210 m^2= 23 W/m^2, this does not meet the requirement. With heat recovery in the system however the requirement of 15 W/m^2 is met as 2805 W/210 m^2= 13 W/m^2 which is below the requirement.

According to BBR19 when A_{temp} is larger than 130 m^2, the installed power for heating and domestic hot water, DHW, should be calculated as follows: 4.5+0,025(A_{temp}-130) =4.5+0,025(210-130) =6.5 kW

For the DHW it can be according to BBR19, 0.5 kW/apartment, having 6 apartments this is 3 kW. Now if added 2.8 (Excel power for heating) with 3 (0.5*6=3 kW) it will be below the BBR19 criterion for installed power since 5.8<6.5 kW. However since the heat pump is used with a COP of 2.4, the installed power will only become 2.4 kW. Either way both options pass the BBR19 criterion.

4.6 Cost of conversion

The cost of conversion is done according to the BI model (2013), see figure 7. This model considers production and construction cost. The sum of these two is the total project cost. The design goals that follow have a direct impact on the cost:

- The new attic design needs to meet a passive house energy performance.

- The apartments of the new design are of maximum 35 m², to avoid an extension of elevators.

- Fiber glass blowing insulation that covers the attic today should be reused to lower the material cost.

- The economic boundary is set to meet or be below the selling price at market value. This value in the year 2014 is 18000 SEK per m².

- The cost calculation should include a payback period of the total production cost with an income after fees of 899 SEK per m² and year.

A comment for each of these points would be;

Passive house designers have a stricter approach then norm fulfilling designer does, as seen in 4.4 of this paper. This could be the reason why the total cost increases 3-10 % for a passive house (SCN2, 2012).

An extension of the elevator to the attic floor could mean a serious setback for the project. An elevator cost is mentioned in the literature review. The additional cost for installing an elevator is 475000 SEK (Larsson et al., 2009).

The attic is covered with 600 mm fiber glass blowing insulation. The plan is to use the insulation again to reduce the cost. This study will set material cost of insulating to zero.

If the investor refurbishes the attic, the intention is to sell it at the price market value. This value is taken from brokers. They also mention that a moderate price increase could happen due to popular demands.

The payback is only used to see if the venture is paid back. If it never pays back then the venture might never be feasible.

4.6.1 General costs

The attic in this study requires scaffolding to allow workers to build the attic windows. The scaffolding is required in front of both facades of the building to create a safe working environment. There are two options for scaffolding here, the first option is for the attic only and the second option is used for all floor levels. The front façade is the façade located at the street side and this side is easier to build scaffolding upon. The difficult side is the inner yard façade, here workers need to carry the gear from the street through the building and out to the inner yard. This option requires more and therefore it will be a bit more expensive, about 110

SEK/m^2. The street side option cost 90 SEK/m^2. The street side area is 367 m^2 and the inner yard facing area is 339 m^2. In order to create attic windows the cost will be $90 \cdot 367 + 110 \cdot 339 = 70320$ SEK (for a few days of work on the dormer windows).

The interviewee from the scaffolding company confirms that the best option to do a conversion of the attic would be at the same time as a façade renovation. They mean because the cost will then be 140 SEK/m^2, and also the dormer windows are finished after a few days making the first scaffolding option overpriced for that matter only.
The second recommended option would be:
$140 \cdot (367+339) = 98840$ SEK (for 2-3 months of façade renovations, including dormer windows)

According to interviews the general pricing of conversion cost per m^2 is a very sensitive question to answer. The interviewed companies were keen on keeping it a secret; however the interests are set to the selling prices. If the building sells at a price of above 25000 SEK/m^2 only then the companies start to get interested in venturing the empty attic spaces. Some of the companies even mentioned 30000 SEK/m^2.

This is due to the processes being hard to apply in reality with all the demands at hand. A projecting cost of a small development is estimated to about 100 000 SEK according to one of the interviewees, and the projecting phase is crucial to have before entrepreneurs can leave a bid of their respective parts of the project. This developments project includes a site analysis, inventory analysis and a preliminary design. With this the entrepreneurs can estimate what the costs will be.

4.6.2 Sektionsdata calculated construction costs

The program Sektionsdata from the company Wikells is used to calculate construction cost of a project. In the program one chooses or creates sections of intended objects that exist in the project, these sections are used to calculate appropriate construction cost. There are five calculations done with the program Sektionsdata. The first calculation was done for ROT (renovation, conversion and extension). The calculation is compiled in Swedish as seen in figure 44. It includes material costs, salaries, cost for subcontractors, profit margins and sums it up as one non taxed number. The cost for ROT in this case is 2 610 000 SEK. Program selections included in the ROT calculation are: Outer walls, inner walls, frames, false ceilings, paint works, carpentries, furnishing and miscellaneous. For a more detailed calculation see appendix C1.

		Trpt							
KAPITEL		SIDA							
7	YTTERVÄGGAR	1		111,947		401.65		130,977	
8	INNERVÄGGAR	2 - 3		85,742		349.23		101,679	
9	BJÄLKLAG	4		68,299		328.90		-	
12	UNDERTAK	5		-		-		138,460	
14	MÅLNINGSARBETEN	6		-		-		498,600	
16	SNICKERIER	7		191,203		146.81		10,643	
18	INREDNINGAR	8		90,949		66.05		-	
19	DIVERSE	9		-		-		705	
				============		========		============	
				548,140	SEK	1,292.64	tim	881,064	SEK
Materialkostnad			548,140						
Arbetslön 1,292.64 tim x 188.00 SEK			243,016						
Underentreprenader			881,064	1,672,220	SEK				
Omkostnadspålägg arbete		252.00 %	612,401						
Omkostnadspålägg UE		10.00 %	88,106	700,507	SEK				
Entreprenörsarvoden		10.00 %		237,273	SEK				
TOTALSUMMA EXKL MOMS				**2,610,000**	**SEK**				
Utskrivet: 24/05/2014 15:32 Filnamn: Kalkyl ROT 20140522 plus 10.wbr		Trpt							

Figure 44: Compiled ROT calculation (Sektionsdata).

The second and third calculations are done for VS (heating and sanitation). The difference in these calculations is that one is with radiators and the other (third) is not. Since the attic is supposed to be heated by the supply air, the radiators are not needed. The calculation is still done to see what difference it would make in costs. The calculation is compiled in Swedish as seen in figure 45. It includes material costs, salaries, cost for subcontractors, profit margins and sums it up as one non taxed number. The cost for VS in this case is 526 483 SEK. Program selections included in the VS calculation are: Apartments, boilers and exchangers. For a more detailed calculation see appendix C2.

		Trpt							
KAPITEL		SIDA							
1	LÄGENHETER	1		206,500		216.84		-	
16	PANNOR, VÄXLARE	2		94,706		35.60		13,879	
				============		========		============	
				301,206	SEK	252.44	tim	13,879	SEK
Materialkostnad (varav delpåslag 12,327 SEK)			301,206						
Arbetslön 252.44 tim x 164.00 SEK			41,400						
Underentreprenader			13,879	356,486	SEK				
Omkostnadspålägg arbete		293.00 %	121,302						
Omkostnadspålägg UE		6.00 %	833	122,135	SEK				
Entreprenörsarvoden		10.00 %		47,862	SEK				
TOTALSUMMA EXKL MOMS				**526,483**	**SEK**				
Utskrivet: 24/05/2014 15:39 Filnamn: Kalkyl VS 20140522 plus 10.wbs		Trpt							

Figure 45: Compiled VS calculation, with radiators (Sektionsdata).

The third calculation, shown in figure 46, is similar to the second calculation, shown in figure 45, but without radiators. The cost for VS in this case is 362 437 SEK, see figure 46. This means that it becomes 526483-362437=164010 SEK cheaper without radiators. For more details about this calculation see appendix C3.

	Trpt							
KAPITEL	SIDA							
1 LÄGENHETER	1		107,215		139.50		-	
16 PANNOR, VÄXLARE	2		94,706		35.60		13,879	
			============		========		============	
			201,921	SEK	175.10	tim	13,879	SEK
Materialkostnad (varav delpåslag 7,772 SEK)		201,921						
Arbetslön 175.10 tim x 164.00 SEK		28,716						
Underentreprenader		13,879	244,517	SEK				
Omkostnadspålägg arbete	**293.00 %**	84,139						
Omkostnadspålägg UE	**6.00 %**	833	84,972	SEK				
Entreprenörsarvoden	**10.00 %**		32,949	SEK				
TOTALSUMMA EXKL MOMS			**362,437**	**SEK**				

Utskrivet: 24/05/2014 15:39
Filnamn: Kalkyl VS utan radiatorer22052014 plus 10.wbs
Trpt

Figure 46: Compiled VS calculation, without radiators (Sektionsdata).

The fourth calculation is done for LUFT (air, ventilation). The calculation is compiled in Swedish as seen in figure 47. It includes material costs, salaries, cost for subcontractors, profit margins and sums it up as one non taxed number. The cost for LUFT in this case is 293 837 SEK. Program selections included in the LUFT calculation are: apartments, common premises, ducts and transferred air device. For a more detailed calculation see appendix C4.

	Trpt							
KAPITEL	SIDA							
1 LÄGENHETER	1		42,648		25.50		3,100	
2 ALLMÄNNA LOKALER	2		146,558		22.03		7,813	
9 KANALER	3		6,387		5.78		18,286	
12 ÖVERLUFTSDON	4		4,440		2.76		-	
			============		========		============	
			200,033	SEK	56.07	tim	29,198	SEK
Materialkostnad (varav delpåslag 21,700 SEK)		200,033						
Arbetslön 56.07 tim x 164.00 SEK		9,196						
Underentreprenader		29,198	238,428	SEK				
Omkostnadspålägg arbete	**293.00 %**	26,945						
Omkostnadspålägg UE	**6.00 %**	1,752	28,697	SEK				
Entreprenörsarvoden	**10.00 %**		26,712	SEK				
TOTALSUMMA EXKL MOMS			**293,837**	**SEK**				

Utskrivet: 24/05/2014 15:38
Filnamn: Luft 20140522 plus 10.wbl
Trpt

Figure 47: Compiled LUFT calculation (Sektionsdata).

The fifth calculation is done for EL (Electricity). The calculation is compiled in Swedish as seen in figure 48. It includes material costs, salaries, cost for subcontractors, profit margins and sums it up as one non taxed number. For EL in this case it is 288 812 SEK. Program chapters included in the EL calculation are: apartments and premises. For a more detailed calculation see appendix C5.

Trpt

KAPITEL	SIDA							
1 LÄGENHETER MM	1		110,899		155.48		-	
8 ÖVRIGA LOKALER	2		46,942		51.48		-	
			============		========		============	
			157,841	SEK	206.96	tim	-	SEK
Materialkostnad (varav delpåslag 4,712 SEK)		157,841						
Arbetslön 206.96 tim x 144.56 SEK		29,919						
Underentreprenader		-	187,760	SEK				
Omkostnadspålägg arbete	**250.00 %**	74,797	74,797	SEK				
Entreprenörsarvoden	**10.00 %**		26,256	SEK				
TOTALSUMMA EXKL MOMS			**288,812**	**SEK**				

Utskrivet: 24/05/2014 15:36
Filnamn: Kalkyl EL 14_05_2014 plus 10.wbe
Trpt

Figure 48: Compiled EL calculation (Sektionsdata).

To get the construction cost all five calculations need to be added together. Following the BI model, as seen in figure 49 there are two summations. The first summation is including the radiators and the second summation is excluding the radiators.
Summation 1 (including radiators) =2610000+526483+293837+288812=3719132 SEK
Summation 2 (excluding radiators) =2610000+362437+293837+288812=3555086 SEK

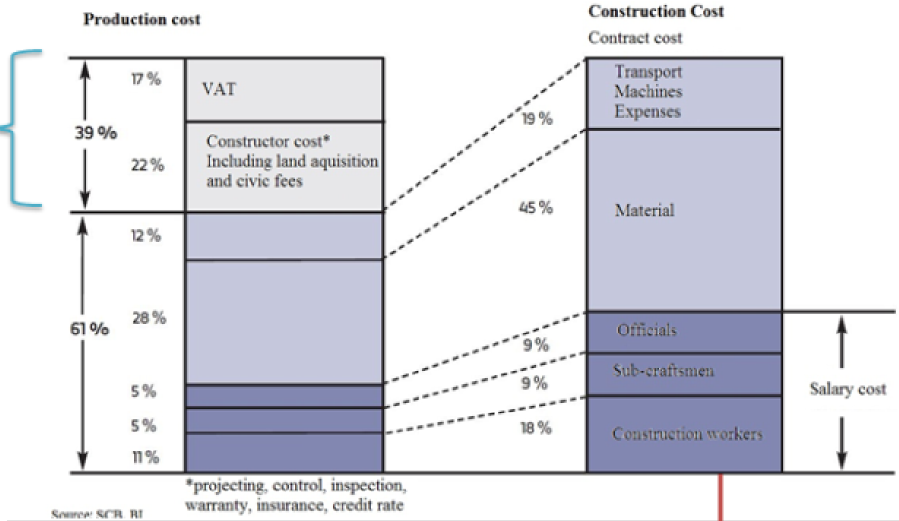
Now having the construction cost, then the next step is the production cost. Production cost is construction cost together with an additional 39 percent of other costs. Other costs in this case are VAT 17 % and constructor cost 22 %, see figure 49. Hence to get the production cost, the construction cost is divided with a factor of 0.61 to add the VAT- and constructor costs. The first summation of construction cost is for a conversion including radiators.

Production cost 1 =Summation1/0.61=3719132/0.61=6096938 SEK

The second production cost summation is when the conversion is set for a passive house adaptation with no radiators for the apartments.

Production cost 2 =Summation2/0.61=3555086/0.61=5828009 SEK

Cost approximations are without considerations of supplement charge of passive house adaptations.



All costs are including a 10% profit for the entrepreneurs.

Construction cost

Sum ROT=2610000SEK

Sum VS(incl radiators)=526483SEK
Sum VS(excluding radiators)=362437SEK

Sum Luft=293837SEK

Sum El=288812SEK

Summation 1 (including radiators) =3719132 SEK

Summation 2 (excluding radiators) =3555086 SEK

Production cost 1=Summation1/0.61=6096938SEK

Production cost 2=Summation2/0.61=5828009SEK

Figure 49: Construction and production cost (BI, 2014).

4.6.3 Cost analysis

The production cost divided by 210 m^2 equals to 29 033 SEK/m^2 and the one excluding the radiators equals to 27 752 SEK/m^2. The later value should be used because it followed the proposed design in earlier chapters of this study.

The selling price is according to broker's 18000 SEK/m^2 for the case study. The production cost 2 is chosen for parametric reasons. This venture is not making any selling profit as, 18000-27752= (-9752) SEK /m^2. Since the cost is calculated for a passive house energy performance, a 3-10 % decrease in cost according to Table 1 can be used. The norm fulfilling costs should land on:

$27752 \cdot 0.97 = 26919$ SEK/m^2 for 3 % or $27752 \cdot 0.90 = 24977$ SEK/m^2 for 10 %

The payback time for the PH production cost (excluding radiators) was calculated numerically in Excel see appendix G and H. With an income of 899 SEK/($m^2{}_{year}$) times 210 m^2= 188790 SEK/year minus expenditures being the investment loan at different discount interest rate the payback is as seen in figure 50 and figure 51 and table 5 and table 6. Please note that no future renovation cost or such has been taken into account, and that any excess income has been mortgaged for every year. For the passive house investment with a rate increase (yearly increase in rent income) of 1 percent see figure 50, and for 2 percent see figure 51.

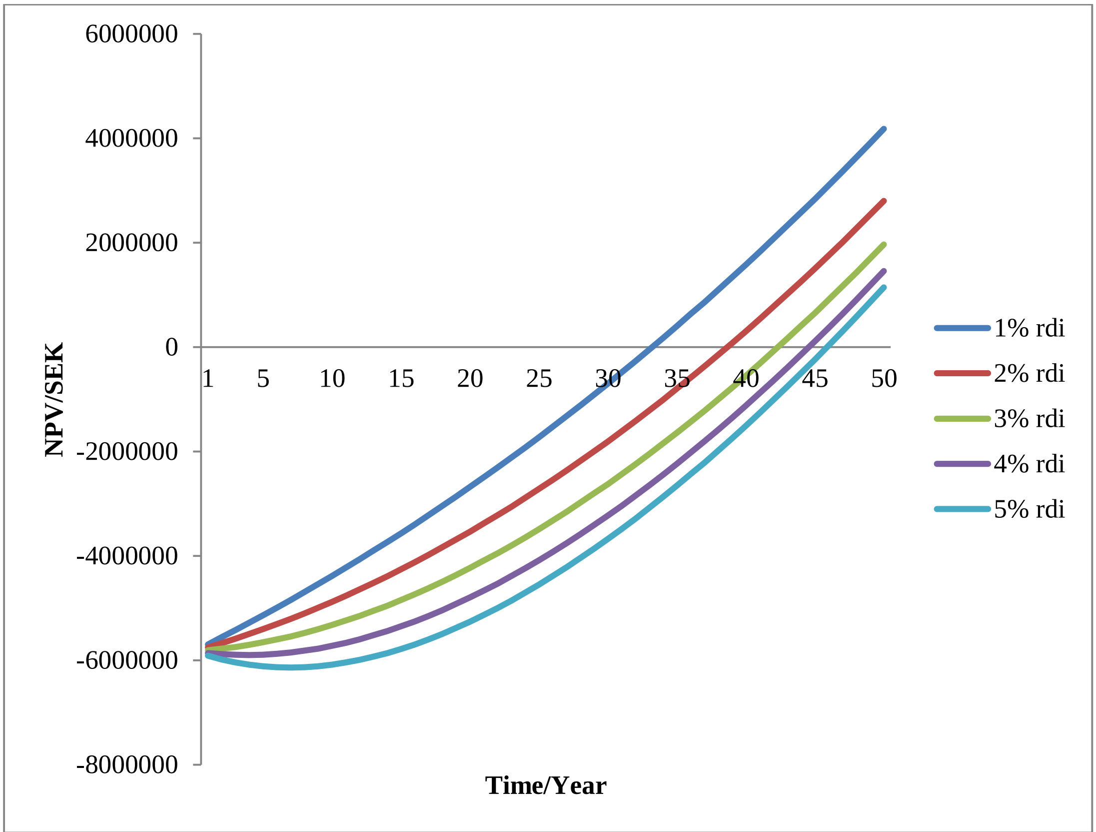


Figure 50: Passive house investment payback with a rate increase of 1 percent (Excel).

Table 5: The payback time and total investment cost (1 % annual income increase) for different discount interest rates (Excel).

Rdi/%	Payback/years	Initial investment cost /SEK	total Investment cost/SEK
1	33.7	-5828009	-7507041
2	39.1	-5828009	-9057701
3	42.5	-5828009	-10051745
4	44.2	-5828009	-10762452
5	45.9	-5828009	-11245069

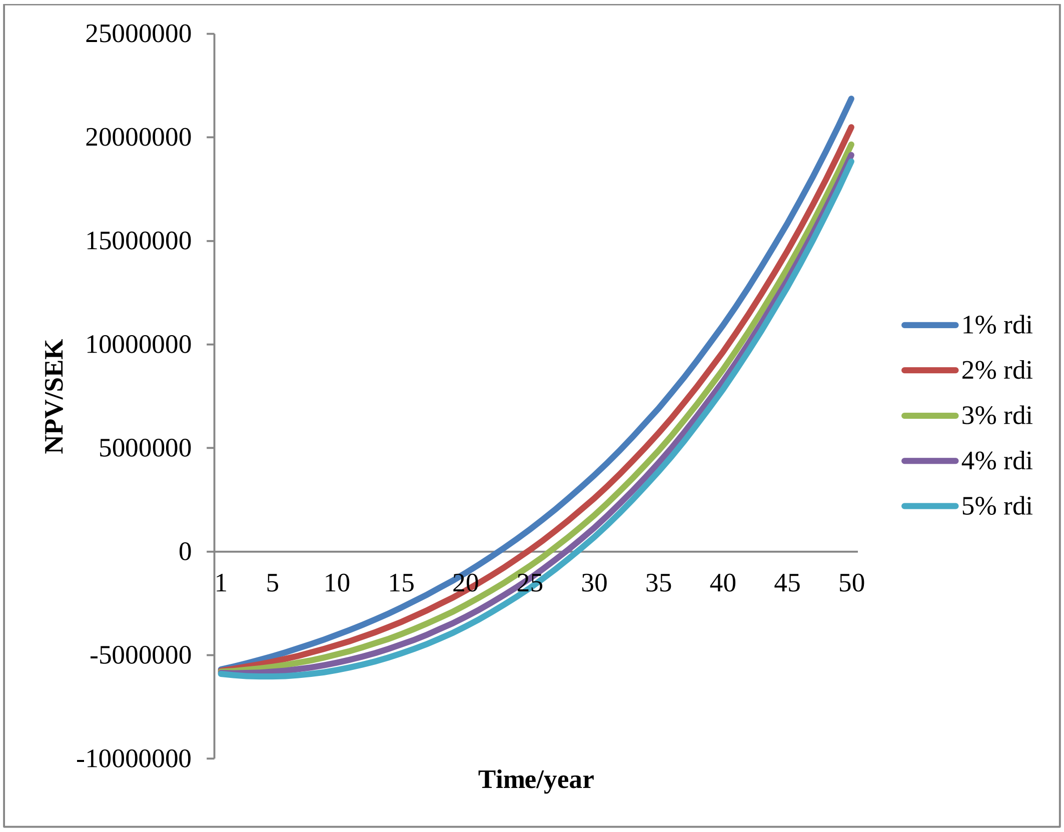


Figure 51: Passive house investment payback with a rate increase of 2 percent (Excel).

Table 6: The payback time and total investment cost (2 % annual income increase) for different discount interest rates (Excel).

rdi/%	Payback/years	Initial investment cost /SEK	total Investment cost/SEK
1	23.0	-5828009	-7223334
2	24.3	-5828009	-8391698
3	25.8	-5828009	-9206963
4	27.7	-5828009	-10024946
5	28.6	-5828009	-10527945

4.7 Ventilation

The requirement supply flow $\dot{V}_0$ is a total constant airflow to the attic and calculated as follows:

$\dot{V}_0 = A_{temp} \cdot q_{demand} + q_{people} + q_{leakage}$ [m³/s]

$A_{temp} = 210$ [m²]

$q_{demand} = 0.35$ [l/s]

$q_{people} = 12 \text{ persons} \cdot 7 \text{ l/s} = 0.084$ [m³/s]

$q_{leakage} = \frac{\text{air leakage} \cdot \text{Volyme}}{3600} = \frac{0.05 \cdot 210 \cdot 2.5}{3600} = 0.007$ [m³/s]

$\dot{V}_0 = 210 \cdot 0.35 + 0.084 + 0.007 \approx 0.16$ [m³/s]

The fresh air intake of 0.16 m³/s needs to be heated through a heat exchanger first. The rotary heat exchanger heats up the incoming cold winter air from -10.1 degrees to 14 degrees, as seen in figure 52, or calculated as t_{rec} with equation 3.

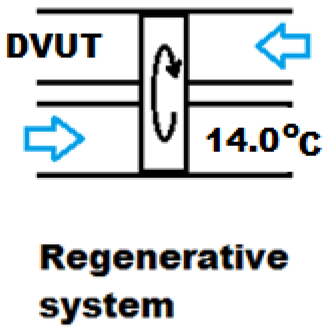


Figure 52: Air temperature after heat exchange.

The temperature t_{rec} calculated with equation 3:

$t_{rec} = t_e + \eta_T (t_{exh} - t_e) = -10.1 + 0.75\big(22 - (-10,1)\big) = 14.0$ °C

In reality the high efficiency η_T of the heat exchanger is only valid with equal flows. The heat exchanger system in this study is calculated with an efficiency of 0.75 and the flow ratio between supply and exhaust is considered equal for both cases of the regenerative systems. The only flows that differ are the AHU compared to the buildings exhaust.

The exit air t_{exit} after the heat exchange can be calculated as follows:

$$t_{exit}=\eta_T(t_e-t_{exh})+t_{exh}=0.75(-10,1-22)+22= -2,1 \quad [°C]$$

In order to reach set point of 18 °C the regenerative system only needs to be heated additionally by 4 degrees for the ventilation loss, which means 0.8 kW and calculated as

$$P_{ventilation\ loss}=\Delta T\cdot C_{p\ air}\cdot \rho_{air}\cdot \dot{V}_0=4°C\cdot\frac{1000\ J}{(kg\cdot K)}\cdot\frac{1.2\ kg}{m^3}\cdot\frac{0.16\ m^3}{s}=768 \quad [W]$$

The attics heat loss $P_{heat\ loss}$ is simplified and calculated as:

$$P_{heat\ loss}=A_{temp}\cdot VFT_{maxDVUT}=210\ m^2\cdot 15\ W/m^2=3.15 \quad [kW]$$

The regenerative systems total power P_{total} in the supply air should be

$$P_{total}=P_{ventilation\ loss}+P_{heat\ loss}=0.8+3.15\approx 4.0 \quad [kW]$$

If the evaporator is to be placed **after the heat exchanger** as seen in figure 10 the air enthalpy h_2 will roughly be 5 kJ/kg with a relative humidity of 100 %, see appendix D2. In appendix D1 the relative humidity is assumed to be 25 % and as the air passes the heat exchanger, the relative humidity increases until it reaches 100 %. The 25 % in relative humidity is assumed because it is in between the average indoor humidity of 40 % and the lowest RH about 10 %.

In order to reach the 4.0 kW of power the other enthalpy h_x needed is calculated as:

$$h_x=h_2-\frac{P_{need}}{(\dot{V}_0\cdot 1.35)}=5-\frac{4.0}{(0.16\cdot 1.35)}= -13.5 \quad [kJ/kg]$$

The temperature of the exit air is -15 °C when the enthalpy h_x is -13.5 kJ/kg, see appendix D2. The exit air being this low could create problems in terms of icing. If this is not a problem for the evaporator it should be possible to provide sufficient with the exit air. Due to the limitations of the study, icing is not included here.

If the evaporator is instead used **with the exhaust air of the building** as seen in figure 11, the enthalpy h_x for the two airflows will be as seen in table 7. Note that the evaporator needs to heat up the air 4 °C to satisfy the ventilation losses, the heat loss needs to be accounted for also.

Table 7: Two alternate airflows for the exhaust air of the building and resulting enthalpies at 25 % relative humidity.

Airflow/(m³/s)	Enthalpy /(kJ/kg)	Power need/kW	Enthalpy x /(kJ/kg)
$\dot{V}_1$=0.707	31	4.0	26.3
$\dot{V}_2$=0.313	31	4.0	20.4

Alternatively a fixed enthalpy gives a needed airflow. Allowing the temperature to only drop down to 10 degrees in order to avoid condensation if the air is below 40 % RH, then airflow needed from the buildings exhaust would mean:

$$\frac{4.0}{((31-20)\cdot 1.2)}=V_X=0.303 \qquad [m^3/s]$$

The V_X value is close to the suggested air flow value V_2=0.313 m^3/s.

In order to get 0.313 m³/s, the duct system as they are today could be rerouted as seen in figure 53. The new duct system reroutes the exhaust air to avoid the kitchen air.

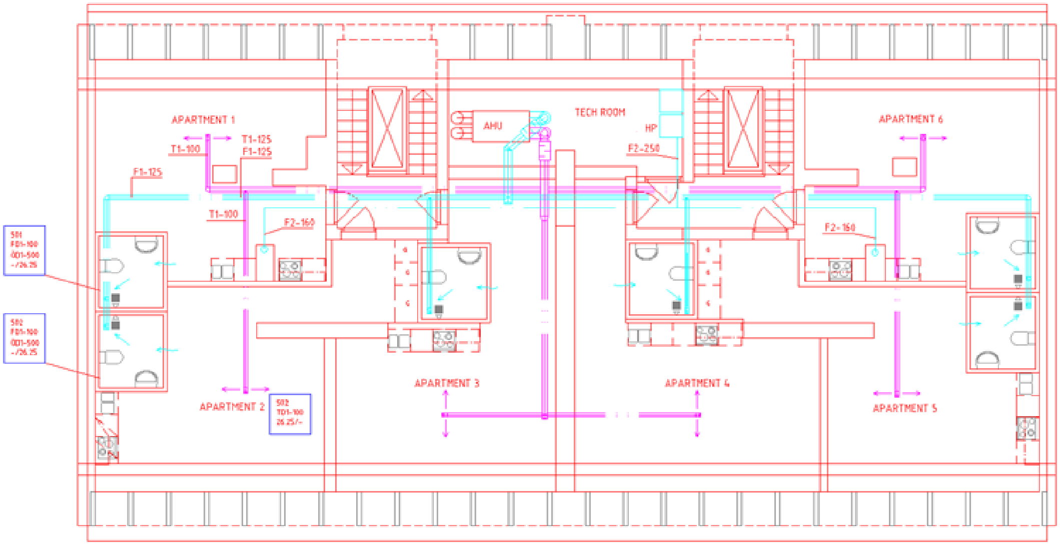


Figure 53: Duct placement (AutoCAD)

The new supply air temperature t_s is calculated using equation 4 with $\dot{V}_0$=0.16 m³/s and from 14 °C adding 4.0 kW as:

$$t_s=14+\frac{4.0}{(0.16\cdot 1.2)}=14+20.8=34.8 \qquad [°C]$$

The internal loads from persons and equipment in the apartments are assumed to give 3 degrees and that is why the set point was assumed at 18 degrees and gives 0.6 kW as:

$$0.16\cdot 1.2\cdot 3=0.576\approx 0.6 \qquad [kW]$$

According to FEBY12 the internal loads can be 47 W/person and 30 kWh/(m^2·year) for household electrical appliances. This can thus be calculated with 12 persons and 210 m^2 as:

$$47\cdot 12+{}^{(30000\cdot 210)}/_{8760}=564+719=1283W\approx 1.3 \qquad [kW]$$

The heat loss of 4.0 kW can thus be reduced accordingly and t_s can instead be calculated as:

$$t_s=14+\frac{(4.0-1.3)}{(0.16*1.2)}=14+14.1=28.1 \qquad [°C]$$

5 Discussion and conclusion

5.1 Discussion

There is today vast knowledge about how to build an energy efficient building. The knowledge seems however dispersed unevenly between companies and key-role persons of projects. Energy efficient and environmental buildings are closely linked to good quality. In order to reach such quality the participants need to be informed and share involvement with great interest. It could mean that participants need to leave room for discussion on all levels of involvement. By doing so the project will probably meet the energy efficiency intended. The tender procedure is henceforth quality over quantity (low pricing) to ensure a better outcome, and according to experts there is a chance that both quality and low pricing could coincide together. This quality behaviour is today pushed by environmental goals or/and economic interests, creating a demand which is being uncertainly fulfilled by a hopefully sustainable supply.

The approach of a building project such as an attic conversion is determined by the intended outcome. If the investor has no prior knowledge of the building process, it might be wise to let the experts handle it. An investor should choose between experts in the field with caution in order to reach energy efficiency, preferably one with proven experience. The projection of the low energy building is crucial to meet the end result intended. There are several calculation programs that meet the directive requirements, but the users are always adding the human factor to each projection. Programs are updating constantly and information of updates might be lost along the way.

A follow-up is highly recommended and can even be said to be necessary, especially after the completion of any energy efficiency project. The user should be followed in the use phase. It is suggested that users should be trained in the operation and maintenance of the house. No such attempt has been found during this study, but could be something to develop or investigate in future studies.

FEBY12 requirements are set for whole buildings and therefore not easy to adapt it to this particular case. There are penalties if the building is over a certain heated area. If the building is three-dimensionally divided, then the requirement is very confusing or hard to interpret. This could be upgraded for the next FEBY report.

The daylight access does not meet the requirements in this study, BBR recommends over 10 % of glazed area but this study only has 8 % (BBR19, 2011). If the daylight factor regardless of window to wall ratio is over 1 %, it would still qualify the BBR requirements. For further studies there seems to exist a connection between site plan and its demands with attic- or roof windows. The glazing area will impact on the attic in several ways. It needs to coexist with fire safety demands, construction solutions of roof trusses and at the same time let sufficient daylight through. Also the attic windows need to coincide with the desires of the tenants. This will cause conflicting desires regarding daylight and design.

The two apartments facing the inner yard has only one acknowledged emergency exit. This is because the manual handled ladders from the rescue services only reach four floors, and

the attic would be the fifth. The apartments facing the street will not have this problem since the mechanical ladder will suffice.
The city of Malmö will decide whether one emergency exit is enough. But if recommendations given by the rescue services are followed, two options for evacuation are needed. An exit via the roof is not recommended due to weather conditions that might occur, like snow or ice. Though the fire safety was part of the limitations done in the thesis, some knowledge was acquired in the area. (Räddningstjänsten Syd, 2014).

The cost calculation done for 2005 by Isacson (2006) seems to correlate with statistics found for Stockholm, and values of this data might be transferred to Malmö. The author calculates for a short term investment option, a long term investor might be as seen from the results a more feasible option.

Another limitation that has been done is the performance and improvements to the existing building. First the technical area could be used for an AHU set for the whole building. If not an AHU, the air heat pump together with an accumulative system and solar energy system should be strongly considered as an investigation and perhaps lucrative investment option.

5.2 Conclusion

The questions asked in the beginning were:
Question A: How should an investor approach conversion of an attic to a penthouse?

Question B: How can the intended penthouse reach passive house energy performance?

Question C: How much does it cost to convert an attic to a penthouse?

Question D: Heating the penthouse through the supply air, with the evaporator in the AHU or in the extract air from the building?

The response or conclusions to these questions are:

Answer A: The approach should be done with knowledge and preferably with experience with the processes and production. The first step is to see if it is possible to do a conversion of the attic, site plans might not allow for more living spaces.
The investor should make sure that every goal and demand is clarified through all phases of the building process and also makes sure that involved parties share the same vision of the end result. Responsibility should be encouraged to facilitate quality of the end result. Follow-up is needed for future reference and to make sure that quality and user behaviour is fortified. Also the investor should strongly consider doing the conversion at the same time as other conversions are to be done, e.g. a façade renovation.

Answer B: A passive house implementation is possible to apply in a similar attic but every case has their own solutions regarding climate shell improvements. If we follow the design recommendations of this study, presented in the introduction, then it is very plausible to create a passive house energy performance. However if the daylight utilization is part of the requirements, it would be one of the biggest challenges since there are strict rules about windows for the attics.

Answer C: The cost of conversion is very dependent on what kind of shape and preconditions the attic has. The cost is also dependent on when a conversion is done. It would be wise to do other renovations or conversions at the same time. New constructions are set to 33 000 SEK per square meter of built area. This conversion ended in the line as predicted by the interviewees. The cost is hardly defendable when each square meter is about 10000 SEK from the selling price. The interesting part is that the gap of 3-10 % in price reduction is notable. It is speculated that this price range could even be 0 %. This could be reason enough to always aim for a passive house energy performance. The Payback time was interesting to see, as when the discount interest rate was higher the expenditures were higher than the income. This could mean that the members of the housing society could be affected. It would seem implausible that members would consider a longer investment with higher fees for some years. However a lower discount interest rate should suffice for a motive to invest. The limitation of the payback calculation should be included if an investment is to be set in motion.

Answer D: A recuperative, balanced ventilation system should be implemented in a passive house conversion. It is possible to heat up the attic through an air source heat pump considering the relative humidity indoors. The study did not include icing. It should be considered however and would most probably mean that the best option would be having the evaporator device in the exhaust air from the building instead.

It would be best to use the technical room for an air handling unit for the whole building instead of only using it for the penthouses. This will surely reduce the future cost for the members of the housing society.

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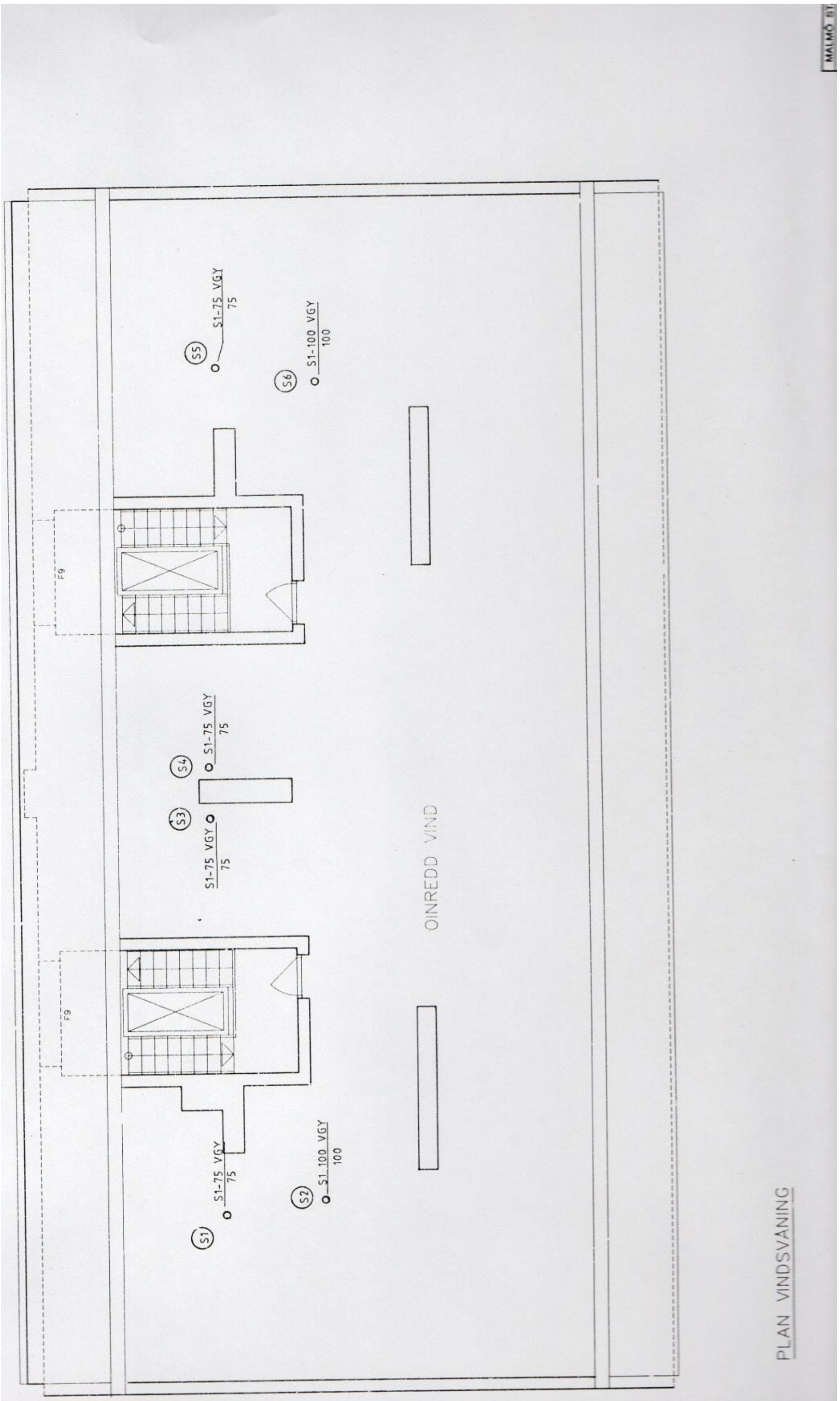
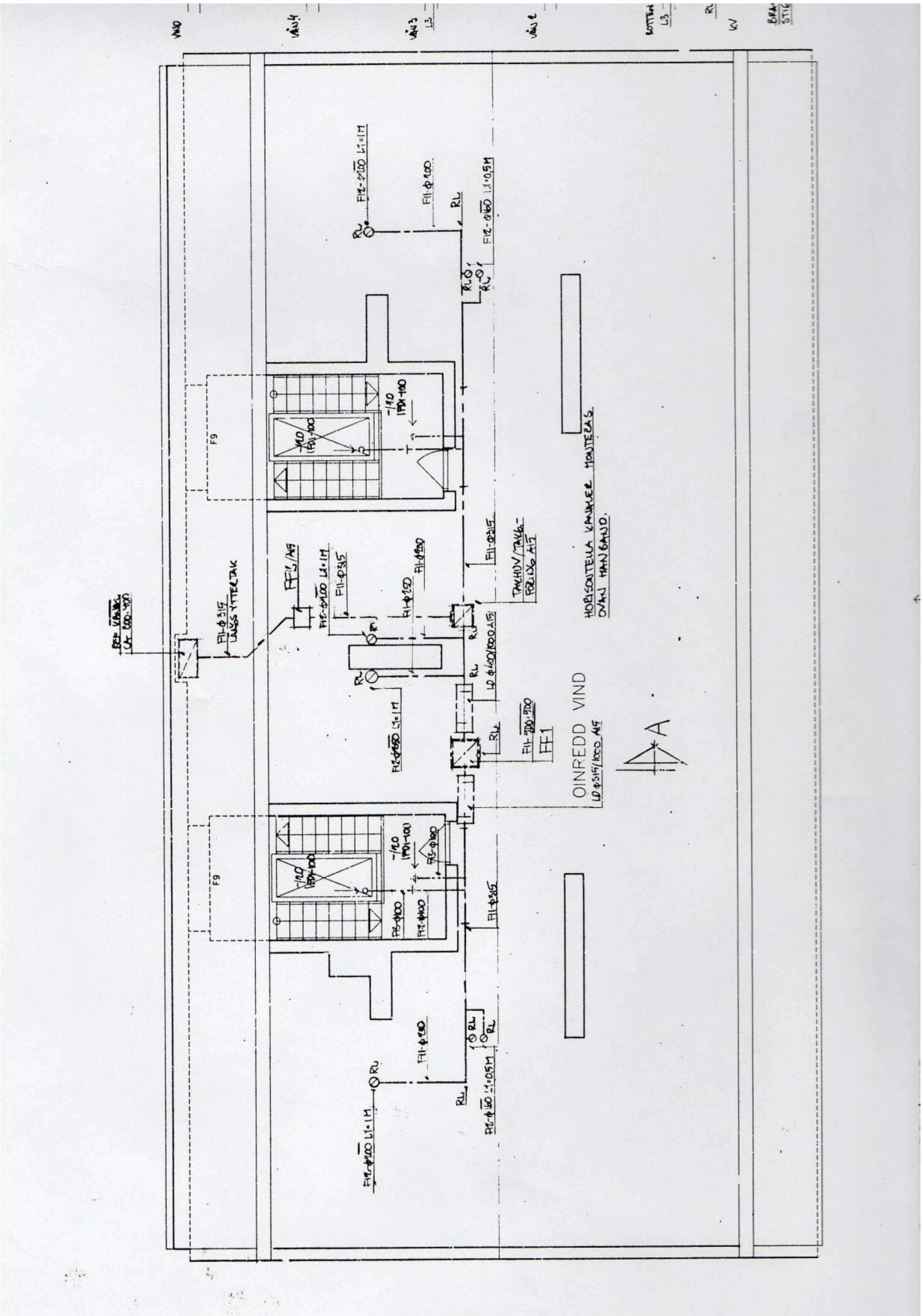
7 Appendix A



Appendix B



Appendix C1

ROT (renovation, conversion and extension), from the program Sektionsdata.

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			07/05/2014		0 (10)

Kapitel	
Förutsättningar	

UTSKRIFT AV: Kalkyl	
TYP AV UTSKRIFT: Standard	
VALDA KOLUMNER: ArtikelNr, Mängd, Material, Tid, Underentreprenader	
VALDA KAPITEL: Alla	
VALDA SORTERINGSSIFFROR: Alla	
SORTERA EFTER: Kapitel	
Som underlag för kalkylen har följande omkostnadspålägg,	
koefficienter och timpris använts:	
Arbetslön i SEK	188.00
Materialkoefficient	1.00
Tidskoefficient	1.00
UE-koefficient	1.00
Spillberäkning	Nej
Omkostnadspålägg arbete	252.00 %
Omkostnadspålägg UE	10.00 %
Entreprenörsarvoden	10.00 %
Databasutgåva: ROT - 05/03/2014	
Vald grossist:	Wikells
Grossister som används:	Wikells (wi) - 05/03/2014

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Filnamn: [Skrivbordet]\Kalkyl ROT 20140522 plus 10.wbr

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
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Kapitel
7 YTTERVÄGGAR

			Mängd	Enhet		Material Enh.-pris	Material Summa SEK	Arbete Tim/Enh.	Arbete Timmar	Underentreprenader Enh.-pris	Underentreprenader Summa SEK	Anm. (P-kod)
		Trpt										
1	**7.086**	**Mansonite roof**										
2	KBC.3111	9 gipsskiva vindskydd	338.0	m²		38.65	13,064	0.14	47.32	-	-	
3	GSN.051	220 masoniteregel	845.0	m		46.40	39,208	0.11	92.95	-	-	
4	GSN.051	220 masonitesyll-hammarband	338.0	m		63.20	21,362	0.11	37.18	-	-	
5	IBE.242	300 sprutad cellulosa-39 52 kg/m³	338.0	m²		-	-	-	-	297.00	100,386	
6	JSF.54	0,20 plastfolie	338.0	m²		5.45	1,842	0.08	27.04	-	-	
7	HSD.1531	28x70 gles panel c 300	1,149.2	m		6.40	7,355	0.05	57.46	-	-	
8	KBC.321	13 gipsskiva (B=900)	338.0	m²		34.20	11,560	0.20	67.60	-	-	
9												
10	**7.086**	**Outerwall**										
11	KBC.3111	9 gipsskiva vindskydd	103.0	m²		38.65	3,981	0.14	14.42	-	-	
12	GSN.051	300 masonitesyll-hammarband	103.0	m		70.40	7,251	0.11	11.33	-	-	
13	IBE.242	300 sprutad cellulosa-39 52 kg/m³	103.0	m²		-	-	-	-	297.00	30,591	
14	JSF.54	0,20 plastfolie	103.0	m²		5.45	561	0.08	8.24	-	-	
15	HSD.1531	28x70 gles panel c 300	350.2	m		6.40	2,241	0.05	17.51	-	-	
16	KBC.321	13 gipsskiva (B=900)	103.0	m²		34.20	3,523	0.20	20.60	-	-	
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												
		Trpt					111,947		401.65		130,977	

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Filnamn: Kalkyl ROT 20140522 plus 10.wbr

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
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Kapitel
8 INNERVÄGGAR

		Mängd	Enhet		Material Enh.-pris	Material Summa SEK	Arbete Tim/Enh.	Arbete Timmar	Underentreprenader Enh.-pris	Underentreprenader Summa SEK	Anm. (P-kod)
	Trpt					28,876		175.83		10,479	
8.085	**Bathroom walls**										
MBE.22	Kakelplattor, färgade	120.0	m²		-	-	-	-	485.00	58,200	
MBE.222	Fuktskydd typ tätduk	120.0	m²		-	-	-	-	275.00	33,000	
KBC.4121	13+13 Glasrocskiva våtrum (B=900)	120.0	m²		260.40	31,248	0.48	57.60	-	-	
HSB.1121	XR 70 akustikregel	360.0	m		15.40	5,544	0.06	21.60	-	-	
HSB.1121	AC 70/55 golvskena	60.0	m		46.15	2,769	0.09	5.40	-	-	
HSB.1121	AC 70/40 takskena	60.0	m		35.90	2,154	0.09	5.40	-	-	
KBC.321	13+13 gipsskiva (B=900)	120.0	m²		68.40	8,208	0.36	43.20	-	-	
8.034	**Teckroom and stairs walls**										
KBC.321	13+13 gipsskiva (B=900)	15.0	m²		68.40	1,026	0.36	5.40	-	-	
HSD.113	45x70 reglar c 450	60.0	m		9.40	564	0.08	4.80	-	-	
IG	GPD 70/100 polyetenduk	15.0	m		4.40	66	0.03	0.45	-	-	
IG	Akustisk fogmassa	30.0	m		6.25	188	0.06	1.80	-	-	
IBE.24	70 mineralullsskiva-36 (B=410)	15.0	m²		44.10	662	0.09	1.35	-	-	
HSD.113	45x70 reglar c 450	60.0	m		9.40	564	0.08	4.80	-	-	
IG	GPD 70/100 polyetenduk	15.0	m		4.40	66	0.03	0.45	-	-	
IBE.24	70 mineralullsskiva-36 (B=410)	15.0	m²		44.10	662	0.09	1.35	-	-	
KBC.321	13+13 gipsskiva (B=900)	15.0	m²		68.40	1,026	0.36	5.40	-	-	
8.061	**Ventilation walls**										
KBC.321	13 gipsskiva (B=900)	20.0	m²		34.20	684	0.20	4.00	-	-	
HSD.113	45x70 reglar c 450	80.0	m		9.40	752	0.08	6.40	-	-	
KBC.321	13 gipsskiva (B=900)	20.0	m²		34.20	684	0.20	4.00	-	-	
	Trpt					85,742		349.23		101,679	

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Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
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Kapitel
9 BJÄLKLAG

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	Trpt										
9.013	**Tegelgolv rivs - nytt regelgolv**										
BED.4	Brandbotten av tegel rivs	230.0	m²		-	-	0.56	128.80	-	-	
KEJ.23	22 spånskiva	230.0	m²		85.85	19,746	0.20	46.00	-	-	
IBF.1	20 mineralullsboard-33	230.0	m²		65.00	14,950	0.06	13.80	-	-	
KEJ.23	22 spånskiva	230.0	m²		85.85	19,746	0.20	46.00	-	-	
IBF.21	45 mineralullsskiva-36	230.0	m²		28.35	6,521	0.06	13.80	-	-	
HSD.124	45x45 reglar	690.0	m		6.45	4,451	0.09	62.10	-	-	
HSD.124	Utsalning i våg befintligt balklag	230.0	m²		12.55	2,887	0.08	18.40	-	-	
BEY	22 golvträ behålles	230.0	m²		-	-	-	-	-	-	
BEY	73x220 balklag behålles	230.0	m²		-	-	-	-	-	-	
BEY	80 spånfyllning behålles	230.0	m²		-	-	-	-	-	-	
BEY	22 råspontad panel behålles	230.0	m²		-	-	-	-	-	-	
BEY	3,2 träfiberskiva behålles	230.0	m²		-	-	-	-	-	-	
	Trpt					68,299		328.90		-	

Utskrivet: 24/05/2014 15:32
Filnamn: Kalkyl ROT 20140522 plus 10.wbr

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			07/05/2014		5 (10)

Kapitel
12 UNDERTAK

#	Kod	Benämning	Mängd	Enhet		Material Enh.-pris	Material Summa SEK	Arbete Tim/Enh.	Arbete Timmar	Underentreprenader Enh.-pris	Underentreprenader Summa SEK	Anm. (P-kod)	#
		Trpt											
1	**12.016**	**Nytt undertak - 40+13 mineralfiber/gips EI30**											1
2	NSF	Mineralfiberundertak i bärverk											2
3	NSF	40+13 mineralfiber + gips EI30	230.0	m²		-	-	-	-	602.00	138,460		3
4													4
5													5
6													6
7													7
8													8
9													9
10													10
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30													30
31													31
32													32
		Trpt					-		-		138,460		

Utskrivet: 24/05/2014 15:32
Filnamn: Kalkyl ROT 20140522 plus 10.wbr

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			07/05/2014		6 (10)

Kapitel 14 MÅLNINGSARBETEN			Mängd	Enhet	Material			Arbete		Underentreprenader		Anm. (P-kod)
						Enh.-pris	Summa SEK	Tim/Enh.	Timmar	Enh.-pris	Summa SEK	
		Trpt										
1	**14.013**	**Målning inomhus väggar-tak på skivor**										
2	LCS.22	Akrylat skivor 56-00010	600.0	m²		-	-	-	-	42.00	25,200	
3	LCS.22	Akrylat skivor 56-02810	600.0	m²		-	-	-	-	77.00	46,200	
4	LCS.22	Akrylat skivor 56-03510	600.0	m²		-	-	-	-	90.00	54,000	
5	LCS.22	Akrylat skivor 56-03512	600.0	m²		-	-	-	-	107.00	64,200	
6	LCS.22	Akrylat skivor 56-04010	600.0	m²		-	-	-	-	96.00	57,600	
7	LCS.22	Väv+färg skivor 56-02819	600.0	m²		-	-	-	-	125.00	75,000	
8	LCS.22	Väv+färg skivor 56-03519	600.0	m²		-	-	-	-	140.00	84,000	
9	LCS.22	Väv+färg skivor i tak 56-03519	600.0	m²		-	-	-	-	154.00	92,400	
		Trpt					-		-		498,600	

Utskrivet: 24/05/2014 15:32
Filnamn: Kalkyl ROT 20140522 plus 10.wbr

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			07/05/2014		7 (10)

Kapitel: 16 SNICKERIER

	Kod	Benämning	Mängd	Enhet	Material Enh.-pris	Material Summa SEK	Arbete Tim/Enh.	Arbete Timmar	Underentreprenader Enh.-pris	Underentreprenader Summa SEK	Anm. (P-kod)
		Trpt									
1	**16.036**	**Roof windows**									
2	BEY	Håltagning 1200x2700 i trätak	9.0	st	-	-	2.50	22.50	-	-	
3	HSD.1313	45x195 C14	20.7	m	30.40	629	0.11	2.28	-	-	
4	NSD.112	1140x1400 takfönster	9.0	st	6,176.00	55,584	4.20	37.80	-	-	
5	NSD.112	1140x950 fasadfönster	9.0	st	5,160.00	46,440	3.60	32.40	-	-	
6	ZSB.11	Elastisk fog grupp 58, B=15	70.2	m	-	-	-	-	81.00	5,686	
7	NSC.11	Drevning med mineralull	70.2	m	10.65	748	0.08	5.62	-	-	
8	NSC.71	Inv smyg av MDF 16x200, vitmålad	70.2	m	60.00	4,212	0.15	10.53	-	-	
9											
10	**16.068**	**Apartment doors**									
11	NSC.222	Innerdörr + målad träkarm									
12	NSC.222	9x21 PP-laminat EI30 35dB	6.0	st	3,502.00	21,012	1.25	7.50	-	-	
13	NSC.11	Drevning med mineralull	30.6	m	10.65	326	0.08	2.45	-	-	
14	ZSB.11	Elastisk fog grupp 58, B=15	61.2	m	-	-	-	-	81.00	4,957	
15	NSC.2	Gummitröskel + släplist	6.0	st	135.00	810	0.22	1.32	-	-	
16	NSC.2	Cylinder inkl tillbehör	6.0	st	575.00	3,450	0.17	1.02	-	-	
17	NSC.2	Trycke av metall	6.0	par	131.00	786	0.11	0.66	-	-	
18	NSC.2	Dörrstängare, standard	6.0	st	1,592.00	9,552	1.15	6.90	-	-	
19											
20	**16.069**	**Bathroom doors**									
21	NSC.222	Innerdörr + målad träkarm									
22	NSC.222	9x21 PP-våtrumsdörr	6.0	st	7,307.00	43,842	1.25	7.50	-	-	
23	NSC.71	Foder, 12x43 vitmålat	63.6	m	17.20	1,094	0.10	6.36	-	-	
24	NSC.2	Badrumströskel av ek	6.0	st	182.00	1,092	0.11	0.66	-	-	
25	NSC.2	Toalettlåstillbehör	6.0	st	140.00	840	0.11	0.66	-	-	
26	NSC.2	Trycke av metall	6.0	par	131.00	786	0.11	0.66	-	-	
27											
28											
29											
30											
31											
32											
		Trpt				191,203		146.81		10,643	

Utskrivet: 24/05/2014 15:32
Filnamn: Kalkyl ROT 20140522 plus 10.wbr

Lunds Tekniska Högskola, 046-222 00 00
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Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			07/05/2014		8 (10)

Kapitel: 18 INREDNINGAR		Mängd	Enhet		Material Enh.-pris	Material Summa SEK	Arbete Tim/Enh.	Arbete Timmar	Underentreprenader Enh.-pris	Underentreprenader Summa SEK	Anm. (P-kod)
	Trpt										
18.018	**Pentry interior**										
XKA.1	Trinette ETN 1241 vit	6.0	st		8,314.00	49,884	3.40	20.40	-	-	
XBD.1	Lådfackskåp B=400	6.0	st		3,525.00	21,150	0.95	5.70	-	-	
XBD.1	Väggskåp B=800	12.0	st		1,165.00	13,980	0.90	10.80	-	-	
XBD.1	Förkromat bygelhandtag	48.0	st		33.00	1,584	0.15	7.20	-	-	
KBC.323	Inklädnad ök skåp H=250	9.6	m		31.00	298	0.36	3.46	-	-	
XBE.2	Bänkskiva av PP L=400	6.0	st		208.00	1,248	0.45	2.70	-	-	
MBE.22	Kakelstänkskydd, H=450 vita	16.8	m		68.00	1,142	0.80	13.44	-	-	
NSM.2	Kakellist, 22x55 vitmålad	16.8	m		99.00	1,663	0.14	2.35	-	-	
	Trpt					90,949		66.05		-	

Utskrivet: 24/05/2014 15:32
Filnamn: Kalkyl ROT 20140522 plus 10.wbr

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			07/05/2014		10 (10)

Kapitel: SAMMANSTÄLLNING		Mängd	Enhet		Material Enh.-pris	Material Summa SEK	Arbete Tim/Enh.	Arbete Timmar	Underentreprenader Enh.-pris	Underentreprenader Summa SEK	Anm. (P-kod)
	Trpt										
KAPITEL	SIDA										
7 YTTERVÄGGAR	1					111,947		401.65		130,977	
8 INNERVÄGGAR	2 - 3					85,742		349.23		101,679	
9 BJÄLKLAG	4					68,299		328.90		-	
12 UNDERTAK	5					-		-		138,460	
14 MÅLNINGSARBETEN	6					-		-		498,600	
16 SNICKERIER	7					191,203		146.81		10,643	
18 INREDNINGAR	8					90,949		66.05		-	
19 DIVERSE	9					-		-		705	
						============		========		============	
						548,140	SEK	1,292.64	tim	881,064	SEK
Materialkostnad					548,140						
Arbetslön 1,292.64 tim x 188.00 SEK					243,016						
Underentreprenader					881,064	1,672,220	SEK				
Omkostnadspålägg arbete	**252.00 %**				612,401						
Omkostnadspålägg UE	**10.00 %**				88,106	700,507	SEK				
Entreprenörsarvoden	**10.00 %**					237,273	SEK				
TOTALSUMMA EXKL MOMS						**2,610,000**	**SEK**				
	Trpt										

Utskrivet: 24/05/2014 15:32
Filnamn: Kalkyl ROT 20140522 plus 10.wbr

Appendix C2

VS including radiators- Sektionsdata

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			14/05/2014		0 (3)

Kapitel	
Förutsättningar	

UTSKRIFT AV: Kalkyl	
TYP AV UTSKRIFT: Standard	
VALDA KOLUMNER: ArtikelNr, Mängd, Material, Tid, Underentreprenader	
VALDA KAPITEL: Alla	
VALDA SORTERINGSSIFFROR: Alla	
SORTERA EFTER: Kapitel	
Som underlag för kalkylen har följande omkostnadspålägg,	
koefficienter och timpris använts:	
Arbetslön i SEK	164.00
Beräkningar med rabatter	Ja
Materialkoefficient	1.00
Tidskoefficient	1.00
UE-koefficient	1.00
Spillberäkning	Nej
Omkostnadspålägg arbete	293.00 %
Omkostnadspålägg UE	6.00 %
Entreprenörsarvoden	10.00 %
Databasutgåva: VS - 05/03/2014	
Vald grossist:	Wikells
Grossister som används:	Wikells (wi) - 05/03/2014

Utskrivet: 24/05/2014 15:39
Filnamn: [Skrivbordet]\Kalkyl VS 20140522 plus 10.wbs

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			14/05/2014		1 (3)

Kapitel: 1 LÄGENHETER

			Mängd	Enhet		Material Enh.-pris	Material Summa SEK	Arbete Tim/Enh.	Arbete Timmar	Underentreprenader Enh.-pris	Underentreprenader Summa SEK	Anm. (P-kod)	
		Trpt											
1	**1.001**	**1 rum och kokvrå med WC/dusch**	**6.0**	st									1
2	4.001	Kök RiR, radiator	6.0	st		4,689.84	28,139	5.06	30.36	-	-		2
3	4.005	WC/dusch, RiR, radiator	6.0	st		10,740.43	64,443	7.89	47.34	-	-		3
4	4.017	Vardagsrum 30 m², radiator	6.0	st		6,344.64	38,068	4.18	25.08	-	-		4
5	4.021	Hall/entré, radiator	6.0	st		2,177.64	13,066	2.61	15.66	-	-		5
6	4.023	Försörjning kv, vv, vs inom bostad	6.0	st		10,464.11	62,785	16.40	98.40	-	-		6
7													7
8													8
9													9
10													10
11													11
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29													29
30													30
31													31
32													32
		Trpt					206,500		216.84		-		

Utskrivet: 24/05/2014 15:39
Filnamn: Kalkyl VS 20140522 plus 10.wbs

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			14/05/2014		2 (3)

Kapitel: 16 PANNOR, VÄXLARE

#	Kod	Benämning	Mängd	Enhet		Material Enh.-pris	Material Summa SEK	Arbete Tim/Enh.	Arbete Timmar	Underentreprenader Enh.-pris	Underentreprenader Summa SEK	Anm. (P-kod)
		Trpt										
1	**16.003**	**Frånluftvärmepump villa**	**2.0**	st								
2	R6249999	Nibe Fighter 200 P vp fl/v 1,5 kW	2.0	st		24,600.00	49,200	3.70	7.40	-	-	
3	R6246582	Nibe RT10 rumstermostat	2.0	st		554.32	1,109	-	-	-	-	
4	10.046	28 Rör p/app isol+plp vs press	6.0	m		204.24	1,225	0.89	5.34	502.41	3,014	
5	9.035	22 Rör p/appr Cu isol+plp kv vv	18.0	m		223.67	4,026	0.81	14.58	492.99	8,874	
6		vvc										
7												
8	**16.021**	**VVB 750 l, 2 l/s vv vvx+tappv.k.**	**1.0**	st								
9	#6946027	AquaCompact Nordic 750-77	1.0	st		33,337.00	33,337	4.30	4.30	-	-	
10	9.098	22 Inskärn kv- o vv-vent	1.0	st		976.60	977	2.12	2.12	602.76	603	
11	R4501074	40 Beulco BA107S kulventil	2.0	st		620.12	1,240	-	-	-	-	
12	R4891634	40 TA STAD injust-ventil	1.0	st		1,805.60	1,806	-	-	-	-	
13	R4464426	15 Ezze kikventil packbox	1.0	st		142.82	143	-	-	-	-	
14	R5130018	15 termom 0 / +120°C, rak 200 mm	3.0	st		182.04	546	-	-	-	-	
15	R4845129	10 Avluftningsv Airex-Minor	1.0	st		629.00	629	-	-	-	-	
16	10.088	88,9 H-tub p/app isol+alpl vs	1.0	m		468.86	469	1.86	1.86	1,388.12	1,388	
		Trpt					94,706		35.60		13,879	

Utskrivet: 24/05/2014 15:39
Filnamn: Kalkyl VS 20140522 plus 10.wbs

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			14/05/2014		3 (3)

Kapitel: SAMMANSTÄLLNING

	Kapitel		Mängd	Enhet		Material Enh.-pris	Material Summa SEK	Arbete Tim/Enh.	Arbete Timmar	Underentreprenader Enh.-pris	Underentreprenader Summa SEK	Anm. (P-kod)
		Trpt										
1	KAPITEL	SIDA										
2	1 LÄGENHETER	1					206,500		216.84		-	
3	16 PANNOR, VÄXLARE	2					94,706		35.60		13,879	
4							============		========		============	
5							301,206	SEK	252.44	tim	13,879	SEK
6												
7	**Materialkostnad (varav delpåslag 12,327 SEK)**					301,206						
8	**Arbetslön 252.44 tim x 164.00 SEK**					41,400						
9	**Underentreprenader**					13,879	356,486	SEK				
10												
11	**Omkostnadspålägg arbete**	**293.00 %**				121,302						
12	**Omkostnadspålägg UE**	**6.00 %**				833	122,135	SEK				
13	**Entreprenörsarvoden**	**10.00 %**					47,862	SEK				
14												
15	**TOTALSUMMA EXKL MOMS**						**526,483**	**SEK**				
16												
17												
18												
19												
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32												
		Trpt										

Utskrivet: 24/05/2014 15:39
Filnamn: Kalkyl VS 20140522 plus 10.wbs

Appendix C3

VS excluding radiators- Sektionsdata

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			14/05/2014		0 (3)

Kapitel	
Förutsättningar	

UTSKRIFT AV: Kalkyl	
TYP AV UTSKRIFT: Standard	
VALDA KOLUMNER: ArtikelNr, Mängd, Material, Tid, Underentreprenader	
VALDA KAPITEL: Alla	
VALDA SORTERINGSSIFFROR: Alla	
SORTERA EFTER: Kapitel	
Som underlag för kalkylen har följande omkostnadspålägg,	
koefficienter och timpris använts:	
Arbetslön i SEK	164.00
Beräkningar med rabatter	Ja
Materialkoefficient	1.00
Tidskoefficient	1.00
UE-koefficient	1.00
Spillberäkning	Nej
Omkostnadspålägg arbete	293.00 %
Omkostnadspålägg UE	6.00 %
Entreprenörsarvoden	10.00 %
Databasutgåva: VS - 05/03/2014	
Vald grossist:	Wikells
Grossister som används:	Wikells (wi) - 05/03/2014

Utskrivet: 24/05/2014 15:39
Filnamn: [Skrivbordet]\Kalkyl VS utan radiatorer22052014 plus 10.wbs

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			14/05/2014		1 (3)

Kapitel		Mängd	Enhet		Material		Arbete		Underentreprenader		Anm. (P-kod)
1 LÄGENHETER					Enh.-pris	Summa SEK	Tim/Enh.	Timmar	Enh.-pris	Summa SEK	
	Trpt										
1.001	**1 rum och kokvrå med WC/dusch**	**6.0**	st								
4.001	Kök RiR, radiator	6.0	st		2,183.52	13,101	2.97	17.82	-	-	
4.005	WC/dusch, RiR, radiator	6.0	st		9,227.89	55,367	6.58	39.48	-	-	
4.023	Försörjning kv, vv, vs inom bostad	6.0	st		6,457.71	38,746	13.70	82.20	-	-	
	Trpt					107,215		139.50		-	

Utskrivet: 24/05/2014 15:39
Filnamn: Kalkyl VS utan radiatorer22052014 plus 10.wbs

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			14/05/2014		2 (3)

Kapitel: **16 PANNOR, VÄXLARE**

		Mängd	Enhet		Material		Arbete		Underentreprenader		Anm. (P-kod)
					Enh.-pris	Summa SEK	Tim/Enh.	Timmar	Enh.-pris	Summa SEK	
	Trpt										
16.003	**Frånluftvärmepump villa**	**2.0**	st								
R6249999	Nibe Fighter 200 P vp fl/v 1,5 kW	2.0	st		24,600.00	49,200	3.70	7.40	-	-	
R6246582	Nibe RT10 rumstermostat	2.0	st		554.32	1,109	-	-	-	-	
10.046	28 Rör p/app isol+plp vs press	6.0	m		204.24	1,225	0.89	5.34	502.41	3,014	
9.035	22 Rör p/appr Cu isol+plp kv vv	18.0	m		223.67	4,026	0.81	14.58	492.99	8,874	
	vvc										
16.021	**VVB 750 l, 2 l/s vv vvx+tappv.k.**	**1.0**	st								
#6946027	AquaCompact Nordic 750-77	1.0	st		33,337.00	33,337	4.30	4.30	-	-	
9.098	22 Inskärn kv- o vv-vent	1.0	st		976.60	977	2.12	2.12	602.76	603	
R4501074	40 Beulco BA107S kulventil	2.0	st		620.12	1,240	-	-	-	-	
R4891634	40 TA STAD injust-ventil	1.0	st		1,805.60	1,806	-	-	-	-	
R4464426	15 Ezze kikventil packbox	1.0	st		142.82	143	-	-	-	-	
R5130018	15 termom 0 / +120°C, rak 200 mm	3.0	st		182.04	546	-	-	-	-	
R4845129	10 Avluftningsv Airex-Minor	1.0	st		629.00	629	-	-	-	-	
10.088	88,9 H-tub p/app isol+alpl vs	1.0	m		468.86	469	1.86	1.86	1,388.12	1,388	
	Trpt					94,706		35.60		13,879	

Utskrivet: 24/05/2014 15:39
Filnamn: Kalkyl VS utan radiatorer22052014 plus 10.wbs

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			14/05/2014		3 (3)

Kapitel: SAMMANSTÄLLNING

Nr			Mängd	Enhet		Material Enh.-pris	Material Summa SEK	Arbete Tim/Enh.	Arbete Timmar	Underentreprenader Enh.-pris	Underentreprenader Summa SEK	Anm. (P-kod)
		Trpt										
1	KAPITEL	SIDA										
2	1 LÄGENHETER	1					107,215		139.50		-	
3	16 PANNOR, VÄXLARE	2					94,706		35.60		13,879	
4							============		========		============	
5							201,921	SEK	175.10	tim	13,879	SEK
6												
7	**Materialkostnad (varav delpåslag 7,772 SEK)**					201,921						
8	**Arbetslön 175.10 tim x 164.00 SEK**					28,716						
9	**Underentreprenader**					13,879	244,517	SEK				
10												
11	**Omkostnadspålägg arbete**	**293.00 %**				84,139						
12	**Omkostnadspålägg UE**	**6.00 %**				833	84,972	SEK				
13	**Entreprenörsarvoden**	**10.00 %**					32,949	SEK				
14												
15	**TOTALSUMMA EXKL MOMS**						**362,437**	**SEK**				
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												
		Trpt										

Utskrivet: 24/05/2014 15:39
Filnamn: Kalkyl VS utan radiatorer22052014 plus 10.wbs

Appendix C4

Luft-Sektionsdata

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			08/05/2014		0 (5)

Kapitel	
Förutsättningar	

UTSKRIFT AV: Kalkyl	
TYP AV UTSKRIFT: Standard	
VALDA KOLUMNER: ArtikelNr, Mängd, Material, Tid, Underentreprenader	
VALDA KAPITEL: Alla	
VALDA SORTERINGSSIFFROR: Alla	
SORTERA EFTER: Kapitel	
Som underlag för kalkylen har följande omkostnadspålägg,	
koefficienter och timpris använts:	
Arbetslön i SEK	164.00
Beräkningar med rabatter	Nej
Materialkoefficient	1.00
Tidskoefficient	1.00
UE-koefficient	1.00
Spillberäkning	Nej
Omkostnadspålägg arbete	293.00 %
Omkostnadspålägg UE	6.00 %
Entreprenörsarvoden	10.00 %
Databasutgåva: Luft - 05/03/2014	
Vald grossist:	Wikells
Grossister som används:	Wikells (wi) - 05/03/2014

Utskrivet: 24/05/2014 15:38
Filnamn: [Skrivbordet]\Luft 20140522 plus 10.wbl

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			08/05/2014		1 (5)

Kapitel
1 LÄGENHETER

		Mängd	Enhet		Material Enh.-pris	Material Summa SEK	Arbete Tim/Enh.	Arbete Timmar	Underentreprenader Enh.-pris	Underentreprenader Summa SEK	Anm. (P-kod)
	Trpt										
1.001	**1 rum och kokvrå**	**6.0**	st								
4.002	Kök	6.0	st		3,383.92	20,304	1.99	11.94	516.59	3,100	
4.004	WC/dusch	6.0	st		799.50	4,797	0.86	5.16	-	-	
4.006	Vardagsrum	6.0	st		2,924.53	17,547	1.40	8.40	-	-	
	Trpt					42,648		25.50		3,100	

Utskrivet: 24/05/2014 15:38
Filnamn: Luft 20140522 plus 10.wbl

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			08/05/2014		2 (5)

Kapitel: 2 ALLMÄNNA LOKALER

			Mängd	Enhet		Material		Arbete		Underentreprenader		Anm.
						Enh.-pris	Summa SEK	Tim/Enh.	Timmar	Enh.-pris	Summa SEK	(P-kod)
		Trpt										
1	**2.016**	**Fläktrum 450 l/s**	**1.0**	st								
2	18.007	T/F-aggr. vvx 200 l/s	1.0	st		113,989.00	113,989	9.54	9.54	-	-	
3	16.007	Kombihuv 500 l/s	1.0	st		23,682.26	23,682	6.73	6.73	4,638.08	4,638	
4	V0501108 fk	315 cirkulär kanal	12.0	m		740.60	8,887	0.48	5.76	-	-	
5	V3000023	315 spiro al-lam 30 fogt	6.0	m		-	-	-	-	387.98	2,328	
6	V3000024	315 spiro al-lam 30 fogt detalj	4.0	st		-	-	-	-	211.64	847	
		Trpt					146,558		22.03		7,813	

Utskrivet: 24/05/2014 15:38
Filnamn: Luft 20140522 plus 10.wbl

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			08/05/2014		3 (5)

Kapitel: 9 KANALER

		Mängd	Enhet		Material Enh.-pris	Material Summa SEK	Arbete Tim/Enh.	Arbete Timmar	Underentreprenader Enh.-pris	Underentreprenader Summa SEK	Anm. (P-kod)
	Trpt										
9.016	**250 grenkanal+del iso 120 värm**	**2.0**	m								
V0501107 gk1	250 cirkulär kanal	2.0	m		514.27	1,029	0.33	0.66	-	-	
V3002641	250 spiro 60+60 vä nät	2.0	m		-	-	-	-	969.60	1,939	
V3002642	250 spiro 60+60 vä nät detalj	0.6	st		-	-	-	-	404.80	243	
9.014	**160 grenkanal+del iso 120 värm**	**18.3**	m								
V0501105 gk1	160 cirkulär kanal	18.3	m		292.82	5,359	0.28	5.12	-	-	
V3002637	160 spiro 60+60 vä nät	18.3	m		-	-	-	-	778.65	14,249	
V3002638	160 spiro 60+60 vä nät detalj	5.5	st		-	-	-	-	337.84	1,855	
	Trpt					6,387		5.78		18,286	

Utskrivet: 24/05/2014 15:38
Filnamn: Luft 20140522 plus 10.wbl

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			08/05/2014		4 (5)

Kapitel
12 ÖVERLUFTSDON

		Mängd	Enhet		Material Enh.-pris	Material Summa SEK	Arbete Tim/Enh.	Arbete Timmar	Underentreprenader Enh.-pris	Underentreprenader Summa SEK	Anm. (P-kod)
	Trpt										
1	**12.002 Överluftsdon, vägg 20-30 l/s**	**6.0**	st								
2	V6502012 h1 KB ÖLR 125 ö-don inkl ram	6.0	par		740.00	4,440	0.46	2.76	-	-	
	Trpt					4,440		2.76		-	

Utskrivet: 24/05/2014 15:38
Filnamn: Luft 20140522 plus 10.wbl

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			08/05/2014		5 (5)

Kapitel
SAMMANSTÄLLNING

			Mängd	Enhet		Material Enh.-pris	Material Summa SEK	Arbete Tim/Enh.	Arbete Timmar	Underentreprenader Enh.-pris	Underentreprenader Summa SEK	Anm. (P-kod)
		Trpt										
KAPITEL		SIDA										
1	LÄGENHETER	1					42,648		25.50		3,100	
2	ALLMÄNNA LOKALER	2					146,558		22.03		7,813	
9	KANALER	3					6,387		5.78		18,286	
12	ÖVERLUFTSDON	4					4,440		2.76		-	
							============		========		============	
							200,033	SEK	56.07	tim	29,198	SEK
Materialkostnad (varav delpåslag 21,700 SEK)						200,033						
Arbetslön 56.07 tim x 164.00 SEK						9,196						
Underentreprenader						29,198	238,428	SEK				
Omkostnadspålägg arbete		**293.00 %**				26,945						
Omkostnadspålägg UE		**6.00 %**				1,752	28,697	SEK				
Entreprenörsarvoden		**10.00 %**					26,712	SEK				
TOTALSUMMA EXKL MOMS							**293,837**	**SEK**				
		Trpt										

Utskrivet: 24/05/2014 15:38
Filnamn: Luft 20140522 plus 10.wbl

Appendix C5

El- Sektionsdata

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			14/05/2014		0 (3)

Kapitel	
Förutsättningar	

UTSKRIFT AV: Kalkyl	
TYP AV UTSKRIFT: Standard	
VALDA KOLUMNER: ArtikelNr, Mängd, Material, Tid, Underentreprenader	
VALDA KAPITEL: Alla	
VALDA SORTERINGSSIFFROR: Alla	
SORTERA EFTER: Kapitel	
Som underlag för kalkylen har följande omkostnadspålägg,	
koefficienter och timpris använts:	
Ortsmultiplikator	1.050
Penningfaktor	137.68
Beräkningar med rabatter	Ja
Materialkoefficient	1.00
Tidskoefficient	1.00
UE-koefficient	1.00
Spillberäkning	Nej
Omkostnadspålägg arbete	250.00 %
Omkostnadspålägg UE	8.00 %
Entreprenörsarvoden	10.00 %
Databasutgåva: EL - 05/03/2014	
Vald grossist:	Wikells
Grossister som används:	Wikells (wi) - 05/03/2014

Utskrivet: 24/05/2014 15:36
Filnamn: [Skrivbordet]\Kalkyl EL 14_05_2014 plus 10.wbe

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			14/05/2014		1 (3)

Kapitel: 1 LÄGENHETER MM		Mängd	Enhet		Material Enh.-pris	Material Summa SEK	Arbete Tim/Enh.	Arbete Timmar	Underentreprenader Enh.-pris	Underentreprenader Summa SEK	Anm. (P-kod)
	Trpt										
1.001	**1 Rum och kokvrå**	**6.0**	st								
4.001	Kök (mindre)	6.0	st		8,445.38	50,672	9.07	54.44	-	-	
4.007	Badrum (mindre)	6.0	st		1,492.85	8,957	2.06	12.39	-	-	
4.014	Vardagsrum	6.0	st		3,448.19	20,689	5.51	33.08	-	-	
4.020	Hall (större)	6.0	st		3,496.31	20,978	6.30	37.79	-	-	
16.041	Antennanl. 10 abon. Kabel-TV	0.6	st		9,897.84	5,939	19.15	11.49	-	-	
16.054	Bredband, infällt	1.2	st		3,053.38	3,664	5.25	6.30	-	-	
	Trpt					110,899		155.48		-	

Utskrivet: 24/05/2014 15:36
Filnamn: Kalkyl EL 14_05_2014 plus 10.wbe

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			14/05/2014		2 (3)

Kapitel
8 ÖVRIGA LOKALER

		Mängd	Enhet		Material		Arbete		Underentreprenader		Anm. (P-kod)
					Enh.-pris	Summa SEK	Tim/Enh.	Timmar	Enh.-pris	Summa SEK	
	Trpt										
8.002	**Värmecentral**	**1.0**	st								
E7212814 dt	Tefem IP44 2x28W	2.0	st		492.00	984	0.30	0.60	-	-	
E8343026 ly	TL5 28W/830HE lysrör	4.0	st		44.40	178	0.02	0.08	-	-	
E0445102 b	EXQ Light 3G1,5 R100	20.0	m		23.92	478	0.12	2.40	-	-	
11.010	Elinst. i värmecentral	1.0	st		29,112.50	29,113	44.25	44.25	-	-	
13.224	Strömställare kapslad HF	1.0	st		266.53	267	0.82	0.82	-	-	
13.230	Uttag 1-vägs kapslat HF	1.0	st		192.67	193	0.44	0.44	-	-	
15.030	Central 8x3 25A	0.5	st		31,460.06	15,730	5.78	2.89	-	-	
	Trpt					46,942		51.48		-	

Utskrivet: 24/05/2014 15:36
Filnamn: Kalkyl EL 14_05_2014 plus 10.wbe

Lunds Tekniska Högskola, 046-222 00 00
Sektionsdata Demoprogram

Kostnadsberäkning

Objekt	Ort	Räknat	Datum	Rev	Sida
			14/05/2014		3 (3)

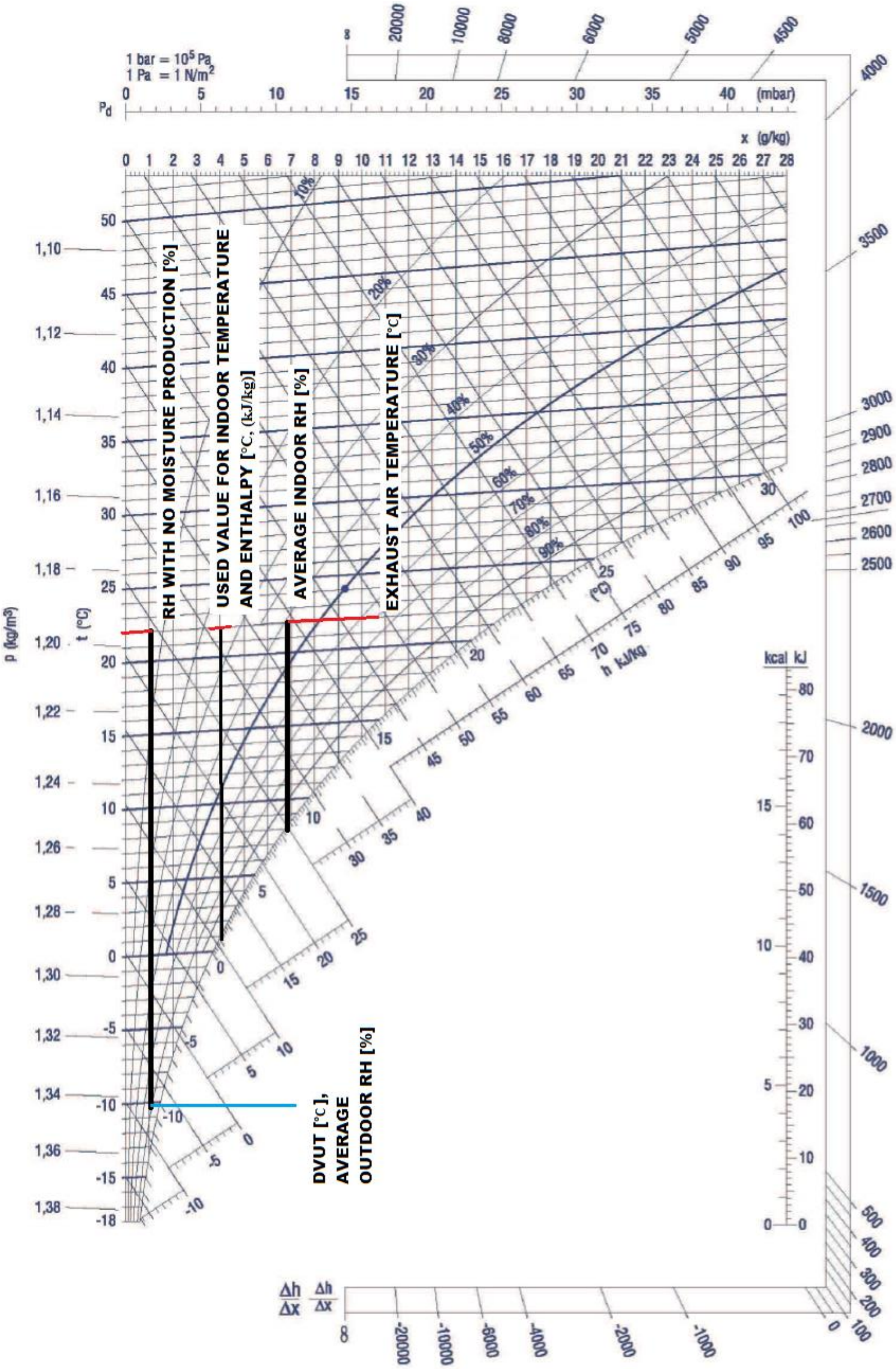
Kapitel
SAMMANSTÄLLNING

		Mängd	Enhet		Material		Arbete		Underentreprenader		Anm.
					Enh.-pris	Summa SEK	Tim/Enh.	Timmar	Enh.-pris	Summa SEK	(P-kod)
	Trpt										
KAPITEL	SIDA										
1 LÄGENHETER MM	1					110,899		155.48		-	
8 ÖVRIGA LOKALER	2					46,942		51.48		-	
						============		========		============	
						157,841	SEK	206.96	tim	-	SEK
Materialkostnad (varav delpåslag 4,712 SEK)					157,841						
Arbetslön 206.96 tim x 144.56 SEK					29,919						
Underentreprenader					-	187,760	SEK				
Omkostnadspålägg arbete	**250.00 %**				74,797	74,797	SEK				
Entreprenörsarvoden	**10.00 %**					26,256	SEK				
TOTALSUMMA EXKL MOMS						**288,812**	**SEK**				
	Trpt										

Utskrivet: 24/05/2014 15:36
Filnamn: Kalkyl EL 14_05_2014 plus 10.wbe

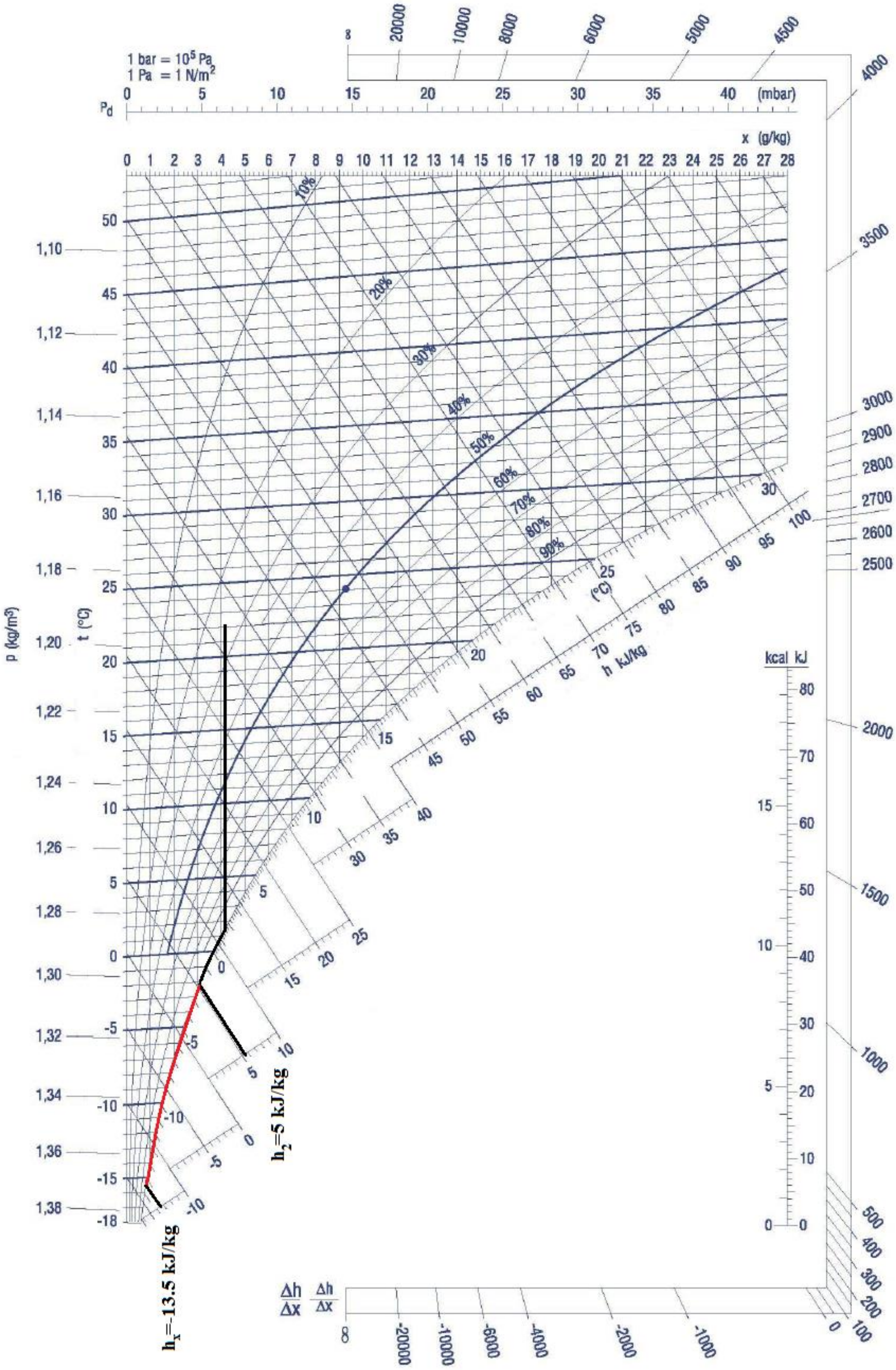
Appendix D1

Phychrometric chart



Appendix D2

Phychrometric chart



Appendix E

Steady state calculation - Excel

Atemp

Atemp is the heated floor area

	A_{temp} (m^2)
Floor 1:	210
Floor 2:	
Floor 3:	
Floor 4:	
Summation:	**210**

Transmission

This sheet calculates the transmission losses through the building envelope.
The U-values are calculated with the material thickness and λ-value (k-value).
The U-values for the windows and the doors are given by the manifacturer.

1.1

In this box, insert *1.1* if you have a house with a minimum amount of thermal bridges.
If you have a "normal" house where thermal bridges was not considered in detail, insert *1.4*.

	U (W/m^2,K)	A (m^2)	UA (W/K)	(W/K) effective
Windows	0.80	15.50	12.40	
Doors	0.00	0.00	0.00	
Wall	0.12	57.00	6.93	
Roof	0.12	285.00	34.65	
Ground floor	0.12	0.00	0.00	
Summation			53.98	59.38

Wall

	λ-value (W/mK)	Thickness (m)	ρ (kg/m³)	m	Cp	R (1/U)
			Area	6.16	m²	
gips	0.22	0.013	900	72.072	0.23	0.05909
trä och isolering	0.044	0.35	50	107.8	0.21	7.95455
gips	0.22	0.009	900	49.896	0.23	0.04091
Rse						0.04
Rsi						0.13
summation					50.6906	8.22455
			U	0.12	(W/m2,K)	

Roof

	λ-value (W/mK)	Thickness (m)	ρ	m	Cp	R (1/U)
			Area	14.60	m²	
	0	0	0	0	0	0
trä och isolering	0.044	0.35	50	255.5	0.21	7.95455
plastfolie	0	0	0	0	0	0
glespanel och luftspalt		0.028	1.2	0.49056		0.1
						0.04
						0.13
					53.655	8.22455
			U	0.12	(W/m2,K)	

This sheet is for calculating the ventilation losses, both intentional and unintentional ventilation.

$$Q_{vent} = \rho^{*}c_{p}{}^{*}q_{vent}{}^{*}(1-\eta\ )+\ \rho^{*}c_{p}{}^{*}q_{leakage}$$

ρ_{air}	1.2	kg/m^3	
$c_{p\ air}$	1000	J/kg K	1J=1Ws
η	0.75		η = efficiency for the heat exchanger.
Atemp	210	m^2	Floor area for all of the levels
Floor height	2.5	m	
Volume	525	m^3	

Intentional ventilation:

$q_{vent,demand}$	0.35	$l/s,m^2$	
q_{vent}	0.0735	m^3/s	$q_{vent} = q_{vent,demand}$ * Atemp

Unintentional ventilation:

In this box you type:
0.2 for an old building
0.1 for a new building
0.05 for a passive house

Air leakage (1/h)	0.05		
$q_{leakage}$	0.0073	m^3/s	$q_{leakage}$=(air leakage * Volyme)/3600

Q_{int_vent}	22.1 W/K
$Q_{leakage}$	8.8 W/K
$Q_{total\_vent\_ with\ heat\ recovery}$	30.8 W/K
$Q_{total\_vent\_ without\ heat\ recovery}$	97.0 W/K

q_leakage = q_50 / k
where;
q_50 is the leakage at 50 Pa over pressure
k is 20 for natural or balanced ventilation and 30 for exhaust air ventilation
SS 24300-1, p 8-9

Place	1-day	2-day	3-day	4-day	5-day	6-day	7-day	8-day	9-day	10-day	11-day	12-day
Kiruna	-30.3	-29.4	-28.6	-28	-26.8	-26.1	-25.7	-25.3	-25	-24.8	-24.7	-24.3
Jokkmokk	-34.8	-34	-33.2	-32	-31.2	-30.9	-29.9	-29.5	-29.1	-29	-28.5	-28.1
Luleå	-27.7	-26.9	-26.1	-25.6	-25	-24.4	-24.4	-23.7	-23.2	-22.9	-22.7	-22.4
Lycksele	-30	-29.5	-28.8	-28	-27.1	-26.7	-26.4	-26	-25.6	-25.5	-25.2	-25
Umeå	-24.5	-23.2	-22.6	-21.9	-21.7	-21.3	-21	-20.8	-20.3	-20	-19.8	-19.5
Östersunc	-25.3	-24.4	-23.8	-23	-22.1	-21.2	-20.7	-20.1	-20.1	-19.3	-19.2	-19
Sundsvall	-24.4	-24.2	-23.5	-22.4	-21.7	-21.4	-20.7	-20.5	-20.3	-20.1	-19.8	-19.6
Sveg	-29.3	-27.9	-27.1	-26	-25.5	-24.7	-24.5	-23.9	-23.5	-23.5	-23.4	-22.9
Malung	-26.9	-25.1	-23.9	-23.6	-22.8	-22.4	-22.1	-21.9	-21.6	-21.3	-20.9	-20.8
Falun	-23	-21.9	-21.3	-20.6	-20.5	-20	-19.9	-19.7	-19.6	-19	-18.8	-18.6
Uppsala	-18.9	-18.3	-17.5	-16.6	-16.3	-15.9	-15.4	-15.3	-15	-14.8	-14.6	-14.4
Stockholn	-17.1	-16.5	-16	-15	-14.8	-14.3	-14.1	-13.7	-13.8	-13.2	-12.9	-12.7
Södertälje	-16.2	-15.4	-14.8	-14.4	-13.8	-13.3	-13.3	-12.9	-12.7	-12.3	-12.1	-11.8
Örebro	-19	-18.1	-17.3	-16.5	-15.9	-15.7	-15.6	-15.3	-14.7	-14.3	-13.9	-13.6
Karlstad	-19.1	-17.9	-17.3	-16.9	-16.4	-16.3	-16.2	-16	-15.8	-15.2	-14.8	-14.3
Norrköpin	-16.6	-16	-14.8	-14.4	-14.1	-13.7	-13.5	-13.3	-12.8	-12.6	-12.5	-12
Linköping	-17.6	-16.5	-15.9	-14.6	-14.3	-13.8	-13.7	-13.4	-12.9	-12.5	-12.3	-11.9
Såtenäs	-15.5	-14.6	-13.8	-13.1	-12.9	-12.7	-12.4	-12.2	-11.9	-11.7	-11.4	-11.3
Säve	-14.6	-14	-13.1	-12.9	-12.8	-12.5	-12.2	-11.9	-11.5	-11	-10.9	-10.6
Jönköping	-17.5	-16.6	-15.9	-15.3	-14.4	-14.1	-14.1	-13.7	-13.5	-13.3	-13.1	-12.8
Visby	-10.5	-9.9	-9.7	-9.3	-9	-8.8	-8.7	-8.5	-8.4	-8.4	-8.2	-8.2
Västervik	-15.1	-14.2	-13.3	-12.9	-12.6	-12.3	-12.1	-11.9	-11.6	-11.4	-11.3	-10.9
Växjö	-14.4	-13.3	-12.9	-12.7	-12.2	-12	-11.9	-11.7	-11.5	-11.2	-10.9	-10.6
Kalmar	-13.3	-12.8	-12.1	-12	-11.6	-11.4	-11	-10.8	-10.8	-10.5	-10.2	-10
Ronneby/	-12.7	-11.8	-11.3	-11.3	-10.9	-10.7	-10.4	-10.2	-9.9	-9.6	-9.4	-9.2
Lund	-11.6	-10.6	-10.1	-10	-9.8	-9.4	-9.4	-9.1	-8.8	-8.5	-8.2	-7.9

This sheet sums the losses from transmission and ventilation.

Dimensioning ambient temperature	-10.1	°C	(see DVUT)
Indoor temperature	21	°C	
ΔT	31.1	°C	
Average temperature Malmö	8	°C	
Degree hours G	113880	Kh	

Transmission losses	59.4	W/K
Ventilations losses without heat recovery	97.0	W/K
Ventilations losses with heat recovery	30.8	W/K

Power need for heating	4862	W
without heat ecovery on the ventilation	23	W/m^2
Power need for heating	2805	W
with heat recovery on the ventilation	13	W/m^2

Energy need for heating	17803	kWh/år
without heat recovery on the ventilation	**85**	**kWh/m^2,year**
Energy need for heating	10270	kWh/år
with heat recovery on the ventilation	**49**	**kWh/m^2,year**

BBR 19 (Swedish Building Regulations)

Maximum specific energy use offices (climatic zone 3)	90	kWh/m^2,år
Maximum specific energy use offices (climatic zone 2)	110	kWh/m^2,år
Maximum specific energy use offices (climatic zone 1)	130	kWh/m^2,år
Maximum specific energy use dwellings (climatic zone 3)	80	kWh/m^2,år
Maximum specific energy use dwellings (climatic zone 2)	100	kWh/m^2,år
Maximum specific energy use dwellings (climatic zone 1)	120	kWh/m^2,år

Appendix F

DB output

Building Area

	Area [m2]
Total Building Area	234.21
Net Conditioned Building Area	234.21
Unconditioned Building Area	0.00

End Uses

	Electricity [kWh]	Natural Gas [kWh]	Additional Fuel [kWh]	District Cooling [kWh]	District Heating [kWh]	Water [m3]
Heating	0.00	0.00	0.00	0.00	8131.83	0.00
Cooling	0.00	0.00	0.00	184.91	0.00	0.00
Interior Lighting	1858.01	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	2839.02	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00
Fans	1005.89	0.00	0.00	0.00	0.00	0.00
Pumps	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	2084.94	44.89
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	5702.92	0.00	0.00	184.91	10216.78	44.89

Note: District heat appears to be the principal heating source based on energy usage.

Appendix G- Payback calculation 1 % annual increase

	Investment 1 (PH)
Nominal cost	5828009
Rent [SEK/(m^2*year)]	1544
Fee [SEK/(m^2*year)]	645
Area [m^2]	210
Annual Instalment	188790
Annual Interest rate	rdi's
Annual Rent increase[%]	1

NPV MULTIPLIKATORS OVER 50 YEARS

Table year	rdi 0.01	rdi 0.02	rdi 0.03	rdi 0.04	rdi 0.05
1	0.9901	0.9804	0.9709	0.9615	0.9524
2	0.9803	0.9612	0.9426	0.9246	0.9070
3	0.9706	0.9423	0.9151	0.8890	0.8638
4	0.9610	0.9238	0.8885	0.8548	0.8227
5	0.9515	0.9057	0.8626	0.8219	0.7835
6	0.9420	0.8880	0.8375	0.7903	0.7462
7	0.9327	0.8706	0.8131	0.7599	0.7107
8	0.9235	0.8535	0.7894	0.7307	0.6768
9	0.9143	0.8368	0.7664	0.7026	0.6446
10	0.9053	0.8203	0.7441	0.6756	0.6139
11	0.8963	0.8043	0.7224	0.6496	0.5847
12	0.8874	0.7885	0.7014	0.6246	0.5568
13	0.8787	0.7730	0.6810	0.6006	0.5303
14	0.8700	0.7579	0.6611	0.5775	0.5051
15	0.8613	0.7430	0.6419	0.5553	0.4810
16	0.8528	0.7284	0.6232	0.5339	0.4581
17	0.8444	0.7142	0.6050	0.5134	0.4363
18	0.8360	0.7002	0.5874	0.4936	0.4155
19	0.8277	0.6864	0.5703	0.4746	0.3957
20	0.8195	0.6730	0.5537	0.4564	0.3769
21	0.8114	0.6598	0.5375	0.4388	0.3589
22	0.8034	0.6468	0.5219	0.4220	0.3418
23	0.7954	0.6342	0.5067	0.4057	0.3256
24	0.7876	0.6217	0.4919	0.3901	0.3101
25	0.7798	0.6095	0.4776	0.3751	0.2953
26	0.7720	0.5976	0.4637	0.3607	0.2812
27	0.7644	0.5859	0.4502	0.3468	0.2678
28	0.7568	0.5744	0.4371	0.3335	0.2551
29	0.7493	0.5631	0.4243	0.3207	0.2429
30	0.7419	0.5521	0.4120	0.3083	0.2314
31	0.7346	0.5412	0.4000	0.2965	0.2204
32	0.7273	0.5306	0.3883	0.2851	0.2099
33	0.7201	0.5202	0.3770	0.2741	0.1999
34	0.7130	0.5100	0.3660	0.2636	0.1904
35	0.7059	0.5000	0.3554	0.2534	0.1813
36	0.6989	0.4902	0.3450	0.2437	0.1727
37	0.6920	0.4806	0.3350	0.2343	0.1644
38	0.6852	0.4712	0.3252	0.2253	0.1566
39	0.6784	0.4619	0.3158	0.2166	0.1491
40	0.6717	0.4529	0.3066	0.2083	0.1420
41	0.6650	0.4440	0.2976	0.2003	0.1353
42	0.6584	0.4353	0.2890	0.1926	0.1288
43	0.6519	0.4268	0.2805	0.1852	0.1227
44	0.6454	0.4184	0.2724	0.1780	0.1169
45	0.6391	0.4102	0.2644	0.1712	0.1113
46	0.6327	0.4022	0.2567	0.1646	0.1060
47	0.6265	0.3943	0.2493	0.1583	0.1009
48	0.6203	0.3865	0.2420	0.1522	0.0961
49	0.6141	0.3790	0.2350	0.1463	0.0916
50	0.6080	0.3715	0.2281	0.1407	0.0872

Figure 54: Net present value factors for different real discount interest rates over 50 years, used for numerical calculations.

ACCUMULATED INCOME NVP OVER 50 YEARS

Table year	G	∑income	income rdi 0.01 NPV
1	-5828009	190678	190678
2		383263	192585
3		577773	194511
4		774229	196456
5		972649	198420
6		1173053	200404
7		1375462	202408
8		1579894	204433
9		1786371	206477
10		1994913	208542
11		2205540	210627
12		2418273	212733
13		2633134	214861
14		2850143	217009
15		3069322	219179
16		3290693	221371
17		3514278	223585
18		3740099	225821
19		3968178	228079
20		4198537	230360
21		4431201	232663
22		4666191	234990
23		4903530	237340
24		5143244	239713
25		5385354	242110
26		5629885	244531
27		5876862	246977
28		6126309	249447
29		6378250	251941
30		6632710	254460
31		6889715	257005
32		7149290	259575
33		7411461	262171
34		7676253	264793
35		7943694	267440
36		8213809	270115
37		8486625	272816
38		8762169	275544
39		9040468	278300
40		9321551	281083
41		9605444	283893
42		9892177	286732
43		10181776	289600
44		10474272	292496
45		10769693	295421
46		11068068	298375
47		11369426	301359
48		11673798	304372
49		11981214	307416
50		12291704	310490

Figure 55: Nominal cost (G) and income (annual instalment accumulated, the rent increases1% per year)

ACCUMULATED EXPENDITURE NVP OVER 50 YEARS

Table	rdi 0.01		rdi 0.02	
year	-58280	∑ expenditure	-116560	∑ expenditure
1	0.990	-57703	0.980	-114275
2	1.970	-114835	1.942	-226309
3	2.941	-171401	2.884	-336146
4	3.902	-227407	3.808	-443830
5	4.853	-282858	4.713	-549402
6	5.795	-337761	5.601	-652904
7	6.728	-392120	6.472	-754376
8	7.652	-445940	7.325	-853859
9	8.566	-499228	8.162	-951392
10	9.471	-551988	8.983	-1047012
11	10.368	-604226	9.787	-1140757
12	11.255	-655947	10.575	-1232664
13	12.134	-707155	11.348	-1322768
14	13.004	-757857	12.106	-1411107
15	13.865	-808057	12.849	-1497712
16	14.718	-857759	13.578	-1582620
17	15.562	-906969	14.292	-1665863
18	16.398	-955693	14.992	-1747474
19	17.226	-1003933	15.678	-1827484
20	18.046	-1051696	16.351	-1905926
21	18.857	-1098987	17.011	-1982830
22	19.660	-1145809	17.658	-2058225
23	20.456	-1192167	18.292	-2132143
24	21.243	-1238067	18.914	-2204611
25	22.023	-1283511	19.523	-2275658
26	22.795	-1328507	20.121	-2345312
27	23.560	-1373056	20.707	-2413600
28	24.316	-1417164	21.281	-2480549
29	25.066	-1460836	21.844	-2546185
30	25.808	-1504076	22.396	-2610535
31	26.542	-1546887	22.938	-2673623
32	27.270	-1589274	23.468	-2735473
33	27.990	-1631242	23.989	-2796111
34	28.703	-1672794	24.499	-2855560
35	29.409	-1713935	24.999	-2913844
36	30.108	-1754668	25.489	-2970984
37	30.800	-1794998	25.969	-3027004
38	31.485	-1834929	26.441	-3081926
39	32.163	-1874464	26.903	-3135771
40	32.835	-1913608	27.355	-3188560
41	33.500	-1952365	27.799	-3240313
42	34.158	-1990738	28.235	-3291053
43	34.810	-2028730	28.662	-3340797
44	35.455	-2066347	29.080	-3389566
45	36.095	-2103591	29.490	-3437378
46	36.727	-2140467	29.892	-3484253
47	37.354	-2176977	30.287	-3530209
48	37.974	-2213126	30.673	-3575264
49	38.588	-2248917	31.052	-3619436
50	39.196	-2284353	31.424	-3662741

Figure 56: Accumulated expenditure for each year over a period of 50 years (1 % annual increase in rent).

ACCUMULATED EXPENDITURE NVP OVER 50 YEARS

Table year	rdi 0.03 -174840	∑ expenditure	rdi 0.04 -233120	∑ expenditure
1	0.971	-169748	0.962	-224154
2	1.913	-334552	1.886	-439687
3	2.829	-494555	2.775	-646930
4	3.717	-649898	3.630	-846202
5	4.580	-800717	4.452	-1037810
6	5.417	-947143	5.242	-1222049
7	6.230	-1089304	6.002	-1399201
8	7.020	-1227325	6.733	-1569540
9	7.786	-1361325	7.435	-1733327
10	8.530	-1491423	8.111	-1890815
11	9.253	-1617731	8.760	-2042245
12	9.954	-1740361	9.385	-2187852
13	10.635	-1859418	9.986	-2327858
14	11.296	-1975008	10.563	-2462479
15	11.938	-2087232	11.118	-2591922
16	12.561	-2196186	11.652	-2716387
17	13.166	-2301968	12.166	-2836065
18	13.754	-2404668	12.659	-2951140
19	14.324	-2504377	13.134	-3061789
20	14.877	-2601182	13.590	-3168182
21	15.415	-2695167	14.029	-3270483
22	15.937	-2786415	14.451	-3368849
23	16.444	-2875005	14.857	-3463432
24	16.936	-2961015	15.247	-3554378
25	17.413	-3044519	15.622	-3641825
26	17.877	-3125592	15.983	-3725909
27	18.327	-3204303	16.330	-3806759
28	18.764	-3280722	16.663	-3884499
29	19.188	-3354915	16.984	-3959250
30	19.600	-3426946	17.292	-4031125
31	20.000	-3496880	17.588	-4100236
32	20.389	-3564777	17.874	-4166689
33	20.766	-3630697	18.148	-4230586
34	21.132	-3694696	18.411	-4292025
35	21.487	-3756831	18.665	-4351101
36	21.832	-3817157	18.908	-4407905
37	22.167	-3875725	19.143	-4462525
38	22.492	-3932588	19.368	-4515043
39	22.808	-3987794	19.584	-4565542
40	23.115	-4041393	19.793	-4614099
41	23.412	-4093430	19.993	-4660787
42	23.701	-4143952	20.186	-4705681
43	23.982	-4193002	20.371	-4748847
44	24.254	-4240624	20.549	-4790353
45	24.519	-4286858	20.720	-4830263
46	24.775	-4331746	20.885	-4868638
47	25.025	-4375327	21.043	-4905537
48	25.267	-4417638	21.195	-4941017
49	25.502	-4458717	21.341	-4975132
50	25.730	-4498599	21.482	-5007935

Figure 57: Accumulated expenditure for each year over a period of 50 years (1 % annual increase in rent).

ACCUMULATED EXPENDITURE NVP OVER 50 YEARS

Table	rdi 0.05	
year	-291400	∑ expenditure
1	0.952	-277524
2	1.859	-541833
3	2.723	-793556
4	3.546	-1033292
5	4.329	-1261611
6	5.076	-1479059
7	5.786	-1686152
8	6.463	-1883383
9	7.108	-2071222
10	7.722	-2250117
11	8.306	-2420493
12	8.863	-2582756
13	9.394	-2737291
14	9.899	-2884468
15	10.380	-3024637
16	10.838	-3158131
17	11.274	-3285268
18	11.690	-3406351
19	12.085	-3521668
20	12.462	-3631494
21	12.821	-3736090
22	13.163	-3835705
23	13.489	-3930576
24	13.799	-4020930
25	14.094	-4106982
26	14.375	-4188935
27	14.643	-4266987
28	14.898	-4341321
29	15.141	-4412116
30	15.372	-4479539
31	15.593	-4543752
32	15.803	-4604907
33	16.003	-4663150
34	16.193	-4718620
35	16.374	-4771448
36	16.547	-4821760
37	16.711	-4869677
38	16.868	-4915312
39	17.017	-4958773
40	17.159	-5000165
41	17.294	-5039587
42	17.423	-5077131
43	17.546	-5112887
44	17.663	-5146940
45	17.774	-5179372
46	17.880	-5210259
47	17.981	-5239676
48	18.077	-5267692
49	18.169	-5294374
50	18.256	-5319785

Figure 58: Accumulated expenditure for each year over a period of 50 years (1 % annual increase in rent).

NPV BALANCE OVER 50 YEARS

Table year	0.01 ∑ income	0.01 ∑ expenditure	0.01 NPV balance
1	190678	-57703	-5695034
2	383263	-114835	-5559581
3	577773	-171401	-5421637
4	774229	-227407	-5281187
5	972649	-282858	-5138218
6	1173053	-337761	-4992717
7	1375462	-392120	-4844667
8	1579894	-445940	-4694055
9	1786371	-499228	-4540866
10	1994913	-551988	-4385085
11	2205540	-604226	-4226696
12	2418273	-655947	-4065683
13	2633134	-707155	-3902031
14	2850143	-757857	-3735723
15	3069322	-808057	-3566743
16	3290693	-857759	-3395075
17	3514278	-906969	-3220700
18	3740099	-955693	-3043603
19	3968178	-1003933	-2863765
20	4198537	-1051696	-2681168
21	4431201	-1098987	-2495795
22	4666191	-1145809	-2307627
23	4903530	-1192167	-2116646
24	5143244	-1238067	-1922832
25	5385354	-1283511	-1726167
26	5629885	-1328507	-1526630
27	5876862	-1373056	-1324203
28	6126309	-1417164	-1118865
29	6378250	-1460836	-910596
30	6632710	-1504076	-699374
31	6889715	-1546887	-485181
32	7149290	-1589274	-267993
33	7411461	-1631242	-47790
34	7676253	-1672794	175450
35	7943694	-1713935	401750
36	8213809	-1754668	631132
37	8486625	-1794998	863617
38	8762169	-1834929	1099231
39	9040468	-1874464	1337995
40	9321551	-1913608	1579934
41	9605444	-1952365	1825071
42	9892177	-1990738	2073430
43	10181776	-2028730	2325037
44	10474272	-2066347	2579916
45	10769693	-2103591	2838093
46	11068068	-2140467	3099592
47	11369426	-2176977	3364440
48	11673798	-2213126	3632664
49	11981214	-2248917	3904288
50	12291704	-2284353	4179342

Figure 59: Net present value of balanced nominal cost, income and expenditure for each year over a period of 50 years (1 % annual increase in rent).

NPV BALANCE OVER 50 YEARS

Table	0.02	0.02	0.03	0.03
year	∑ expenditure	NPV balance 2	∑ expenditure	NPV balance 3
1	-114275	-5751606	-169748	-5807079
2	-226309	-5671055	-334552	-5779298
3	-336146	-5586382	-494555	-5744791
4	-443830	-5497610	-649898	-5703679
5	-549402	-5404762	-800717	-5656077
6	-652904	-5307859	-947143	-5602099
7	-754376	-5206924	-1089304	-5541852
8	-853859	-5101974	-1227325	-5475440
9	-951392	-4993030	-1361325	-5402963
10	-1047012	-4880108	-1491423	-5324519
11	-1140757	-4763226	-1617731	-5240201
12	-1232664	-4642400	-1740361	-5150097
13	-1322768	-4517644	-1859418	-5054294
14	-1411107	-4388973	-1975008	-4952875
15	-1497712	-4256399	-2087232	-4845919
16	-1582620	-4119936	-2196186	-4733502
17	-1665863	-3979594	-2301968	-4615699
18	-1747474	-3835384	-2404668	-4492578
19	-1827484	-3687316	-2504377	-4364208
20	-1905926	-3535398	-2601182	-4230653
21	-1982830	-3379638	-2695167	-4091975
22	-2058225	-3220044	-2786415	-3948233
23	-2132143	-3056621	-2875005	-3799484
24	-2204611	-2889376	-2961015	-3645780
25	-2275658	-2718313	-3044519	-3487174
26	-2345312	-2543435	-3125592	-3323716
27	-2413600	-2364747	-3204303	-3155450
28	-2480549	-2182249	-3280722	-2982422
29	-2546185	-1995945	-3354915	-2804674
30	-2610535	-1805834	-3426946	-2622245
31	-2673623	-1611917	-3496880	-2435174
32	-2735473	-1414192	-3564777	-2243496
33	-2796111	-1212659	-3630697	-2047245
34	-2855560	-1007316	-3694696	-1846452
35	-2913844	-798159	-3756831	-1641146
36	-2970984	-585184	-3817157	-1431357
37	-3027004	-368388	-3875725	-1217110
38	-3081926	-147766	-3932588	-998428
39	-3135771	76689	-3987794	-775335
40	-3188560	304982	-4041393	-547851
41	-3240313	537122	-4093430	-315995
42	-3291053	773115	-4143952	-79784
43	-3340797	1012971	-4193002	160765
44	-3389566	1256697	-4240624	405639
45	-3437378	1504305	-4286858	654825
46	-3484253	1755805	-4331746	908312
47	-3530209	2011208	-4375327	1166090
48	-3575264	2270525	-4417638	1428151
49	-3619436	2533769	-4458717	1694489
50	-3662741	2800954	-4498599	1965096

Figure 60: Net present value of balanced nominal cost, income and expenditure for each year over a period of 50 years (1 % annual increase in rent).

NPV BALANCE OVER 50 YEARS

Table year	0.04 ∑expenditure	0.04 NPV balance 4	0.05 ∑ expenditure	0.05 NPV balance 5
1	-224154	-5861485	-277524	-5914855
2	-439687	-5884433	-541833	-5986579
3	-646930	-5897166	-793556	-6043792
4	-846202	-5899983	-1033292	-6087072
5	-1037810	-5893171	-1261611	-6116972
6	-1222049	-5877005	-1479059	-6134015
7	-1399201	-5851748	-1686152	-6138699
8	-1569540	-5817655	-1883383	-6131498
9	-1733327	-5774965	-2071222	-6112860
10	-1890815	-5723911	-2250117	-6083213
11	-2042245	-5664715	-2420493	-6042962
12	-2187852	-5597588	-2582756	-5992491
13	-2327858	-5522733	-2737291	-5932167
14	-2462479	-5440345	-2884468	-5862335
15	-2591922	-5350609	-3024637	-5783324
16	-2716387	-5253703	-3158131	-5695447
17	-2836065	-5149796	-3285268	-5598999
18	-2951140	-5039050	-3406351	-5494261
19	-3061789	-4921620	-3521668	-5381499
20	-3168182	-4797653	-3631494	-5260965
21	-3270483	-4667291	-3736090	-5132898
22	-3368849	-4530668	-3835705	-4997523
23	-3463432	-4387911	-3930576	-4855055
24	-3554378	-4239143	-4020930	-4705696
25	-3641825	-4084480	-4106982	-4549637
26	-3725909	-3924032	-4188935	-4387059
27	-3806759	-3757906	-4266987	-4218133
28	-3884499	-3586200	-4341321	-4043021
29	-3959250	-3409009	-4412116	-3861875
30	-4031125	-3226424	-4479539	-3674838
31	-4100236	-3038530	-4543752	-3482046
32	-4166689	-2845408	-4604907	-3283626
33	-4230586	-2647134	-4663150	-3079698
34	-4292025	-2443781	-4718620	-2870375
35	-4351101	-2235416	-4771448	-2655763
36	-4407905	-2022106	-4821760	-2435960
37	-4462525	-1803909	-4869677	-2211061
38	-4515043	-1580884	-4915312	-1981152
39	-4565542	-1353083	-4958773	-1746314
40	-4614099	-1120557	-5000165	-1506623
41	-4660787	-883352	-5039587	-1262151
42	-4705681	-641513	-5077131	-1012963
43	-4748847	-395080	-5112887	-759119
44	-4790353	-144090	-5146940	-500677
45	-4830263	111421	-5179372	-237688
46	-4868638	371421	-5210259	29799
47	-4905537	635880	-5239676	301741
48	-4941017	904773	-5267692	578097
49	-4975132	1178074	-5294374	858831
50	-5007935	1455761	-5319785	1143910

Figure 61: Net present value of balanced nominal cost, income and expenditure for each year over a period of 50 years (1 % annual increase in rent).

PAYBACK CALCULATION

	Sum income	Sum expenditure	NPV balance
33	7411461	-1631242	-47790
34	7676253	-1672794	175450
			127661
		years payback	33.72761614
38	8762169	-3081926	-147766
39	9040468	-3135771	76689
			-71077
		years payback	39.07895182
42	9892177	-4143952	-79784
43	10181776	-4193002	160765
			80981
		years payback	42.50372169
44	10474272	-4790353	-144090
45	10769693	-4830263	111421
			-32670
		years payback	44.22673009
45	10769693	-5179372	-237688
46	11068068	-5210259	29799
			-207889
		years payback	45.87462937

rdi/%	Payback/years	Initial investment/SEK	Investment cost/SEK
1	33.7	-5828009	-7507041
2	39.1	-5828009	-9057701
3	42.5	-5828009	-10051745
4	44.2	-5828009	-10762452
5	49.9	-5828009	-11245069

Figure 62: Payback calculation of investment when the rent increases 1 % per year.

Appendix H-Payback calculation 2 % annual increase

	Investment 1 (PH)
Nominal cost	5828009
Rent [SEK/(m^2*year)]	1544
Fee [SEK/(m^2*year)]	645
Area [m^2]	210
Annual Instalment	188790
Annual Interest rate	rdi's
Annual Rent increase [%]	**2**

ACCUMULATED INCOME NVP OVER 50 YEARS

year	G	∑ income	income rdi 0.01 NPV
1	-5828009	196342	196342
2		400537	204195
3		612900	212363
4		833758	220858
5		1063449	229692
6		1302329	238880
7		1550764	248435
8		1809136	258372
9		2077843	268707
10		2357298	279455
11		2647932	290634
12		2950191	302259
13		3264540	314349
14		3591463	326923
15		3931463	340000
16		4285063	353600
17		4652807	367744
18		5035261	382454
19		5433013	397752
20		5846676	413662
21		6276884	430209
22		6724301	447417
23		7189615	465314
24		7673541	483926
25		8176824	503283
26		8700239	523415
27		9244590	544351
28		9810715	566125
29		10399485	588770
30		11011806	612321
31		11648620	636814
32		12310907	662286
33		12999685	688778
34		13716014	716329
35		14460996	744982
36		15235777	774781
37		16041550	805773
38		16879553	838004
39		17751077	871524
40		18657462	906385
41		19600102	942640
42		20580448	980346
43		21600007	1019560
44		22660349	1060342
45		23763104	1102756
46		24909970	1146866
47		26102711	1192740
48		27343161	1240450
49		28633229	1290068
50		29974899	1341671

Figure 63: Nominal cost (G) and income (annual instalment accumulated, the rent increases 2 % per year).

ACCUMULATED EXPENDITURE NVP OVER 50 YEARS

	rdi 0.01		rdi 0.02	
year	-58280	∑expenditure	-116560	∑expenditure
1	0.990	-57703	0.980	-114275
2	1.970	-114835	1.942	-226309
3	2.941	-171401	2.884	-336146
4	3.902	-227407	3.808	-443830
5	4.853	-282858	4.713	-549402
6	5.795	-337761	5.601	-652904
7	6.728	-392120	6.472	-754376
8	7.652	-445940	7.325	-853859
9	8.566	-499228	8.162	-951392
10	9.471	-551988	8.983	-1047012
11	10.368	-604226	9.787	-1140757
12	11.255	-655947	10.575	-1232664
13	12.134	-707155	11.348	-1322768
14	13.004	-757857	12.106	-1411107
15	13.865	-808057	12.849	-1497712
16	14.718	-857759	13.578	-1582620
17	15.562	-906969	14.292	-1665863
18	16.398	-955693	14.992	-1747474
19	17.226	-1003933	15.678	-1827484
20	18.046	-1051696	16.351	-1905926
21	18.857	-1098987	17.011	-1982830
22	19.660	-1145809	17.658	-2058225
23	20.456	-1192167	18.292	-2132143
24	21.243	-1238067	18.914	-2204611
25	22.023	-1283511	19.523	-2275658
26	22.795	-1328507	20.121	-2345312
27	23.560	-1373056	20.707	-2413600
28	24.316	-1417164	21.281	-2480549
29	25.066	-1460836	21.844	-2546185
30	25.808	-1504076	22.396	-2610535
31	26.542	-1546887	22.938	-2673623
32	27.270	-1589274	23.468	-2735473
33	27.990	-1631242	23.989	-2796111
34	28.703	-1672794	24.499	-2855560
35	29.409	-1713935	24.999	-2913844
36	30.108	-1754668	25.489	-2970984
37	30.800	-1794998	25.969	-3027004
38	31.485	-1834929	26.441	-3081926
39	32.163	-1874464	26.903	-3135771
40	32.835	-1913608	27.355	-3188560
41	33.500	-1952365	27.799	-3240313
42	34.158	-1990738	28.235	-3291053
43	34.810	-2028730	28.662	-3340797
44	35.455	-2066347	29.080	-3389566
45	36.095	-2103591	29.490	-3437378
46	36.727	-2140467	29.892	-3484253
47	37.354	-2176977	30.287	-3530209
48	37.974	-2213126	30.673	-3575264
49	38.588	-2248917	31.052	-3619436
50	39.196	-2284353	31.424	-3662741

Figure 64: Accumulated expenditure for each year over a period of 50 years (2 % annual increase in rent).

ACCUMULATED EXPENDITURE NVP OVER 50 YEARS

year	rdi 0.03 -174840	∑expenditure	rdi 0.04 -233120	∑expenditure
1	0.971	-169748	0.962	-224154
2	1.913	-334552	1.886	-439687
3	2.829	-494555	2.775	-646930
4	3.717	-649898	3.630	-846202
5	4.580	-800717	4.452	-1037810
6	5.417	-947143	5.242	-1222049
7	6.230	-1089304	6.002	-1399201
8	7.020	-1227325	6.733	-1569540
9	7.786	-1361325	7.435	-1733327
10	8.530	-1491423	8.111	-1890815
11	9.253	-1617731	8.760	-2042245
12	9.954	-1740361	9.385	-2187852
13	10.635	-1859418	9.986	-2327858
14	11.296	-1975008	10.563	-2462479
15	11.938	-2087232	11.118	-2591922
16	12.561	-2196186	11.652	-2716387
17	13.166	-2301968	12.166	-2836065
18	13.754	-2404668	12.659	-2951140
19	14.324	-2504377	13.134	-3061789
20	14.877	-2601182	13.590	-3168182
21	15.415	-2695167	14.029	-3270483
22	15.937	-2786415	14.451	-3368849
23	16.444	-2875005	14.857	-3463432
24	16.936	-2961015	15.247	-3554378
25	17.413	-3044519	15.622	-3641825
26	17.877	-3125592	15.983	-3725909
27	18.327	-3204303	16.330	-3806759
28	18.764	-3280722	16.663	-3884499
29	19.188	-3354915	16.984	-3959250
30	19.600	-3426946	17.292	-4031125
31	20.000	-3496880	17.588	-4100236
32	20.389	-3564777	17.874	-4166689
33	20.766	-3630697	18.148	-4230586
34	21.132	-3694696	18.411	-4292025
35	21.487	-3756831	18.665	-4351101
36	21.832	-3817157	18.908	-4407905
37	22.167	-3875725	19.143	-4462525
38	22.492	-3932588	19.368	-4515043
39	22.808	-3987794	19.584	-4565542
40	23.115	-4041393	19.793	-4614099
41	23.412	-4093430	19.993	-4660787
42	23.701	-4143952	20.186	-4705681
43	23.982	-4193002	20.371	-4748847
44	24.254	-4240624	20.549	-4790353
45	24.519	-4286858	20.720	-4830263
46	24.775	-4331746	20.885	-4868638
47	25.025	-4375327	21.043	-4905537
48	25.267	-4417638	21.195	-4941017
49	25.502	-4458717	21.341	-4975132
50	25.730	-4498599	21.482	-5007935

Figure 65: Accumulated expenditure for each year over a period of 50 years (2 % annual increase in rent).

ACCUMULATED EXPENDITURE NVP OVER 50 YEARS

year	rdi 0.05 -291400	∑expenditure
1	0.952	-277524
2	1.859	-541833
3	2.723	-793556
4	3.546	-1033292
5	4.329	-1261611
6	5.076	-1479059
7	5.786	-1686152
8	6.463	-1883383
9	7.108	-2071222
10	7.722	-2250117
11	8.306	-2420493
12	8.863	-2582756
13	9.394	-2737291
14	9.899	-2884468
15	10.380	-3024637
16	10.838	-3158131
17	11.274	-3285268
18	11.690	-3406351
19	12.085	-3521668
20	12.462	-3631494
21	12.821	-3736090
22	13.163	-3835705
23	13.489	-3930576
24	13.799	-4020930
25	14.094	-4106982
26	14.375	-4188935
27	14.643	-4266987
28	14.898	-4341321
29	15.141	-4412116
30	15.372	-4479539
31	15.593	-4543752
32	15.803	-4604907
33	16.003	-4663150
34	16.193	-4718620
35	16.374	-4771448
36	16.547	-4821760
37	16.711	-4869677
38	16.868	-4915312
39	17.017	-4958773
40	17.159	-5000165
41	17.294	-5039587
42	17.423	-5077131
43	17.546	-5112887
44	17.663	-5146940
45	17.774	-5179372
46	17.880	-5210259
47	17.981	-5239676
48	18.077	-5267692
49	18.169	-5294374
50	18.256	-5319785

Figure 66: Accumulated expenditure for each year over a period of 50 years (2 % annual increase in rent).

NPV BALANCE OVER 50 YEARS

Table year	0.01 ∑ income	0.01 ∑ expenditure	0.01 NPV balance
1	196342	-57703	-5689370
2	400537	-114835	-5542307
3	612900	-171401	-5386510
4	833758	-227407	-5221658
5	1063449	-282858	-5047418
6	1302329	-337761	-4863441
7	1550764	-392120	-4669365
8	1809136	-445940	-4464814
9	2077843	-499228	-4249394
10	2357298	-551988	-4022699
11	2647932	-604226	-3784303
12	2950191	-655947	-3533765
13	3264540	-707155	-3270625
14	3591463	-757857	-2994403
15	3931463	-808057	-2704602
16	4285063	-857759	-2400705
17	4652807	-906969	-2082171
18	5035261	-955693	-1748440
19	5433013	-1003933	-1398929
20	5846676	-1051696	-1033030
21	6276884	-1098987	-650111
22	*6724301*	*-1145809*	*-249516*
23	*7189615*	*-1192167*	*169439*
24	7673541	-1238067	607466
25	8176824	-1283511	1065304
26	8700239	-1328507	1543723
27	9244590	-1373056	2043525
28	9810715	-1417164	2565542
29	10399485	-1460836	3110640
30	11011806	-1504076	3679722
31	11648620	-1546887	4273724
32	12310907	-1589274	4893624
33	12999685	-1631242	5540434
34	13716014	-1672794	6215211
35	14460996	-1713935	6919052
36	15235777	-1754668	7653100
37	16041550	-1794998	8418543
38	16879553	-1834929	9216615
39	17751077	-1874464	10048604
40	18657462	-1913608	10915844
41	19600102	-1952365	11819728
42	20580448	-1990738	12761701
43	21600007	-2028730	13743268
44	22660349	-2066347	14765993
45	23763104	-2103591	15831504
46	24909970	-2140467	16941495
47	26102711	-2176977	18097725
48	27343161	-2213126	19302026
49	28633229	-2248917	20556303
50	29974899	-2284353	21862537

Figure 67: Net present value of balanced nominal cost, income and expenditure for each year over a period of 50 years (2 % annual increase in rent).

NPV BALANCE OVER 50 YEARS

Table	0.02	0.02	0.03	0.03
year	∑expenditure	NPV balance 2	∑ expenditure	NPV balance 3
1	-114275	-5745942	-169748	-5801415
2	-226309	-5653781	-334552	-5762024
3	-336146	-5551255	-494555	-5709664
4	-443830	-5438081	-649898	-5644150
5	-549402	-5313961	-800717	-5565277
6	-652904	-5178584	-947143	-5472823
7	-754376	-5031622	-1089304	-5366550
8	-853859	-4872733	-1227325	-5246198
9	-951392	-4701558	-1361325	-5111491
10	-1047012	-4517722	-1491423	-4962134
11	-1140757	-4320834	-1617731	-4797808
12	-1232664	-4110482	-1740361	-4618179
13	-1322768	-3886238	-1859418	-4422888
14	-1411107	-3647652	-1975008	-4211554
15	-1497712	-3394258	-2087232	-3983778
16	-1582620	-3125566	-2196186	-3739132
17	-1665863	-2841065	-2301968	-3477169
18	-1747474	-2540221	-2404668	-3197416
19	-1827484	-2222480	-2504377	-2899372
20	-1905926	-1887259	-2601182	-2582515
21	-1982830	-1533954	-2695167	-2246292
22	-2058225	-1161933	-2786415	-1890123
23	-2132143	-770537	-2875005	-1513399
24	-2204611	-359079	-2961015	-1115483
25	-2275658	73158	-3044519	-695704
26	-2345312	526918	-3125592	-253362
27	-2413600	1002981	-3204303	212278
28	-2480549	1502157	-3280722	701984
29	-2546185	2025291	-3354915	1216562
30	-2610535	2573263	-3426946	1756851
31	-2673623	3146989	-3496880	2323731
32	-2735473	3747424	-3564777	2918120
33	-2796111	4375564	-3630697	3540979
34	-2855560	5032444	-3694696	4193309
35	-2913844	5719143	-3756831	4876155
36	-2970984	6436784	-3817157	5590611
37	-3027004	7186537	-3875725	6337815
38	-3081926	7969619	-3932588	7118956
39	-3135771	8787298	-3987794	7935274
40	-3188560	9640893	-4041393	8788060
41	-3240313	10531779	-4093430	9678663
42	-3291053	11461386	-4143952	10608486
43	-3340797	12431201	-4193002	11578996
44	-3389566	13442774	-4240624	12591716
45	-3437378	14497717	-4286858	13648237
46	-3484253	15597708	-4331746	14750215
47	-3530209	16744492	-4375327	15899375
48	-3575264	17939887	-4417638	17097514
49	-3619436	19185784	-4458717	18346503
50	-3662741	20484149	-4498599	19648292

Figure 68: Net present value of balanced nominal cost, income and expenditure for each year over a period of 50 years (2 % annual increase in rent).

NPV BALANCE OVER 50 YEARS

Table year	0.04 ∑ expenditure	0.04 NPV balance 4	0.05 ∑ expenditure	0.05 NPV balance 5
1	-224154	-5855822	-277524	-5909192
2	-439687	-5867159	-541833	-5969305
3	-646930	-5862039	-793556	-6008665
4	-846202	-5840454	-1033292	-6027543
5	-1037810	-5802370	-1261611	-6026171
6	-1222049	-5747729	-1479059	-6004739
7	-1399201	-5676446	-1686152	-5963397
8	-1569540	-5588413	-1883383	-5902256
9	-1733327	-5483493	-2071222	-5821388
10	-1890815	-5361526	-2250117	-5720828
11	-2042245	-5222323	-2420493	-5600570
12	-2187852	-5065670	-2582756	-5460574
13	-2327858	-4891327	-2737291	-5300760
14	-2462479	-4699025	-2884468	-5121014
15	-2591922	-4488468	-3024637	-4921183
16	-2716387	-4259333	-3158131	-4701077
17	-2836065	-4011267	-3285268	-4460469
18	-2951140	-3743887	-3406351	-4199098
19	-3061789	-3456784	-3521668	-3916663
20	-3168182	-3149515	-3631494	-3612827
21	-3270483	-2821608	-3736090	-3287214
22	-3368849	-2472557	-3835705	-2939413
23	-3463432	-2101826	-3930576	-2568971
24	-3554378	-1708846	-4020930	-2175398
25	-3641825	-1293010	-4106982	-1758167
26	-3725909	-853679	-4188935	-1316706
27	-3806759	-390178	-4266987	-850406
28	-3884499	98207	-4341321	-358615
29	-3959250	612227	-4412116	159361
30	-4031125	1152672	-4479539	704258
31	-4100236	1720375	-4543752	1276859
32	-4166689	2316209	-4604907	1877991
33	-4230586	2941090	-4663150	2508526
34	-4292025	3595979	-4718620	3169385
35	-4351101	4281885	-4771448	3861539
36	-4407905	4999863	-4821760	4586008
37	-4462525	5751016	-4869677	5343864
38	-4515043	6536501	-4915312	6136233
39	-4565542	7357526	-4958773	6964295
40	-4614099	8215354	-5000165	7829287
41	-4660787	9111305	-5039587	8732506
42	-4705681	10046758	-5077131	9675308
43	-4748847	11023151	-5112887	10659111
44	-4790353	12041987	-5146940	11685400
45	-4830263	13104832	-5179372	12755724
46	-4868638	14213323	-5210259	13871702
47	-4905537	15369165	-5239676	15035026
48	-4941017	16574135	-5267692	16247460
49	-4975132	17830088	-5294374	17510846
50	-5007935	19138956	-5319785	18827106

Figure 69: Net present value of balanced nominal cost, income and expenditure for each year over a period of 50 years (2 % annual increase in rent).

PAYBACK CALCULATION

	∑ income	∑ expenditure	NPV balance
22	6724301	-1145809	-249516
23	0	0	-5828009
			-6077525
		years payback	23.04281333
24	7673541	-2204611	-359079
25	8176824	-2275658	73158
			-285921
		years payback	24.25586682
26	8700239	-3125592	-253362
27	9244590	-3204303	212278
			-41084
		years payback	25.80645999
27	9244590	-3806759	-390178
28	9810715	-3884499	98207
			-291971
		years payback	27.74830227
28	9810715	-4341321	-358615
29	10399485	-4412116	159361
			-199254
		years payback	28.55562139

rdi/%	Payback/years	Initial investment/SEK	Investment cost/SEK
1	23.0	-5828009	-7223334
2	24.3	-5828009	-8391698
3	25.8	-5828009	-9206963
4	27.7	-5828009	-10024946
5	28.6	-5828009	-10527945

Figure 70: Payback calculation of investment when the rent increases 2 % per year.

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