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Feasibility study of modifying Gävle Folkets Hus's ventilation system to improve efficiency

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PREFACE

The members of this project are grateful to those who have collaborated on it, supporting us throughout the execution of the thesis. Without them, the achievement of the goal would have been not possible.

In first place, we want to thank our supervisors, Mr. Roland Forsberg and Mr. Peter Hansson. They have provided us their knowledge and experience in order to guide us along the consecutive stages of the project. They have also furnished us with indispensable material as data, drawings, books and measurement instruments.

We are also grateful to the owner of Folkets Hus, Mr. Fred Funcke, for providing us an office inside the house so we could work on it whenever it was needed. He also gave us energy data of the building and contacted to the housekeepers.

We want to thank Mr. Bosse for support us checking the building and making measurements easier. We are grateful to Mr. Kenneth who provided us essential information about the edifice's ventilation system and gave us keys to access to each room.

Finally, we want to thank you our examiner, Mr. Mathias Cehlin, and the Department of Technology and Built Environment of Högskolan i Gävle for giving us the opportunity to carry out this thesis in this cozy country.

ABSTRACT

As the title of the thesis indicates "Feasibility study of modifying Gävle Folkets Hus's ventilation system to improve efficiency", the target of this project is to suggest improvements on the ventilation system of the building in question in order to enhance energy efficiency of it, focusing on reducing energy losses and optimizing energy consumption. Implicitly, the modifications are also channeled to create an adequate indoor air quality.

"Gävle Folkets Hus", is located in Södra Centralgatan 10, 80250 Gävle, Sweden. The edifice was built in 1946 and some modifications were made in 1980. Inside this 5584 m^2, 5 floors and 300 rooms building many activities are performed: restaurant, theater, offices, etc.

The major parts of the project are explained as follows. Firstly, the whole energy balance of the building is calculated: gains from people, appliances, lighting, sun and district heating and losses from ventilation, transmission and hot tap water. Regarding the calculations of the energy balance, many aspects have been studied such as the ventilation, tap water and heating systems, the analysis of the architectural planes, the thermal transmission coefficients of the materials used in the building, the level of occupation and activities to which the building is submitted and the climatological conditions to which the building is exposed.The total quantity of energy inputs reaches 909,64 MWh and the quantity of energy outputs is 826,41MWh. Inputs varies 10% from outputs which is a reasonable value.

Subsequently, the whole ventilation system is measured so as to identify if the air distribution is adequate. The capability of the ventilation system is compared with the ventilation requirements for new Swedish buildings according to the Swedish Code BBR 2008 and Socialstyrelsen recommendations. High quality equipment from the company SWECO has been used to do these measurements.

Finally, a feasibility study of improving the ventilation system is done. Economic studies of a new ventilation installation and a heating pump are done. It is also considered the possibility of installing presence detectors and electronic fan controllers.

The investments for the three improvements are 1.000.000 SEK, 200.000 SEK and 20.000 SEK respectively. These studies improve the energy efficiency and therefore, produce benefits. The whole new ventilation installation has a Net Present Value (NPV) of 169.933 SEK, being the payback in 11 years. Concerning the heating pump, NPV is 15.448 SEK and its payback is 8 years. Finally, the installation of detectors has a NPV of 60.528 SEK and its payback is only 1 year.

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1. INTRODUCTION

1.1 GLOBAL VIEW

1.1.1 WORLD ENERGY

Nowadays the total world consumption is more than 110.000 TWh, and it still vastly dominated fossil fuels, which exceed 80%. Oil is the most important of them, around 37%, followed by coal and natural gas, which both surpass more than 24%. The proportion of renewable energy is almost invariable during the last 10 years contributing a 7% of the total. Nuclear energy supply represents the 5% remaining [1]. World energy supply distribution is shown in the next figure:

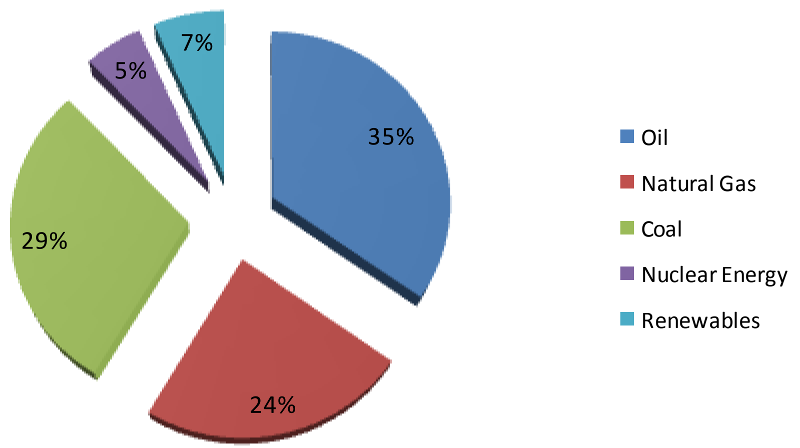

Figure 1: World Energy Consumption by fuel [1]

By the next figure2 [28] it is possible to see the evolution of energy consumption in the last 2 decades distributed by sectors. As it is possible to see, both Transport and Industry sectors rose especially during the last 10 years, up to around 56% for both. However, Residential and service has risen more than the other two, and nowadays it represents around 36% of the overall energy. In subsequent chapters this last sector will be analyzed, since our study is included in this sector. The rest energy uses still with 9%.

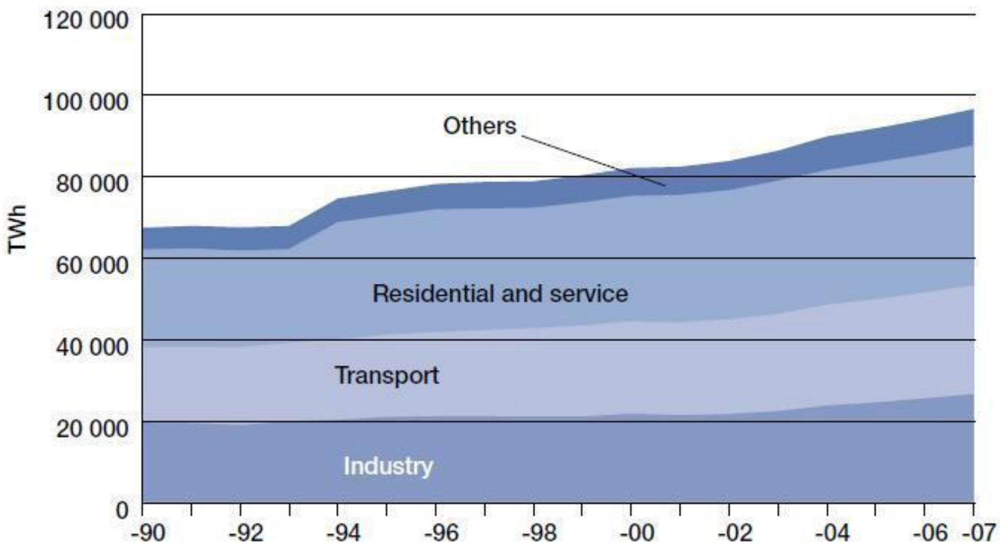

Figure 2: World Energy Consumption by sector, 1990-2007 [28]

By figure 3 [24] it is possible to analyze the evolution of CO_2 world emissions (CO_2 emissions to total primary energy consumption TPES) since 1990, where it can be seen a total raised of it about 2% per year due to the carbonization from countries like China (1,07% per year) or India (1,09% per year), some of the major contributors. And without the participation of the large developed countries like these "*it was impossible to reduce the world's emissions of greenhouse gases*" [24]:

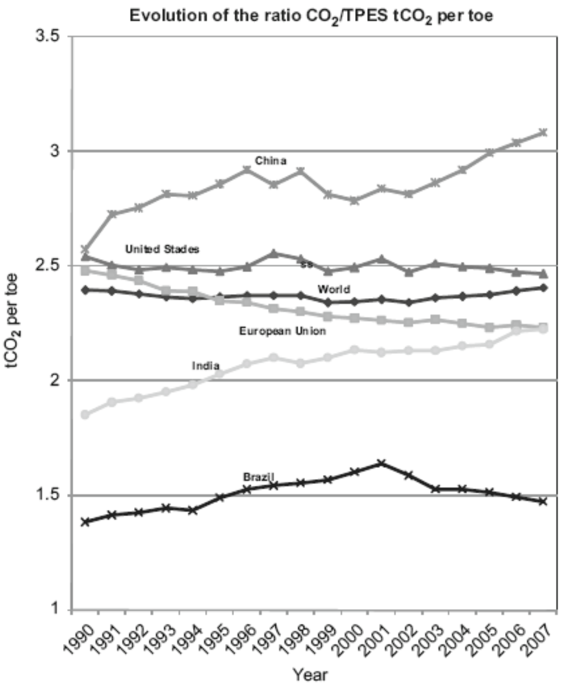

Figure 3: Evolution if the ratio CO_2/TPES (tCO_2 per toe) [24]

1.1.2 SWEDEN ENERGY SITUATION

1.1.2.1 ENERGY CONSUMPTIONS

On one hand, next figure 4 [3]shows the percentages of energy supply from different energetic origins in Sweden in 2009. The total energy supply is 568 TWh, it means 5% of the total world energy supply.

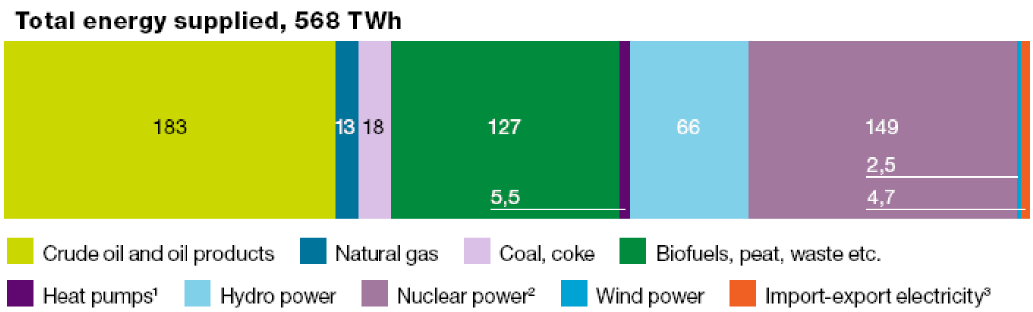

Figure 4: Supply of energy in Sweden 2009, by fuel (TWh) [3]

Using percentages, by the next figure:

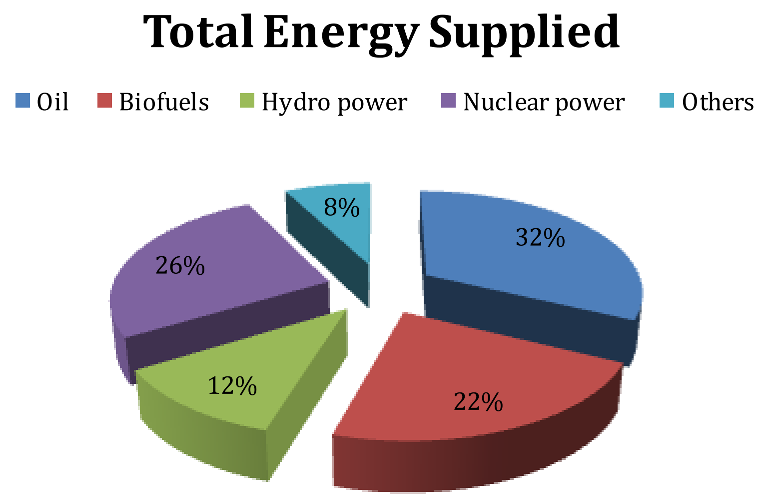

Figure 5: Supply of energy in Sweden 2009, by fuel (%)

As it is possible to see, in comparison with world energy consumption it is striking the high percentage of biofuels, which represents 22% of the total, and Nuclear power with 26%. Moreover, both Natural Gas and Coal only supplied around 3% of the total.

On the other hand, the total final energy amounts 376 TWh, and therefore, the difference between supply and final use, that is 192 TWh, correspond to energy losses by energy conversion and distribution. Figure 6 shows the final application of energy classified by sector and the quantity of every kind of energy used in each one. The total final energy Industry uses 134 TWh, transport does 93 TWh and finally residential and services consumes 149 TWh[3].

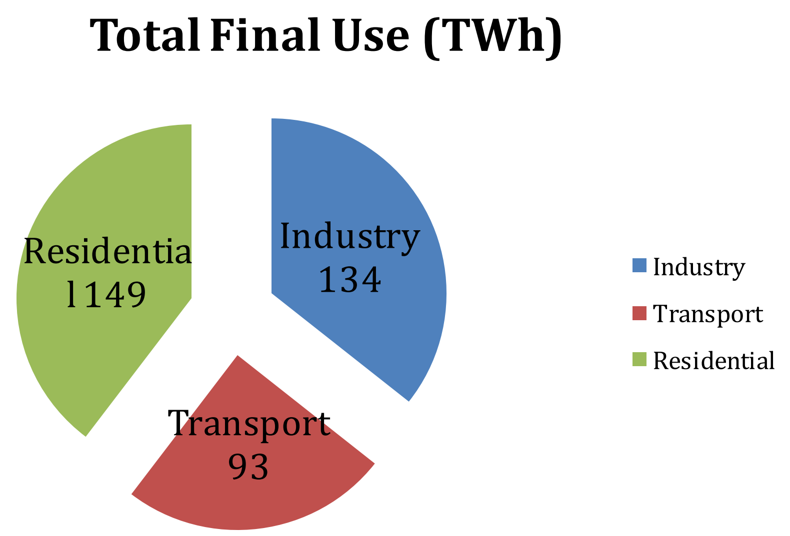

Figure 6: Use of energy in Sweden 2009, by sector (TWh)

Observing an historical diagram of the Sweden's entire energy uses, figure 7 [3], one can see that the total amount had been rising irregularly from 70's until 2007. Regardless the ambient temperatures, it is already corrected on the graphic for climate conditions in order to be able to compare energy use from one year to another.From then, a remarkable decrease started that affects practically all sectors. It is early to say whether this is just a cyclical effect that usually occurs every 7-8 years, or this is a importance decrease for strong changes in energy uses.

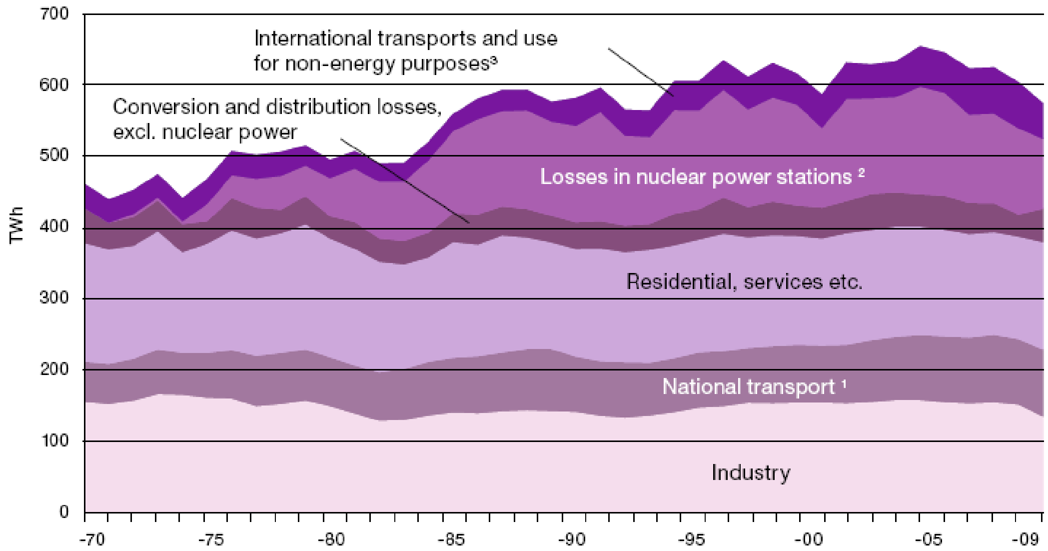

Figure 7: Total energy use in Sweden by sector, 1970-2009

The principal energy carriers for the residential and service sector are electricity and district heating. Variations in energy use are due partly to temperature differences from one year to another.

- Swedish energy policy:

To minimize the environmental problems, in 2009 the Swedish Parliament (the Riksdag) adopted an integrated energy and climate policy. The Government's climate and energy policy targets by 2020, taking 2009 as a reference, are: 40% of reduction in greenhouse gas emissions; at least 50% of renewable energy; 20% more efficient energy use; and at least the use of 10% of renewable energy in the transport sector [9]. For achieve that, for example, a carbon taxation of fossil fuels was introduced in 1991, with 0,25 SEK/Kg of CO2 and has risen to about 1,05 SEK/Kg in 2009 [10].

1.2 THE RESIDENTIAL AND SERVICE SECTOR

Particularly in residential services sector the principal energy carriers are principally electricity with a 50%, secondly district heating with a 31%, and finally Biofuels and Oil with around 10% each one [3]. The total amounts in TWh can be seen in the following graphic (figure 8). In this sector are included residential buildings, holiday homes and non-residential premises (excluding industrial premises). Therefore, the building under study contains as part of this sector, and it will be exhaustively studied.

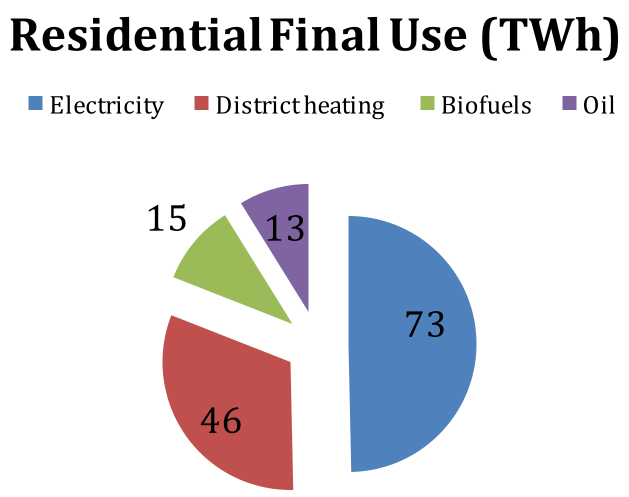

Figure 8: 2009energy uses in residential sector in Sweden (TWh)

As it was said previously (see figure 6), the percentage of energy use in the residential and service sector is 39% of Sweden's total ultimate energy use, amounting 149 TWh in 2009. And of this quantity, about 87% is used in residential buildings and non-residential premises.

In this sector, about 60% of the energy is employed for space heating and domestic hot water production. Particularly in space heating for non-residential premises and public buildings such the building under study, district heating is the main source of heat with a 68%. An 6% of this floor area is heated by electricity only and about 2% by oil alone. In absolute terms, district heating amounted to 14,8 TWh, electric heating did 2,9 TWh, 0,8 TWh concerning oil, gas reached 0,3 TWh of gas and biofuel amounted to 0,5 TWh. [3]

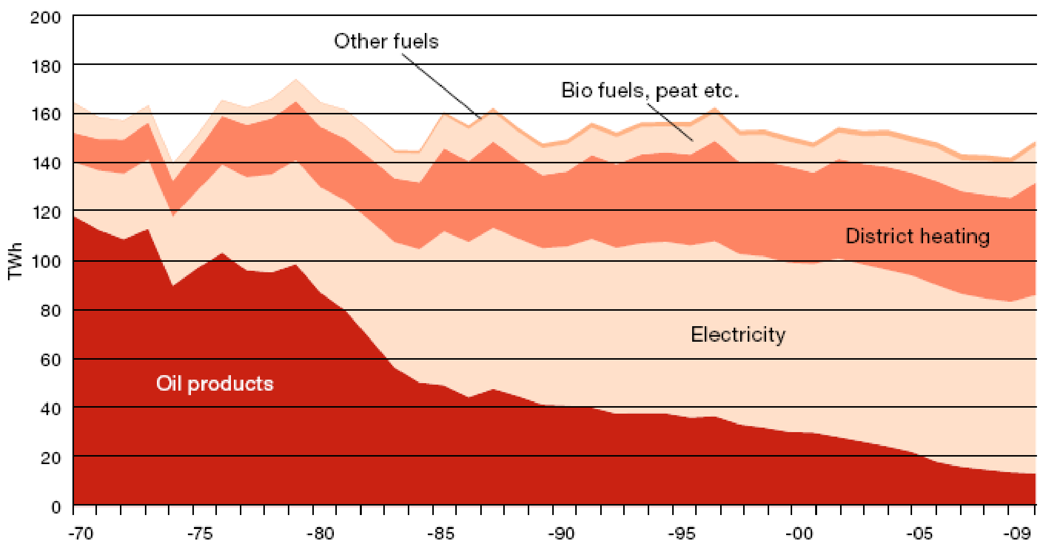

Figure 9: Final energy use within the residential and service sector in Sweden, 1970-2009

In figure 9 [3], it is possible to see the energy amounts of the different final energy carriers since 1970. In the last 30 yearshad no important alteration in spite ofthe large amount of years, the total heated floor area of commercial premises is greater and population numbers have risen. Therefore, the sector has been reducing its use of energy to some extent since 1970, by continues system improvements and replaced of oil by district heating or electric heating. That provided high efficiency in the point of use (energy "ready for use") but cause more conversion losses that are no considered in the last graphic.

The increasing in numbers of heat pumps could be another reason for the reduction in energy use in the sector. Heat pumps deliver about three times as much thermal energy as they use in the form of electrical energy. Therefore their use reduces the metered use of energy for space heating and domestic hot water production in buildings.

Other important factor that reduces energy use for space heating and domestic hot water production in residential buildings and non-residential premises includes various building measures, such as retrofitting additional thermal insulation or upgrading windows in older buildings.

On the other hand, by the figure 10 [3] is checked the evolution of the electricity use in this sector:

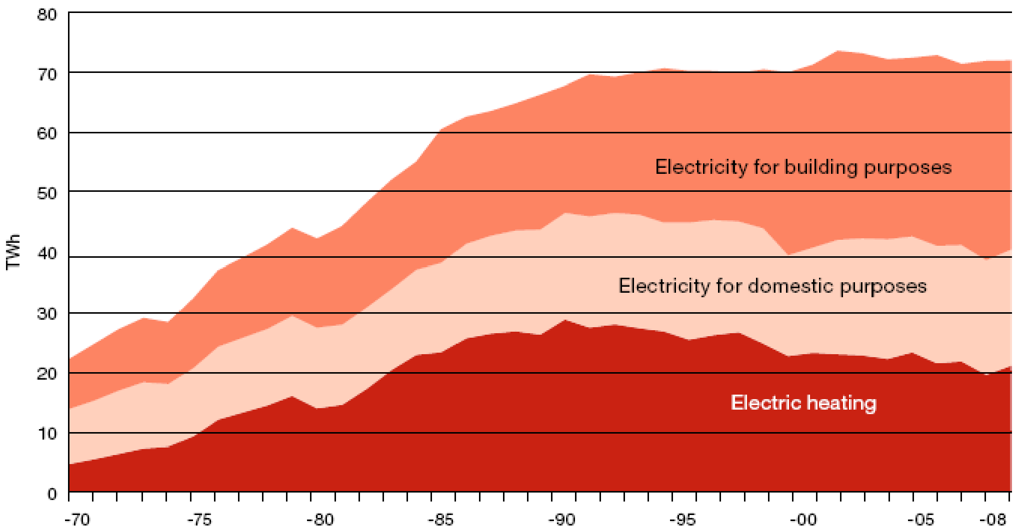

Figure 10: Electricity use in the residential and services sector in Sweden, 1970-2008

The amount of electricity used have increased until 1990 with 70 TWh, and this value remained more or less constant until nowadays. The amount of electricity for space heating have been decreasing every year in part due to the replacement of it by district heating, as it will be analyzed subsequently. On the contrary the amount of electricity for building purposes have been increasing every year, compensating the reduction of electric heating uses and keeping the total amount of electricity in the sector constant, and this is the highest amount of the total. A possible explanation for this could be the increasing concern for achieves a good indoor climate, in which it is included ventilation conditions (higher ratings or longer running times), increasing the amount of electricity used for it.

In order to obtain more details about the use of energy and electricity in different uses such as lighting, ventilation and appliances in non-residential building of the sector, the Swedish Energy Agency started an investigation in 2005 in about 1000 different buildings, called STIL2 [4]. In it, it is possible to obtain data about offices building, very useful in our project since the elevated number of offices in it. As the research show, the use of electricity is 102 KWh/m^2, which main part is due to the 21% of lighting, and ventilation also consumes major use of electricity, amounting a 17% in offices. Therefore, ventilation is an important point for further improvements in efficiency of electricity consumption and for saving resources. In subsequent chapter, the project will focus in these enhancements.

1.2.1 POLICY MEASURES AND INCENTIVES

Many policy measures are introduced in this sector, since "*the residential sector consists of a large number of consumers with similar equipment, and can therefore be considered to be fairly homogeneous. Due to this uniformity and simplicity in demand structures (the major end uses are considered to be well known to 'everybody'), this sector is the principal focus of most energy policies*." [23]

In this way, several policy measures and incentives have been introduced for the purpose of accomplishes the targets in the country's energy and climate policy. These measures can be divided into: "*Economic policy measures*", which consist of taxes and fees; "*Information*", that can effect changes in behavior and attitudes, but the desired changes are voluntary; "*Research, development, demonstration and commercialization activities*" can also be said to be form of long-term policy measure, due to the knowledge of the effects of changes are essential if we are eventually to achieve energy and environmental objectives; which are controls in form of prohibitions or requirements either quantitative or technical. Some examples of *Administrative policy measures* are:

- **Building regulation**

Regulations governing the energy efficiency of buildings are administrative policy measures, and a whole range of policy measures is used for the purpose of improve energy conservation and management in buildings. The regulations include specific requirements for energy use in buildings. For that, only new buildings must be designed and constructed to achieve lower heat losses and cooling requirements, high efficient use of heating and cooling, and higher efficient use of electricity. The National Board of

Housing, Building and Planning's Building Regulations are an example of these measures.

- **Energy declarations:**

Based on a directive 2002/91/eC from EU, *Act Concerning Energy Declarations for Buildings* is another administrative policy measure with the objective of improving efficient energy use and good indoor environmental conditions in buildings. In it, it is specified that owners of detached houses, apartment buildings and commercial premises are required to provide information in an energy declaration on the buildings' energy use. The energy certificate in Sweden needs:

- Sum of measured delivered annual energy in KWh/m^2
- Measured delivered electricity use in KWh/m^2 stated separately
- Obligatory Ventilation Control (OVK) – Yes/No
- Voluntary radon gas measurement(s) – Yes/No
- Recommendations cost-effective energy measures
- Misc. building info

Concerning the second point, measured delivered electricity is the one used for pumps, fans and external lighting in the case of buildings heated by non-electricity.

- **Tax reduction for small-scale building work**

By these tax reductions, several energy saving measures can be tax deductible, reducing the number of building work by no-legal ways and to increasing the demand for legitimate building work.

ROT- deduction (valid for Swedish citizens only) means that you can apply for a tax credit amounting to 50 % of the labor cost, maximum 50.000 Kr/year and part owner. If you are two part owners the total tax credit possibility is 100.000 Kr/year. Ideal time to replace windows and reduce your heating bills at the same time [16].

The ROT deduction is only for private building owners, not for commercial building owners as Folkets Hus.

- **Grants for conversion of heating systems**

The main purpose is to reduce the use of oil, support efficient and environmental use of energy, as well as to reduce the use of electricity for heating purposes in residential buildings. By these grants, owners of properties having direct electric heating can receive a grant for the conversion of heating systems to district heating, to rock, earth or lake water heat pumps, or to fuelled boilers.

About *information*, since 1998, local authority energy and climate advisors have provided cost free information and advice to domestic consumers on ways of improving their efficiencies of energy use. The parts of the Building Regulations concerning energy conservation (BFS 2008:20, BBR 16) were revised on 1st February 2009 so that, for example, buildings must make better use of their energy input. On 2nd July 2009, the Government published a new Ordinance requiring public authorities and courts to improve their efficiencies of energy use, with effect from 1st September 2009. The Swedish Energy Agency is responsible for coordinating and assisting this work. These measures are intended to achieve the target set by the Energy Services Directive, and also have a beneficial effect on achieving the climate target.

In the other hand, to reduce the environmental impact of energy use in residential buildings and commercial and public premises is other objective, i.e. providing a good built environment. But to achieve that is complex and with many different aspects. The target is to reduce specific energy use of heated areas by 20 % by 2020, and by 50 % by 2050 [3]. This is to be achieved through improvements in the efficiency of energy use reducing the need for energy input, and by increasing the proportion of energy provided from renewable sources.

The prediction for 2020 says that this objective will be very difficult or impossible to achieve. However, the target for reduced energy use in buildings could be achieved if additional actions are taken.

1.3 DISTRICT HEATING AND DISTRICT COOLING

District heating can be defined in technical terms as the centralized production and supply of hot water, distributed through a piping system and used for the space heating of buildings. At customer level the heat network is connected to the central heating by heat exchangers, and the water used in the district heating system is not mixed with the water of the central heating system.

In Sweden, the first municipal district heating system was in Karlstad in 1948 [6]. It has been used since around 1950 because of in the second half of the 1940s Sweden authorities considered district heating as a good way of increasing electricity production in the country by providing a heat sink for combined heat and power, producing both electricity and heat for the hot water distribution system. The use of district heating grew during the followings years as a result of the extensive investments in new housing in conjunction with the need of modernization or replacement of boilers. Nowadays district heating is the commonest form of heating for apartment buildings and commercial and the main form of heating in 245 out of 290 country's municipalities.

Historically, until the beginning of the 1980s most district heating plants were owned by local authorities, but 130 companies supply about 98% of the country's district heating production nowadays [8], and the local municipality owns most of those companies.

One of district heating's advantages is its flexibility in respect of choice of fuel. As can be seen in the figure 11 [5], in 1980, the 90% of the fuel input for district heating plants was oil.

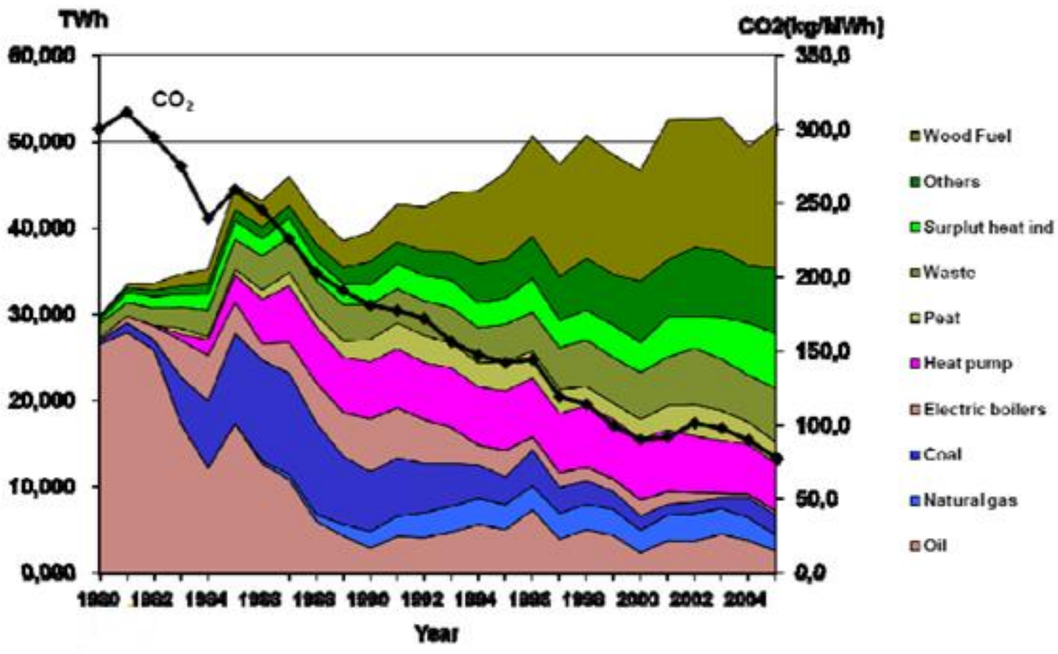

Figure 11: Energy amounts for District heating over the years, and CO_2 emitted

Nowadays, the fuel mixture is more varied, with renewable choices like biofuels, being the main energy source. If it is compared the Swedish' district heating system with the system one from other countries, the use of fossil fuels (i.e. oil, coal and natural gas) in the actual Swedish District Heating sector is very limited, as can be seen in the previous figure, and they are only used for peaks in the demand. "The major reasons for this are the lack of such resources domestically in Sweden and the active Swedish policy-making discouraging fossil-fuel use"[7].

Since Sweden has a lack of fossil fuels it is impossible to keep under control the prices of these resources and by analyzing figure 12, it is clear to see the general raise of prices in the last years, and the strong changes in short periods due to international events, becomes Sweden as a mere observer.

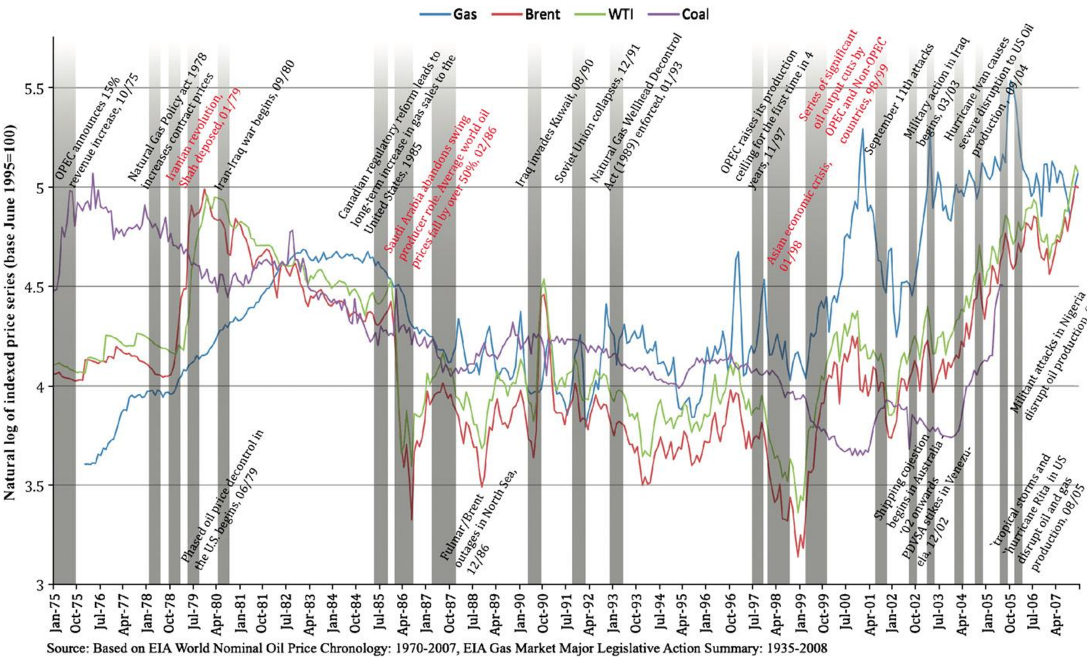

Figure 12:Energy market institutional background [22]

In terms of environment, by using district heating, contaminant emissions as sulphur dioxide, particulates, soot and nitrogen oxide are reduced. Therefore the air quality in urban areas is improved. This has been accomplished because district heating plants have advanced flue gas cleaning instead of individual boilers. In addition to this, a high reduction of CO_2 emissions is achieving, improving the environment situation with a reduction of the carbon footprint.

Energy policy has favored district heating through various forms of state support, as for example grants for the extension of existing district heating systems and the connection of group heating systems and even individual buildings to existing systems. Until the 1st of March 2007, a conversion grant was available for changing from oil heating to heating from district heating, rock, lake water or earth heat pumps as well as biofuel-fired boilers, as we said before. Grants are still available for conversion from direct electric heating to one of the above alternative systems.

Obviously, district heating requires an expensive infrastructure and has a high cost of replacing systems. Consequently, customers are dependent on their supplier company. However, if the energy prices are studied, the heating market can be regarded as a competitive one. In figure 13[3] one can see that the price of district heating (domestic heating on the graphic) is very low in comparison with other energy solutions.

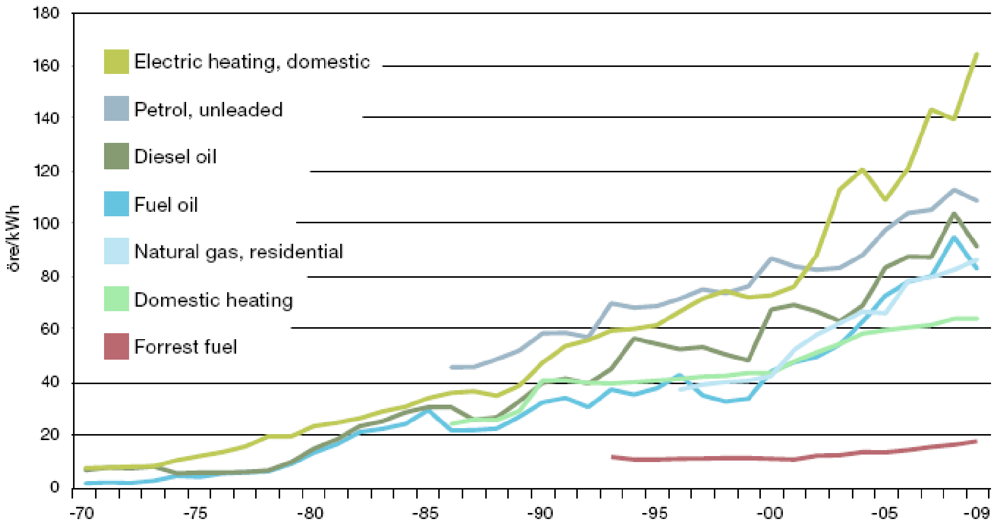

Figure 13: Commercial energy prices in Sweden, including tax, 1970-2009

Analyzing the graphic, it is very striking the hard rise of electric heating price in the last 10 years, period in which it have increased its price a 100%. That is one reason for the decreased of the use of electricity for heating purposes, as it was analyzed previously (see figure 10).

As price is not the unique important point in good supply energy system, a strict legislation is applying to all who produce or supply district heating. It is intended to reinforce the position of district heating customers, increasing the transparency of district heating production and supply activities. The requirements relate primarily to the relationship between companies and their customers. In this law, appears the District Heating Council, who will arbitrate between district heating companies and individual customers if they cannot agree in contract conditions. This council is an independent organizational unit within the Swedish Energy Agency. Moreover, in order to achieve a high protection for the customers, the new law prevent from an interruption of their supplies.

The District Heating Market is very complex, and for assist consumers in obtaining a price overview, Energy Markets Inspector has published new regulations that describe companies' liability to provide pricing information, and how such information must be provided.

Nowadays, over52 TWh[3] of district heating are supplied, and about 46 TWh (see figure 8) of them (that represents a 90% of the total) are for residential and service sector, mainly for heating purposes. District heating supplies over half of the total heating requirement of residential and commercial premises in Sweden, with more than 600 district heating systems in all Sweden:

It is the commonest form of heating in multi-family buildings, supplying heat to about 82 % of the heated floor area, whereas about 66% of commercial premises are heated by it. In detached houses, on the other hand, the proportion is only about 9 % [5].

Figure 14: Location of district heating plants in Sweden

1.4 BUILDING STUDY

1.4.1 LOCATION

The building in question, "Gävle Folkets Hus", is located in Södra Centralgatan 10, 802 50 Gävle, Sweden. The edifice was built in 1946 and some modifications were made in 1980.

Figure 15: European map

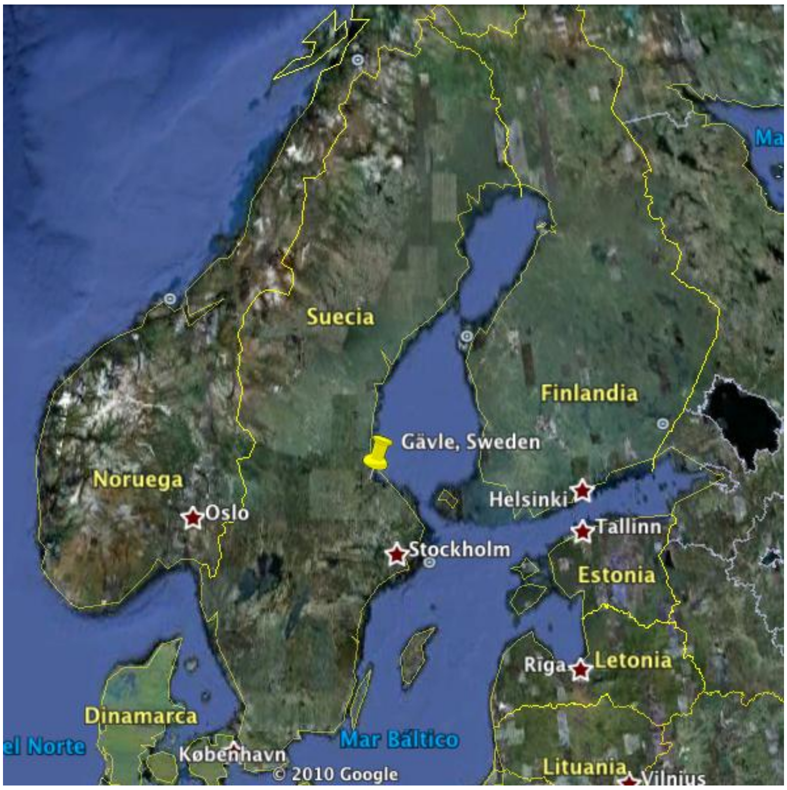

Figure 16: Swedish map

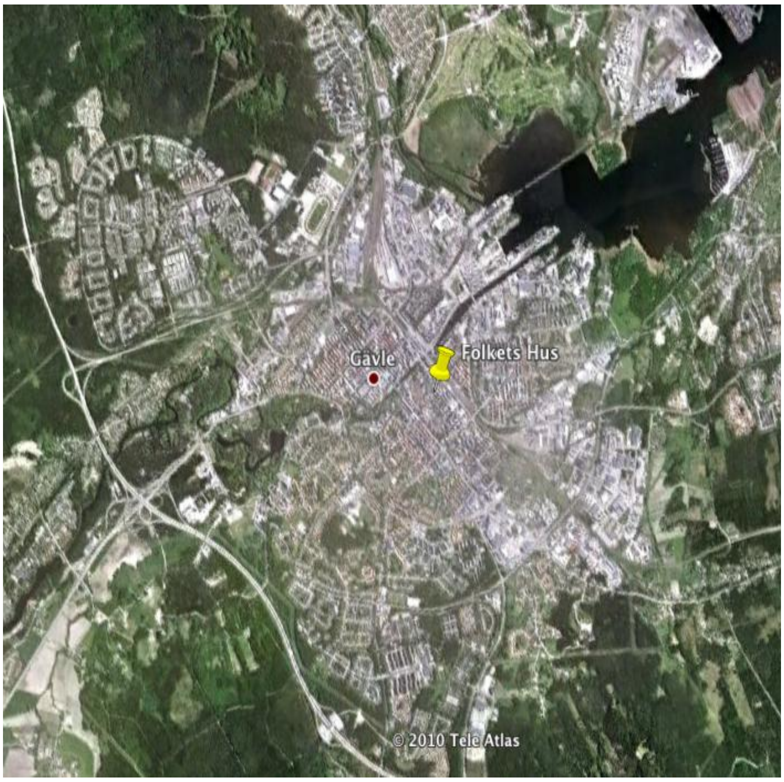

Figure 17: Gävle

Figure 18: Folkets Hus

1.4.2 AREA

The building has a heated area of5584 m^2distributed in 5 floors, basement, ground floor and three more floors upstairs.

1.4.3 USES

Inside that building many activities are performed. The owner of the building rents out all the offices that his company does not need. Local radio station, politic organization and blind organization are some of the renters.

However, Folkets Hus is known for his theatre and his meetings rooms where a lot of companies decide to do conferences.

1.4.4 STRUCTURE

The information about the building under study provided by the government is incomplete due to the age of the edifice. Moreover, the companies that worked in it don't exist anymore. The last updated drawings were made in 1970, and only a plan of constructive details of the corner re-built zone rebuild is found. As a result, some parameters have had to be estimated by using bibliography about typical structure construction in Sweden in the period when the building was built.

1.5 PURPOSE

"Gävle Folkets Hus" was built in 1946 and partially rebuilt in 1980. By that time, energy savings and indoor air quality were not as important as they are now for the builders. In the last decades, many studies have been devoted to improve the energy efficiency in buildings and offer an adequate environment to the users. Thus, the emblematic "Gävle Folkets Hus" is not up to date to the current standards of energy saving and indoor air quality as the new buildings are. It is also important to take into account that there is a Swedish Code, BBR, which imposes the minimum environment requirements to new buildings. However, as the building in question is an old one, old building code is valid for Folkets Hus.

That said, the project is a viability study of modifying the ventilation system with the intention of enhancing energy efficiency and indoor air quality as well as accomplish the requirements of the Swedish Code. Moreover, this project could be useful to further studies about "Gävle Folkets Hus" as it is found a calculated energy balance of the entire edifice.

1.6 TIMING

In the annex 7.5 is found the timing of the project, which the main for parts of it are differentiated.

- Gather information: weeks 40 to 42.
- Calculate energy balance of the building: weeks 42 to 48.
- Measure the ventilation system: weeks 48 to 1.
- Study and propose modifications: weeks 2 to 6.
- Revision: weeks 7 to 10.
- Write the manuscript: weeks 51 to 11.
- Presentation: week 12.

As it is shown, the project has been elaborated in 25 weeks.

1.7 LIMITATIONS

The main limitations found in this project are due to the lack of data and its deficient quality. The drawings provided were old, not updated and in a non-digital format so all the measurements were made by hand making them inexact. In the drawings, it is also missed half first floor so the parameters have been extrapolated from the second floor because the distribution and activities are similar between the two of them. Furthermore, there is not any schema of the ventilation system inside the building so the distribution of the ducts has been estimated by the ventilation parameters in each room.

Apart from the drawings, it has been not possible to find sufficient information about the building. The only data supplied belonged to the district heating and water consumption; there was no information about building materials, electricity consumption, modifications on structure or systems etc. As a consequence, many parameters have been estimated taking as reference similar buildings.

It is also important to remark the lack of availability of the owner of the building as well as the housekeepers. This fact has meant numerous impediments to access to the rooms and delays receiving critical information. Consequently, the numerous setbacks encountered have enlarged the overall duration of the project and overload the amount of work during the last weeks.

1.8 METHOD

The first weeks of the project were appointed to gather information about energy balances in buildings, IAQ and ventilation systems as well as data, statistics and drawings concerning Gävle Folkets Hus.

After setting the main purposes together with the owner of the building and the supervisors, the calculation of the energy balance was initiated. Along the next weeks all the rooms were checked making a note of the appliances, people and activities exerted in them. Simultaneously, the whole structure and the facades were examined in order to calculate the energy exchanges through them. Energy losses from hot tap water were also estimated.

The next step was measuring ventilation parameters of the whole ventilation system. All the ventilation devices were measured by using high performance measurement instruments from SWECO. After gathering all this data the estimation of the ventilation losses was possible.

After completing the whole energy balance and revising the ventilation system, the study of improving the air quality and efficiency was begun. After receiving the budgets for a new installation and heating pump economic studies were made. The installation of presence detectors and electronic fan controllers was also studied.

It is important to say that along the extent of the entire project, many meetings with the supervisors have been arranged as well as continuous communication with them via email. The supervisors also revised the whole project accurately before its presentation. This two-way feedback permitted to control the trajectory of the project at every moment.

2. THEORY

2.1. VENTILATION SYSTEM

The primary purpose of HVAC engineer is to provide a comfortable and healthy indoor environment for building occupants. Control of internal and external sources of pollutants, removal of unacceptable air, occupants' activities and preferences, supply of acceptable air, thermal regulation and proper construction, operation and maintenance of building systems are factors that influence the comfort and indoor air quality (IAQ).

Ventilation and infiltration take part only of the acceptable thermal comfort and indoor air quality problem. These aspects must have been taken in to account for HVAC designers, occupants and building owners.

2.1.1 INDOOR ENVIRONMENTAL HEALTH

The Human health and illness that are determined by factors in the indoor environment are included for the indoor environmental health. The theory and practice of controlling indoor environment and assessing factors that can potentially affect health are also referred by indoor environmental health. Chemical, biological, physical and ergonomic risks have to be evaluated and really considered for the practice of indoor environmental health. Design, operation and maintenance of buildings and their HVAC systems affect significantly the building occupants health. That is the main reason why engineers have to understand perfectly the fundamentals of indoor environmental health. In many cases, buildings and systems can be designed and operated to reduce the contact between potential risks and occupants. Unfortunately, if one doesn't consider the environmental health can guide to conditions that worsen or even create new dangerous risks.

2.1.1.1 BACKGROUND

The workplace air pollutants, the occupational health is the area most clearly defined of indoor environmental health. Evaluations of the exposure incidents and laboratory studies with humans and animals have created a reasonable accord on workplaces, to determinate if they are safe or not for around 1000 chemicals and particles.

Therefore, many countries regulate how the workers are exposed to these agents. However, the concentration of chemicals that meet occupational health criteria is normally higher than the levels found in nonindustrial spaces like schools, offices and residence. Where the exposure can be longer and can involve a mixture of many contaminants.

The most accepted definition of health, illness, and discomfort is given by the constitution of the World Health Organization (WHO): "*Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity."* Concerning the comfort, there are a few definitions as well. Comfort includes both perception of the environment and the response to its' implications. The perception is if the environments its' hot/cold, humid/dry and the response encompasses if its' too hot, too cold and so on. Occupant response is taken to represent the acceptability, it may be a more useful concept because permit the progress to a concrete aim. Acceptability is the base of a number of values covering regions and cultures, and may change when the expectations change.

There are two new types of diseases identified related with exposure to indoor air: sick building syndrome (SBS) and building related illness (BRI). This is because concern about the health effects connected with indoor air has increased in the recent decades. Building occupants complained about poor health associated with exposure to indoor air and those complaints were reported.

SBS includes a number of adverse health symptoms related to occupancy in a building, with mucosal irritation, fatigue, headache, lower respiratory symptoms and nausea. There is no exactly definition of SBS but the most accepted define it as acute discomfort that persist for more than two weeks and a substantial percentage of complaints relief once one leaves the building.

2.1.1.2 THERMAL COMFORT

Providing conditions for human thermal comfort is a principal purpose of HVAC. Human satisfaction involves many inputs influenced by physical, physiological and other processes. In these following lines it is explained a summary of the fundamentals of human thermoregulation and comfort. Engineers have to take it into account these things for operating systems and designing for the comfort and health of building occupants.

Comfort happens when body temperatures are compressed within thin ranges and skin moisture is low.

Building occupants reduce the discomfort sensation by changing their behaviors' like altering clothing, altering activity, changing posture or location, changing the thermostat setting, opening the window, complaining or leaving the space.

Surprisingly, the temperature that people take for the thermal comfort under similar conditions of clothing, humidity and air movement is more or less the same and it not really depends on the geography, climates, living conditions and cultures differ widely all over the world.

2.1.1.3 HUMAN THERMOREGULATION

Body regulates the heat dissipated and regulated to keep normal body temperatures. One suffers overheating if the heat loss is insufficient (hyperthermia) and suffers body cooling if the heat loss is excessive (hypothermia). To talk about some range temperatures, it has to be known that skin temperature greater then 45°C causes pain, as well as skin temperatures less than 18°C. Between 33 and 34°C is the skin temperature associated with comfort, and decrease once the activity increase. In contrast, internal temperature rises with the increasing activity. [17]

2.1.1.4 SUSTAINABILITY RATING SYSTEMS

Good indoor air quality is the main point to maintain health and high productivity. Therefore, sustainable buildings rating systems place a great importance on creating and maintaining acceptable IAQ (indoor air quality). There is a rating system called LEED (Leadership in Energy and Environmental Design) that was the first developed to focus in IAQ problems.

2.1.2 BASIC CONCEPTS AND TERMINOLOGY

Outdoor airflow through a building dilutes and removes contaminants. However, it is necessary to condition this outdoor air, and it may takes an important portion of the total conditioning load. For proper design of the HVAC equipment and evaluation of energy consumption it has to be known the magnitude of outdoor airflow into the building. In fact, proper ventilation and infiltration airflows are important for providing comfort for occupants, especially for buildings without mechanical cooling and dehumidification. In addition, airflow between zones affects fires and the movement of smoke.

2.1.2.1 VENTILATION AND INFILTRATION

Ventilation and infiltration are two different ways of air exchange between outdoor air and air already in a building.

Ventilation is the intentional introduction of outside air into a building, subdivided into natural and mechanical ventilation. Natural ventilation is the introduction through open windows and doors, grilles and other penetrations and it is driven by pressure differential, natural or artificially produced. Mechanical or forced ventilation, as it is shown in Figure 19 [17], is the intentional movement of air using fans to supply or exhaust vents.

Infiltration and exfiltration are the flow of outdoor air into or out of a building through cracks and other unintentional openings and through the normal use of exterior doors for entrance and exit.

Infiltration and exfiltration are driven by natural or artificial pressure difference.

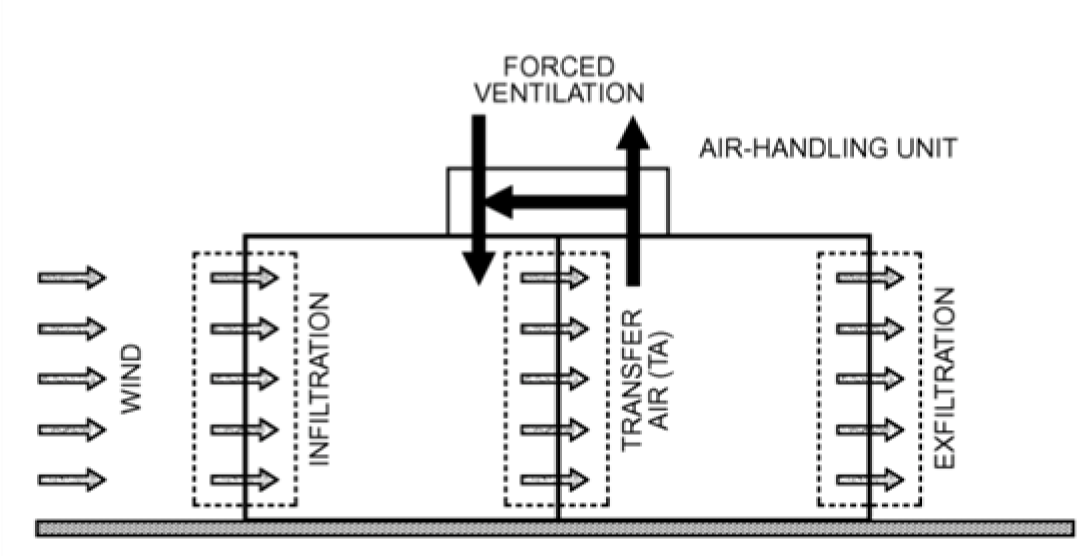

Figure 19: Two-Space Building with Mechanical Ventilation, Infiltration and Exfiltration

Ventilation and infiltration vary considerably in how they affect energy consumption, air quality and thermal comfort. Both can differ with weather conditions, use and building operation. Ventilation is expected to dominate in front of infiltration but all must be considered in the design and operation of an HVAC system.

2.1.2.2 VENTILATION AIR

As it is said indoor air quality depends on ventilation air. This ventilation air may be mechanical or natural ventilation, infiltration or exfiltration, transfer air or a combination of them.

Buildings should be air tight for ventilation to work properly. Nowadays, new buildings have mechanical ventilation and are pressurized to reduce infiltration.The main point of mechanical infiltration is the control of air exchange when the system is correctly designed, installed and operated. It is easier to provide acceptable IAQ and thermal comfort. This is not the case of Folkets Hus since it has no proper ventilation system for the 1^{st}, 2^{nd} and 3^{rd} floors.

In commercial and institutional buildings, natural ventilation is supposed to be a problem in terms of energy conservation and comfort. Therefore, in these kinds of buildings, if there is a mechanicalventilation, the use of an heat exchanger helps in terms of taking advantage of warmindoor air.

Occupants can control air contaminants and interior air temperature using the natural ventilation, especially through operable windows. The point is that this outside air from natural ventilation can have an additional energy cost if it has to be heated.

If there are no operable windows, small exhaust fans should be placed at least in kitchens and bathrooms. If the exhaust air has to be vented to the outside depends on local building codes.

2.1.2.3 FORCED-AIR DISTRIBUTION SYSTEMS

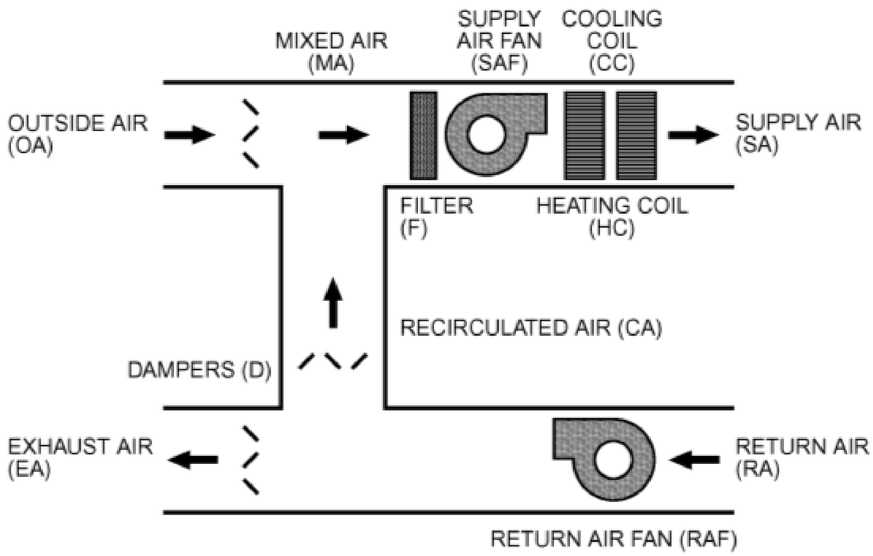

Figure 20: Simple All-Air-Handling Unit with Associated Airflows

Figure 20 [17] shows and example of air distribution with forced air systems. It is a simple air handling unit that conditions air for a building.

RA (return air) is air coming from the conditioned space and it is sent back to the air handler. RA is partly vented to the environment, EA (exhaust air), or reused, CA (recirculated air). OA (outside air) is air brought into the system and it may need treatment to be used in a building. MA (mixed air) is the combination between OA and RA and both, after being conditioned are delivered to the conditioned space as a SA (supply air). It has to be said that the new Swedish code forbids the air recirculation.

2.1.2.4 ROOM AIR MOVEMENT

IAQ and comfort are also determined by the air movement within spaces, due to the diffusion of ventilation air. Displacement flow and mixing flow are two different patterns to typify air movement in rooms.

Displacement flow, shown in Figure 21 [18], is the one which mixing air takes place out of the occupied zone. This fact is desirable for removing pollutants that already exist in a room. Displacement flow is produced by a laminar-flow air distribution system that sweeps air across a space.

Mixing flow is shown in Figure 22 [18]. In this type of ventilation, supply and exhaust devices are normally situated reaching the ceiling. The position of these devices causes a very poor mixing in the room because much part of the supply air is vented outside without mixing with room air. The lack of mixing flow is called short-circuiting flow. It has to be really well designed, installed and operated to avoid short-circuit.

Ideally, the mixing would be perfect. To obtain the uniform mixing the supply air has to be instantly and evenly distributed. With mixing flow systems that have a good mixing and with displacement flow that permits the correct mixing it can be possible to get the uniform mixing.

Figure 23 [18] shows a hybrid method of conditioning and ventilating spaces. It is known as underfloor air distribution (UAD). Supply air is introduced through the floor. Floor diffusers delivered this supply air and encourage air mixing near the floor to acclimate it. Once the supply air is mixed, it moves vertically through the space to the exhausts located near or in the ceiling. This vertical movement of the air is in the same direction than contaminants created by occupants and equipment. UAD system has floor to ceiling displacement flow and a perfect mixing.

For evaluation of IAQ and thermal comfort, the room space is divided in two different zones: occupied zone and remaining volume of the space. Occupied zone is defined as the lowest 1,8 m of the room but sometimes layers near the ground and walls are not taken into account.

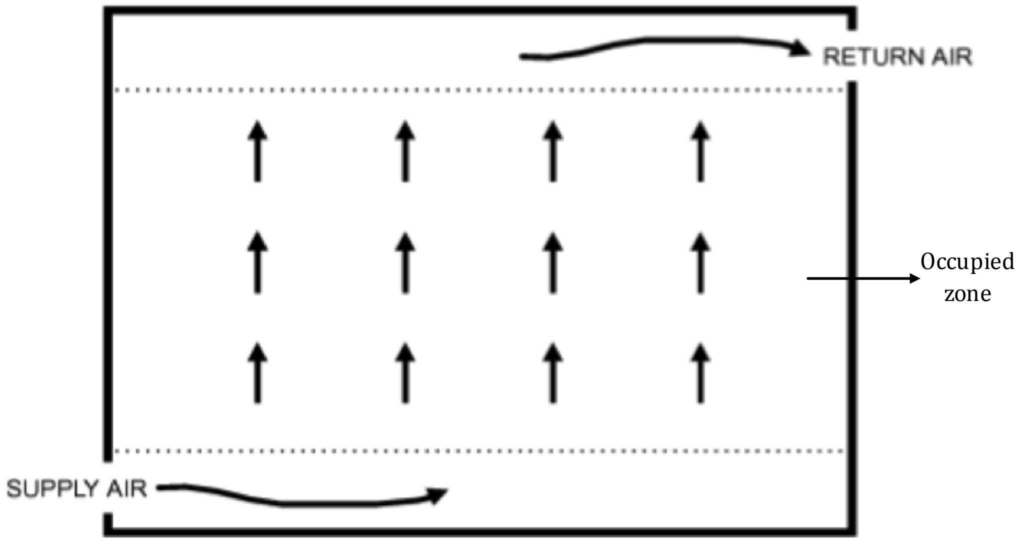

Figure 21: Displacement Flow Within a Space

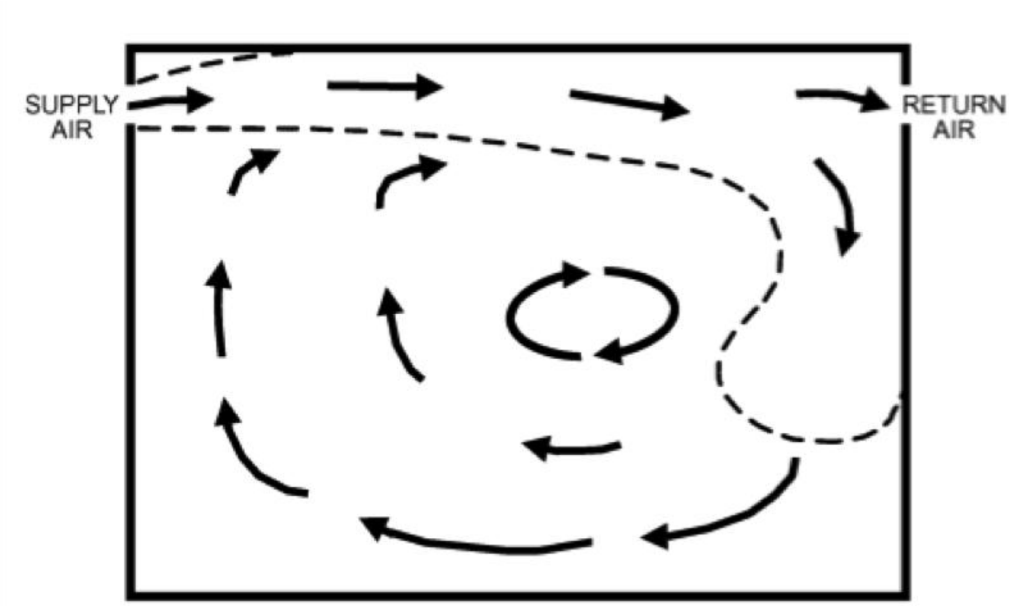

Figure 22: Entrainment Flow Within a Space

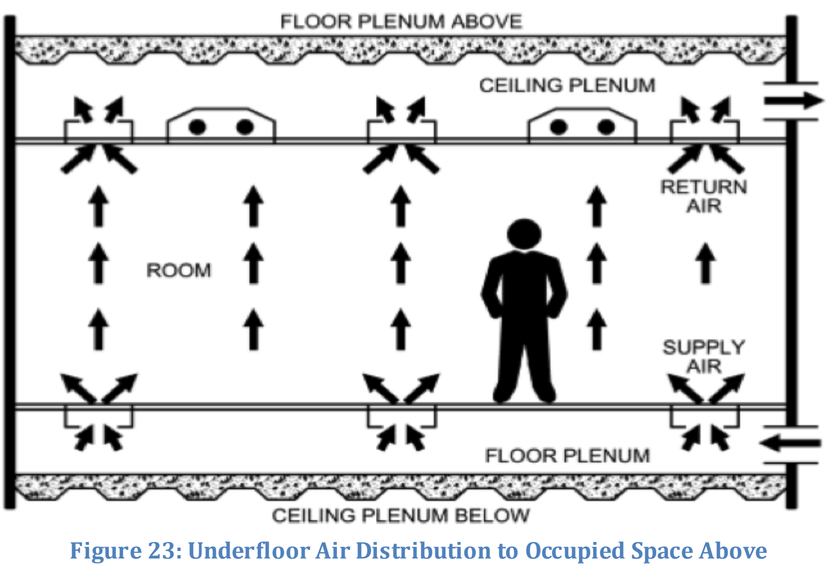

Figure 23: Underfloor Air Distribution to Occupied Space Above

2.1.3 MECHANICAL SYSTEMS

When mechanical equipment is operating, like supply or exhaust devices, the pressure difference across the building envelope is affected. It is known that the sum of all airflows, in and out, through openings and induced by the equipment balance to zero. The pressure difference caused by mechanical equipment has to be known, and it depends on the location and the relation between pressure difference and airflow rate for each opening.

When a whole-building exhaust system is installed in a building, air exhausted from the building must be balanced by increasing airflow into the building through other openings. Due to this balance, in some locations outflow become inflow. For supply fans, is exactly the reverse situation, inflow become outflow. Thus, mechanical system causes important effects and they have to be considered. The rate of radon entry into a building can be increased and interfere with the correctly operation of combustion device venting if the exhaust system is improperly designed causes depressurization.

Mechanical systems can create infiltration in single-zone buildings. For example in family houses, when internal doors are closed, is created positive indoor or outdoor pressure differentials for rooms with only supply registers. In the other hand the room or hallway with the exhaust device tends to depressurize relative to outside. The resistance of internal door undercuts, often partially blocked by carpeting, causes this, to flow from the supply register to the return. Average 3 to 6 Pa [19] is the measure for the magnitudes of indoor/outdoor pressure differentials created. The pressure differentials can be significantly reduced if the airflow system has ducted air return, distributed or proper sized transfer grilles.

The performance of mechanical systems can also be affected by building envelope air tightness and interzonal airflow resistance. In ventilation systems the actual airflow rate delivered depends on the pressure they work against.

2.1.4 NATURAL VENTILATION

Natural ventilation is the airflow of incoming outdoor air through intentional openings in the building. Wind and thermal pressures cause it. Building occupants can control temperature and contaminants with natural ventilation, but it is only possible in mild climates. It is not considered useful in hot and humid or cold climates. When there is no mechanical air conditioning available, the temperature can be controlled by natural ventilation in order to provide cooling. The location, control and arrangement or ventilation openings should unite the driving forces of wind and temperature to obtain the desired conditions.

However, natural ventilation and intentional openings cannot guarantee the desire temperature and humidity control or either the air quality coming from outside because it depends on natural effects.

2.1.4.1 NATURAL VENTILATION OPENINGS

Natural ventilation openings include:

<u>Windows</u> transmit light and provide ventilation when open. The difference is found in the way they can be opened. They may open by vertical or horizontal sliding; by tilting on horizontal pivots at or near the center; or by swinging on pivots at the top, bottom, or side. The type of opening is important because affects airflow rate and is also important for weather protection.

<u>Roof ventilators</u> provide a weather-resistant air outlet. The location of the ventilator on the roof, the ventilator airflow resistance, ventilation ability to use kinetic energy to induce flow and the height of the draft determine the capacity.

There are four types or natural-draft or gravity roof ventilators: stationary, pivoting, oscillating or rotating. When one installs a fan has to take into account the ruggedness, corrosion resistance, storm proofing features, dampers and operating mechanisms, noise, cost, and maintenance. The problem of these natural ventilations is that they don't work if there is not enough wind. They can be supplemented with power-driven supply fans that only have to be energized when the natural exhaust capacity is too low. A natural-draft roof ventilator has to receive full and unrestricted wind. For that, is very important the position of the ventilator.

Stacks or vertical flues have to be located in a position where wind can act on them from any direction. If there is no wind, the stack effect extracts air from room to outside.

2.1.4.2 CEILING HEIGHTS

In buildings that depend on natural ventilation for cooling, the heights between floor and ceiling are increased until 3,2 m [20]. Higher ceilings allow to provide cooler outside air near the floors and warm air and contaminants to rise above the occupied portions of rooms. This air is vented outside from the ceiling zones. In these cases exist a displacement flow from the floor to the ceiling.

2.1.5 RESIDENTIAL AIR LEAKAGE

Residential buildings infiltration is dominated by envelope leakage. In new constructions it is tent toward tighter building envelopes.

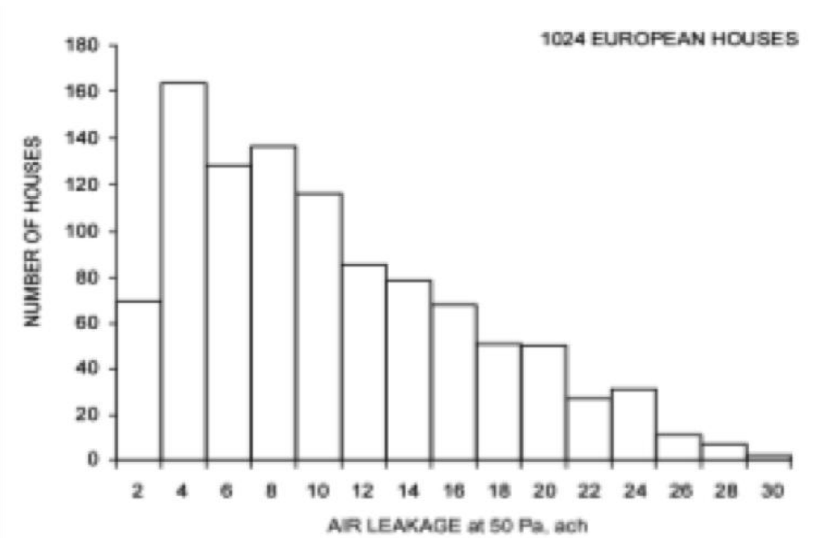

Figure 24: Envelope Leakage Measurements Europe

Figure 24 [20] summarizes envelope leakage measured in European houses. These figures show the large range of measured envelope tightness.

2.1.5.1 LEAKAGE DISTRIBUTION

The following points summarize the percentages of whole-building air leakage area associated with various components and systems. Values in parentheses include the range determined for each component and the mean of the range.

Walls. There is leakage through the interior and exterior walls. Leakage can occur through cracks below de bottom of the gypsum wallboard, plugs, plumbing penetrations and the top plates of walls into the attic.

Ceiling details. Leakage through the ceiling is particularly insidious because the effectiveness of insulation on the attic floor decreases and contributes to infiltration heat loss. In buildings without attics it also reduces the effectiveness of ceiling insulation producing moisture problems.

Forcer-air heating and/or cooling system. Location of the heating equipment and cooling equipment, aid-handler, ductwork, the venting assembly of a fuel burning device and the existence and location of a combustion air supply, affect air leakage.

Diffusion through walls. It is not an important flow mechanisms compared to infiltration through holes and other openings in the structure.

2.2 SWEDISH CODE

There is a code named "Regelsamling för byggande, BBR 2008" [25] which provides regulations and guidelines to new building constructions in the Swedish country. Even though "Gävle Folkets Hus" is an old building and this code does not apply to it, it is useful to compare the new buildings' requirements with the one under study. The main parameters extracted to this project are the specific energy consumption factor and the minimum outside airflow rate.

2.2.1 SPECIFIC ENERGY CONSUMPTION FACTOR

Inthe section 9:3 the maximum specific energy consumption factor is provided:

"9:3 Non-residential buildings

They should be designed to have specific energy consumption lower or equal to 100 kWh per m² of floor area (A_{temp}) years in the Southern climate and 120 kWh per m² of floor area (A_{temp}) years in the Northern climate. For rooms with outside air flow over 0.35 l/s·m² may be an addition equal to 70 (q - 0, 35) kWh per m² of floor area (A_{temp}) years in the Southern climate and 90 (q - 0, 35) kWh per m2 floor area (A_{temp}) years in the Northern climate, where "q" is the average external air throughout the heating season (l/s·m²). (BFS 2006:12)."[25]

The definition of A_{temp} is also shown in 9:12:

"A_{temp}: Floor area in temperature-controlled spaces intended to be heated to more than 10°C limited by climate monitor inside" [25]

Gävle climate is included in the Northern climate, also explained in 9:12:

"Northern climate: Norrbotten, Västerbotten, Jämtland, Västernorrland, Gävleborg, Dalarna County and Värmland." [25]

The section 9:71 denotes the definition of the specific energy consumption factor:

"9:71 Measuring System

The building's energy will continuously be monitored by measurement systems. The measurement system should be able to function so that the energy for the desired time period can be calculated. (BFS 2006:12). [25]

General advice

Measurement of the building's energy use and verification of performance levels in sections 9:2 and 9:3 can be done by reading and summing up of the building delivered energy (kWh) used for heating, cooling, hot water, and operation of building installations (pumps, fans, etc.) and other building electricity (excluding household and Operational electricity)."[25]

Therefore, the specific energy consumption factor is calculated by adding the district heating consumption, the total consumption of the devices used in the ventilation and heating systems and the external lighting. According to BBR, this number must equal or lower than 120 kWh/m^2. Also notice that if there is some area which is not ventilated or heated, it has not to be taken into account.

2.2.2 MINIMUM OUTSIDE AIRFLOW RATE

In the section 6:25 the purpose of the ventilation is explained:

" 6:25 Ventilation
Ventilation systems should be designed so that the required outside air flow can be supplied to the building. They should also be able to remove harmful substances, damp, unpleasant smell, excretion products from people and materials, and pollution from activities in the building. (BFS 2006:12).

General advice

The design of the buildings ventilation flow should take into account the influence of personal stress, activity, moisture addition, material emissions and emissions from soil and water. [...]

[...]"[25]

Subsequently, the minimum outside airflow rate is provided:

"6:251[30] Ventilation Flow

Ventilation systems should be designed for a minimum outside air flow equivalent to 0.35 l/s per m2 of floor area. Rooms should be able to have continuous ventilation during use. [...] " [25]

General advices are also given:

"General advice

The requirements for ventilation flow should be verified by calculation and measurement. The design of the outside air flow should take into account that the flow could decline due to dirt in air ducts, change of pressure drop across filters, etc.

[...]

[...]

General advice

After a period of reduced air flow, normal airflow should be used to renew the air volume in the room before it is reused. (BFS 2006:12).

Reduction of ventilation flows may give rise to health risks. The reduction must not cause damage to the building and its facilities caused by such moisture. (BFS 2006:12)." [25]

2.3 MEASURING INSTRUMENTS

2.3.1 TERMOANEMOMETER

To calculate the mechanical ventilation losses, the supply and exhaust airflowhave been measured in each of the rooms of the house, as well as the total air flow of the system in the aggregate room. It has been used a termoanemometer for the measure of total exhaust and supply airflow. Velocical Plus is a multiparameter ventilation system that is capable to monitor air velocity, temperature, differential pressure and humidity,as well as calculating volumetric flow rates and dew point temperatures.

The accuracy of the termoanemometer used is 0,01 m/s for air velocity and 0,1°C for temperature.

Figure 25: Termoanemometer

2.3.2 ANEMOMETER

For the measure of the air flows inside the house two different anemometers have been used. The number of supply and exhaust devices varies in each room.

Figure 26: Exhaust device

Figure 27: Anemometer 1

The accuracy of this anemometer is 1l/s for air flow rate.

Figure 28: Anemometer 2

The accuracy of this anemometer is 0,1 l/s for air flow rate.

2.4 GÄVLE CLIMATE

As the energy demand is affected by temperature conditions, there could be variations from one year to another. To enable proper comparisons to be made, it is necessary to correct for climatic conditions in order to arrive at a statistically average year regarding the climatic conditions. For understand the climate and compare it internationally it is used the concept of degree-day. That is essentially a simple way to characterize the severity of a particular climate and a simplification of historical weather data. Degree-day data is easy to obtain, and very easy to work with. By them, it is possible to apply the following equation:

$$E = U \cdot A \cdot DegreeDays \qquad (1)$$

In the following table and graphic is showed the normal temperature and 2009 temperature in Gävle, as well as degree days and degree hours [12]:

	Normal Temp.	2009 Temp.	Degree Days 2009	Degree hour 2009
January	-5,1	-3	802	19.255
February	-4,9	-5,9	731	17.553
March	-2,2	-0,8	671	16.114
April	3,3	6,4	515	12.357
May	8,7	11,3	232	5.577
June	13,8	12,5	43	1.027
July	16,6	16,4	0	0
August	15,3	16	15	352
September	10,7	12,4	242	5.812
October	5,3	3,6	442	10.596
November	0,9	4,4	598	14.353
December	-2,1	-4,8	761	18.257
Total			5.052	121.253

Table 1: Normal temperature and 2009' temperature in Gävle, 2009 degree days and 2009 degree hours [12]

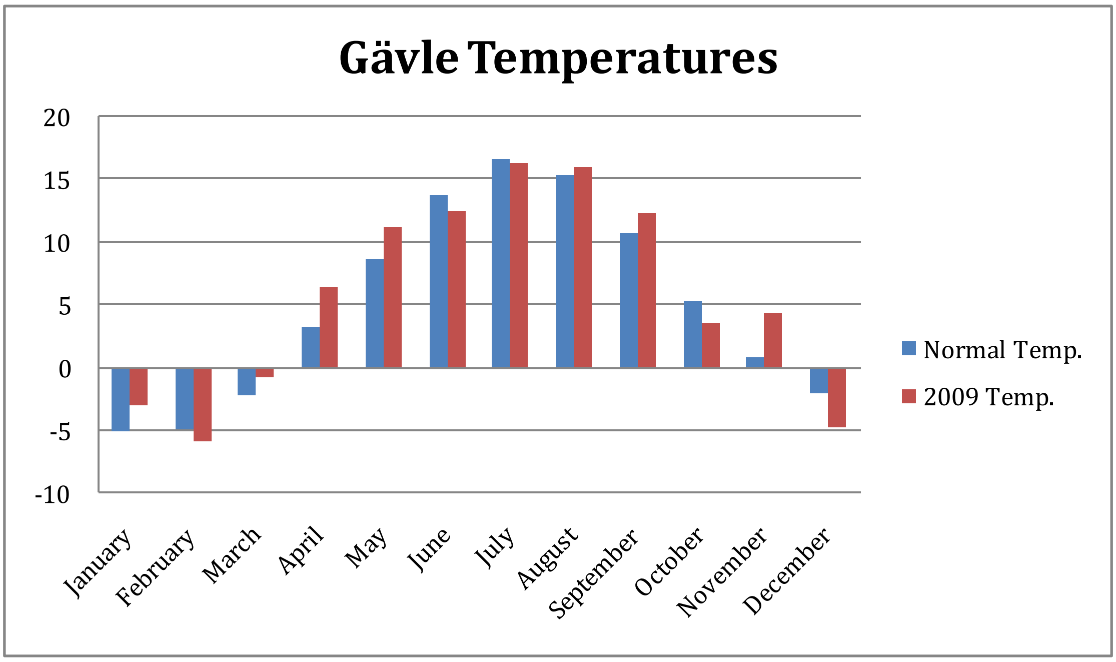

Figure 29: Gävle Normal Temperatures & Temperatures in 2009 [12]

2.5 ENERGY BALANCE

2.5.1 INTRODUCCTION

Indoor climate and indoor air quality is controlled using the energy. The main uses of energy in buildings are for:

- Heating
- Cooling
- Drying and humidifying
- Ventilation
- Hot water supply
- Lighting
- Cooking, washing or producing goods and services
- Electrical appliances.

The amount of energy consumed for each purpose depends on climate, local habits, energy policies and cost.

It is often suspected that high technology and high-energy consumption are needed to obtain a high comfort level or that energy saving result in not as good as indoor environment quality. The truth is that building scientists admit that high-quality energy services do not necessarily incur a high-energy use and that with a reasonable amount of energy and power and with a low environmental impact it is possible to obtain a good environment quality.

The thermal balance of a building is shown in Figure 30. The building has transmissions through the envelope and by ventilation. Depending on the indoor and outdoor temperature difference these transmissions are heat gains or losses. The building also has internal heat gains from lighting,, electrical appliances, metabolic activity, etc. It suffers passive solar heat gains, especially through windows or, in some cases, specific passive solar devices. External power is used for maintaining thermal comfort at a comfortable level. It is also used for ventilation and for air conditioning.

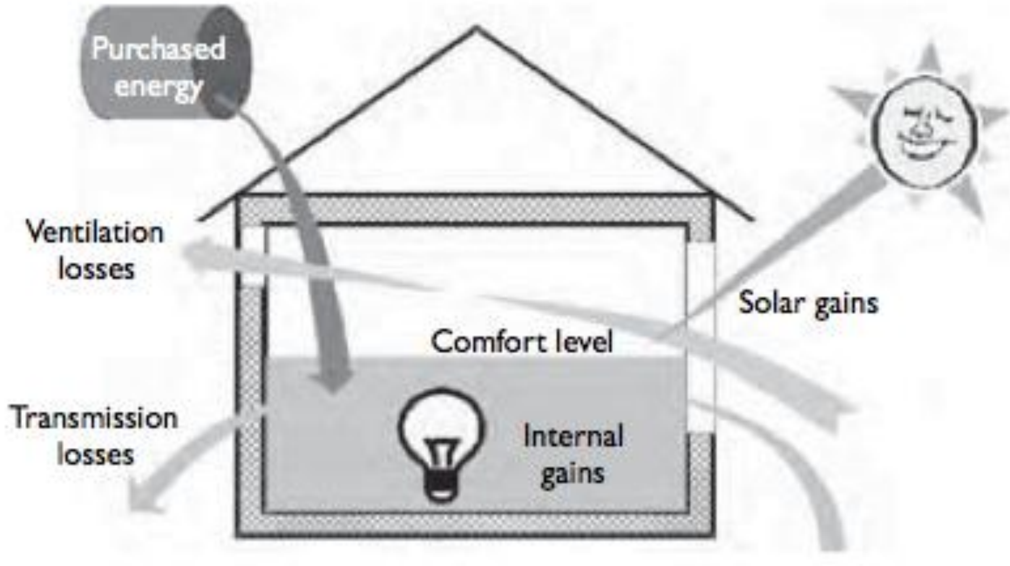

Figure 30: Heat Balance of a Building [21]

Therefore, the equation used to calculate "Gävle Folkets Hus'" energy balance is:

$$Q_{dh} + Q_s + Q_{app} + Q_{us} + Q_{vl} + Q_{tl} + Q_{htw} = \Delta Q \qquad (2)$$

Where:

- Q_{dh} : purchased district heating
- Q_s : solar gains
- Q_{app} : internal gains from appliances and lighting
- Q_{us}: internal gains from users
- Q_{vl}: ventilation losses
- Q_{tl}: transmission losses
- Q_{htw}: hot tap water consumption
- ΔQ: energy balance difference

It is important to remark that ventilation, transmission and hot tap water losses are negative values.

2.5.2 ENERGY INPUTS

2.5.2.1 DISTRICT HEATING

District heating is the centralized production and supply of hot water, distributed through a piping system and used for the space heating of buildings. At customer level the heat network is connected to thecentral heating by heat exchangers, and the water used in the district heating system is not mixed with the water of the central heating system.

In Folkets Hus, the hot water from the district heating has three uses. It is used for the radiators, principal system to heat the building. It is also used for the hot tap water and for heating the supply air from the ventilation system.

2.5.2.2 RADIATION

Solar radiation in the daytime through windows greatly affects the energy balance of a building. During the winter, when the energy demands are high, solar radiation will immediately contribute to reduce the heating needs.

For calculate that, it will be necessary to apply the following formula:

$$Q_{total} = \sum_{i}^{mont\,hs} Q \cdot K1 \cdot K2 \cdot \frac{n^{o}\,day}{mont\,h} \cdot A \qquad (3)$$

Where Q_{total} is the solar power in Wh; Q is energy per unit of area and day ($\frac{Wh}{m^2 day}$); A is glass windows' area (in m^2); and K1 and K2 are factors between 0 and 1, that reduce the real radiation energy gains due to cloudy days, and due to the glass of the windows does not allow all the radiation get in the building. K1 and K2 values are exposed in chapter 3.1.1.3.3.

2.5.2.3 PEOPLE

Table 2 [20] gives representative rates at which humans emit sensible heat and moisture in different states of activity. In spaces with high density, such as auditoriums, these sensible and latent heat gains are a significantly fraction of the total load. Even if it is for short time occupancy spaces, the amount of extra sensible heat and moisture introduces by people may be significant.

Table 2 summarizes design data for common conditions.

Degree of Activity		Total Heat, W: Adult Male	Total Heat, W: Adjusted, M/F[a]	Sensible Heat, W	Latent Heat, W	% Sensible Heat that is Radiant[b]: Low V	% Sensible Heat that is Radiant[b]: High V
Seated at theater	Theater, matinee	115	95	65	30		
Seated at theater, night	Theater, night	115	105	70	35	60	27
Seated, very light work	Offices, hotels, apartments	130	115	70	45		
Moderately active office work	Offices, hotels, apartments	140	130	75	55		
Standing, light work; walking	Department store; retail store	160	130	75	55	58	38
Walking, standing	Drug store, bank	160	145	75	70		
Sedentary work	Restaurant[c]	145	160	80	80		
Light bench work	Factory	235	220	80	140		
Moderate dancing	Dance hall	265	250	90	160	49	35
Walking 4.8 km/h; light machine work	Factory	295	295	110	185		
Bowling[d]	Bowling alley	440	425	170	255		
Heavy work	Factory	440	425	170	255	54	19
Heavy machine work; lifting	Factory	470	470	185	285		
Athletics	Gymnasium	585	525	210	315		

Notes:
1. Tabulated values are based on 24°C room dry-bulb temperature. For 27°C room dry bulb, total heat remains the same, but sensible heat values should be decreased by approximately 20%, and latent heat values increased accordingly.
2. Also see Table 4, Chapter 9, for additional rates of metabolic heat generation.
3. All values are rounded to nearest 5 W.

[a] Adjusted heat gain is based on normal percentage of men, women, and children for the application listed, and assumes that gain from an adult female is 85% of that for an adult male, and gain from a child is 75% of that for an adult male.
[b] Values approximated from data in Table 6, Chapter 9, where *V* is air velocity with limits shown in that table.
[c] Adjusted heat gain includes 18 W for food per individual (9 W sensible and 9 W latent).
[d] Figure one person per alley actually bowling, and all others as sitting (117 W) or standing or walking slowly (231 W).

Table 2: Representative Rates at Which Heat Moisture Are Given Off by Human Beings in Different States of Activity

2.5.2.4 APPLIANCES

Heat gains from all appliances (electrical, gas or steam) have to be taken into account to calculate a heating load estimate. Due to the variety of appliances, applications, schedules, use and installations, this estimate can oscillate significantly. Usually, their nameplate is the only place where information about heat gain is available. The actual heat gain can be over-estimate.

2.5.2.4.1 COOKING APPLIANCES

Representative heat gains are listed in Tables 3A to 3C [20] for a large variety of frequent cooking appliances. It is assumed that there is a properly designed exhaust hood connected to a fan exhaust system. This fan exhaust system operates at an exhaust rate for complete capture of the thermal and effluent column. Not well-operated hood systems load the space with convective component of the heat gain.

	Energy Rate, W		Rate of Heat Gain, W					
Appliance	Rated	Standby	Sensible Radiant	Sensible Convective	Latent	Total	Usage Factor F_u	Radiation Factor F_r
Cabinet: hot serving (large), insulated*	1993	352	117	234	0	352	0.18	0.33
Cabinet: hot serving (large), uninsulated	1993	1026	205	821	0	1026	0.51	0.2
Cabinet: proofing (large)*	5099	410	352	0	59	410	0.08	0.86
Cabinet: proofing (small-15 shelf)	4191	1143	0	264	879	1143	0.27	0
Coffee brewing urn	3810	352	59	88	205	352	0.08	0.17
Drawer warmers, 2-drawer (moist holding)*	1202	147	0	0	59	59	0.12	0
Egg cooker	3194	205	88	117	0	205	0.06	0.43
Espresso machine*	2403	352	117	234	0	352	0.15	0.33
Food warmer: steam table (2-well-type)	1495	1026	88	176	762	1026	0.69	0.08
Freezer (small)	791	322	147	176	0	322	0.41	0.45
Hot dog roller*	996	703	264	440	0	703	0.71	0.38
Hot plate: single burner, high speed	1114	879	264	615	0	879	0.79	0.3
Hot-food case (dry holding)*	9115	733	264	469	0	733	0.08	0.36
Hot-food case (moist holding)*	9115	967	264	528	176	967	0.11	0.27
Microwave oven: commercial (heavy duty)	3194	0	0	0	0	0	0	0
Oven: countertop conveyorized bake/finishing*	6008	3693	645	3048	0	3693	0.61	0.17
Panini*	1700	938	352	586	0	938	0.55	0.38
Popcorn popper*	586	59	29	29	0	59	0.1	0.5
Rapid-cook oven (quartz-halogen)*	12 016	0	0	0	0	0	0	0
Rapid-cook oven (microwave/convection)*	7297	1202	293	909	0	293	0.16	0.24
Reach-in refrigerator*	1407	352	88	264	0	352	0.25	0.25
Refrigerated prep table*	586	264	176	88	0	264	0.45	0.67
Steamer (bun)	1495	205	176	29	0	205	0.14	0.86
Toaster: 4-slice pop up (large): cooking	1788	879	59	410	293	762	0.49	0.07
Toaster: contact (vertical)	3312	1553	791	762	0	1553	0.47	0.51
Toaster: conveyor (large)	9613	3019	879	2139	0	3019	0.31	0.29
Toaster: small conveyor	1700	1084	117	967	0	1084	0.64	0.11
Waffle iron	909	352	234	117	0	352	0.39	0.67

Source: Swierczyna et al. (2008, 2009).

Table 3A: Recommended Rates of Radiant and Convective Heat Gain from Unhooded Electric Appliances During Idle (Ready-to-cook) Conditions

Appliance	Energy Rate, W Rated	Energy Rate, W Standby	Rate of Heat Gain, W Sensible Radiant	Usage Factor F_u	Radiation Factor F_r
Broiler: underfired 900 mm	10 814	9056	3165	0.84	0.35
Cheesemelter*	3605	3488	1348	0.97	0.39
Fryer: kettle	29 014	528	147	0.02	0.28
Fryer: open deep-fat, 1-vat	14 008	821	293	0.06	0.36
Fryer: pressure	13 511	791	147	0.06	0.19
Griddle: double sided 900 mm (clamshell down)*	21 218	2022	410	0.1	0.2
Griddle: double sided 900 mm (clamshell up)*	21 218	3370	1055	0.16	0.31
Griddle: flat 900 mm	17 115	3370	1319	0.2	0.39
Griddle-small 900 mm*	8997	1788	791	0.2	0.44
Induction cooktop*	21 013	0	0	0	0
Induction wok*	3488	0	0	0	0
Oven: combi: combi-mode*	16 411	1612	234	0.1	0.15
Oven: combi: convection mode	16 412	1612	410	0.1	0.25
Oven: convection full-size	12 103	1964	440	0.16	0.22
Oven: convection half-size*	5510	1084	147	0.2	0.14
Pasta cooker*	22 010	2491	0	0.11	0
Range top: top off/oven on*	4865	1172	293	0.24	0.25
Range top: 3 elements on/oven off	15 005	4513	1846	0.3	0.41
Range top: 6 elements on/oven off	15 005	9730	4074	0.65	0.42
Range top: 6 elements on/oven on	19 870	10 668	4250	0.54	0.4
Range: hot-top	15 826	15 035	3458	0.95	0.23
Rotisserie*	11 107	4044	1319	0.36	0.33
Salamander*	7004	6829	2051	0.97	0.3
Steam kettle: large (225 L), simmer lid down*	32 414	762	29	0.02	0.04
Steam kettle: small (150 L), simmer lid down*	21 599	528	88	0.02	0.17
Steamer: compartment: atmospheric*	9789	4484	59	0.46	0.01
Tilting skillet/braising pan	9642	1553	0	0.16	0

Source: Swierczyna et al. (2008, 2009).

Table 3B: Recommended Rates of Radiant Heat Gain from Hooded Electric Appliances During Idle (Ready-to-cook) Conditions

Appliance	Energy Rate, Btu/h Rated	Energy Rate, Btu/h Standby/ Washing	Rate of Heat Gain, W Unhooded Sensible Radiant	Unhooded Sensible Convective	Unhooded Latent	Unhooded Total	Hooded Sensible/ Radiant	Usage Factor F_u	Radiation Factor F_r
Dishwasher (conveyor type, chemical sanitizing) standby	13 716	1671/12 778	0	1304	3954	5258	0	0.36	0.00
Dishwasher (conveyor type, hot-water sanitizing) standby	13 716	1671/N/A	0	1392	4973	6366	0	N/A	0.00
Dishwasher (door-type, hot-water sanitizing) standby	5393	352/3898	0	580	818	1398	0	0.26	0.00
Dishwasher (door-type, chemical sanitizing) washing	5393	352/3898	0	580	818	1398	0	0.26	0.00
Dishwasher* (under-counter type, chemical sanitizing) standby	7796	352/5480	0	668	1222	1890	0	0.35	0.00
Dishwasher* (under-counter type, hot-water sanitizing) standby	7796	498/5774	234	305	882	1421	234	0.27	0.34
Booster heater*	38 099	0	147	0	0	0	147	0	N/A

Source: Swierczyna et al. (2008, 2009). *Note*: Heat load values are prorated for 30% washing and 70% standby.

Table 3C: Recommended Rates of Radiant and Convective Heat Gain from Ware washing Equipment During Idle (Standby) or Washing Conditions

2.5.2.4.2 OFFICE EQUIPMENT

Computers, printers, photocopiers, and all the typical office equipment generate very important amount of heat gains. Sometimes it is greater than all other heat gains combined.

It has been developed a method to measure heat gains from equipment.

Is not common that nameplate of office equipment reflect the actual power consumption. It is understood that actual power consumption is equal to the total heat gain, but the relation with nameplate value varies significantly. ASHRAE found that "*for general office equipment with nameplate power consumption of less than 1000 W, the actual ratio of total heat gain to nameplate ranged from 25% to 50%, but when all tested equipment is considered, the range is broader. Generally, if the nameplate value is the only information known and no actual heat gain data are available for similar equipment, it is conservative to use 50% of nameplate as heat gain and more nearly correct if 25% of nameplate is used*". [20]

Tables 4 to 6 [20] show typical values for small office containing equipment. For bigger areas with many equipment devices experience some degree diversity if all items are not working at the same time at any given time.

Equipment	Description	Nameplate Power Consumption, W	Average Power Consumption, W
Desktop computer[a]	Manufacturer A (model A); 2.8 GHz processor, 1 GB RAM	480	73
	Manufacturer A (model B); 2.6 GHz processor, 2 GB RAM	480	49
	Manufacturer B (model A); 3.0 GHz processor, 2 GB RAM	690	77
	Manufacturer B (model B); 3.0 GHz processor, 2 GB RAM	690	48
	Manufacturer A (model C); 2.3 GHz processor, 3 GB RAM	1200	97
Laptop computer[b]	Manufacturer 1; 2.0 GHz processor, 2 GB RAM, 430 mm screen	130	36
	Manufacturer 1; 1.8 GHz processor, 1 GB RAM, 430 mm screen	90	23
	Manufacturer 1; 2.0 GHz processor, 2 GB RAM, 355 mm screen	90	31
	Manufacturer 2; 2.13 GHz processor, 1 GB RAM, 355 mm screen, tablet PC	90	29
	Manufacturer 2; 366 MHz processor, 130 MB RAM, 355 mm screen)	70	22
	Manufacturer 3; 900 MHz processor, 256 MB RAM (265 mm screen)	50	12
Flat-panel monitor[c]	Manufacturer X (model A); 760 mm screen	383	90
	Manufacturer X (model B); 560 mm screen	360	36
	Manufacturer Y (model A), 480 mm screen	288	28
	Manufacturer Y (model B), 430 mm screen	240	27
	Manufacturer Z (model A), 430 mm screen	240	29
	Manufacturer Z (model C), 380 mm screen	240	19

Table 4: Recommended Heat Gain from Typical Computer Equipment

Equipment	Description	Nameplate Power Consumption, W	Average Power Consumption, W
Laser printer, typical desktop, small-office type[a]	Printing speed up to 10 pages per minute	430	137
	Printing speed up to 35 pages per minute	890	74
	Printing speed up to 19 pages per minute	508	88
	Printing speed up to 17 pages per minute	508	98
	Printing speed up to 19 pages per minute	635	110
	Printing speed up to 24 page per minute	1344	130
Multifunction (copy, print, scan)[b]	Small, desktop type	600	30
		40	15
	Medium, desktop type	700	135
Scanner[b]	Small, desktop type	19	16
Copy machine[c]	Large, multiuser, office type	1750	800 (idle 260 W)
		1440	550 (idle 135 W)
		1850	1060 (idle 305 W)
Fax machine	Medium	936	90
	Small	40	20
Plotter	Manufacturer A	400	250
	Manufacturer B	456	140

Table 5: Recommended Heat Gain from Typical Laser Printers and Copiers

Equipment	Maximum Input Rating, W	Recommended Rate of Heat Gain, W
Mail-processing equipment		
Folding machine	125	80
Inserting machine, 3600 to 6800 pieces/h	600 to 3300	390 to 2150
Labeling machine, 1500 to 30 000 pieces/h	600 to 6600	390 to 4300
Postage meter	230	150
Vending machines		
Cigarette	72	72
Cold food/beverage	1150 to 1920	575 to 960
Hot beverage	1,725	862
Snack	240 to 275	240 to 275
Other		
Bar code printer	440	370
Cash registers	60	48
Check processing workstation, 12 pockets	4800	2470
Coffee maker, 10 cups	1500	1050 sens., 450 latent
Microfiche reader	85	85
Microfilm reader	520	520
Microfilm reader/printer	1150	1150
Microwave oven, 28 L	600	400
Paper shredder	250 to 3000	200 to 2420
Water cooler, 30 L/h	700	350

Table 6: Recommended Heat Gain from Miscellaneous Office Equipment

2.5.2.4.3 LIGHTING

Lighting also has an effect in internal heat gains. It is often a major space heating load component. It is necessary to estimate the space heat gain it imposes. It is not easy to calculate this load component. The problem with lighting is the heat storage, because of that; the rate of heating load at any given moment can vary from the heat equivalent of power supplied to these lights.

Light-emitting elements or lamps generate the primary source of heat, although ballast and other appurtenances in the luminaries may generate significant additional heat. Rate of sensible heat gain from lighting may be calculated from:

$$Q = W \cdot F_u \cdot F_{sa} \quad (4)$$

Where:

- Q = heat gain, W
- W = total light wattage, W
- F_u = lighting use factor
- F_{sa} = lighting special allowance factor

Ratings of all lamps installed give the total light wattage. Ballasts are addressed by a different factor.

The lighting use factor is the relation between lighting energy consumption, including lamps and ballast, and the total installed wattage.

The allowance factor is the relation between the lighting fixtures' power consumption and the nominal power consumption of the lamps. This value is 1 for incandescent lights. A list of typical non-incandescent light fixtures is shown in table 7 [19].

Description	Ballast	Watts/Lamp	Lamps/Fixture	Lamp Watts	Fixture Watts	Special Allowance Factor	Description	Ballast	Watts/Lamp	Lamps/Fixture	Lamp Watts	Fixture Watts	Special Allowance Factor
Compact Fluorescent Fixtures													
Twin, (1) 5 W lamp	Mag-Std	5	1	5	9	1.80	Twin, (2) 40 W lamp	Mag-Std	40	2	80	85	1.06
Twin, (1) 7 W lamp	Mag-Std	7	1	7	10	1.43	Quad, (1) 13 W lamp	Electronic	13	1	13	15	1.15
Twin, (1) 9 W lamp	Mag-Std	9	1	9	11	1.22	Quad, (1) 26 W lamp	Electronic	26	1	26	27	1.04
Quad, (1) 13 W lamp	Mag-Std	13	1	13	17	1.31	Quad, (2) 18 W lamp	Electronic	18	2	36	38	1.06
Quad, (2) 18 W lamp	Mag-Std	18	2	36	45	1.25	Quad, (2) 26 W lamp	Electronic	26	2	52	50	0.96
Quad, (2) 22 W lamp	Mag-Std	22	2	44	48	1.09	Twin or multi, (2) 32 W lamp	Electronic	32	2	64	62	0.97
Quad, (2) 26 W lamp	Mag-Std	26	2	52	66	1.27							
Fluorescent Fixtures													
(1) 450 mm, T8 lamp	Mag-Std	15	1	15	19	1.27	(4) 1200 mm, T8 lamp	Electronic	32	4	128	120	0.94
(1) 450 mm, T12 lamp	Mag-Std	15	1	15	19	1.27	(1) 1500 mm, T12 lamp	Mag-Std	50	1	50	63	1.26
(2) 450 mm, T8 lamp	Mag-Std	15	2	30	36	1.20	(2) 1500 mm, T12 lamp	Mag-Std	50	2	100	128	1.28
(2) 450 mm, T12 lamp	Mag-Std	15	2	30	36	1.20	(1) 1500 mm, T12 HO lamp	Mag-Std	75	1	75	92	1.23
(1) 600 mm, T8 lamp	Mag-Std	17	1	17	24	1.41	(2) 1500 mm, T12 HO lamp	Mag-Std	75	2	150	168	1.12
(1) 600 mm, T12 lamp	Mag-Std	20	1	20	28	1.40	(1) 1500 mm, T12 ES VHO lamp	Mag-Std	135	1	135	165	1.22
(2) 600 mm, T12 lamp	Mag-Std	20	2	40	56	1.40	(2) 1500 mm, T12 ES VHO lamp	Mag-Std	135	2	270	310	1.15
(1) 600 mm, T12 HO lamp	Mag-Std	35	1	35	62	1.77	(1) 1500 mm, T12 HO lamp	Mag-ES	75	1	75	88	1.17
(2) 600 mm, T12 HO lamp	Mag-Std	35	2	70	90	1.29	(2) 1500 mm, T12 HO lamp	Mag-ES	75	2	150	176	1.17
(1) 600 mm, T8 lamp	Electronic	17	1	17	16	0.94	(1) 1500 mm, T12 lamp	Electronic	50	1	50	44	0.88
(2) 600 mm, T8 lamp	Electronic	17	2	34	31	0.91	(2) 1500 mm, T12 lamp	Electronic	50	2	100	88	0.88
(1) 900 mm, T12 lamp	Mag-Std	30	1	30	46	1.53	(1) 1500 mm, T12 HO lamp	Electronic	75	1	75	69	0.92
(2) 900 mm, T12 lamp	Mag-Std	30	2	60	81	1.35	(2) 1500 mm, T12 HO lamp	Electronic	75	2	150	138	0.92
(1) 900 mm, T12 ES lamp	Mag-Std	25	1	25	42	1.68	(1) 1500 mm, T8 lamp	Electronic	40	1	40	36	0.90
(2) 900 mm, T12 ES lamp	Mag-Std	25	2	50	73	1.46	(2) 1500 mm, T8 lamp	Electronic	40	2	80	72	0.90
(1) 900 mm, T12 HO lamp	Mag-Std	50	1	50	70	1.40	(3) 1500 mm, T8 lamp	Electronic	40	3	120	106	0.88
(2) 900 mm, T12 HO lamp	Mag-Std	50	2	100	114	1.14	(4) 1500 mm, T8 lamp	Electronic	40	4	160	134	0.84
(2) 900 mm, T12 lamp	Mag-ES	30	2	60	74	1.23	(1) 1800 mm, T12 lamp	Mag-Std	55	1	55	76	1.38
(2) 900 mm, T12 ES lamp	Mag-ES	25	2	50	66	1.32	(2) 1800 mm, T12 lamp	Mag-Std	55	2	110	122	1.11
(1) 900 mm, T12 lamp	Electronic	30	1	30	31	1.03	(3) 1800 mm, T12 lamp	Mag-Std	55	3	165	202	1.22
(1) 900 mm, T12 ES lamp	Electronic	25	1	25	26	1.04	(4) 1800 mm, T12 lamp	Mag-Std	55	4	220	244	1.11
(1) 900 mm, T8 lamp	Electronic	25	1	25	24	0.96	(1) 1800 mm, T12 HO lamp	Mag-Std	85	1	85	120	1.41
(2) 900 mm, T12 lamp	Electronic	30	2	60	58	0.97	(2) 1800 mm, T12 HO lamp	Mag-Std	85	2	170	220	1.29
(2) 900 mm, T12 ES lamp	Electronic	25	2	50	50	1.00	(1) 1800 mm, T12 VHO lamp	Mag-Std	160	1	160	180	1.13
(2) 900 mm, T8 lamp	Electronic	25	2	50	46	0.92	(2) 1800 mm, T12 VHO lamp	Mag-Std	160	2	320	330	1.03
(2) 900 mm, T8 HO lamp	Electronic	25	2	50	50	1.00	(2) 1800 mm, T12 lamp	Mag-ES	55	2	110	122	1.11
(2) 900 mm, T8 VHO lamp	Electronic	25	2	50	70	1.40	(4) 1800 mm, T12 lamp	Mag-ES	55	4	220	244	1.11
(1) 1200 mm, T12 lamp	Mag-Std	40	1	40	55	1.38	(2) 1800 mm, T12 HO lamp	Mag-ES	85	2	170	194	1.14
(2) 1200 mm, T12 lamp	Mag-Std	40	2	80	92	1.15	(4) 1800 mm, T12 HO lamp	Mag-ES	85	4	340	388	1.14
(3) 1200 mm, T12 lamp	Mag-Std	40	3	120	140	1.17	(1) 1800 mm, T12 lamp	Electronic	55	1	55	68	1.24
(4) 1200 mm, T12 lamp	Mag-Std	40	4	160	184	1.15	(2) 1800 mm, T12 lamp	Electronic	55	2	110	108	0.98
(1) 1200 mm, T12 ES lamp	Mag-Std	34	1	34	48	1.41	(3) 1800 mm, T12 lamp	Electronic	55	3	165	176	1.07
(2) 1200 mm, T12 ES lamp	Mag-Std	34	2	68	82	1.21	(4) 1800 mm, T12 lamp	Electronic	55	4	220	216	0.98
(3) 1200 mm, T12 ES lamp	Mag-Std	34	3	102	100	0.98	(1) 2400 mm, T12 ES lamp	Mag-Std	60	1	60	75	1.25
(4) 1200 mm, T12 ES lamp	Mag-Std	34	4	136	164	1.21	(2) 2400 mm, T12 ES lamp	Mag-Std	60	2	120	128	1.07
(1) 1200 mm, T12 ES lamp	Mag-ES	34	1	34	43	1.26	(3) 2400 mm, T12 ES lamp	Mag-Std	60	3	180	203	1.13
(2) 1200 mm, T12 ES lamp	Mag-ES	34	2	68	72	1.06	(4) 2400 mm, T12 ES lamp	Mag-Std	60	4	240	256	1.07
(3) 1200 mm, T12 ES lamp	Mag-ES	34	3	102	115	1.13	(1) 2400 mm, T12 ES HO lamp	Mag-Std	95	1	95	112	1.18
(4) 1200 mm, T12 ES lamp	Mag-ES	34	4	136	144	1.06	(2) 2400 mm, T12 ES HO lamp	Mag-Std	95	2	190	227	1.19
(1) 1200 mm, T8 lamp	Mag-ES	32	1	32	35	1.09	(3) 2400 mm, T12 ES HO lamp	Mag-Std	95	3	285	380	1.33
(2) 1200 mm, T8 lamp	Mag-ES	32	2	64	71	1.11	(4) 2400 mm, T12 ES HO lamp	Mag-Std	95	4	380	454	1.19
(3) 1200 mm, T8 lamp	Mag-ES	32	3	96	110	1.15	(1) 2400 mm, T12 ES VHO lamp	Mag-Std	185	1	185	205	1.11
(4) 1200 mm, T8 lamp	Mag-ES	32	4	128	142	1.11	(2) 2400 mm, T12 ES VHO lamp	Mag-Std	185	2	370	380	1.03
(1) 1200 mm, T12 ES lamp	Electronic	34	1	34	32	0.94	(3) 2400 mm, T12 ES VHO lamp	Mag-Std	185	3	555	585	1.05
(2) 1200 mm, T12 ES lamp	Electronic	34	2	68	60	0.88	(4) 2400 mm, T12 ES VHO lamp	Mag-Std	185	4	740	760	1.03
(3) 1200 mm, T12 ES lamp	Electronic	34	3	102	92	0.90	(2) 2400 mm, T12 ES lamp	Mag-ES	60	2	120	123	1.03
(4) 1200 mm, T12 ES lamp	Electronic	34	4	136	120	0.88	(3) 2400 mm, T12 ES lamp	Mag-ES	60	3	180	210	1.17
(1) 1200 mm, T8 lamp	Electronic	32	1	32	32	1.00	(4) 2400 mm, T12 ES lamp	Mag-ES	60	4	240	246	1.03
(2) 1200 mm, T8 lamp	Electronic	32	2	64	60	0.94	(2) 2400 mm, T12 ES HO lamp	Mag-ES	95	2	190	207	1.09
(3) 1200 mm, T8 lamp	Electronic	32	3	96	93	0.97	(4) 2400 mm, T12 ES HO lamp	Mag-ES	95	4	380	414	1.09

Table 7: Typical Non-incandescent Light Fixtures

2.5.3 ENERGY OUTPUTS

2.5.3.1 TRANSMISSION LOSSES

When a surface is between two diverse environments with different temperature, a heat transfer occurs from hot side to cold side. This transmission is produced in 3 phases, as can be seen in figure 31 [11]:

1. From inside air (hottest ambient) to the internal side of the wall.
2. Through the wall.
3. From the extern side of the wall to the exterior air (coldest ambient).

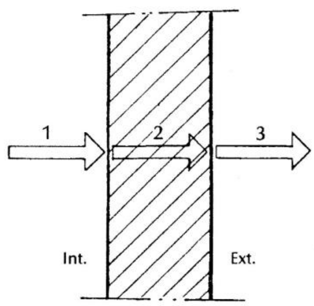

Figure 31: Transmission Looses Through a Single Wall

Phase 2 is produced by conduction and phases 1 and 3 by convection and radiation.
By Fourier's Law:

$$Q = \lambda \frac{A}{L}(T_1 - T_2) = A \cdot \frac{T_1 - T_2}{R} \quad (5)$$

Where:

$$R = \frac{L}{\lambda} \quad (6)$$

is the thermal resistance, similar to an electric resistance, in °C/W. Where L is the thickness of the surface (in meters), λ is the thermal conductivity of the material (in W/m·K) and A is area (in m²).

Therefore, the amount of heat transferred depends not only on the thickness and the temperature difference "(T_1-T_2)", but also on the thermal conductivity of the material "λ".

In order to obtain the total thermal resistance of a surface is necessary to consider other secondary resistances, known as internal and external superficial thermal resistances (R_{SI} and R_{SE}, showed in figure 32 [11]), due to the difficulties of heat changes between the wall and the air.

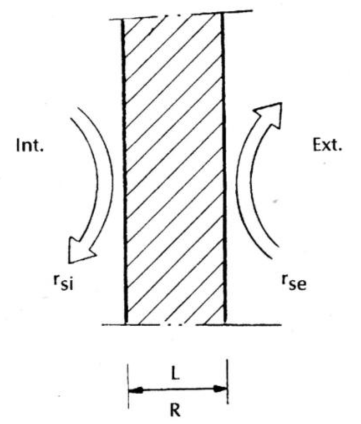

Figure 32: Internal and External Resistances in a normal Wall

Thus, the total thermal resistance of a surface will be:

$$R = R_{si} + R + R_{se} \qquad (7)$$

Where the superficial thermal resistances are:

R_{SI}=0,13 m²K/W

R_{SE}=0,04 m²K/W

Usually, the walls are built using various materials, with different λ and thickness each one, as can be see in figure 33 [11]:

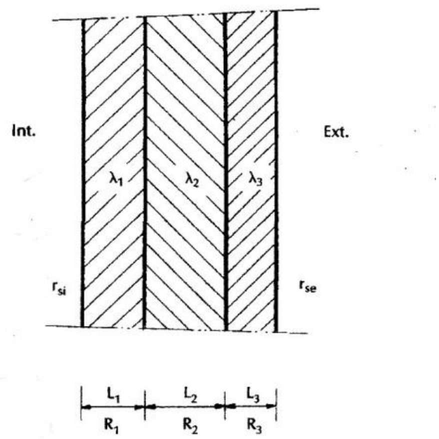

Figure 33: Several Material's Wall

Therefore, the total thermal resistance will be the sum of the partial thermal resistances:

$$R_T = R_{si} + R_1 + R_2 + R_3 + R_{se} \qquad (8)$$

Usually, other factor is used due to its facility of use: the U-value. For calculate the U-value in each part of the structure, is necessary to know the materials and its thickness. If that information is known, it is possible to use the following formula:

$$U = \frac{1}{R_{si} + \sum_{j=1}^{n} R_j + R_{se}} \qquad (9)$$

With the different U-value obtained, the energy transferred through the different structural parts can be calculated:

$$E = Q \cdot t = U \cdot A \cdot \Delta T \cdot t \qquad (10)$$

Where "E" is energy in MWh or kWh, "U" is U-Value in $W/m^2 \cdot °C$, "t" is time in h and "ΔT" is the temperature difference from inside to outside in °C. With the intention of make this calculation easier the parameter "degree hour" is used. Then, the formula can be written like this:

$$E = U \cdot A \cdot Dh \qquad (11)$$

Therefore, in order to calculate the amount of energy transmitted through the building envelope, it is necessary to know the U-value as well as the surface area of it. The building has not the same kind of structure in its entire envelope though. Considering the different in materials and thickness, its envelope is divided in roof and externals walls. The last one is also subdivided: walls, doors and windows. Moreover, it was necessary to calculate the transmission through the floor. Thermal bridges were not included.

2.5.3.2 VENTILATION LOSSES

Around the 20% of the heating inputs in a building are used to heat up the supply air used to ventilation [26]. The algorithm used to calculate the ventilation losses is:

$$\dot{Q} = \dot{V} \cdot \rho \cdot c_p \cdot (T_{room} - T_{supp}) \qquad (12)$$

"$\dot{V}$" Is the total volume of supply air heated (m^3/s). "ρ" and "c_p" are the density (kg/m^3) and the heat capacity (J/kg·K) of air. The temperature gradient which the supply air is heated up is comprised between the temperature of the air supplied "T_{supp}" and the temperature of the room in steady state "T_{room}".

It is important to remark that if the air is pre-heated before entering the room, this energy used must be considered as ventilation losses. Many buildings use exchangers to reduce this pre-heating consumption. The formula used in this case is the same as the one described previously but obviously, with different temperature ranges.

2.5.3.3 HOT TAP WATER

The energy used to warm a specific amount of water "q_{htw}" from low temperature "T_L" to high "T_H" depends on the heat capacity of the water "c_w":

$$Q = q_{\hbar tw} \cdot c_w \cdot \Delta T_{\hbar tw} \qquad (13)$$

The units of heat capacity of water are J/m³·K. Concerning water to sanitary use, the high temperature must reach at least until 55°C in order to avoid microbiological agents like "Legionella". In order to keep this minimum degrees many Swedish buildings are equipped with circulating hot tap water, known as VVC in Swedish, which sustains the temperature no lower than 55°C in any part of the system. The energy consumed by VVC system could be assumed as the losses along the piping system, which this system has to compensate.Therefore, the use of VVC does not contribute in the energy balance.

2.6 ECONOMIC FEASIBILITY STUDY

2.6.1 NPV

In financial terms, the net present value is used in order to know if an investment is profitable. The "NPV" is defined as the sum of the present values of the individual cash flows. Each cash inflow/outflow is discounted back to its present value and then they are summed:

$$NPV = NPV_t = \sum_{t=0}^{t} \frac{R_t}{(1+i)^t} \qquad (14)$$

"t" is the period during the cash flow is considered. The discount rate "i" represents the rate of return on an investment in the financial markets with similar risk can achieve. Finally, "R_t" is the net cash flow (the amount of cash, inflow minus outflow) at time t. Typically, "R_0" is consider as the amount invested in the period 0, which is an outflow.

If the "NPV" exceeds 0 the invested is cost-effective and money is earned. If it rates below 0 is a non-profitable investment.

2.6.2 IRR

A further value to evaluate the desirability of investments or projects is the internal rate of return IRR. This rate complements the NPV because the internal rate of return indicates the efficiency of the investment while the net present value shows the magnitude of an investment.

The internal rate of return on an investment is the discount rate that makes its net present value "NPV" equal to zero:

$$0 = \sum_{t=0}^{t} \frac{R_t}{(1+IRR)^t} \qquad (15)$$

An investment is considered acceptable if its internal rate of return is greater than the discount rate or cost of capital.

2.6.3 PAYBACK

As neither NPV nor IRR provide information about when the investment starts to be profitable, the value Payback is used. This value informs which period the investment begins earning benefits. By calculating the accumulated net cash flows in each period, the Payback could be identified when this value switches from negative to positive value.

3. PROCESS AND RESULTS

3.1 ENERGY BALANCE

As chapter 2.5.1 explains, the global energy balance formula is:

$$Q_{dh} + Q_s + Q_{app} + Q_{us} + Q_{vl} + Q_{tl} + Q_{htw} = \Delta Q \qquad (2)$$

The following tables and figures summarize the overall energy balance of 2009:

Inputs	Total 2009	%
District heating	632,122	69,49%
Solar gains	85,33	9,38%
Internal gains. Appliances	153,43	16,87%
Internal gains. Users	38,75	4,26%
Total input (MWh)	**909,63**	**100%**

Outputs	Total 2009	%
Transmission losses	582,00	70,42%
Ventilation losses. Infiltration	160,45	19,42%
Ventilation losses. Pre-heating	53,56	6,48%
Ventilation losses	15,07	1,82%
Hot tap water	15,34	1,86%
Total output (MWh)	**826,41**	**100%**

Difference (MWh)	**83,22**	**10%**

Table 8: Overall Energy Balance of 2009

It is important to remark that ventilation, transmission and hot tap water losses are negative values.

In the following chapters an accurate study of each term of the energy balance is explained.

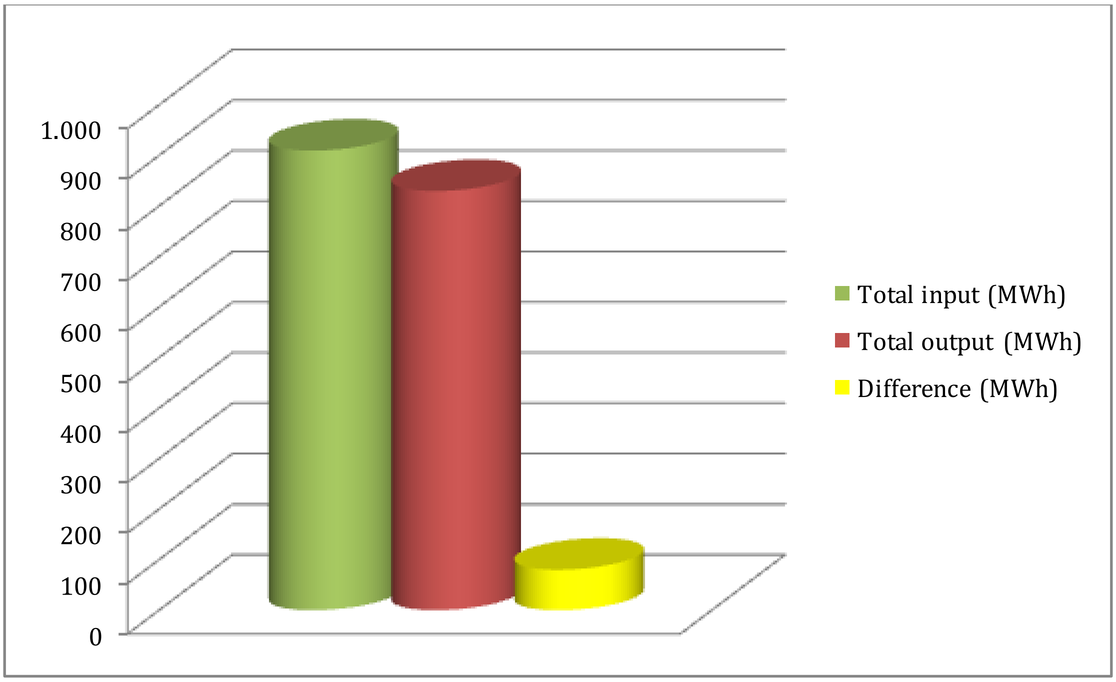

Figure 34: Overall Energy Balance Graph in 2009

Next graphs illustrate the energy inputs and outputs:

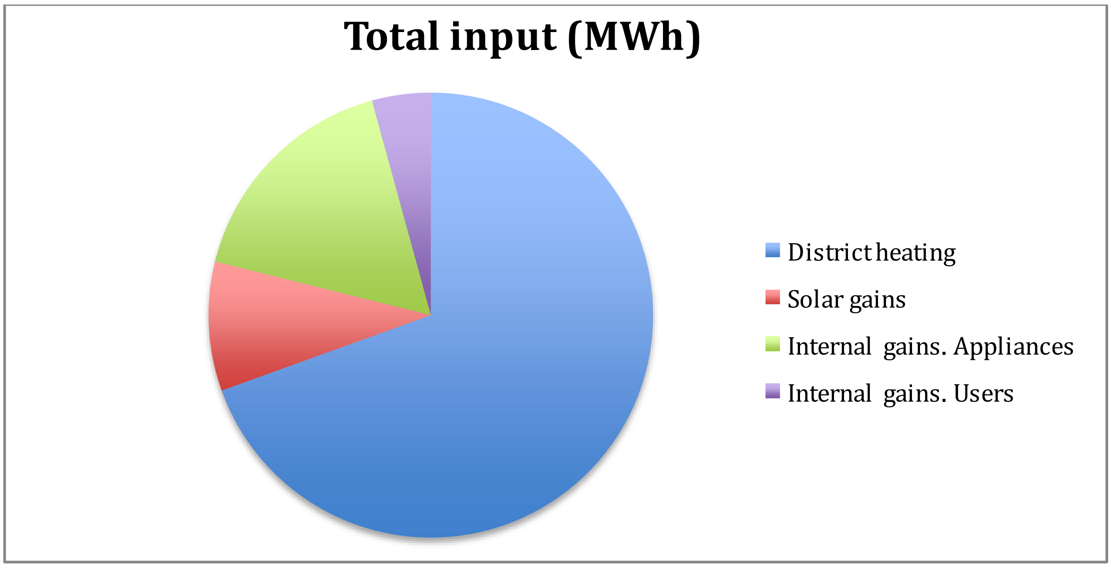

Figure 35: Energy Inputs Table in 2009

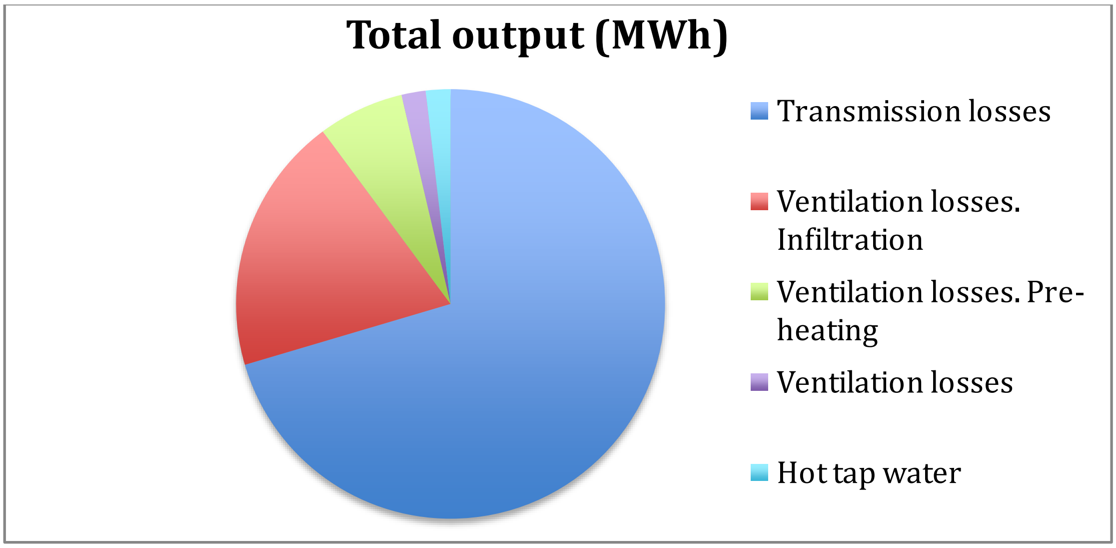

Figure 36: Energy Outputs Table in 2009

3.1.1 ENERGY INPUTS

3.1.1.1 DISTRICT HEATING

The district heating wattage consumption "Q_{dh}" has been extracted from the monthly bills provided by the company "Gävle Energy". They are found in the annex 7.2 and summarized below:

District heating (kWh)	
jan-09	108.150
feb-09	93.720
mar-09	83.872
apr-09	38.520
may-09	18.060
jun-09	16.550
jul-09	4.270
aug-09	5.020
sep-09	16.540
oct-09	65.830
nov-09	63.840
dic-09	117.750
Total 2009	**632.122**

Table 9: District Heating Consumption in 2009

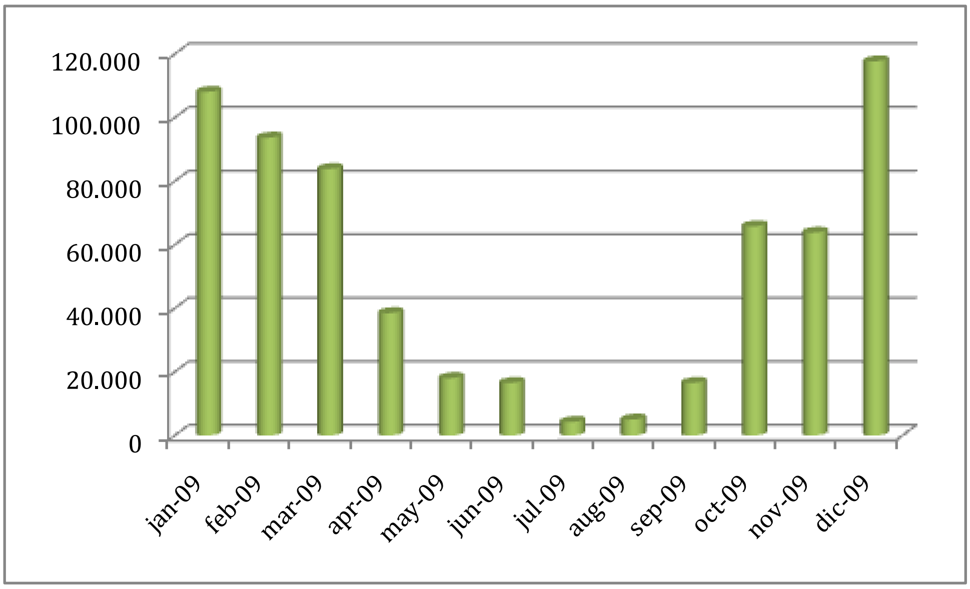

Figure 37: District Heating Consumption Graph in 2009

3.1.1.2 INTERNAL GAINS

3.1.1.2.1 USERS

The dissipate heating from the users "Q_{us}" is calculated by using the subsequent formula:

$$Q_{us} = \sum_{act} q_{act} \cdot N_{act} \cdot F_{uact} \cdot h_{year} \qquad (16)$$

The amount of users "N_{act}" has been calculated by inspecting the number of people doing a specific activity within the building and by estimating the capacity of places like the theater, bar, hall, dining rooms and meeting rooms. The list of users found in each room of the building is shown in the rooms' checklist, annex 7.7.

The specific heating rate per activity "q_{act}" has been extracted from table 2 adding up both sensible and latent heat. This parameter depends on the metabolism of the human body.

The usage factor "F_{uact}" has been estimated regarding the average daily hours spent (in a working day) in order to do a specific activity by a user. Therefore, the product "$N_{act} \cdot F_{uact}$" results the adjusted number of users.

Having said that, the results of each addend are shown in the following table:

Activity	Places	Nact	Average daily hours (h/day)	Fuact	Nact·Fuact	qact (W)	qact·Nact·Fuact (W)
Seated at theater	Theater	400	1	0,04	16,67	95	1.583
Seated, very light work	Meeting rooms, acupuncture rooms	66	2	0,08	5,50	115	633
Moderately active office work	Offices, reception	74	8	0,33	24,67	130	3.207
Sedentary work, dinning	Restaurant, bar, hall	282	2	0,08	23,50	160	3.760
Standing, light work; walking	Theater, bar	23	2	0,08	1,92	130	249
Light bench work	Restaurant's kitchen	9	8	0,33	3,00	220	660

Table 10: Heating from Users

By summing up each addend results the total power gain. Multiplying it by the yearly hours, the total heat gain is calculated:

Total heat power (kW)	10,09
Yearly hours (h/year)	3.840
Total heat gain (kWh/year)	**38.752**

The 160 W heating rate includes 18 W for food per individual. The yearly hours are adjustedto 20 working days per month. During summer time, the building does not gain any energy benefit from users as the environment is already warm. As a result, the hours of the summer months, June, July and August hours are not considered. Half May and half September’s are not considered either. Therefore, the yearly hours result by multiplying 24 h/day by 20 day/month by 8 month/year, which results 3840 h/year.

3.1.1.2.2 APPLIANCES

The heating gain from the appliances, including lighting, "Q_{app}" is calculated via the ensuing algorithm:

$$Q_{app} = \sum_{app} q_{app} \cdot N_{app} \cdot F_{uapp} \cdot h_{year} \qquad (17)$$

Each type of appliance "N_{app}" has been counted by inspecting every room of the building. The list of appliances found is detailed in the rooms' checklist, annex 7.7.

The specific heating rate per each appliance "q_{app}" has been extracted from tables 3A to 6. The heating rate for the non-incandescent light has been provided by table 7. The fluorescent category most installed inside the building is a 1200mm T12 with magnetic ballast and two lamps per fixture, which dissipates 92W. The incandescent lighting extensively found within the edifice consumes 55W. The focus installed dissipates around 500W each fixture.

The usage factor "F_{uapp}" for every appliance has been estimated considering the average daily hours (in a working day) they are turned on. As for the lighting, this factor depends on the type of room they are installed. Thus, the product "$N_{app} \cdot F_{uapp}$" results the adjusted number of appliances. The "F_u" utilized for lighting are:

Place	Average daily hours (h/day)	Fu
Theater, stage, orchestra pit, stage basement, makeup room, projection room, bar, hall, wardrobe, junk room, electric room, maintenance room, server room	1	0,04
Meeting room, stairs, toilet, kitchen, dressing room, laundry, music room, laundry, room, acupuncture room	2	0,08
Office, photocopier room, restaurant's kitchen, restaurant's bar, dining room, bedroom, reception	8	0,33
Corridor, elevator, restaurant's freezer, main entrance, entrance hall, ventilation equipment, heating equipment	24	1,00

Table 11: Fu for Lighting

Taking into consideration the previous parameters and applying the formula, the results are exposed in the next table:

	Napp	Average daily hours (h/day)	Fuapp	Napp·Fuapp	qapp (W)	qapp· Napp·Fuapp (W)
Incandescent	476	Table 11	Table 11	105,07	55	5.779
Fluorescent	546,5	Table 11	Table 11	161,26	92	14.836
Focus	41	Table 11	Table 11	4,33	500	2.167
Computer	117	8	0,33	39,0	205	7.995
Speakers	26	2	0,08	2,2	10	22
Fax	9	1	0,04	0,4	20	8
Photocopier	22	1	0,04	0,9	800	733
Plotter	4	1	0,04	0,2	195	33
Microwave	18	1	0,04	0,8	400	300
Refrigerator	22	24	1,00	22,0	110	2.429
Oven	11	1	0,04	0,5	4169	1.911
TV	7	2	0,08	0,6	100	58
Projector	7	1	0,04	0,3	200	56
Cash register	3	2	0,08	0,3	48	12
Fan	7	1	0,04	0,3	12	4
Hi-fi eq.	3	2	0,08	0,3	7	2
Dishwasher	2	1	0,04	0,1	416	35
Coffee maker	6	1	0,04	0,3	352	88
Griddle	11	2	0,08	0,9	1319	1.209
Fryer	2	2	0,08	0,2	293	49
Dishwasher	2	2	0,08	0,2	410	68
Freezer	4	24	1,00	4,0	540	2.160
Audio mixer	2	2	0,08	0,2	3	1
DVD player	2	2	0,08	0,2	25	4

Table 12: Heating from Appliances

By summing up each addend results the total power gain. Multiplying it by the yearly hours the total heat gain is calculated:

Total heat power (kW)	39,96
Yearly hours (h/year)	3.840
Total heat gain (kWh/year)	**153.430**

The yearly hours are adjustedto 20 working days per month. During summer time, the building does not gain any energy benefit from appliances as the environment is already warm. As a result, the hours of the summer months, June, July and August hours are not considered. Half May and half September's are not considered either. Therefore, the yearly hours result by multiplying 24 h/day by 20 day/month by 8 month/year, which results 3840 h/year.

3.1.1.3 RADIATION GAINS

3.1.1.3.1 CALCULATE ENERGY FROM SOLAR RADIATION

The first step consists on knowing the quantity of energy from solar radiation obviously considering the orientation of the wall. Concerning the Gävle's latitude, 60°, it is provided in the next table, in Wh/m²·day. Observably, the building orientation is not exact; the walls are built with some angle respect the cardinal points. This angle is about 30°, and has been taken into account in the following values [13]:

Month	North (Wh/m²·day)	East (Wh/m²·day)	South (Wh/m²·day)	West (Wh/m²·day)
January	130	160	2.360	1.440
February	370	640	4.280	2.900
March	900	1.720	5.740	4.520
April	990	3.320	6.370	5.850
May	3.050	4.460	5.980	6.150
June	3.870	5.230	5.820	6.350
July	3.510	4.910	5.820	6.280
August	2.380	3.720	6.070	5.850
September	1.230	2.200	5.760	4.820
October	530	1.010	4.960	3.570
November	200	270	3.040	1.910
December	80	80	1.770	1.060

Table 13: Energy from Solar Radiation [13]

Even though these values, although the radiation is coming in the building through the windows, during the warm season this radiation has no effect in the building, due to the building has already have a high temperature and it is not possible to storage more heat in its structure. Therefore, the warmest months have not to take into account. In this case, will be removed the radiation gains between middle of May until middle of September.

3.1.1.3.2 CALCULATE AREAS

The second step consists on calculating the area of windows in each orientation of the building studied, it is because the amount of energy received from the sun depends directly on their area.

As it has been seen, the structure has windows and doors with various sizes differently oriented. The ensuing table is a summary of the different type of windows and doors found in the external walls of the building:

Type	HxW	A [m^2]
A	1,3x1,2	1,56
B	1,8x1,55	2,79
C	1,5x1	1,5
D	1,7x1,2	2,04

Table 14: Area of different types of windows and doors

Per each orientation, the total glass windows' area is provided by the following tables. In these calculations, it was unconsidered the patio walls due to the little contribution to the total amount, regarding the slight sunshine angle and the low distance between two opposite walls in the patio:

-North:

Type	North	Area [m^2]
A	44	68,64
B	-	-
C	-	-
D	4	8,16
Others [m^2]	50,86	50,86
TOTAL		127,66

-East:

Type	East	Area [m^2]
A	42	65,52
B	5	13,95
C	4	6
D	-	-
Others [m^2]	23,76	23,76
TOTAL		109,23

-South:

Type	South	Area [m^2]
A	26	40,56
B	-	-
C	3	4,5
D	-	-
Others [m^2]	-	-
TOTAL		45,06

-West:

Type	West	Area [m^2]
A	43	67,08
B	10	27,9
C	10	15
D	-	-
Others [m^2]	4,8	4,8
TOTAL		114,78

Table 15: Total glass windows area

3.1.1.3.3 CALCULATE FACTORS

In addition, it is necessary to use two factors to precise these values. The solar energy input is reduced for the cloudy days "K1" [13], and it varies every month, as it depends on the climate. Another factor "K2" [14]specifies the kind of the windows. In "Folkets Hus", as it was commented earlier, the windows installed are double-glassed:

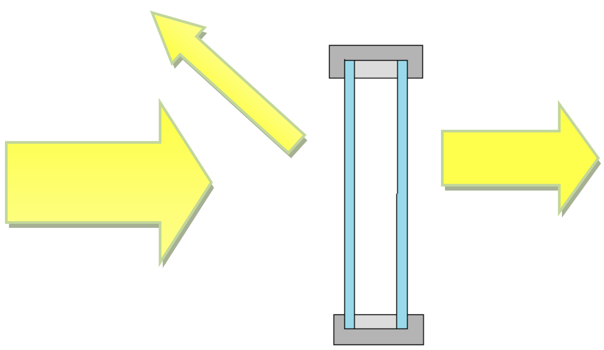

Figure 38: Solar Energy Transmission in Windows

$$K2 = 0{,}8$$

This factor reduces in percentage the solar energy through the window, and it is the same the entire year.

Having said that, the formula applied has been explained in chapter 2.5.2.2:

$$Q_{total} = \sum_{i}^{mont\ hs} Q \cdot K1 \cdot K2 \cdot \frac{n^{\underline{o}}\ day}{mont\ h} \cdot A \qquad (3)$$

And the constants are indicated in the next table:

Month	K1	K2
January	0,45	0,8
February	0,49	0,8
March	0,58	0,8
April	0,58	0,8
May	0,63	0,8
September	0,58	0,8
October	0,51	0,8
November	0,42	0,8
December	0,43	0,8

Table 16: Calculate Factors per Month

3.1.1.3.4 RESULTS

Considering the values and the factors, the sum of energy per each orientation is:

-North:

	North (Wh/m2)	North (Wh)	Nº day per month	K2	K1	Q (Wh)	Q (KWh)	Q (KJ)
Jan.	130	16595,8	31	0,45	0,8	185209	185	666753
Feb.	370	47234,2	28	0,49	0,8	518443	518	1866393
Mar	900	114894	31	0,58	0,8	1652635	1652	5949487
April	990	126383,4	30	0,58	0,8	1759257	1759	6333325
May	3050	389363	15	0,63	0,8	2943584	2943	10596903
Sept.	1230	157021,8	15	0,58	0,8	1092872	1092	3934338
Oct.	530	67659,8	31	0,51	0,8	855761	855	3080740
Nov.	200	25532	30	0,42	0,8	257363	257	926505
Dec.	80	10212,8	31	0,43	0,8	108909	108	392073
						TOTAL	**9374,03**	**33746519**

-East:

	East (Wh/m2)	East (Wh)	Nº day per month	K2	K1	Q (Wh)	Q (KWh)	Q (KJ)
Jan.	160	17477	31	0,45	0,8	195041	195	702148
Feb.	640	69907	28	0,49	0,8	767301	767	2762285
Mar	1720	187876	31	0,58	0,8	2702403	2702	9728649
April	3320	362644	30	0,58	0,8	5047999	5048	18172796
May	4460	487166	15	0,63	0,8	3682973	3683	13258704
Sept.	2200	240306	15	0,58	0,8	1672530	1673	6021107
Oct.	1010	110322	31	0,51	0,8	1395356	1395	5023283
Nov.	270	29492	30	0,42	0,8	297280	297	1070209
Dec.	80	8738	31	0,43	0,8	93186	93	335471
						TOTAL	**15854**	**57074653**

-South:

	South (Wh/m2)	South (Wh)	Nº day per month	K2	K1	Q (Wh)	Q (KWh)	Q (KJ)
Jan.	2360	106342	31	0,45	0,8	1186772	1187	4272380
Feb.	4280	192857	28	0,49	0,8	2116796	2117	7620466
Mar	5740	258644	31	0,58	0,8	3720341	3720	13393228
April	6370	287032	30	0,58	0,8	3995488	3995	14383758
May	5980	269459	15	0,63	0,8	2037109	2037	7333591
Sept.	5760	259546	15	0,58	0,8	1806437	1806	6503175
Oct.	4960	223498	31	0,51	0,8	2826798	2827	10176472
Nov.	3040	136982	30	0,42	0,8	1380783	1381	4970817
Dec.	1770	79756	31	0,43	0,8	850520	851	3061872
						TOTAL	**19921**	**71715758**

-West:

	West (Wh/m2)	West (Wh)	Nº day per month	K2	K1	Q (Wh)	Q (KWh)	Q (KJ)
Jan.	1440	165283	31	0,45	0,8	1844561	1845	6640418
Feb.	2900	332862	28	0,49	0,8	3653493	3653	13152576
Mar	4520	518806	31	0,58	0,8	7462500	7462	26864999
April	5850	671463	30	0,58	0,8	9346765	9347	33648354
May	6150	705897	15	0,63	0,8	5336581	5337	19211693
Sept.	4820	553240	15	0,58	0,8	3850548	3851	13861971
Oct.	3570	409765	31	0,51	0,8	5182703	5183	18657730
Nov.	1910	219230	30	0,42	0,8	2209836	2210	7955411
Dec.	1060	121667	31	0,43	0,8	1297455	1297	4670837
						TOTAL	**40184**	**144663989**

Table 17: Radiation gains per each orientation

Finally, the overall energy received from sunshine is:

Month	Q (Wh)	Q (MWh)
January	3.411.583	3,412
February	7.056.034	7,056
March	15.537.879	15,538
April	20.149.509	20,150
May	14.000.248	14,000
September	8.422.386	8,422
October	10.260.618	10,261
November	4.145.262	4,145
December	2.350.070	2,350
	TOTAL	**85,334**

Table 18: Total Radiation Gains

3.1.2 ENERGY OUTPUTS

3.1.2.1 TRANSMISSION LOSSES

3.1.2.1.1 U-VALUE

3.1.2.1.1.1 EXTERNAL WALLS

a) Walls:

Due to the impossibility of knowing the exactly composition of it, it was necessary to revise specific bibliography [15], about the buildings that were built in the same years than "Folkets Hus". By using it:

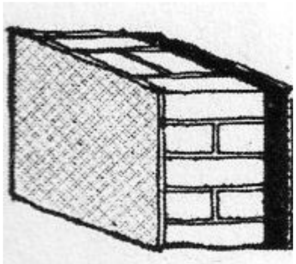

Figure 39: Type of External Wall [15]

Where the different layers from the exterior to interior are:

1. Bricks
2. Interior insulation

And for that type of composition, the U-value is [15]:

$$U = 0{,}8 \frac{W}{K \cdot m^2}$$

b) Doors & windows:

In the building, the windows are with double-glass window, and the glass used is clear glass:

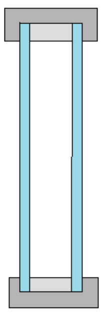

Figure 40: Type of Windows

For this type of window the U-value is [14]:

$$U = 3\ \frac{W}{K \cdot m^2}$$

3.1.2.1.1.2 ROOF

Like the same reasons for the walls, it was necessary to revise bibliography [15] about the buildings that were built in the same years than "Folkets Hus". Therefore:

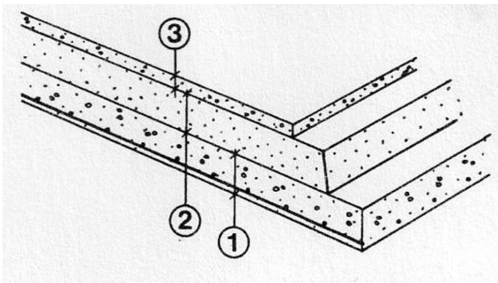

Figure 41: Type of Roof [15]

Where each layer is:

4. Reinforced concrete with smooth lower surface
5. Filling of granulated blast furnace slag
6. Screed concrete finish

And whose U-value is [15]:

$$U = 0{,}45\ \frac{W}{K \cdot m^2}$$

3.1.2.1.1.2 FLOOR

In this case, is not possible to use the same method than previous cases. The transmission is not only through the wall, it is throughthe wall and the ground. Therefore, the U-values have a particular way of calculation.

As the building has a basement in its all area, the transmission between the building and the ground is done through the floor as well as through part of basement's walls. Owing to it, it is necessary to differentiate these two types of transmission: type "a" buried walls and type "b" floor.

In addition to this, there are several zones with different R-value for the ground, and consequently, diverse U-value, depending on the distance from the exterior ground level in type "a"; and depending on the distance from the wall in type "b".

The thermal resistance is, in this case:

$$R_{Total} = R_{si} + R_{wall} + R_{ground} + R_{se} \qquad (18)$$

Considering here the U-value of the wall 0.8 [15], in which is included R_{si} and R_{se}:

$$R_{Total} = \frac{1}{0{,}8} + R_{ground}$$

Having said that, the heat transmission is calculated by using the equation explained in 2.5.3.1:

$$E = U \cdot A \cdot Dh \qquad (11)$$

a) Buried walls:

In this case, there are 3 U-values. These are:

Distance	R_{ground}	R_{total}	U_{value}
0-1	0,35	1,600	**0,625**
1-2	1,1	2,350	**0,426**
>2	2,2	3,450	**0,290**

Table 19: Buried Walls U-Value

"Distance" is the height between the exterior ground level and the level of the wall under study, in meters.

b) Floor:

In this other case, there are also 3 values for U also. These are:

Distance	R_{ground}	R_{total}	U_{value}
0-1	0,7	1,950	**0,513**
1-6	2,2	3,450	**0,290**
>6	2,7	3,950	**0,253**

Table 20: Floor's U-Values

"Distance" is the length between the closer exterior wall, and the point under study.

3.1.2.1.2 CALCULATED AREAS

3.1.2.1.1.2 EXTERNAL WALLS

a) Walls:

The external walls are found along the building envelope as well as the ones found in the inside patio. By using the drawings, it was possible to calculate the total area of the walls in each orientation, and secondly, it was possible to subtract the area of each window and door. With this procedure, the building has for externals walls, depending on the orientation:

Orientation	Area [m^2]
North	304,59
East	390,92
South	338
West	414,17
TOTAL	1447,68

Table 21: External Walls Area

Concerning the inside patio, the area of the walls is, according to their orientation:

Orientation	Area [m^2]
North	57,79
East	106,07
West	113,74
South	63,5
TOTAL	341,1

Table 22: Patio Walls Area

Consequently, the total area of the external walls in the building is:

$$A_w = A_{ew} + A_{pw} = 1447{,}68 + 341{,}1 = \mathbf{1788{,}78}\boldsymbol{m^2}$$

b) Windows & doors:

The building has windows and doors with different sizes, and they also have diverse orientation. The next table is a summary of the various type of windows and doors in the building:

Type	HxW	Area [m²]
A	1,3x1,2	1,56
B	1,8x1,55	2,79
C	1,5x1	1,5
D	1,7x1,2	2,04

Table 23: Area of different types of windows and doors

In the subsequent table, it is exposed the amount of every type of window in the building for each orientation. Type "Others" includes the doors and display windows' area:

Type	N	E	S	W
A	44	42	26	43
B	0	5	0	10
C	0	4	3	10
D	4	0	0	0
Others [m²]	50,86	23,76	0	4,8

Table 24: Number of each type of window for each orientation

Regarding the inside patio windows, two more types are found:

Type	HxW	Area [m^2]
E	1,3x1,3	1,69
F	1,3x0,9	1,17

Table 25: Types of windows inside the patio

They are also classified according to their orientation:

Type	N	E	W
E	12	20	16
F	6	9	6
Others [m^2]	-	-	2,6

Table 26: Number of each type of window for each orientation in the patio

Altogether, the area of windows, doors and display windows is:

$$A_{wi} = A_{ewi} + A_{pwi} = 396{,}73 + 108{,}29 = \mathbf{505{,}02m^2}$$

3.1.2.1.1.3 ROOF

Relating to the roof, it is divided into the patio's roof, and the normal roof. Moreover, the normal one is also subdivided into "A", "B", "C" types and the patio is also subdivided into "D", "E" as two different heights are considered. The area of each part is exposed in the following table:

Normal Roof	
Type	Area [m^2]
A	349,2
B	349,2
C	319,06
TOTAL	**1017,46**

Table 27: Normal Roof Area

Patio	
Part	**Area (m2)**
D	269,86
E	104,8
TOTAL	**374,66**

Table 28: Patio Roof Area

$$A_r = A_{nr} + A_{pr} = 1017{,}46 + 374{,}66 = \mathbf{1392{,}12 m^2}$$

3.1.2.1.1.4 FLOOR

a) Buried Wall:

In this case, it was necessary to calculate the depth of the wall that was buried under the ground for each orientation:

Orientation	Depth (m)
North	4
South	5,2
East	3,6
West	5,3

Table 29: Depth of the wall in each orientation

b) Floor:

In this other case, it was necessary to calculate the distance between opposite walls of the basement in order to obtain their transmission losses:

Distance	Longitude (m)
North-South	42,7
East-West	37,1

Table 30: Distance between opposite walls of the whole building

3.1.2.1.2 LOSSES

Concerning the floor, as it was previously said, the calculations are more complex:

a) Buried Walls:

NORTH	Section	Longitude [m]	Amplitude [m]	Area [m^2]	R_{ground} [m^2K/W]	R_{total} [m^2K/W]	U_{value} [W/m^2K]	Total [W/K]
	0-1	1	39,9	39,9	0,35	1,600	0,625	**24,94**
	1-2	1	39,9	39,9	1,1	2,350	0,426	**16,98**
	2-4	2	39,9	79,8	2,2	3,450	0,290	**23,13**
							TOTAL	**65,05**

SOUTH	Section	Longitude [m]	Amplitude [m]	Area [m^2]	R_{ground} [m^2K/W]	R_{total} [m^2K/W]	U_{value} [W/m^2K]	Total [W/K]
	0-1	1	46,5	46,5	0,35	1,600	0,625	**29,06**
	1-2	1	46,5	46,5	1,1	2,350	0,426	**19,79**
	2-5,2	3,2	46,5	148,8	2,2	3,450	0,290	**43,13**
							TOTAL	**91,98**

EAST	Section	Longitude [m]	Amplitude [m]	Area [m^2]	R_{ground} [m^2K/W]	R_{total} [m^2K/W]	U_{value} [W/m^2K]	Total [W/K]
	0-1	1	37,5	37,5	0,35	1,600	0,625	**23,44**
	1-2	1	37,5	37,5	1,1	2,350	0,426	**15,96**
	2-3,6	1,6	37,5	60	2,2	3,450	0,290	**17,39**
							TOTAL	**56,79**

WEST	Section	Longitude [m]	Amplitude [m]	Area [m^2]	R_{ground} [m^2K/W]	R_{total} [m^2K/W]	U_{value} [W/m^2K]	Total [W/K]
	0-1	1	52,7	52,7	0,35	1,600	0,625	**32,94**
	1-2	1	52,7	52,7	1,1	2,350	0,426	**22,43**
	2-5,3	3,3	52,7	173,91	2,2	3,450	0,290	**50,41**
							TOTAL	**105,7**

Table 31: Buried Walls Losses per each Orientation

b) Directly Floor:

NORTH	Section	Longitude [m]	Amplitude [m]	Area [m^2]	R_{ground} [m^2K/W]	R_{total} [m^2K/W]	U_{value} [W/m^2K]	Total [W/K]
	0-1	1	47,1	47,1	0,7	1,950	0,513	**24,15**
	1-6	5	47,1	235,5	2,2	3,450	0,290	**68,26**
	6-21,35	15,35	37,1	569,49	2,7	3,950	0,253	**144,17**
							TOTAL	**236,59**

SOUTH	Section	Longitude [m]	Amplitude [m]	Area [m^2]	R_{ground} [m^2K/W]	R_{total} [m^2K/W]	U_{value} [W/m^2K]	Total [W/K]
	0-1	1	47,1	47,1	0,7	1,950	0,513	**24,15**
	1-6	5	47,1	235,5	2,2	3,450	0,290	**68,26**
	6-21,35	15,35	37,1	569,49	2,7	3,950	0,253	**144,17**
							TOTAL	**236,59**

EAST	Section	Longitude [m]	Amplitude [m]	Area [m^2]	R [m^2K/W]	R_{total} [m^2K/W]	U_{value} [W/m^2K]	Total [W/K]
	0-1	1	42,7	42,7	0,7	1,950	0,513	**21,90**
	1-6	5	42,7	213,5	2,2	3,450	0,290	**61,88**
	6-18,55	12,55	42,7	535,89	2,7	3,950	0,253	**135,67**
							TOTAL	**219,45**

WEST	Section	Longitude [m]	Amplitude [m]	Area [m^2]	R [m^2K/W]	R_{total} [m^2K/W]	U_{value} [W/m^2K]	Total [W/K]
	0-1	1	42,7	42,7	0,7	1,950	0,513	**21,90**
	1-6	5	42,7	213,5	2,2	3,450	0,290	**61,88**
	6-18,55	12,55	42,7	535,89	2,7	3,950	0,253	**135,67**
							TOTAL	**219,45**

Table 32: Directly Floor Losses per each Orientation

The previous values are added up in the following tables:

Buried Walls	
Orientation	**Total [W/K]**
North	65,05
South	91,98
East	56,79
West	105,77
TOTAL	**319,58**

Floor	
Section	**Total [W/K]**
North	236,59
South	236,59
East	219,45
West	219,45
TOTAL	**912,07**

Table 33: Buried Walls and Floor Losses

Calculating the total losses without considering the degree-hours, it is obtained:

Part	Area [m²]	U_{value} [W/m²K]	Total [W/K]
Walls	1788,78	0,8	1431,02
Windows	505,02	3	1515,06
Roof	1392,12	0,45	626,45
Buried Walls	-	-	319,58
Floor	-	-	912,07
		TOTAL	**4804,19**

Table 34: Losses without Considering the Degree-Hours

Finally, considering these values and the degree-hours, the sum of transmission energy losses of the building is, by using equation 11:

Month	Degree-hours [K·h]	Energy [MWh]
January	19.254,9	92,50
February	17.552,5	84,33
March	16.114,2	77,42
April	12.357,2	59,37
May	5.576,9	26,79
June	1.027,3	4,94
July	0,0	0,00
August	352,2	1,69
September	5.811,7	27,92
October	10.596,1	50,91
November	14.353,1	68,96
December	18.256,9	87,71
	TOTAL	**582,52**

Table 35: Transmission Losses

3.1.2.2 VENTILATION LOSSES

The District Heating supplies energy for several purposes: hot tap water, radiators and to heat up the ventilation supply air at certain areas of the building.

The heat used for the supply air heating, can be calculated by the following formula:

$$\dot{Q}_{heat} = \dot{V} \cdot \rho \cdot c_p \cdot (T_{supp} - T_{out}) \qquad (19)$$

$\dot{V}$ is the treaty air flow upstream of the final device due to ventilation; ρ is the density of air; c_p is the specific heat capacity of air; T_{supp} is the temperature after treatment, i.e. supply temperature; and T_{out} is the outdoor temperature.

These all temperatures were measured directly by thermometer. The outdoor temperature is the main for a normal year in Gävle, 5°C, except for the restaurant subsystem which has a exchange ventilation system that permit to heat up the outdoor temperature up to 14°C.

The different ventilation air flows, temperatures and supply air heating in the building are:

Using for air:

$$c_p = 1{,}005 \text{ kJ/kg·K}$$

$$\rho = 1{,}205 \text{ kg/m}^3$$

Subsystem	$\dot{V}$ (m3/h)	$\dot{V}$ (m3/s)	T_{supply} (°C)	T_{out} (°C)	$\dot{Q}_{heat}$ (kW)
Hall + meeting rooms	2625,2	0,729	18	5	11,47
Restaurant + bar	1918,8	0,533	20	14	3,87
Theater	2592,0	0,720	16	5	9,59
Scene + make up rooms	3697,2	1,027	16	5	13,68
ABF café	1600,0	0,444	18	5	6,99

Table 36: Ventilation Air Flows , Temperatures and supply air heating

By multiplying the supply air heating and the number of working hours of each ventilation system, it is obtained the total ventilation heating losses:

Subsystem	$\dot{Q}_{heat}$ (kW)	Working hours/year	kWh/year
Hall + meeting rooms	11,47	1033,2	11.862
Restaurant + bar	3,87	1623,6	6.288
Theater	9,59	1033,2	9.910
Scene + make up rooms	13,68	1033,2	14.135
ABF café	6,99	1623,6	11.360
TOTAL			**53.555**

Table 37: Ventilation pre-heating losses

On the other hand, inside the rooms the supply air is heated up from the supply temperature to room temperature. If we use formula 12 exposed in 2.5.3.2:

$$\dot{Q} = \dot{V} \cdot \rho \cdot c_p \cdot (T_{room} - T_{supp}) \qquad (12)$$

Where c_p and ρ have the same value than before; $\dot{V}$ is the ventilation air flow of all rooms with supply ventilation system; T_{supp} is the supply temperature, which depends on each system; and T_{room} is the room temperature, 20°C for all building. Therefore, by using the equation 12:

Subsystem	$\dot{V}$ (m3/h)	$\dot{V}$ (m3/s)	T_{room} (°C)	T_{supp} (°C)	$\dot{Q}$ (kW)
Hall + meeting rooms	2625,2	0,729	20	18	1,76
Restaurant + bar	1918,8	0,533	22	20	1,29
Theater	2592,0	0,720	20	16	3,48
Scene + make up rooms	3697,2	1,027	20	16	4,97
Meeting rooms 0.51	576,0	0,160	20	18	0,38
Meeting rooms 0.52	576,0	0,160	20	18	0,38
Meeting rooms 0.53	1080,0	0,300	20	18	0,72
ABF café	1600,0	0,444	20	18	1,07
Meeting room 2.1 + Kitchen 2.2	255,0	0,071	20	18	0,17

Table 38: Rooms Air-Flows and Temperatures data

By multiplying the power by the number of working hours of each ventilation subsystem, it is obtained the total necessary heat:

Subsystem	$\dot{Q}$ (kW)	Working hours/year	kWh/year
Hall + meeting rooms	1,76	1033,2	1.825
Restaurant + bar	1,29	1623,6	2.096
Theater	3,48	1033,2	3.604
Scene + make up rooms	4,97	1033,2	5.140
Meeting rooms 0.51	0,38	393,6	153
Meeting rooms 0.52	0,38	393,6	153
Meeting rooms 0.53	0,72	393,6	286
ABF café	1,07	1623,6	1.748
Meeting room 2.1 + Kitchen 2.2	0,17	393,6	68
TOTAL			**15.071**

Table 39: Ventilation Losses

Lastly, it is necessary to consider the ventilation heat losses due to the infiltration in the zone of the building where there is only exhaust ventilation, i.e. the office's part: the floors 1, 2 and 3. Since the infiltration air flow in the building is quite hard to estimate, it has been calculated by measuring the amount of air that is going out of the room through exhaust ventilation, which is $\dot{V}$, as it should be the same value. These losses are divided into 3 groups, each one for each floor of the building with exhaust ventilation only.

Using formula 12 and taking into account that the yearly main outdoor temperature in Gävle is 5°C, and the indoor temperature is 20°C:

Subsystem	$\dot{V}$ (l/s)	$\dot{V}$ (m3/s)	T_{room} (°C)	T_{supp} (°C)	$\dot{Q}$ (kW)
1st	176,4	0,176	20	5	3,19
2nd	406,9	0,407	20	5	7,39
3rd	425	0,425	20	5	7,72

Table 40: Offices Air-Flows , Temperatures and supply air heating data

The usage factor of this ventilation system is 1 as the exhaust fans are working 24 hours per day during all year. Therefore, the infiltration losses in these parts of the building are:

Subsystem	$\dot{Q}$(kW)	Working hour/year	kWh/year
1st	3,19	8760	28.070
2nd	7,39	8760	64.749
3rd	7,72	8760	67.630
Total			160.449

Table 41: Offices Infiltration Losses

3.1.2.3 HOT TAP WATER

The total water consumption at "Gävle Folkets Hus" in 2009 was 765 m^3. The experience says that the fraction of hot tap water is around 35%, so 269.15 m^3. The formula used to calculate the energy losses from warming tap water is explained in chapter 2.5.3.3 and exposed next:

$$Q_{htw} = q_{htw} \cdot c_w \cdot \Delta T_{htw} \qquad (13)$$

In Gävle, the average ground temperature is about 6°C. In order to avoid microbiological agents as "Legionella", tap water should be heated at least until 55°C and the temperature never has to decrease below 50°C. Therefore, tap water should be heated 49°C. Subsequently, the calculation of "Q_{htw}" is shown:

q_{htw} (m3/year)	C_w (kJ/m3·°C)	ΔT_{htw} (°C)	Q_{htw} (kJ/year)
269,15	4187	49	55.219.621

Energy consumption (kJ/year)	55.219.621
kJ/kWh	3.600
Energy consumption (kWh/year)	**15.339**

Table 42: Hot tap water energy consumption

"Gävle Folkets Hus" is equipped with circulating hot tap water, known as VVC in Swedish. The energy consumed by VVC system could be assumed as the losses along the piping system, which this system has to compensate.Therefore, the use of VVC does not contribute in the energy balance.

3.2 SPECIFIC ENERGY CONSUMPTION FACTOR

As chapter 2.2 defines, the specific energy consumption factor χ is calculated through the subsequent algorithm:

$$\chi = \frac{Q_{dh} + E_{eq} + E_{el}}{S_h} \qquad (20)$$

The parameter "S_h" is the heated and/or ventilated area, i.e., the area whose surface is heated and/or ventilated by the devices used for space heating. This area has been measured on the drawings provided in Annex 7.1. "E_{eq}" is the yearly energy consumption of the devices installed in the ventilation systems. Due to the impossibility of inspection the devices used in the heating system has been not taken into account:

$$E_{eq} = \sum_{eq} W_{eq} \cdot N_{eq} \cdot F_{ueq} \cdot h_{year} \qquad (21)$$

The different devices "N_{eq}" have been inspected in the aggregate room, the rooms provided by own ventilation systems and the roof.

"W_{eq}" represents the power consumption of each device. The consumption of some fans has been possible to identify in his nameplates. As for each system, the flow rate is known; the power of the rest of the fans has been extracted from the ensuing graph [27]:

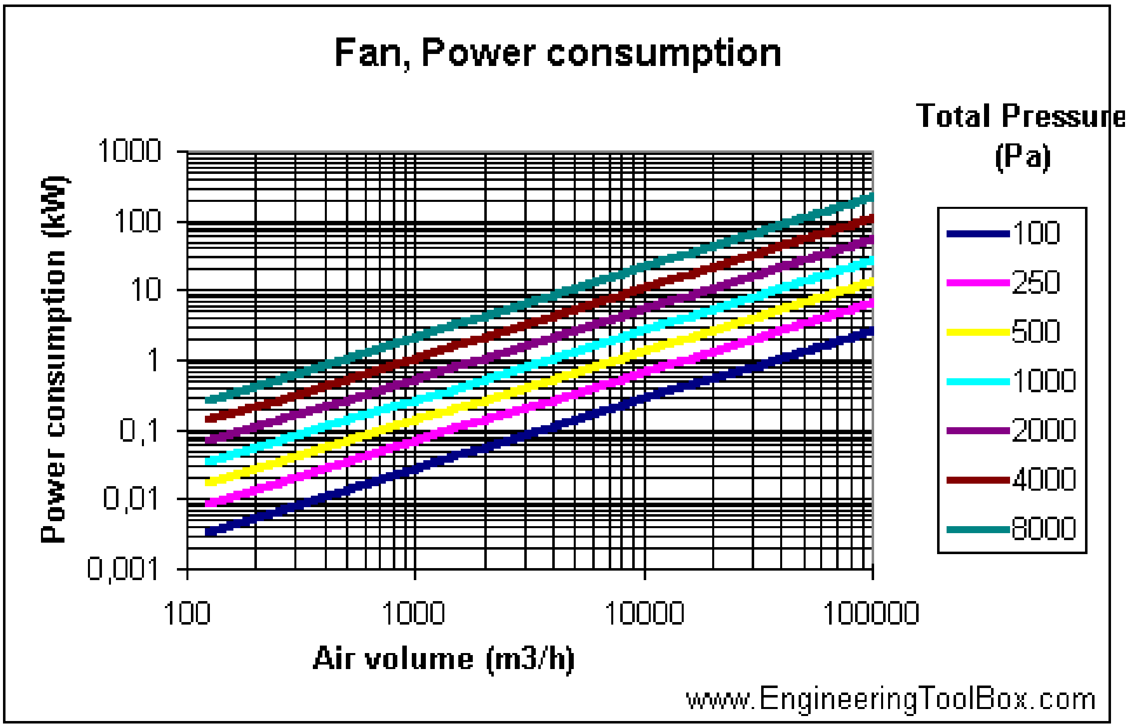

Figure 42: Fan power consumption graph [27]

It has to be said that the values of this graph should be divided by the efficiency, which has been assumed as 65%. It also has been considered a medium pressure value, 2000 Pa.

The own ventilation systems of the meeting rooms are provided by electrical heaters. These heaters warm the air "V_{heater}" from the outside temperature to the measured temperature of the supply air, 18°C. Knowing that, their electrical consumption "W_{heater}" is calculated by the subsequent formula:

$$\dot{W}_{heater} = \dot{V}_{heater} \cdot c_p \cdot \rho \cdot (T_{room} - T_{out}) \qquad (22)$$

By using the previous algorithm, the calculations are shown below:

Ventilation heater	V_{heater} (m3/h)	V_{heater} (m3/s)	T_{room} (°C)	T_{out} (°C)	W_{heater}(kW)
Meeting rooms 0.51	576,0	0,160	18	5	2,52
Meeting rooms 0.52	576,0	0,160	18	5	2,52
Meeting rooms 0.53	1080,0	0,300	18	5	4,72
Meeting room 2.1 + Kitchen 2.2	255,0	0,071	18	5	1,12

Table 43: Heaters Consumption

Using for air:

$$c_p = 1{,}005 \text{ kJ/kg·K}$$

$$\rho = 1{,}205 \text{ kg/m}^3$$

The usage factor "F_{ueq}" has been estimated considering the average daily hours the devices are on, which depend on the activity done in the ventilated area. The ventilation subsystems of the hall, scene and theater are turned on 4 hours before the activity start. Thus, the product "N_{eq}· F_{ueq}" results the adjusted number of equipment:

Ventilation sub-system	Device	Neq	Average daily hours (h/day)	Fueq	Neq·Fueq
1st, 2nd, 3rd floor exhaust system	Exhaust fan	10	24	1	10
Restaurant + bar	Supply fan	1	8	0,33	0,33
	Exhaust fan	1	8	0,33	0,33
Scene + makeup rooms	Supply fan	1	5	0,21	0,21
	Exhaust fan	1	5	0,21	0,21
Theater	Supply fan	1	5	0,21	0,21
	Exhaust fan	1	5	0,21	0,21
Hall + meeting rooms	Supply fan	1	5	0,21	0,21
	Exhaust fan	1	5	0,21	0,21
ABF Café	Supply fan	1	8	0,33	0,33
	Exhaust fan	1	8	0,33	0,33
Meeting room 0.51	Supply fan	1	2	0,08	0,08
	Exhaust fan	1	2	0,08	0,08
	Heater	1	2	0,08	0,08
Meeting room 0.52	Supply fan	1	2	0,08	0,08
	Exhaust fan	1	2	0,08	0,08
	Heater	1	2	0,08	0,08
Meeting room 0.53	Supply fan	1	2	0,08	0,08
	Exhaust fan	1	2	0,08	0,08
	Heater	1	2	0,08	0,08
Meeting room 2.1 + Kitchen 2.2	Supply fan	1	2	0,08	0,08
	Exhaust fan	1	2	0,08	0,08
	Heater	1	2	0,08	0,08

Table 44: Ventilation devices data

Regarding the previous parameters and using the formula, the results are shown in the next table. The nameplate consumption and nominal flow rate of some fans are highlighted in blue:

Ventilation sub-system	Device	Flow rate (m3/h)	Weq (W)	Neq·Fueq	Weq·Neq·Fueq (W)	Duty time (h/year)
1st, 2nd, 3rd floor exhaust system	Exhaust fan	3.630	308	10	3.077	8760
Restaurant + bar	Supply fan	13.700	7.500	0,33	2.475	4920
	Exhaust fan	12.800	7.000	0,33	2.310	4920
Scene + makeup rooms	Supply fan	3.300	1.500	0,21	315	4920
	Exhaust fan	2.300	2.200	0,21	462	4920
Theater	Supply fan	13.700	7.500	0,21	1.575	4920
	Exhaust fan	13.500	5.500	0,21	1.155	4920
Hall + meeting rooms	Supply fan	13.700	7.500	0,21	1.575	4920
	Exhaust fan	13.500	5.500	0,21	1.155	4920
ABF Café	Supply fan	1.600	1.538	0,33	508	4920
	Exhaust fan	2.050	2.308	0,33	762	4920
Meeting room 0.51	Supply fan	576	462	0,08	37	4920
	Exhaust fan	300	308	0,08	25	4920
	Heater	576	2.519	0,08	202	4920
Meeting room 0.52	Supply fan	576	462	0,08	37	4920
	Exhaust fan	300	308	0,08	25	4920
	Exhaust fan	576	2.519	0,08	202	4920
Meeting room 0.53	Supply fan	1.080	769	0,08	62	4920
	Exhaust fan	750	462	0,08	37	4920
	Heater	1.080	4.723	0,08	378	4920
Meeting room 2.1 + Kitchen 2.2	Supply fan	255	308	0,08	25	4920
	Exhaust fan	360	308	0,08	25	4920
	Heater	255	1.115	0,08	89	4920

Table 45: Energy Consumption of Devices

Except for the exhaust fans of the 1st, 2nd and 3rd floor, the number 8760 h/year is adjusted to the actual working days, 205. Therefore, the 8760 h/year is multiplied by "205/365" as there are 20 working days per month and 35 days of vacation.

The electricity used in external lighting, "E_{el}" has not been considered due to the lack of data and his low value in respect of the rest of energy terms.

Having said that, the calculation of the specific energy consumption factor is possible:

Specific energy consumption factor	
District heating (kWh/year)	632.122
Equipment (kWh/year)	93.040

Total (kWh/year)	725.162
Total heated Surface (m2)	5.584
Specific energy consumption factor (kWh/year·m2)	**129,86**

Table 46: Specific Energy Consumption Factor Calculation

3.3 ECONOMIC FEASIBILITY STUDY

3.3.1 NEW VENTILATION INSTALLATION

As the offices found in 1st, 2nd and 3rd floor are not provided by a mechanical supply ventilation system, its installation is needed. In order to follow Socialstyrelsen recommendations, the new system would be able to supply around 1.300 l/s to the current offices. In principle, the new aggregate room would be installed in the roof and it would be provided by exchanger. Obviously,the exhaust air would go through the exchanger before being expelled to the outside.

- **Investment**

Mr. Roland Forsberg has estimated the cost of the new ventilation system, which means an investment of 1.000.000 SEK approximately.

- **Savings**

The new installation will eliminate the current infiltration losses of the old installation and it will eliminate its electrical consumption. According to the district heating's monthly bills of 2009, see annex 7.2, the price per kWh is 0.52 SEK/kWh. Electricity cost is around 1 SEK/kWh. Therefore, the savings would be:

Savings	kWh/year	SEK/kWh	SEK/year
Infiltration losses	160.449	0,52	83.433
Ventilation equipment	26.954	1,00	26.954
Total			110.387

Table 47: New ventilation installation savings

- **Costs**

The new installation would imply electricity consumption and new ventilation losses. The new aggregate would not operate all the time as the current one does. The fans would be functioning 2 hours before the 8 hours of office work. Therefore, they would operate 10 hours during 205 working days which means 2.050 h/year. This means there would be a reduction of 77% of the current duty time:

Duty time (h/year)	New time duty (h/year)	Duty time reduction %
8.760	2.050	77%

Table 48: Duty time reduction

The consumption of the supply and exhaust fans has been estimated from the amount of air it will impulse and by using the fan consumption graph, figure 42. The new fans which have to impulse 1.292.9 l/s, that is 4.654 m^3/h, would consume 2,5 kW each, considering an efficiency of 80% and an increase of pressure of 1000 Pa:

V (m3/h)	kW	New time duty (h/year)	New Qeq (kWh/year)
4.654	5	2.050	10.250

Table 49: Consumption of the new fans

In conclusion, the overall electricity consumption of the new ventilation system would be 10.250 kWh/year.

Moreover, there is a cost of heating the air supplied into the rooms. In order to calculate the outlet temperature of the exchanger "T_{supp}" it has been used the subsequent formula:

$$T_{supp} = T_{out} + \eta \cdot (T_{room} - T_{out}) \qquad (23)$$

"T_{room}" and "T_{out}" are the room and the yearly average outside temperatures, respectively. New exchangers have 75% of efficiency, as a result:

T_{room}(°C)	T_{out} (°C)	η exchanger	T_{supp} (°C)
20,00	5,00	75%	16,25

Table 50: New supply temperature calculation table

Inside the room, the new supply air would be heated from the supply temperature to the room temperature, which is 20°C. Thus, one can determine the ventilation losses by using formula 12 using for air:

$$c_p = 1{,}005 \text{ kJ/kg·K}$$

$$\rho = 1{,}205 \text{ kg/m}^3$$

If the previous algorithm is applied:

V (l/s)	V (m3/s)	T_{room} (°C)	T_{supp} (°C)	Q_{vh} (kW)
1.292,9	1,2929	20,00	16,25	5,87

Table 51: New ventilation losses calculation

In terms of yearly energy consumption:

Total power losses (kW)	5,872
New duty time (h/year)	2.050
Total energy losses (kwh/year)	**12.037**

As the maintenance cost is considered negligible, once the energy is determined the cost calculation is trivial:

Costs	kWh/year	SEK/kWh	SEK/year
New ventilation losses	12.037	0,52	6.259
New ventilation equipment	10.250	1,00	10.250
Total			**16.509**

Table 52: Savings calculation

- **NPV, IRR and Payback**

By using the formulas exposed in chapter 2.6, the economical viability of a new installation is summarized in the following table:

Discount rate	5%
IRR	7%
NPV	**163.933**
Payback	**11**

Table 53: Economical viability of a new ventilation installation

It has been chosen a discount rate of 5%, which is a reasonable value considering the rate of return on an investment a bank can offer to the investor. The cash flows and the evolution of the NPV_t along the years are found in annex 7.6. In the table, the NPV_t result is obtained by using formula (14). Same formula indicates NPV is the result of adding up every NPV_t. IRR is obtained by using formula (15). By observing in the same table the evolution of the accumulated cash flow, one can identify the payback at year 11.

3.4.1 HEATING PUMP

As there is a significant quantity of air ejected to the outside, exactly 1008.3 l/s, to install a heating pump could be considered. This pump installed in the roof would collect the existing exhaust air 20°C to generate heat water. This water could be use for hot tap water and/or radiators.

- **Investment**

Mr. Roland Forsberg has estimated the cost of the heating pump, which takes an investment of 200.000 SEK approximately.

- **Savings**

By knowing the COP or coefficient of performance of the heating pump and the electricity consumption of its compressor, it is possible to calculate the heat power generated by using the definition of the Coefficient of performance, COP:

$$COP = \frac{\dot{Q_h}}{\dot{W_c}} \qquad (24)$$

That means that the overall amount of heat power produced would be:

W_c (kW)	8
COP	3,06
Q_h (kW)	24,488

Table 54: Heat power production calculation

As the exhaust air is expelled uninterruptedly, the heat pump could work, as maximum, 8760 h/year. On the other hand, during some months the energy demand of radiators and hot tap water would be lower than the heating pump energy production. In these months the pump would have to function less time than the maximum. In order to calculate the monthly hours and the overall heating production the following calculations are made. First one has to estimate the demand of hot tap water during summer months as the radiators are shut off:

Month	Qdh (kWh)	Qhtw (%)	Qhtw (kWh)
Jan	108.150	11%	1.687
Feb	93.720	11%	1.687
Mar	83.872	11%	1.687
Apr	38.520	11%	1.687
1st half May	9.030	5%	767
2nd half May	9.030	5%	767
Jun	16.550	3%	460
Jul	4.270	1%	153
Aug	5.020	1%	153
1st half Sep	8.270	3%	460
2nd half Sep	8.270	5%	767
Oct	65.830	11%	1.687
Nov	63.840	11%	1.687
Dec	117.750	11%	1.687
Total	632.122	100%	15.339

Table 55: Energy demand per month

Regarding table 55, the common sense says that the percentage of hot tap water consumption must be the same during working months and lower in summer ones. Therefore, a reasonable percentage distribution "Q_{htw}" has been estimated. Subsequently, the heating production and the duty time of the pump is calculated:

Month	Radiators	Heating pump use	Energy demand (kWh)	Maximum duty time (h/month)	Qh (kWh)	Duty time (h/month)
jan	ON	Radiators	108.150	730	17.876	730,0
feb	ON	Radiators	93.720	730	17.876	730,0
mar	ON	Radiators	83.872	730	17.876	730,0
apr	ON	Radiators	38.520	730	17.876	730,0
1st half may	ON	Radiators	9.030	365	8.938	365,0
2nd half may	OFF	Hot tap water	767	365	767	31,3
jun	OFF	Hot tap water	460	730	460	18,8
jul	OFF	Hot tap water	153	730	153	6,3
aug	OFF	Hot tap water	153	730	153	6,3
1st half sep	OFF	Hot tap water	460	365	460	18,8
2nd half sep	ON	Radiators	8.270	365	8.270	337,7
oct	ON	Radiators	65.830	730	17.876	730,0
nov	ON	Radiators	63.840	730	17.876	730,0
dic	ON	Radiators	117.750	730	17.876	730,0
Total			590.976	8.760	144.336	5.894

Table 56: Heat pump use

As it is shown on table 56, during the months radiators are on, the energy demand is the district heating, while off, hot tap water is. The maximum energy the heating pump is able to provide is 24,488 kW multiply by 730 h/month, which results 17.876 kWh. Therefore, during the months whose demand exceeds the maximum heat supply the heating pump would have to work the maximum number of hours. In the opposite case, its duty time would be reduced to satisfy the demand. The calculation of the reduced duty time is trivial, as it results to divide the monthly kWh by the heating power" $\dot{Q}_h$".

Having said this, know the savings is simple:

Savings	kWh/year	SEK/kWh	SEK/year
Heating production	144.336	0,52	75.055
Total			**75.055**

Table 57: Heat pump system savings

- **Costs**

As the maintenance cost is considered negligible, the single cost implied is the electrical consumption of the pump's compressor "$\dot{W}_c$ ". This compressor would be operating 5.894 h/year:

Costs	kWh/year	SEK/kWh	SEK/year
Heating pump consumption	47.153	1,00	47.153
Total			**47.153**

Table 58: Heat pump cost

- **NPV, IRR and Payback**

By using the formulas exposed in chapter 2.6, the economical viability of a new installation is summarized in the following table:

Discount rate	5%
IRR	**7%**
NPV	**15.448**
Payback	**8**

Table 59: Economical viability of a heating pump installation

It has been chosen a discount rate of 5%, which is a reasonable value considering the rate of return on an investment a bank can offer to the investor. The cash flows and the evolution of the NPV_t along the years are found in annex 7.6.In the table, the NPV_t result is obtained by using formula (14). Same formula indicates NPV is the result of adding up every NPV_t. IRR is obtained by using formula (15). By observing in the same table the evolution of the accumulated cash flow, one can identify the payback at year 8.

3.4.2 DETECTORS INSTALLATION

As the exhaust fans are working continuously the whole year expelling air at 20°C, it is highly recommended the installation of detectors inside the offices and meeting rooms of 1st, 2nd and 3rd floor. These detectors would be connected to electronic devices which would turn on/off the exhaust fans placed on the roof depending on the amount of air needed.

- **Investment**

As obtaining a budget for an installation of detectors has been not possible, it is considered a fictitious investment of 20.000 SEK, which is a general value.

- **Savings**

Once the detectors would be installed, the exhaust fans would work on average as many hours as the new ventilation installation previously studied, 2050 h/year. This means that the infiltration losses and the electrical consumption of the exhaust fans would be reduced a 77%:

Current Weq (kWh/year)	Duty time reduction (%)	Weq reduction (kWh/year)
26.954	77%	20.646

Table 60: Reduction of the electrical consumption of the exhaust fans

Current Infiltration losses (kWh/year)	Duty time reduction (%)	Infiltration losses reduction (kWh/year)
160.449	77%	122.901

Table 61: Reduction of the infiltration losses

Thus, in terms of capital:

Savings	kWh/year	SEK/kWh	SEK/year
Infiltration losses reduction	122.901	0,52	63.909
Ventilation eq. reduction	20.646	1,00	20.646
Total			**84.555**

Table 62: Detectors installation savings

- **Costs**

The single cost implied is the electrical consumption of the detectors and electronic devices and its, which are both regarded as negligible.

- **NPV, IRR and Payback**

By using the formulas exposed in chapter 2.6, the economical viability of a new installation is summarized in the following table:

Discount rate	5%
IRR	**323%**
NPV	**60.528**
Payback	**1**

Table 63: Economical viability of detectors installation

It has been chosen a discount rate of 5%, which is a reasonable value considering the rate of return on an investment a bank can offer to the investor. The cash flows and the evolution of the NPV_t along the years are found in annex 7.6.In the table, the NPV_t result is obtained by using formula (14). Same formula indicates NPV is the result of adding up every NPV_t. IRR is obtained by using formula (15). By observing in the same table the evolution of the accumulated cash flow, one can identify the payback at year 1.

4. DISCUSSION

4.1. VENTILATION REPORT

4.1.1. INTRODUCTION

One of the main purposes of the project is to describe the existing ventilation state of "Gävle Folkets Hus". In order to accomplish it and owing to the lack of information about the ventilation system, it was decided to check every single room of the building. Prior to deepen the ventilation parameters, it is necessary to expose the code which has been used to identify each room. The code room has the format "FRR", where "F" corresponds to the belonging floor and "RR" the room number. The number has been assigned under drawing. Each floor is characterized in the following way:

Floor	"F"
Basement	B
Ground floor	0
1st floor	1
2nd floor	2
3rd floor	3

Table 64: Floor code

4.1.2 VENTILATION SYSTEM

This building has two different system of ventilation. Natural infiltration and a mechanical supply/exhaust air system.

The principal characteristic of the ventilation system is to use as supply air the outside air coming directly from the infiltration through rooms' windows. This is found in every room which has a window, especially in the first, second and third floor; which are mainly offices. Every single window is provided by a supply air device which allows outside infiltration, in addition to the one coming from the non-perfectly tightness. Next picture shows the mentioned device:

Figure 43: Supply window device 1

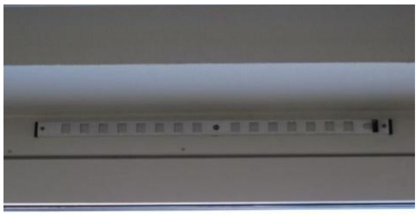

Figure 44: Supply window device 2

On the other hand, there are only few zones, the most important, which are equipped by a mechanical supply air system. The building has 3 aggregate rooms, two of them located in the basement, rooms B33 and B59, and one in the first floor, 1ABFcafe.

Figure 45: Aggregate room B59

Figure 46: Aggregate room B33

- B33 has one ventilation system to provide rooms B: 20- 25, 27- 38.
- B59 has two ventilation systems. One of them provide all restaurant, kitchen and the bar zone in the basement. B: 13,16-19 , 0: 9, 9A- 31 and 1: 7

The other one provide the Salon, the Stage and make up rooms located in the ground floor and basement.

B: 39-58 and 0: 33-48.

- 1ABcafe has only one system to provide his own rooms.

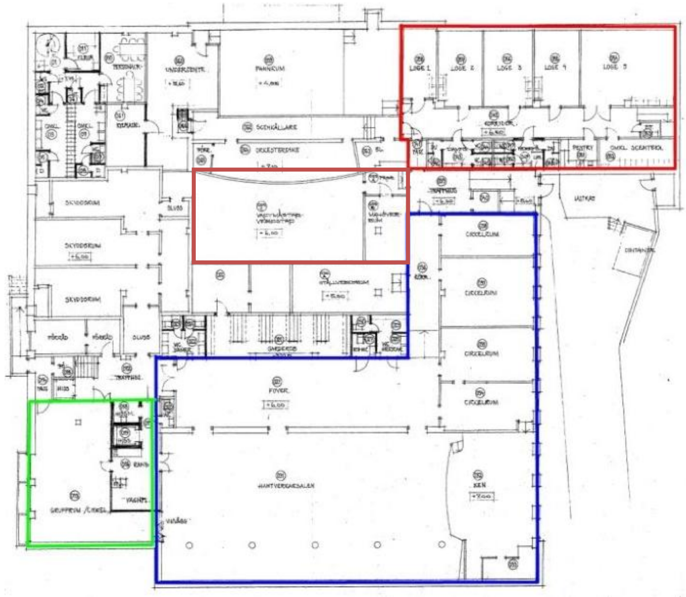

Figure 47: Basement

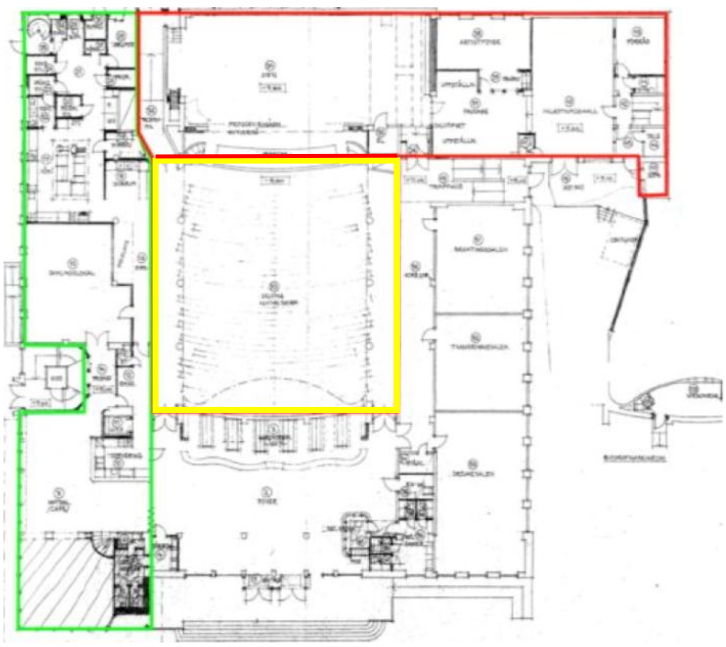

Figure 48: Ground floor

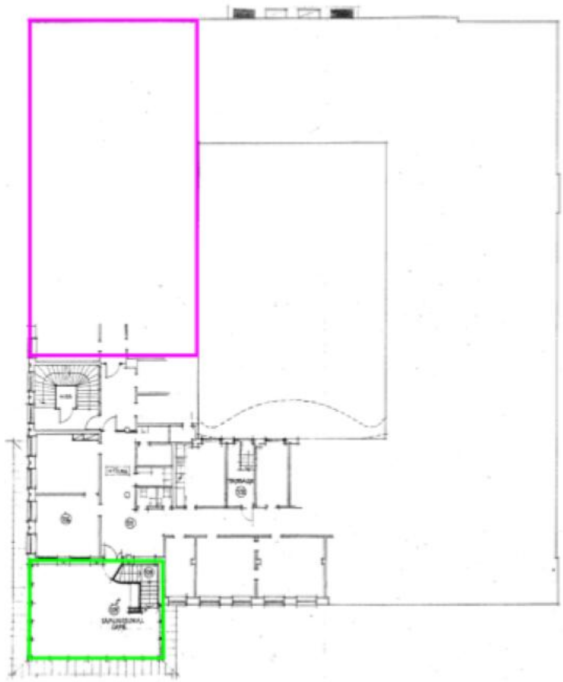

Figure 49: First floor

Moreover, there are some rooms which are equipped with their own supply air system. Those rooms are B: 35,37,38 , 0: 51-53 and 2: 1-5.

Figure 51: Room with his own supply air system 2

Figure 50: Room with his own supply air system 1

4.1.3 MIXING VENTILATION

The supply devices and are placed in such a position that the supply air is mixed with the already polluted air. They are located in the walls with a considerable high, almost reaching the ceiling. The exhaust air devices are usually located at the same high in the opposite wall. By using this placement, the air movement, which is crated, does not allow the whole polluted air to be extracted. That is typical in mixing ventilation rooms where a fraction of polluted air is always present in it.

Figure 52: Example of mixing ventilation 1

Figure 53: Example of mixing ventilation 2

4.1.4 THEATRE

The theatre is a really important place in the building, because it has capacity for nearly 400 people. The main problem of the theatre is that is a bad example of mixing ventilation, the supply devices are situated in the walls reaching the ceiling and the exhaust devices are below the stage. The positions of those devices are shown inthe following pictures.

Figure 54: Theatre 1

Figure 55: Theatre 2

4.1.5 LACK OF AIR EXTRACTION IN SOME ROOMS

Due to deficient design of the ventilation system some rooms have been found with no return air system. These rooms are found mainly in the basement, B: 43-50.

4.1.6 UNHOODED KITCHEN APPLIANCES

Despite the restaurant's kitchen, the small stoves and ovens found in the offices' kitchen of the edifice are unhooded. Therefore, there is no extraction of the heating load and smell's food.

Figure 56: Unhooded kitchen

4.1.7 MINIMUM OUTSIDE AIR AND SOCIALSTYRELSEN RECOMMENDATIONS

As it explains chapter 2.2, the BRR Swedish code imposes a minimum outside to new non-residential buildings of 0.35 l/m^2. Moreover, in order to provide a good indoor air quality it is also recommended to add 7 l per person. There is a summary table in the annex 7.7it is found a summary of the ventilation rate found in every room of the building and a comparison with the required and recommended minimum outside air. The ensuing table shows the rooms that would achieve the minimum outside air if Folkets Hus was a new building:

%	Achieve	Do not achieve
Basement	33,33	66,67
Ground	28,30	71,70
1	15,38	84,62
2	36,11	63,89
3	39,13	60,87

Table 65: % of Rooms that achieve BBR

To check all this ventilation, it has not taken into account the exchange flow between rooms. The number of rooms that do not reach the recommendation is too high. The problem is that these recommendations are quite new, and the building was built in 1946 and rebuilt in 1980.

4.1.8 VENTILATION DEFICIENCIES

4.1.8.1 POOR AIR QUALITY

The mixing ventilation causes a poor quality of the air. The problem is that with this type of ventilation the air is mixed in all room, including the polluted air. Therefore there is some unpolluted air that is sending outside and some polluted air that stays inside the room.

A better system is the displacement ventilation. Supply devices are situated next to the floor, adding fresh air that goes up once gets warm, becoming polluted and being expulsed by the exhaust devices situated next to the ceiling.

The lack of special exhaust devices in the kitchens causes a poor air quality. It should be a fume extractor above every cooker to throw out the polluted air.

Outside air coming directly from the infiltration through rooms' windows has some disadvantages. The main problem is that the incoming air is not filtered, pollutants enter from outside as well as odors and noises.

4.1.8.2 ENERGY LOSSES

The air extraction system in the offices of the 1st, 2nd and 3rd floors involves the expulsion of air directly outside through a total of 10 fans who are on the roof of the building.

It has to be found an alternative to use this hot air.

4.2 ENERGY BALANCE

The energy balance of "Gävle Folkets Hus" previously performed is not perfectly balanced. The difference between inputs and outputs should be around 5% to be considered tolerable, at highest the 10%. The reasons of it could be :

The inaccuracy of calculations due to not having appropriate information and data of the building could be the main motive. It is know that in big enterprises, many imprecision from the lowest levels imply elevated costs to the highest ones. Concerning this thesis the small imprecisions are:

- Inexact U-values of the structure as they have been assumed by using bibliography concerning similar buildings.
- Imprecise surface values of the building envelope as they have been calculated by using old and poor non-digital format drawings.
- Other inaccuracies due to the lack of information about activities, modifications and facts occurred in 2009. Some energy information belongs to 2009 and some measurements have been done by the end of 2010 with possibly disparate factors.
- Human and instrumental errors during the measuring and inspecting.

Regarding the district heating consumption, there is a decrease along summer time due to the increase of outside temperature. Therefore, a small amount of heating energy is needed and the radiators are shut off. On the contrary, the maximum consumptions are found during winter months.

The building in question has significant solar gains, it represents the 9% of the total energy inputs. Gävle Folkets Hus has a considerable number of windows and its walls exposed to the solar radiation. The different orientations of the walls and the different solar gains along the year have been taken into account.

The internal gains, users and appliances, are significative reaching the 21% of the energy inputs. This value demonstrates the high degree of activity.

Concerning the energy outputs, one can observe that losses due to infiltration in the 1st, 2nd and 3rd floor are significative. They represent the 19% if the whole outputs. This fact could indicate that, if one extrapolates this value to the rest of the building, infiltration could reach the 30% of the losses. This detail could partly explain the 10% of energy difference found in the balance.

Relating to the transmission losses, it has to be said that they represent the 70% of the total energy outputs. Losses through windows, walls, roof and external structures in contact with the outside are really significant. These transmission losses have been calculated assuming U-Values and structure information, as it is said previously.

Without considering the infiltration, the rest of the ventilation losses only represents 8%, which is a low value compared with non-residential buildings, which should be around 20%. The explanation of this low percentage is simple. "Folkets Hus" has few full-ventilated areas, pointing that full-ventilated means a complete supply and exhaust air system. Moreover, these full-ventilated areas have a low usage factor except for the restaurant and ABF Café.

Regarding the specific energy consumption factor, the value 129, kWh/m^2 could be considered excellent taking into account that old buildings use to exceed values around 160-170 kWh/m^2. A justification to this could be the same as before, the inexistence of supply equipment in the offices and the low usage factor in the rest of full-ventilated areas.

4.3 VENTILATION

This project is a quantitative analysis of ventilation rather than qualitative. Ventilation parameters such as temperature and airflow have been measured. On the contrary, there is no measuring of moisture, CO_2 and other pollution agents. However, by knowing non-numerical ventilation details it is possible to rate the air quality in general.

Doubtlessly, ventilation is the weakness of "Folkets Hus". People who are working in its offices are not provided by a proper air quality and thermal comfort. Concerning this, there was one fact that really impressed the project team: many office workers, especially women, were complaining about how cold they feel in winter and their necessity of using small heaters to fight against. This reaction is completely understandable but should not be the reaction from a person who is working there.

As it is explained in the ventilation report, the "supply" air the offices receive comes from infiltration. Therefore; pollution, dust and odors enter to their offices. Furthermore, they are supplied by outside air which could reach -20°C in winter.

In terms of energy, this infiltration is unnecessarily heated and subsequently expelled to the outside 24 hours a day and 365 without making use of its energy. Exhaust fans which extract the air from offices are also working uninterruptedly.

As it is previously said, the rest of the areas are provided by supply filtered and warmer air. However, their ventilation systems are not designed optimally. The abuse of mixing ventilation, which a clear instance of it is the theater, entails also an indoor air quality that could be improved. Moreover, the aggregate systems are not energy efficient as they are not provided by exchangers, excluding for the restaurant´s aggregate.

It is also important to remark that there are some areas which do not reach the minimum flow rate BBR requires to new buildings and even more which do not follow the Socialstyrelsen advices.

In conclusion, "Folkets Hus" has a poor ventilation. Moreover, its ventilation system is not energy efficient. Therefore, it is necessary to find solutions to improve the air quality, thermal comfort and energy efficiency. Efforts must be channeled particularly to the offices. The rest of ventilation areas are also improvable, but the offices have to be the primary considered.

4.4 ECONOMIC STUDIES

4.4.1 NEW VENTILATION INSTALLATION

The installation of a new ventilation system is the one with the highest investment. It should provide supply air to these areas which are not equipped with mechanical incoming air.

The new system improves the air quality and the human health. Supply air is not coming directly from the infiltration through rooms' windows, it is filtered. This means the incoming air is free of pollutants and odors.

Furthermore, this new ventilation system improves the energy efficiency since the incoming air is preheated in the aggregate room, as it is provided with a heat exchanger. With the current infiltration devices, outside air is entering during the winter at -20°C, and it has to be heated from -20°C to 20°C.

Therefore, this system saves energy as it is said in chapter 3.3.1.

The problem is that the investment is really hard and the savings are not that high. The investment starts earning benefits after 11 years.

4.4.2 HEATING PUMP

As it is said before, the exhaust air from 1st, 2nd and 3rd floor is expulsed directly outside.This means energy from this heated air is not used.With a heating pump, exhaust air can be used to heat water used in hot tap water and/or radiators, decreasing the use of district heating energy.

During cold months, the heating pump would be working full time since all energy produced would be used due to the high demand in radiators.On the other hand, during summer, when radiators are shut off, the only demand is for hot tap water. The heating pump is able to provide this energy even working few hours a day.

With this investment, the air quality is not improved, but it is significantly improved the energy efficiency.Taking into account all savings, in terms of economy, the investment starts earning benefits in 8 years.

4.4.3 DETECTORS

The installation of timers and detectors is the less expensive investment of the three studied. The aim of these timers and detectors is to turn on/off the exhaust fans located on the roof depending on the amount of air needed. There is a big difference in terms of energy if the exhaust system is working 10 hours a day instead of 24 hours a day. Therefore, the electrical consumptionof the exhaust fans would be reduced a 77%, as well as the current infiltration losses.

The quantity of electricity needed to connect these detectors is really insignificant compared with the quantity of electricity they save. This 20.000 SEK investment starts to earn benefits in only 1 year.

5. CONCLUSION

The aim of the project was to check all ventilation system, make an analysis of the current situation and study possible improvements that could be carried out to achieve economical and energetic savings.

When deciding what kind of measures were more appropriate, it had been seen that most problems were in the 1st 2nd and 3rd floor, where there was a lack of supply air system and the exhaust fans were working 24 hours a day ejecting heated air directly to the outside.

According to the analysis, three measures have been considered. The installation of a new ventilation system for these three floors improves the air quality and saves energy. This is important for building occupants and for the owner of the building. It is needed a new aggregate room for a new system with an exchanger. The investment of 1.000.000 SEK is recoverable in 11 years. The use of a heating pump to harness the hot air ejected has an investment of 200.000 SEK recoverable in 8 years. New pipes and ducts are needed to drive the exhaust air to the heating pump and to drive heated water to the main system. Finally, installing detectors has an investment of 20.000 SEK and it is recoverable in only 1 year. Savings are considerably high and the installation is not complicated.

Fromnow on, it is time forthe building ownerto decidewhat hispreferences are. If the three payback times are compared, the conclusion is that installing detectors is the best option and the whole new ventilation system is the worst. However, other factors need to be considered. If the accumulated cash-flow is considered, it is possible to see that a medium term, the new ventilation system and detectors have higher benefits than using a heating pump. Moreover, it is not compulsory to install only one of these three improvements. Detectors can accompany the whole new installation or heating pump.

It has to be said that different decisions can be taken depending on the aim that is wanted to achieve. The most economical benefit is not always the most environmental one.

To conclude, different studies can be developed. A complete study of building air quality would be interesting for its' occupants. A study of theatre and scene areas would be also interesting in order to check the current ventilation system, whose devices provide mixing ventilation. This thesis should be the starting point forfurther studies of how to carry out the installation of the improvements mentioned.

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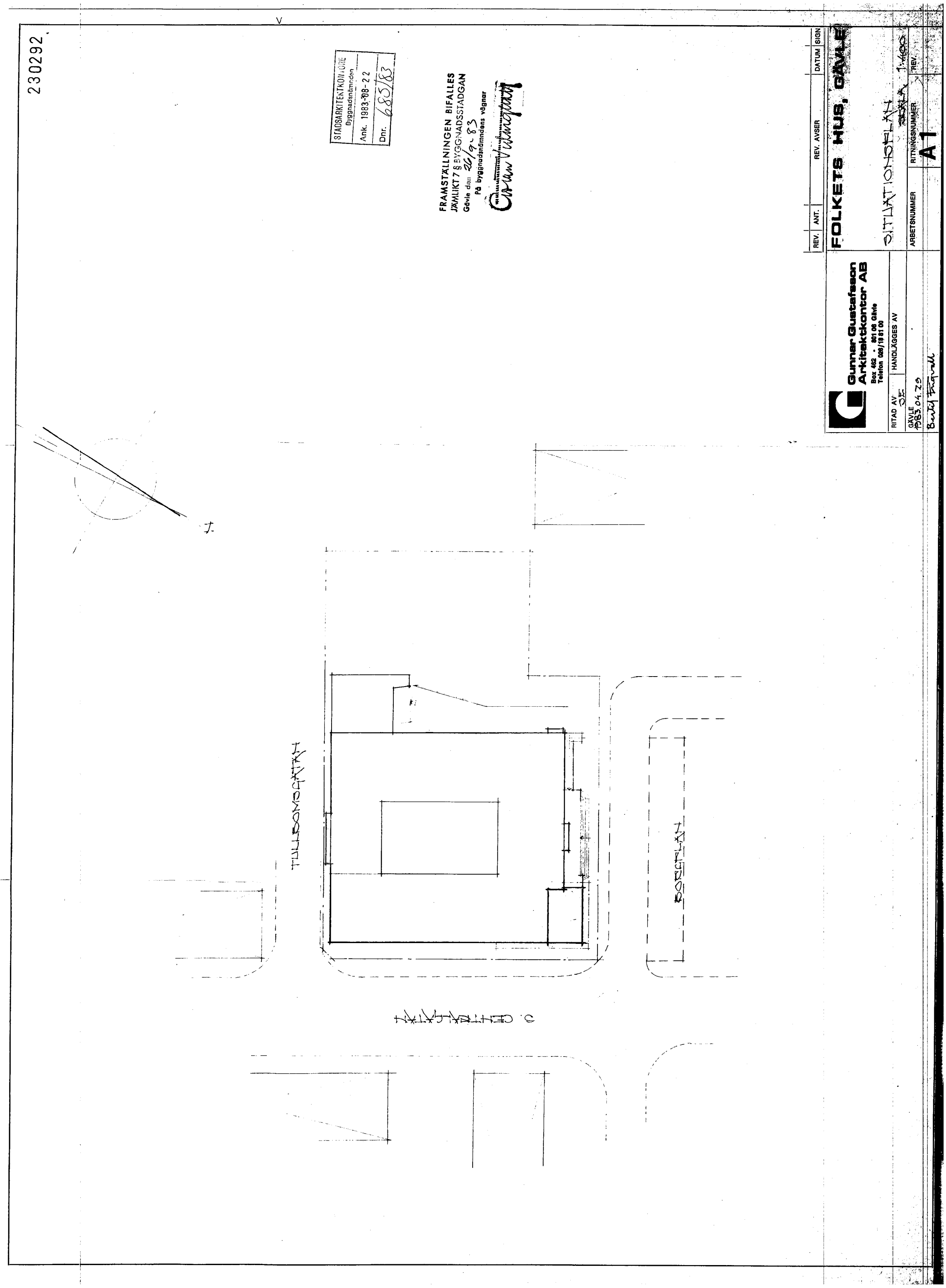
7. APPENDIXES

7.1 DRAWINGS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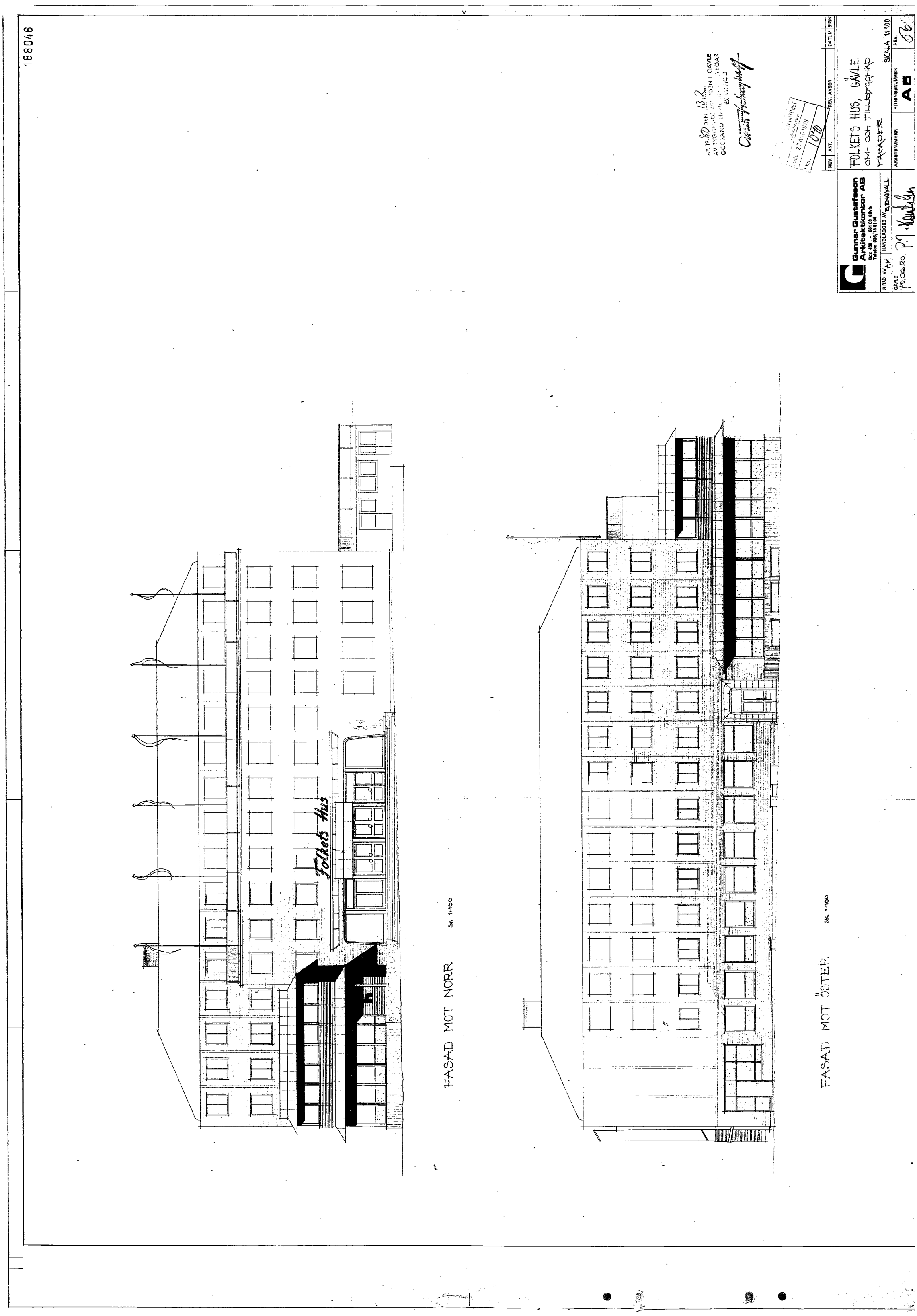
Gunnar Gustafsson Arkitektkontor AB
A1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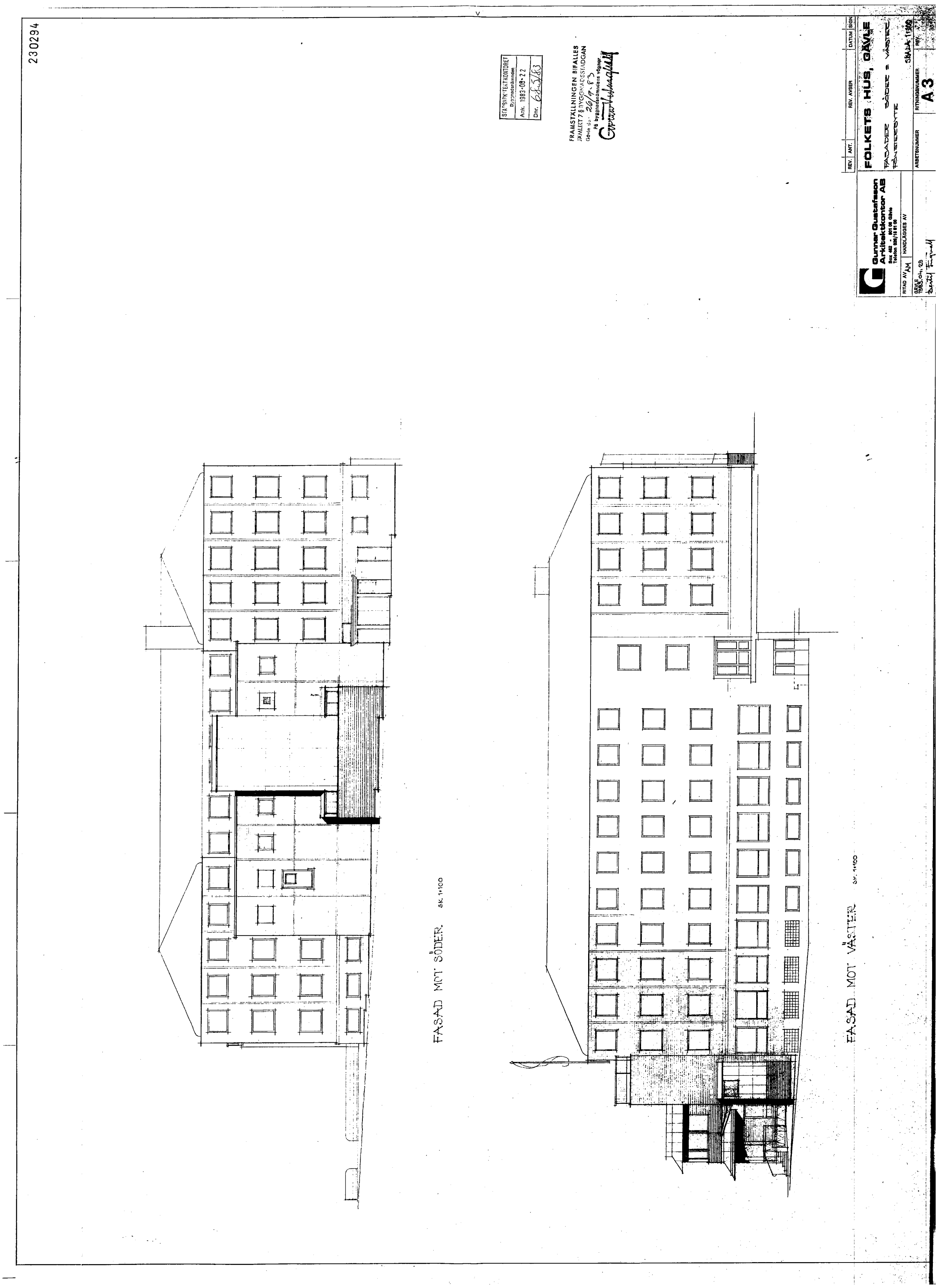
Folkets Hus
FASAD MOT NORR
FASAD MOT ÖSTER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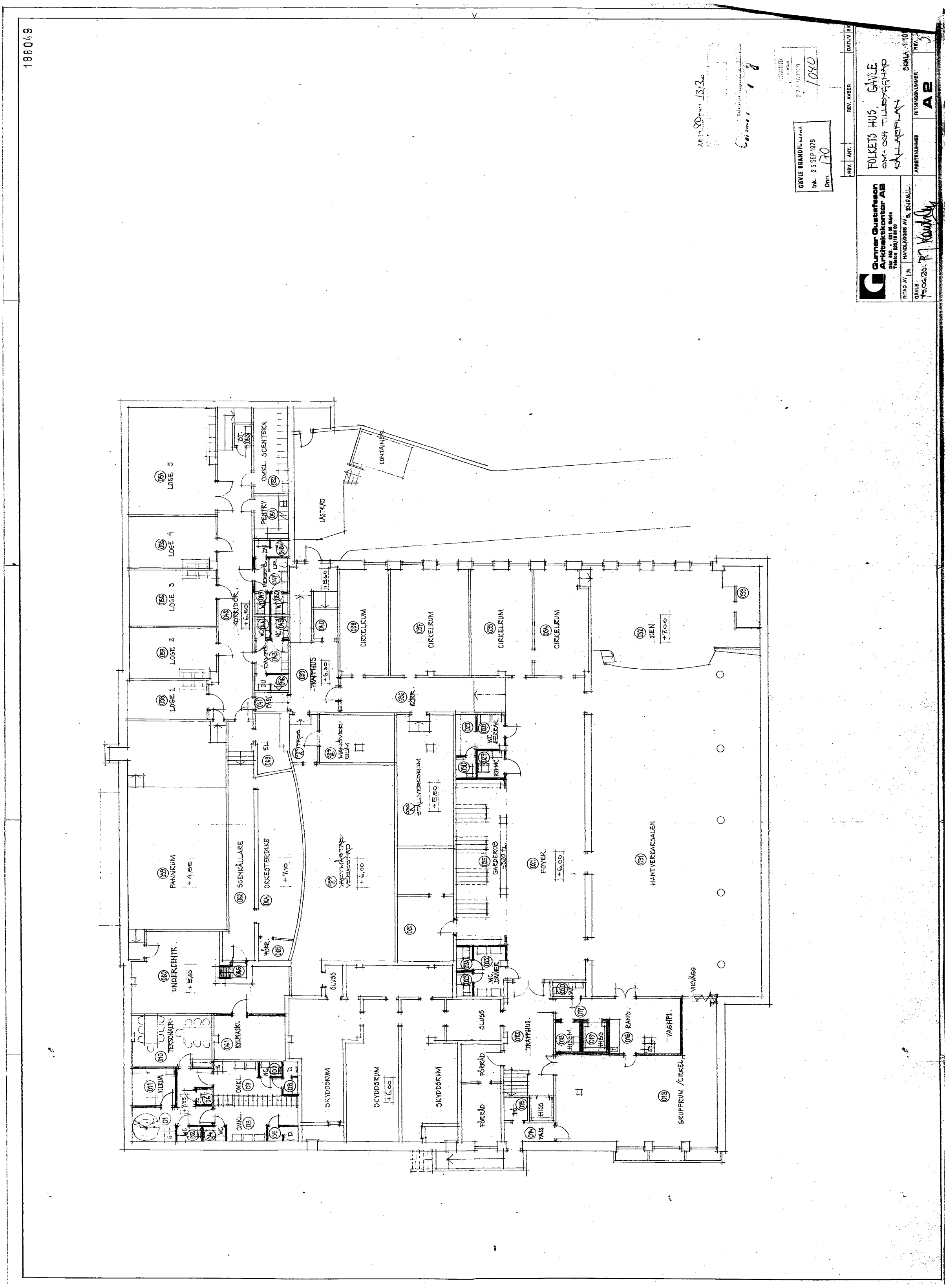

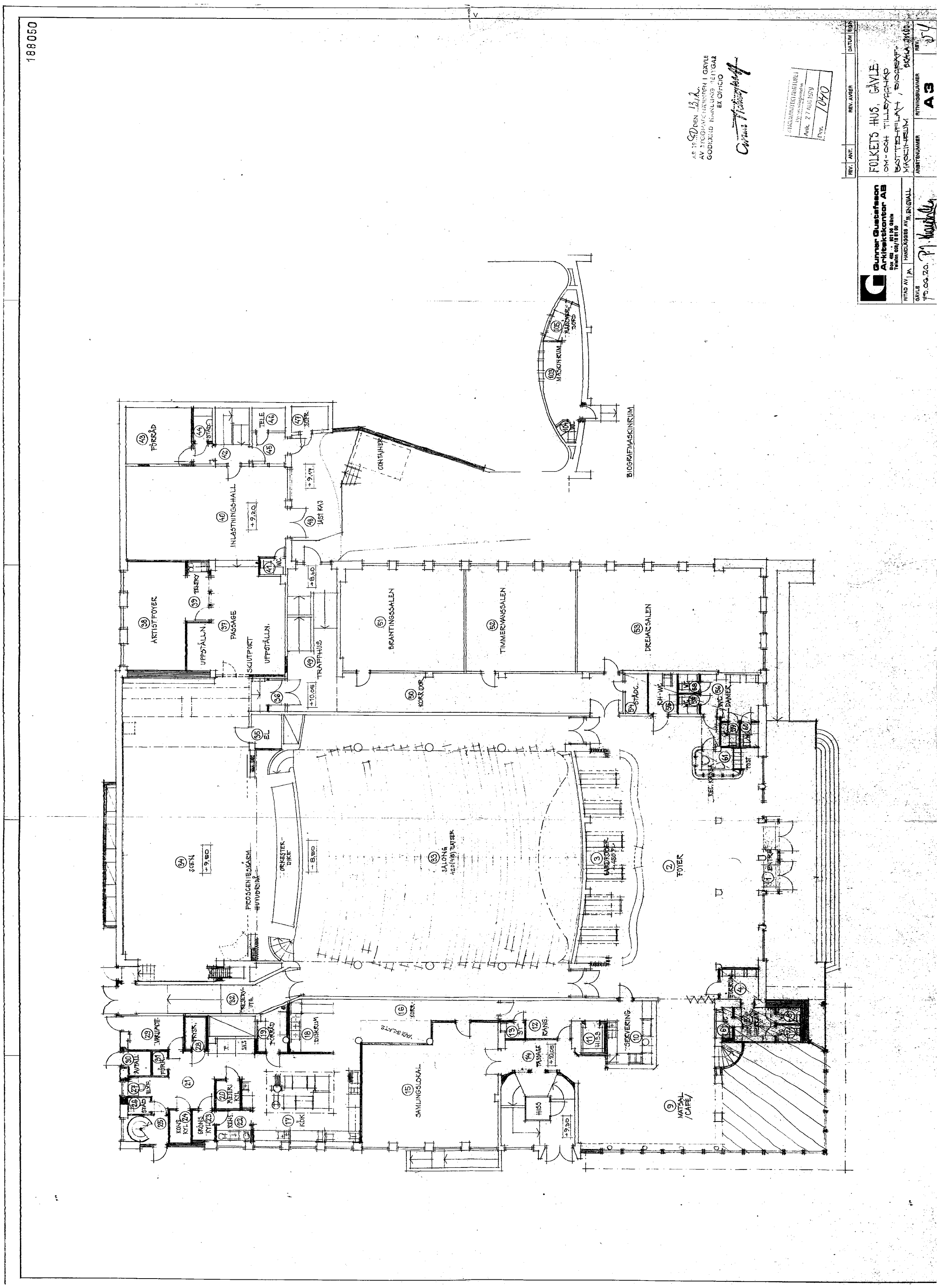
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FOLKETS HUS, GÄVLE
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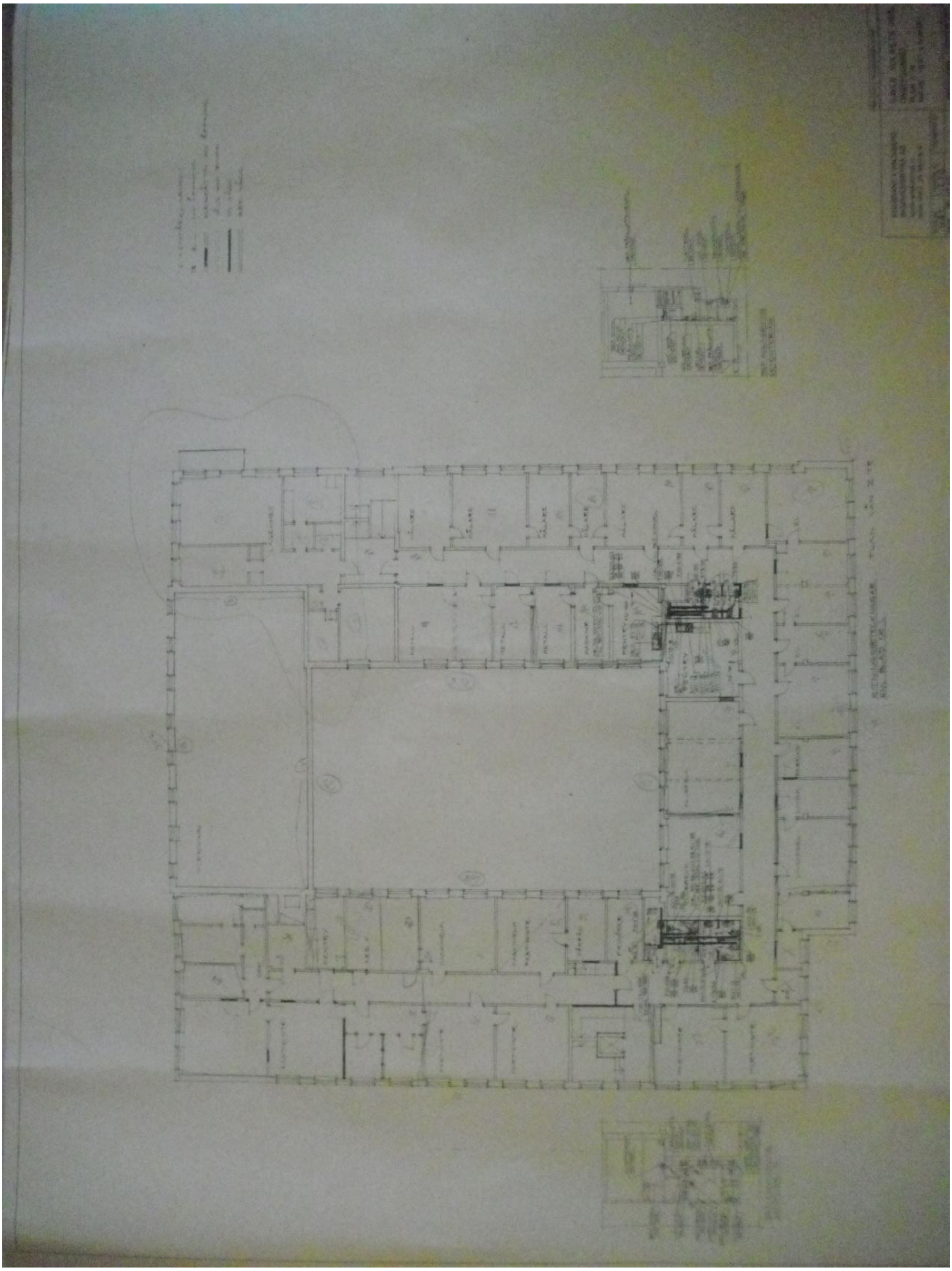
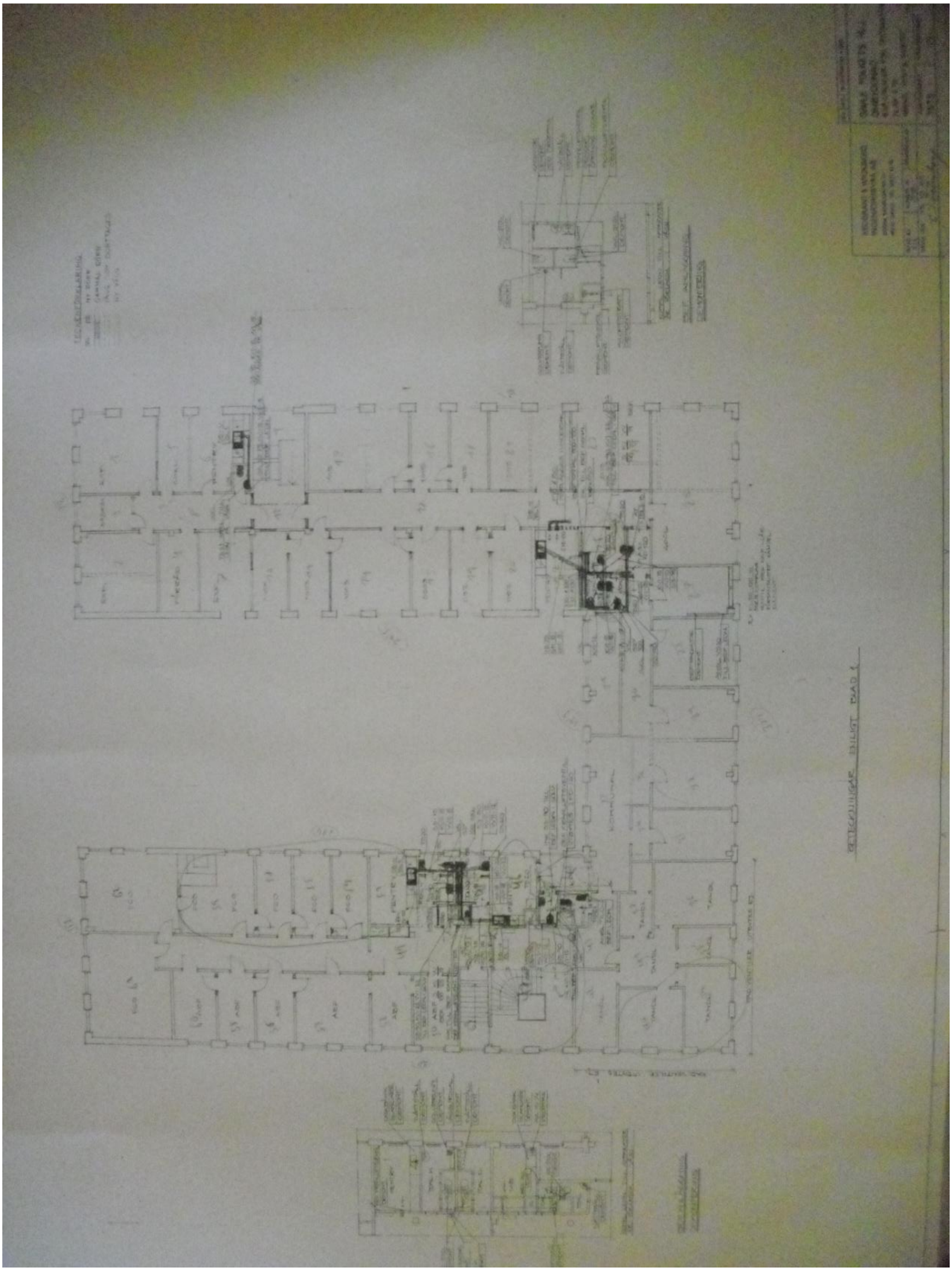
INLASTNINGSHALL
ARTISTFOYER
PASSAGE
BRANTINGSSALEN
TIMMERMANSSALEN
DREJARSALEN
SCEN
SALONG
FOYER
SAMLINGSLOKAL
MATSAL /CAFE
A3





7.2 DISTRICT HEATING CONSUMPTION

SPECIFIKATION

Mätarställning

Mätarnr: 15788

	Datum	Mätarst MWh
Årsavläsning	2008-12-31	5067,642
Ändrat E-värde årlig	2008-12-31	5067,642
Prisändring	2009-01-01	5067,642
Beräknad ställning	2009-01-31	5175,792
Debiterad förbrukning		108,150 MWh
Föregående avläsning (Årsavläsning)	2008-12-31	5067,642

Beräknad årsanvändning och årskostnad

Årsförbrukning; beräknad	721 MWh
Årskostnad; beräknad	405 319 kr
Abonnerad effekt	830 kW

Övriga avgifter

Övrigt

Dröjsmålsränta för 2009-01-14 - 2009-01-22 för faktura 20842587618, 10,00 % 104,38 kr

Upplysningar

Eventuell anmärkning mot fakturan ska göras senast 15 dagar före förfallodatum.

Anmäl flytt till oss skriftligen eller via vår hemsida www.gavleenergi.se senast 15 dagar före flyttdatum!

Vid strömavbrott på nätområde Gävle (GVL) eller Forsbacka (FOB) kan du nå oss på jourtelefon 026-178560.

Beräknad årsförbrukning och årskostnad på el omräknas månadsvis.

1303 FLXSS.DAT

SPECIFIKATION

Mätarställning

Mätarnr: 15788

	Datum	Mätarst MWh	
Föregående beräknad	2009-01-31	5175,792	
Beräknad ställning	2009-02-28	5269,522	
Debiterad förbrukning			93,730 MWh
Föregående avläsning (Årsavläsning)	2008-12-31	5067,642	

Beräknad årsanvändning och årskostnad

Årsförbrukning; beräknad	721 MWh
Årskostnad; beräknad	405 319 kr
Abonnerad effekt	830 kW

Övriga avgifter

Gävle Energi AB

Efterdeb. mätarfel	20090225	44 MWh à 330,30 kr	14 533,20 kr

Upplysningar

Anmäl flytt till oss skriftligen eller via vår hemsida www.gavleenergi.se senast 15 dagar före flyttdatum!

Vid strömavbrott på nätområde Gävle (GVL) eller Forsbacka (FOB) kan du nå oss på jourtelefon 026-178560.

Beräknad årsförbrukning och årskostnad på el omräknas månadsvis.

193 FLXSG.DAT

SPECIFIKATION

Mätarställning

Mätarnr: 25709

	Datum	Mätarst MWh
Föregående beräknad	2009-02-28	5269,522
Mätare ned, t.o.m.	2009-01-29	5137,044
Ny mätare, fr.o.m.	2009-01-30	0,000
Mätare ned, t.o.m.	2009-03-25	202,570
Ny mätare, fr.o.m.	2009-03-26	0,000
Ordinarie avläsning	2009-03-31	13,780
Debiterad förbrukning		83,872 MWh
Föregående avläsning (Årsavläsning)	2008-12-31	5067,642

Beräknad årsanvändning och årskostnad

Årsförbrukning; beräknad	721 MWh
Årskostnad; beräknad	421 504 kr
Abonnerad effekt	830 kW

Upplysningar

Anmäl flytt till oss skriftligen eller via vår hemsida www.gavleenergi.se senast 15 dagar före flyttdatum!

Vid strömavbrott på nätområde Gävle (GVL) eller Forsbacka (FOB) kan du nå oss på jourtelefon 026-178560.

Beräknad årsförbrukning och årskostnad på el omräknas månadsvis.

340 FLXSS.DAT

SPECIFIKATION

Mätarställning

Mätarnr: 25709

	Datum	Mätarst MWh
Ordinarie avläsning	2009-03-31	13,780
Ordinarie avläsning	2009-04-30	52,300
Debiterad förbrukning		38,520 MWh
Föregående avläsning (Ordinarie avläsning)	2009-03-31	13,780

Beräknad årsanvändning och årskostnad

Årsförbrukning; beräknad	721 MWh
Årskostnad; beräknad	421 504 kr
Abonnerad effekt	830 kW

Upplysningar

Anmäl flytt till oss skriftligen eller via vår hemsida www.gavleenergi.se senast 15 dagar före flyttdatum!

Vid strömavbrott på nätområde Gävle (GVL) eller Forsbacka (FOB) kan du nå oss på jourtelefon 026-178560.

Beräknad årsförbrukning och årskostnad på el omräknas månadsvis.

1255 FLXSS.DAT

SPECIFIKATION

Mätarställning

Mätarnr: 25709

	Datum	Mätarst MWh
Ordinarie avläsning	2009-04-30	52,300
Ordinarie avläsning	2009-05-31	70,360
Debiterad förbrukning		18,060 MWh
Föregående avläsning (Ordinarie avläsning)	2009-04-30	52,300

Beräknad årsanvändning och årskostnad

Årsförbrukning; beräknad	721 MWh
Årskostnad; beräknad	421 504 kr
Abonnerad effekt	830 kW

Övriga avgifter

Övrigt

Påminnelseavgift, faktura 20914287014, momsfri 50,00 kr

Upplysningar

Anmäl flytt till oss skriftligen eller via vår hemsida www.gavleenergi.se senast 15 dagar före flyttdatum!

Vid strömavbrott på nätområde Gävle (GVL) eller Forsbacka (FOB) kan du nå oss på jourtelefon 026-178560.

Beräknad årsförbrukning och årskostnad på el omräknas månadsvis.

1290 FLXSS.DAT

SPECIFIKATION

Mätarställning

Mätarnr: 25709

	Datum	Mätarst MWh
Ordinarie avläsning	2009-06-30	86,910
Ordinarie avläsning	2009-07-31	91,180
Debiterad förbrukning		4,270 MWh
Föregående avläsning (Ordinarie avläsning)	2009-06-30	86,910

Beräknad årsanvändning och årskostnad

Årsförbrukning; beräknad	721 MWh
Årskostnad; beräknad	421 504 kr
Abonnerad effekt	830 kW

Upplysningar

Anmäl flytt till oss skriftligen eller via vår hemsida www.gavleenergi.se senast 15 dagar före flyttdatum!

Vid strömavbrott på nätområde Gävle (GVL) eller Forsbacka (FOB) kan du nå oss på jourtelefon 026-178560.

Beräknad årsförbrukning och årskostnad på el omräknas månadsvis.

2063 FLXS.DAT

SPECIFIKATION

Mätarställning

Mätarnr: 25709

	Datum	Mätarst MWh
Ordinarie avläsning	2009-07-31	91,180
Ordinarie avläsning	2009-08-31	96,200
Debiterad förbrukning		5,020 MWh
Föregående avläsning (Ordinarie avläsning)	2009-07-31	91,180

Beräknad årsanvändning och årskostnad

Årsförbrukning; beräknad	721 MWh
Årskostnad; beräknad	421 504 kr
Abonnerad effekt	830 kW

Upplysningar

Anmäl flytt till oss skriftligen eller via vår hemsida www.gavleenergi.se senast 15 dagar före flyttdatum!

Vid strömavbrott på nätområde Gävle (GVL) eller Forsbacka (FOB) kan du nå oss på jourtelefon 026-178560.

Beräknad årsförbrukning och årskostnad på el omräknas månadsvis.

2182 FLXS.DAT

SPECIFIKATION

Mätarställning

Mätarnr: 25709

	Datum	Mätarst MWh
Ordinarie avläsning	2009-08-31	96,200
Ordinarie avläsning	2009-09-30	112,740
Debiterad förbrukning		16,540 MWh
Föregående avläsning (Ordinarie avläsning)	2009-08-31	96,200

Beräknad årsanvändning och årskostnad

Årsförbrukning; beräknad	721 MWh
Årskostnad; beräknad	421 504 kr
Abonnerad effekt	830 kW

Övriga avgifter

Övrigt

Påminnelseavgift, faktura 20929573416, momsfri	50,00 kr

Upplysningar

Anmäl flytt till oss skriftligen eller via vår hemsida www.gavleenergi.se senast 15 dagar före flyttdatum!

Vid strömavbrott på nätområde Gävle (GVL) eller Forsbacka (FOB) kan du nå oss på jourtelefon 026-178560.

Beräknad årsförbrukning och årskostnad på el omräknas månadsvis.

2165 FLXS.DAT

SPECIFIKATION

Mätarställning

Mätarnr: 25709

	Datum	Mätarst MWh
Ordinarie avläsning	2009-09-30	112,740
Ordinarie avläsning	2009-10-31	178,570
Debiterad förbrukning		65,830 MWh
Föregående avläsning (Ordinarie avläsning)	2009-09-30	112,740

Beräknad årsanvändning och årskostnad

Årsförbrukning; beräknad	721 MWh
Årskostnad; beräknad	438 130 kr
Abonnerad effekt	830 kW

Övriga avgifter

Övrigt

Dröjsmålsränta för 2009-10-12 - 2009-10-21 för faktura 20933517813, 8,50 %	26,38 kr

Upplysningar

Anmäl flytt till oss skriftligen eller via vår hemsida www.gavleenergi.se senast 15 dagar före flyttdatum!

Vid strömavbrott på nätområde Gävle (GVL) eller Forsbacka (FOB) kan du nå oss på jourtelefon 026-178560.

Beräknad årsförbrukning och årskostnad på el omräknas månadsvis.

2025 FLX3.DAT

SPECIFIKATION

Mätarställning

Mätarnr.: 257709

	Datum	Mätarst MWh
Ordinarie avläsning	2009-10-31	178,570
Ordinarie avläsning	2009-11-30	242,410
Debiterad förbrukning		63,840 MWh
Föregående avläsning (Ordinarie avläsning)	2009-10-31	178,570

Beräknad årsanvändning och årskostnad

Årsförbrukning; beräknad	721 MWh
Årskostnad; beräknad	440 480 kr
Abonnerad effekt	830 kW

Upplysningar

Elnätavgifterna höjs med ca 6 procent från och med den 1 januari 2010.
Mer information finns på vår hemsida www.gavleenergi.se.

Anmäl flytt till oss skriftligen eller via vår hemsida
www.gavleenergi.se senast 15 dagar före flyttdatum!

Vid strömavbrott på nätområde Gävle (GVL) eller Forsbacka (FOB) kan
du nå oss på jourtelefon 026-178560.

Vi på Gävle Energi önskar dig en riktigt God Jul och ett Gott Nytt År!

22111 PLXS.DAT

SPECIFIKATION

Mätarställning

Mätarnr: 25709

	Datum	Mätarst MWh
Ordinarie avläsning	2009-11-30	242,410
Årsavläsning	2009-12-31	360,160
Debiterad förbrukning		117,750 MWh
Föregående avläsning (Ordinarie avläsning)	2009-11-30	242,410

Beräknad årsanvändning och årskostnad

Årsförbrukning; beräknad	680 MWh
Årskostnad; beräknad	422 777 kr
Abonnerad effekt	830 kW

Övriga avgifter

Övrigt

Påminnelseavgift, faktura 20941199117, momsfri 50,00 kr

Upplysningar

Elnätavgifterna höjs med ca 6 procent från och med den 1 januari 2010. Mer information finns på vår hemsida www.gavleenergi.se.

Anmäl flytt till oss skriftligen eller via vår hemsida www.gavleenergi.se senast 15 dagar före flyttdatum!

Vid strömavbrott på nätområde Gävle (GVL) eller Forsbacka (FOB) kan du nå oss på jourtelefon 026-178560.

295 FLXG.DAT

7.3 METEOROLOGIC DATA

Meteorologi och klimatologi

Temperatur och relativ fuktighet

7:1

Normaltemperatur i °C för månaderna och året, 1931–1960

Källa: Klimatdata för Sverige, Statens Institut för Byggnadsforskning

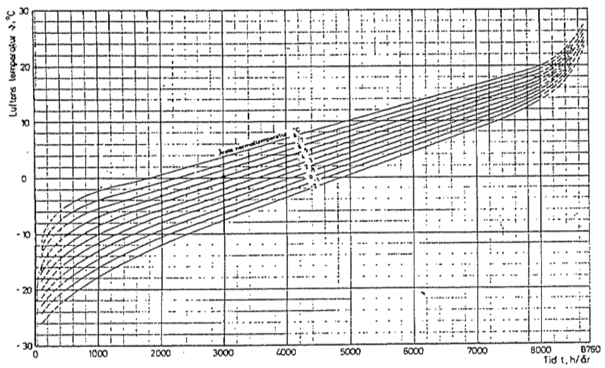
Station	Året	Jan	Feb	Mar	Apr	Maj	Jun	Jul	Aug	Sep	Okt	Nov	Dec
Malmberget	0,2	−10,4	−10,5	−7,1	−1,9	4,0	10,2	13,9	11,5	6,0	−0,4	−5,2	−8,0
Karesuando	−1,5	−13,8	−13,9	−9,9	−3,6	3,0	9,8	13,7	11,2	5,4	−1,6	−7,3	−11,2
Kiruna	−1,2	−12,2	−12,4	−8,9	−3,5	2,7	9,2	12,9	10,5	5,1	−1,5	−6,8	−10,1
Pajala	−0,1	−13,1	−12,6	−7,9	−1,4	5,2	11,4	15,0	12,3	6,6	−0,5	−6,0	−9,8
Stensele	0,7	−12,2	−11,0	−6,8	−0,2	5,9	11,0	14,3	12,2	7,1	1,0	−4,2	−8,3
Luleå flygplats	2,0	−10,0	−10,2	−6,5	−0,5	6,1	12,1	16,0	14,0	9,0	2,5	−2,6	−6,5
Haparanda	1,6	−10,6	−10,9	−7,4	−0,9	5,8	12,3	16,3	14,0	8,4	2,1	−2,7	−6,8
Nordmaling	3,0	−8,2	−7,7	−4,3	1,1	6,8	11,7	15,4	14,0	9,3	3,3	−1,0	−4,4
Hällnäs	1,3	−11,8	−10,7	−6,3	0,1	6,7	12,0	15,4	13,3	7,8	1,0	−3,9	−8,1
Umeå	3,4	−7,8	−7,7	−4,4	1,3	7,5	12,7	16,3	14,6	9,5	3,5	−0,9	−4,3
Offer	2,8	−10,2	−8,7	−4,2	2,1	8,1	13,0	16,0	14,1	9,1	2,7	−2,3	−6,4
Härnösand	4,4	−6,2	−5,8	−2,8	2,2	7,8	12,7	16,3	15,0	10,4	4,9	0,7	−2,7
Sundsvalls flygplats	3,9	−6,9	−6,3	−3,0	2,1	7,5	12,7	15,8	14,5	9,9	4,3	0,0	−3,4
Söderhamn F 15	4,7	−5,4	−5,2	−2,2	2,9	8,1	13,1	16,2	15,0	10,4	5,0	0,6	−2,4
Eggegrund	5,5	−2,9	−3,6	−1,9	2,1	6,6	12,0	16,0	15,8	11,8	6,9	2,8	0,1
Gävle	5,0	−5,1	−4,9	−2,2	3,3	8,7	13,8	16,6	15,3	10,7	5,3	0,9	−2,1
Frösön F 4	2,9	−7,9	−6,8	−3,5	1,5	7,0	11,4	14,5	13,0	8,4	3,0	−1,4	−4,5
Björkedet	1,3	−9,3	−8,5	−5,5	−0,4	4,8	9,4	12,6	11,1	7,0	2,1	−2,1	−5,6
Gisselås	1,2	−11,2	−9,7	−6,0	0,4	6,5	11,2	14,2	12,0	7,1	1,1	−3,8	−7,6
Östersund	2,7	−8,5	−7,5	−4,3	1,1	6,8	11,3	14,5	13,1	8,6	3,2	−1,1	−4,7
Sveg	2,1	−10,3	−8,6	−4,6	1,5	7,5	11,9	14,6	12,7	7,9	2,2	−2,9	−6,9
Rommehed	4,6	−6,2	−5,7	−2,4	3,2	9,2	13,6	16,2	14,5	10,0	4,8	0,3	−2,9
Edsbyn	3,9	−7,2	−6,4	−2,8	2,9	8,7	13,2	15,8	14,1	9,3	3,8	−0,7	−4,2
Mora	3,5	−8,5	−7,7	−3,6	2,8	9,0	13,3	15,7	13,8	9,1	3,7	−1,1	−4,9
Malung	2,9	−8,9	−7,8	−4,0	2,0	8,2	12,5	15,0	13,2	8,5	3,2	−1,7	−5,4
Falun	4,6	−7,0	−6,3	−2,6	3,4	9,7	14,1	16,7	14,9	10,1	4,8	0,4	−3,4
Västerås F 1	5,9	−4,1	−4,1	−1,4	4,1	10,1	14,6	17,2	15,8	11,3	6,3	1,9	−1,0
Uppsala	5,7	−4,4	−4,5	−1,7	3,9	9,9	14,4	17,2	15,8	11,2	5,9	1,6	−1,3
Norrtälje	5,9	−3,5	−3,8	−1,4	3,7	9,0	13,9	17,0	16,0	11,7	6,5	2,3	−0,7
Bromma flygplats	6,3	−3,5	−3,8	−1,2	4,2	10,0	14,7	17,6	16,4	12,0	6,8	2,5	−0,4
Stockholm	6,6	−2,9	−3,1	−0,7	4,4	10,1	14,9	17,8	16,6	12,2	7,1	2,8	0,1
Örebro	5,9	−4,0	−3,9	−1,0	4,5	10,4	14,6	17,1	15,6	11,1	6,0	1,7	−1,0
Nyköping	6,2	−3,3	−3,5	−0,8	−4,3	9,7	14,4	17,1	16,1	11,8	6,6	2,4	−0,4
Norrköping	6,9	−3,0	−3,1	−0,3	5,2	10,9	15,6	18,3	17,0	12,4	7,2	2,8	0,0
Motala	6,4	−2,8	−3,2	−0,7	4,6	10,1	14,5	17,0	16,0	11,9	6,9	2,7	0,0
Linköping	6,8	−2,9	−3,0	−0,1	5,3	11,0	15,4	17,7	16,4	12,2	7,1	2,7	0,0
Karlstad flygplats	5,9	−4,3	−4,1	−1,1	4,2	10,1	14,4	17,1	15,9	11,5	6,4	2,2	−0,9
Åmål	6,1	−3,7	−3,7	−0,7	4,5	10,2	14,5	16,9	15,6	11,3	6,3	2,2	−0,6
Vänersborg	6,6	−2,6	−2,8	−0,5	4,5	10,1	14,3	16,7	16,0	12,1	7,4	3,2	0,5
Skara	5,8	−3,3	−3,6	−1,1	4,7	10,2	14,3	16,5	15,2	11,0	6,3	2,3	−0,5
Strömstad	6,6	−2,9	−3,0	−0,1	4,8	10,5	14,4	16,9	16,0	12,1	7,3	2,9	0,0
Göteborg	7,9	−0,9	−1,2	1,3	6,0	11,5	15,2	17,5	16,8	13,1	8,6	4,5	1,8
Halmstad F 14	7,2	−1,6	−1,7	0,7	5,4	10,7	14,6	16,7	16,0	12,6	8,0	3,9	1,1
Kalmar F 12	7,0	−1,7	−1,9	0,0	5,1	9,8	14,5	17,2	16,3	12,3	7,6	3,6	0,9
Västervik	6,9	−2,0	−2,2	0,0	4,8	9,7	14,6	17,4	16,4	12,3	7,6	3,5	0,8
Visby	7,2	−0,6	−1,4	0,0	4,3	9,0	13,9	17,1	16,6	12,9	8,3	4,4	1,8
Ronneby	7,1	−1,5	−1,4	0,5	5,1	10,2	14,3	16,9	16,0	12,4	7,8	4,1	1,2
Karlshamn	7,6	−0,9	−0,9	1,1	5,4	10,5	14,8	17,3	16,4	12,9	8,4	4,6	1,7
Hagshults flygplats	5,6	−3,4	−3,5	−1,0	4,0	9,4	13,4	15,5	14,5	10,8	6,0	2,1	−0,6
Huskvarna	6,5	−2,4	−2,6	−0,2	4,9	10,1	14,5	16,8	15,7	11,6	6,8	3,0	0,3
Jönköping	6,1	−2,6	−3,0	−0,7	4,3	9,3	13,8	16,3	15,2	11,4	6,6	2,7	0,0
Borås	6,3	−2,9	−3,0	−0,4	4,7	10,5	14,2	16,5	15,4	11,4	6,7	2,7	−0,1
Nässjö	5,4	−4,1	−4,1	−1,2	3,9	9,6	13,7	16,1	14,8	10,7	5,7	1,5	−1,3
Växjö	6,5	−2,8	−2,7	−0,1	5,0	10,5	14,6	16,6	15,6	11,6	6,8	2,8	−0,1
Malmö flygplats	8,0	−0,5	−0,7	1,4	6,0	11,0	15,0	17,2	16,7	13,5	8,9	4,9	2,0
Kristianstad	7,7	−0,9	−0,9	1,2	5,9	11,1	15,2	17,4	16,5	12,9	8,3	4,5	1,6
Lund	8,0	−0,7	−0,8	1,3	6,2	11,3	15,2	17,4	16,8	13,5	8,7	4,8	1,9
Alnarp	7,8	−0,8	−1,0	1,2	5,9	11,1	15,0	17,1	16,6	13,3	8,5	4,6	1,8
Ystad	7,8	−0,2	−0,6	1,2	5,3	10,1	14,1	16,7	16,4	13,4	9,2	5,3	2,4

VVS-HANDBOKEN

1. **Varaktighet för uteluftens temperatur som funktion av årets normaltemperatur under tiden 1931—1960**

Drifttid: Hela dygnet

Tillämpning av figuren ges på sid 7:36.



2. **Summa gradtimmar per år vid uppvärmning till viss temperatur samt drifttid för värmeanläggning under tiden 1931—1960**

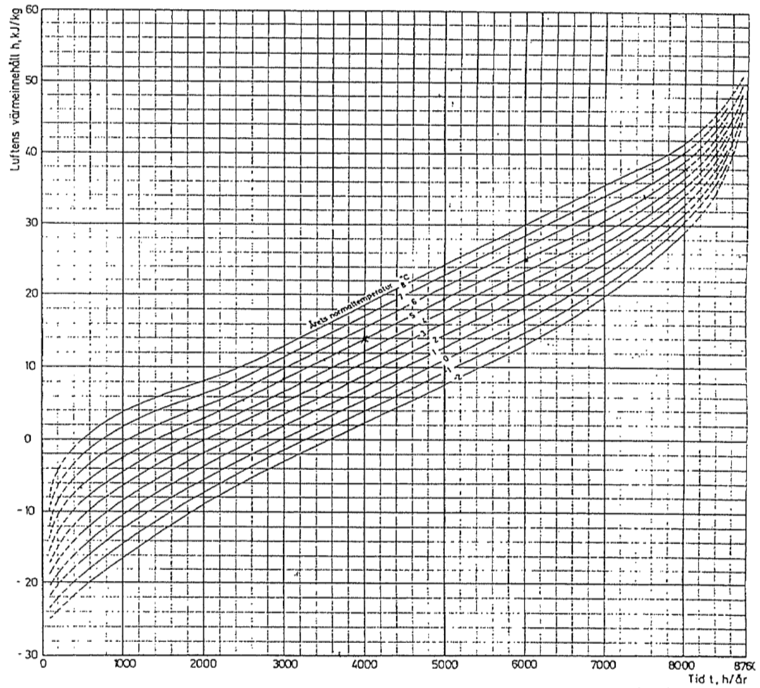
Vid uppvärmning till 11°C och högre temperatur, antas uppvärmningen sluta då utetemperaturen överstiger 11°C.

Temp °C	Summa gradtimmar, som funktion av årets normaltemperatur i °C										
	−2	−1	0	1	2	3	4	5	6	7	8
5	80750	73500	66500	59700	53200	47000	41000	35200	29700	24500	19500
6	87000	79500	72300	65300	58500	52000	45800	39700	33900	28400	23000
7	93500	85800	78300	71100	64100	57400	50800	44500	38400	32600	26900
8	100200	92200	84600	77200	69900	62900	56200	49600	43200	37100	31100
9	107200	99000	91200	83500	76000	68800	61800	54900	48200	42000	35500
10	114500	106000	98000	90100	82400	74900	67700	60600	53600	47100	40300
11	121900	113300	105100	97000	89000	81400	73900	66500	59300	52500	45400
12	129500	120700	112300	104000	95800	88000	80200	72600	65100	58100	50700
13	137000	128100	119500	111000	102500	94500	86500	78700	70900	63600	55900
14	144600	135400	126700	118000	109300	101100	92900	84700	76700	69200	61200
15	152100	142800	133900	125000	116100	107600	99200	90800	82500	74800	66500
16	159700	150200	141100	132100	122900	114200	105500	96900	88300	80400	71800
17	167200	157600	148300	139100	129600	120700	111800	103000	94100	85900	77000
18	174800	165000	155500	146100	136400	127300	118100	109100	99900	91500	82300
19	182300	172300	162700	153100	143200	133800	124500	115200	105700	97100	87600
20	189900	179700	169900	160100	149900	140400	130800	121300	111500	102600	92800
21	197400	187100	177100	167100	156700	146900	137100	127300	117300	108200	98100
22	205000	194500	184300	174100	163500	153500	143400	133400	123100	113800	103400
23	212500	201900	191500	181100	170200	160000	149700	139500	128900	119300	108600
24	220100	209200	198700	188100	177000	166600	156100	145600	134700	124900	113900
25	227600	216600	205900	195100	183800	173100	162400	151700	140500	130500	119200
	Drifttid i h/år för värmeanläggning, som funktion av årets normaltemperatur, då uppvärmning sker till minst 11 °C.										
	7550	7380	7200	7010	6770	6550	6320	6080	5800	5570	5270

Varaktighet för uteluftens värmeinnehåll som funktion av årets normaltemperatur under tiden 1931—1960

Drifttid: Hela dygnet

Tillämpning av figuren ges på sid 7:36.



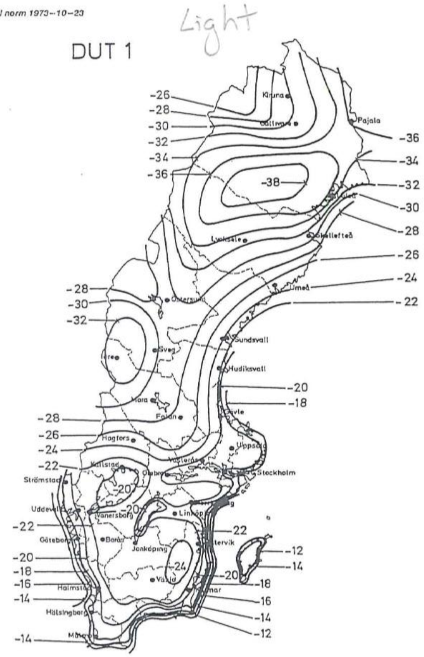
Meteorologi och klimatologi

Dim temperaturer vintertid

7:22

Dimensionerande utetemperatur för värmeanläggning, DUT 1 ®

Källa: SBN 75 figur 35:11 c, förslag till norm 1973–10–23



Dimensionerande lägsta utetemperatur

Vid beräkning av maximal erforderlig värmeeffekt används den dimensionerande utetemperatur, som erhålls ur 7:22—1 eller 7:23—1 enligt följande:

för byggnad med lätt väggkonstruktion (ytvikt< 100 kg/m²) fastställs den dimensionerande temperaturen (DUT 1) med ledning av 7:22—1.

för byggnad med tung väggkonstruktion (ytvikt>100 kg/m²) fastställs den dimensionerande temperaturen (DUT 5) med ledning av 7:23—1.

Avlästa DUT-värden enligt ovan korrigeras om ifrågavarande byggnad ligger på en plats, som bedöms vara kallare än trakten i genomsnitt.

7:22—1 är uppritad för byggnad med tidskonstanten R = = 24 h, 7:23—1 för byggnad med tidskonstanten R = 80 h.

Vid noggrannare värmebehovsberäkning interpoleras ett DUT-värde, om R ligger mellan 24 h och 80 h.

För byggnad med extremt lätt väggkonstruktion (ned mot 50 kg/m²) används lämpligen värdet DUT 1 minskat med 2° à 4°C beroende på R-värdets storlek.

I nu vanliga flervånings stenhus är tidskonstanten av storleksordningen 160 h hos innerrum och 100 h hos hörnrum (hörnrum har större avkylningsfaktor och därför mindre värmetröghet än innerrum). Vid mineralullsisolerade regelhus med träbjälklag är R av storleksordningen 30 h om inredningens och värmeanläggningens inverkan försummas.

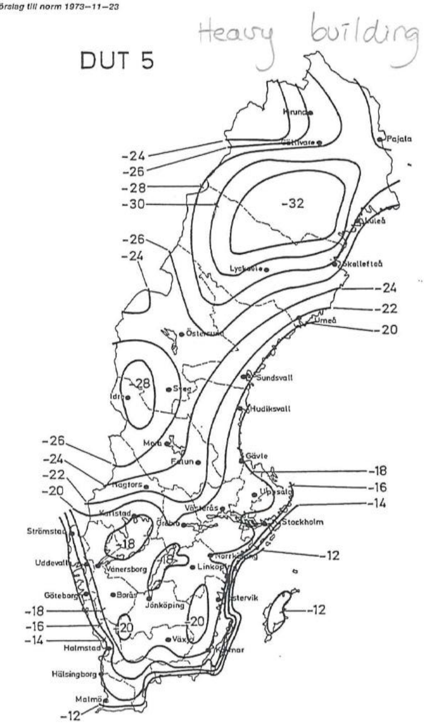
Meteorolog... klimatolo...

Dim tempera...er vintertid

7:23

Dimensionerande utetemperatur för värmeanläggning, DUT 5 ®

Källa: SBN 75, figur 35:11 d, förslag till norm 1973–11–23



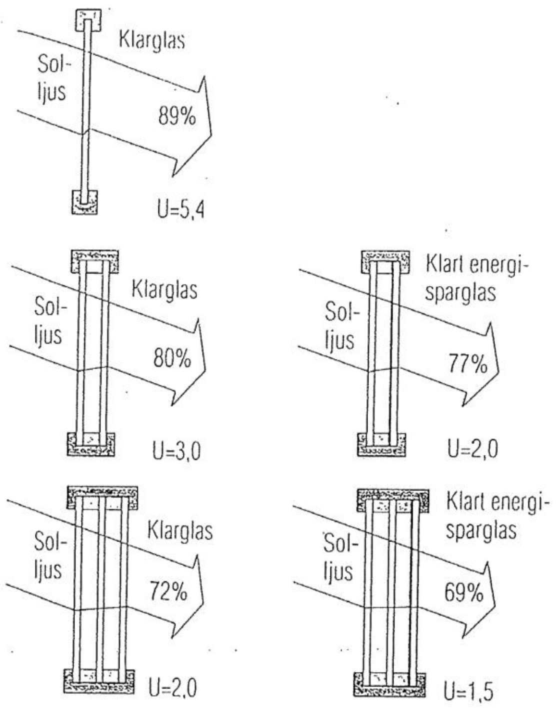
7.4 CALCULATIONS DATA

II:2.1.2 Dygnssummor den 15:e i varje månad av strålning mot vertikala ytor, Wh/m^2dygn

Månad	Horisont-avskärmning,°	Vertikala ytans orientering N −180	−150	−120	E −90	−60	−30	S 0	30	60	W 90	120	150
Latitud 68° N													
Januari	0	0	0	0	10	80	130	160	130	80	10	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0
Februari	0	160	160	240	770	1 730	2 740	3 140	2 740	1 730	770	240	160
	10	90	90	90	120	170	220	240	220	170	120	90	90
Mars	0	530	630	1 280	2 470	3 900	5 170	5 770	5 170	3 900	2 470	1 280	630
	10	500	510	820	1 790	3 180	4 590	5 210	4 590	3 180	1 790	820	510
April	0	1 320	1 920	3 230	4 700	5 920	6 570	6 690	6 570	5 920	4 700	3 230	1 920
	10	1 040	1 440	2 530	3 970	5 350	6 310	6 660	6 310	5 350	3 970	2 530	1 440
Maj	0	2 940	3 530	4 850	6 010	6 560	6 490	6 370	6 490	6 560	6 010	4 850	3 530
	10	1 960	2 660	4 030	5 350	6 220	6 450	6 330	6 450	6 220	5 350	4 030	2 660
Juni	0	4 890	5 290	6 160	6 820	6 860	6 520	6 310	6 520	6 860	6 820	6 160	5 290
	10	3 060	3 690	5 090	6 220	6 690	6 470	6 270	6 470	6 690	6 220	5 090	3 690
Juli	0	3 910	4 410	5 540	6 500	6 760	6 510	6 340	6 510	6 760	6 500	5 540	4 410
	10	2 500	3 190	4 600	5 830	6 500	6 470	6 300	6 470	6 500	5 830	4 600	3 190
Augusti	0	1 850	2 460	3 800	5 130	6 070	6 390	6 390	6 390	6 070	5 130	3 800	2 460
	10	1 410	2 020	3 270	4 650	5 750	6 320	6 370	6 320	5 750	4 650	3 270	2 020
September	0	720	1 000	1 860	3 120	4 460	5 500	5 920	5 500	4 460	3 120	1 860	1 000
	10	690	770	1 410	2 570	3 940	5 150	5 750	5 150	3 940	2 570	1 410	770
Oktober	0	290	290	550	1 370	2 590	3 820	4 370	3 820	2 590	1 370	550	290
	10	250	250	270	710	1 720	2 770	3 150	2 770	1 720	710	270	250
November	0	30	30	30	140	530	910	1 040	910	530	140	30	30
	10	20	20	20	20	30	50	50	50	30	20	20	20
December	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0
Latitud 64° N													
Januari	0	50	50	50	220	750	1 260	1 440	1 260	750	220	50	50
	10	30	30	30	40	50	70	80	70	50	40	30	30
Februari	0	260	270	440	1 180	2 370	3 600	4 120	3 600	2 370	1 180	440	270
	10	220	220	230	510	1 410	2 260	2 580	2 260	1 410	510	230	220
Mars	0	630	770	1 510	2 780	4 250	5 510	6 110	5 510	4 250	2 780	1 510	770
	10	610	630	1 140	2 270	3 730	5 120	5 790	5 120	3 730	2 270	1 140	630
April	0	1 320	1 940	3 260	4 710	5 890	6 500	6 590	6 500	5 890	4 710	3 260	1 940
	10	1 110	1 540	2 680	4 100	5 410	6 260	6 560	6 260	5 410	4 100	2 680	1 540
Maj	0	2 540	3 200	4 590	5 780	6 360	6 250	6 070	6 250	6 360	5 780	4 590	3 200
	10	2 000	2 720	4 090	5 360	6 120	6 230	6 050	6 230	6 120	5 360	4 090	2 720
Juni	0	3 690	4 260	5 510	6 460	6 610	6 160	5 890	6 160	6 610	6 460	5 510	4 260
	10	2 690	3 390	4 800	5 930	6 390	6 130	5 860	6 130	6 390	5 930	4 800	3 390
Juli	0	3 170	3 790	5 130	6 190	6 520	6 210	5 970	6 210	6 520	6 190	5 130	3 790
	10	2 500	3 200	4 620	5 790	6 340	6 190	5 950	6 190	6 340	5 790	4 620	3 200
Augusti	0	1 740	2 380	3 730	5 050	5 960	6 250	6 200	6 250	5 960	5 050	3 730	2 380
	10	1 340	1 920	3 130	4 470	5 550	6 110	6 170	6 110	5 550	4 470	3 130	1 920
September	0	810	1 120	2 030	3 330	4 660	5 670	6 070	5 670	4 660	3 330	2 030	1 120
	10	780	880	1 570	2 760	4 130	5 310	5 910	5 310	4 130	2 760	1 570	880
Oktober	0	400	410	800	1 780	3 150	4 490	5 110	4 490	3 150	1 780	800	410
	10	360	360	430	1 080	2 300	3 590	4 080	3 590	2 300	1 080	430	360
November	0	100	100	120	470	1 260	2 070	2 380	2 070	1 260	470	120	100
	10	60	60	60	80	110	150	170	150	110	80	60	60
December	0	10	10	10	80	360	610	700	610	360	80	10	10
	10	10	10	10	10	20	30	30	30	20	10	10	10

II:2.1.2 Dygnssummor den 15:e i varje månad av strålning mot vertikala ytor, Wh/m^2dygn 151

Månad	Horisont-avskärmning,°	Vertikala ytans orientering N −180	−150	−120	E −90	−60	−30	S 0	30	60	W 90	120	150
Latitud 60° N													
Januari	0	130	130	160	550	1 440	2 360	2 710	2 360	1 440	550	160	130
	10	70	70	70	90	140	180	200	180	140	90	70	70
Februari	0	370	370	640	1 550	2 900	4 280	4 880	4 280	2 900	1 550	640	370
	10	340	340	400	1 030	2 240	3 530	4 020	3 530	2 240	1 030	400	340
Mars	0	730	900	1 720	3 050	4 520	5 740	6 320	5 740	4 520	3 050	1 720	900
	10	710	730	1 290	2 460	3 920	5 290	5 970	5 290	3 920	2 460	1 290	730
April	0	1 350	1 990	3 320	4 750	5 850	6 370	6 410	6 370	5 850	4 750	3 320	1 990
	10	1 170	1 640	2 810	4 220	5 420	6 160	6 390	6 160	5 420	4 220	2 810	1 640
Maj	0	2 350	3 050	4 460	5 630	6 150	5 980	5 730	5 980	6 150	5 630	4 460	3 050
	10	1 840	2 570	3 910	5 130	5 840	5 920	5 710	5 920	5 840	5 130	3 910	2 570
Juni	0	3 210	3 870	5 230	6 190	6 350	5 820	5 460	5 820	6 350	6 190	5 230	3 870
	10	2 420	3 180	4 570	5 650	6 070	5 790	5 430	5 790	6 070	5 650	4 570	3 180
Juli	0	2 830	3 510	4 910	5 960	6 280	5 820	5 580	5 890	6 280	5 960	4 910	3 510
	10	2 270	3 020	4 410	5 540	6 050	5 870	5 560	5 870	6 050	5 540	4 410	3 020
Augusti	0	1 700	2 380	3 720	5 020	5 850	6 070	5 970	6 070	5 850	5 020	3 720	2 380
	10	1 400	2 020	3 240	4 550	5 520	5 950	5 940	5 950	5 520	4 550	3 240	2 020
September	0	900	1 230	2 200	3 520	4 820	5 760	6 130	5 760	4 820	3 520	2 200	1 230
	10	880	1 070	1 930	3 200	4 530	5 580	6 080	5 580	4 530	3 200	1 930	1 070
Oktober	0	510	530	1 010	2 110	3 570	4 960	5 620	4 960	3 570	2 110	1 010	530
	10	470	480	650	1 500	2 850	4 290	4 870	4 290	2 850	1 500	650	480
November	0	200	200	270	840	1 910	3 040	3 480	3 040	1 910	840	270	200
	10	160	160	160	300	990	1 590	1 810	1 590	990	300	160	160
December	0	80	80	90	350	1 060	1 770	2 030	1 770	1 060	350	90	80
	10	40	40	50	60	90	120	130	120	90	60	50	40
Latitud 56° N													
Januari	0	230	230	300	910	2 050	3 260	3 730	3 260	2 050	910	300	230
	10	190	190	200	460	1 350	2 180	2 490	2 180	1 350	460	200	190
Februari	0	480	480	870	1 920	3 370	4 810	5 470	4 810	3 370	1 920	870	480
	10	450	450	610	1 440	2 790	4 240	4 820	4 240	2 790	1 440	610	450
Mars	0	820	1 020	1 920	3 280	4 720	5 860	6 420	5 860	4 720	3 280	1 920	1 020
	10	810	900	1 640	2 930	4 370	5 620	6 260	5 620	4 370	2 930	1 640	900
April	0	1 370	2 030	3 360	4 760	5 770	6 190	6 180	6 190	5 770	4 760	3 360	2 030
	10	1 230	1 750	2 950	4 320	5 410	6 010	6 160	6 010	5 410	4 320	2 950	1 750
Maj	0	2 230	2 980	4 390	5 500	5 950	5 690	5 360	5 690	5 950	5 500	4 390	2 980
	10	1 890	2 650	4 000	5 150	5 730	5 640	5 350	5 640	5 730	5 150	4 000	2 650
Juni	0	2 950	3 670	5 060	5 980	6 090	5 470	5 030	5 470	6 090	5 980	5 060	3 670
	10	2 470	3 250	4 630	5 620	5 900	5 450	5 020	5 450	5 900	5 620	4 630	3 250
Juli	0	2 630	3 380	4 790	5 790	6 050	5 560	5 160	5 560	6 050	5 790	4 790	3 380
	10	2 080	2 870	4 210	5 280	5 730	5 510	5 140	5 510	5 730	5 280	4 210	2 870
Augusti	0	1 680	2 380	3 720	4 970	5 720	5 850	5 680	5 850	5 720	4 970	3 720	2 380
	10	1 460	2 110	3 360	4 610	5 460	5 750	5 670	5 750	5 460	4 610	3 360	2 110
September	0	980	1 330	2 350	3 680	4 920	5 760	6 100	5 760	4 920	3 680	2 350	1 330
	10	960	1 170	2 080	3 360	4 630	5 580	6 050	5 580	4 630	3 360	2 080	1 170
Oktober	0	610	650	1 250	2 450	3 940	5 320	5 990	5 320	3 940	2 450	1 250	650
	10	590	590	920	1 950	3 380	4 850	5 500	4 850	3 380	1 950	920	590
November	0	300	300	440	1 190	2 460	3 800	4 340	3 800	2 460	1 190	440	300
	10	270	270	280	720	1 800	2 900	3 310	2 900	1 800	720	280	270
December	0	170	170	210	680	1 700	2 750	3 150	2 750	1 700	680	210	170
	10	120	120	120	180	640	1 020	1 160	1 020	640	180	120	120



Ett vanligt 4 mm enkelglas dämpar solljuset med ca 10% och släpper alltså in ca 90%. För varje extra glas minskar man ljusinsläppet med ca 10% En fyrglasruta släpper in 65% av solljuset. [illegible] referensruta att jämföra med märker ögat dämpningen först vid 50-55% ljusreducering.

Energisparglasets beläggning påverkar inte ljusreduktionen nämnvärt. Minskningen med procentenheter i illustrationen är enbart beräknad och försumbar.

CALCULATION FACTORS FOR WINDOWS ACCORDING TO SUN RADIATION

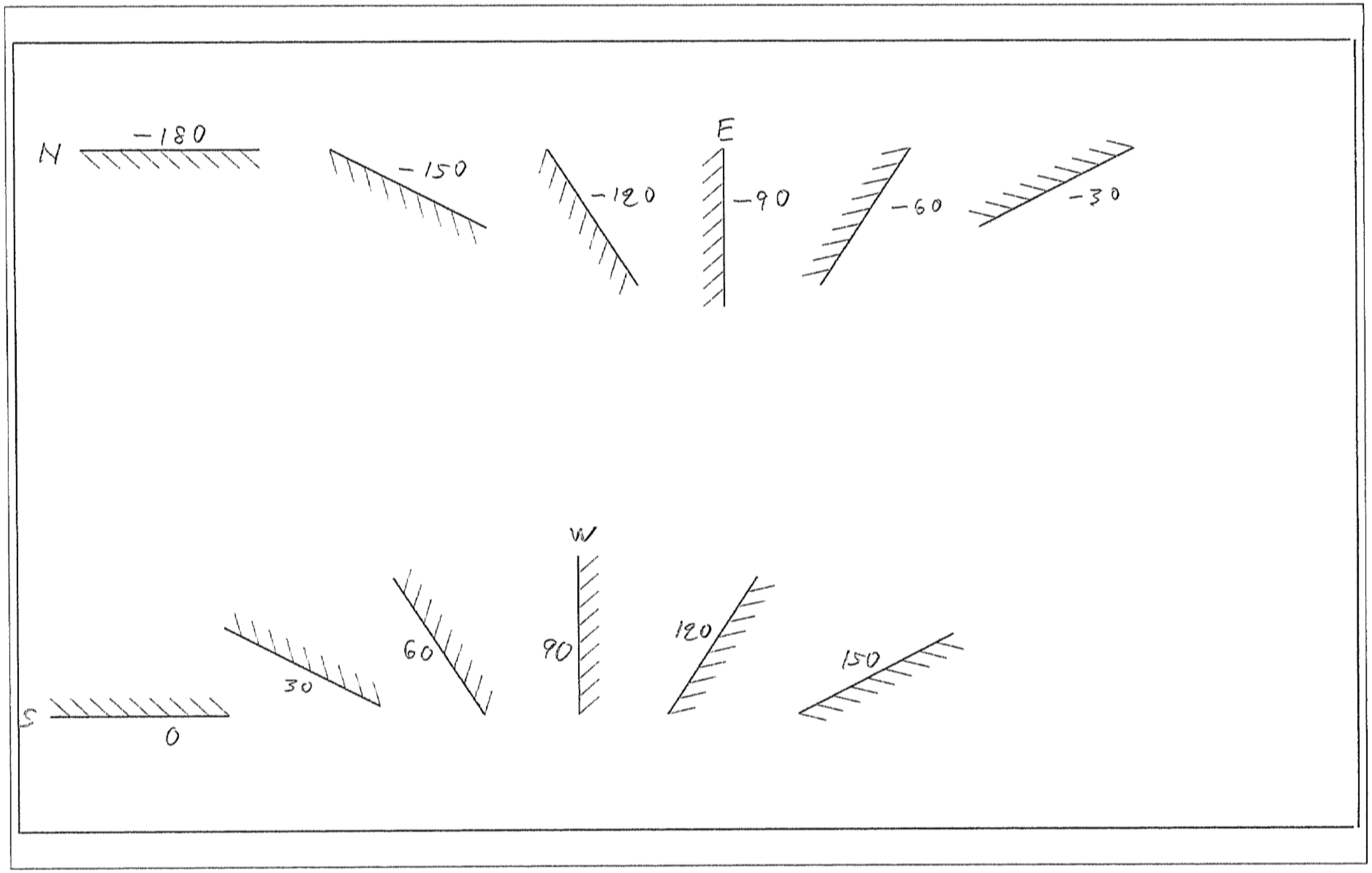
WINDOWS TYPE	U-VALUE	CALCULATION FACTOR
1-glass, normally	5.4	0.90
2-glass, normally	2.9 – 3.0	0.80
3-glass, normally	1.9 – 2.0	0.72
Special glass	1.0 – 1.5	0.69
2-glass, energy glass	1.0 – 1.5	0.70

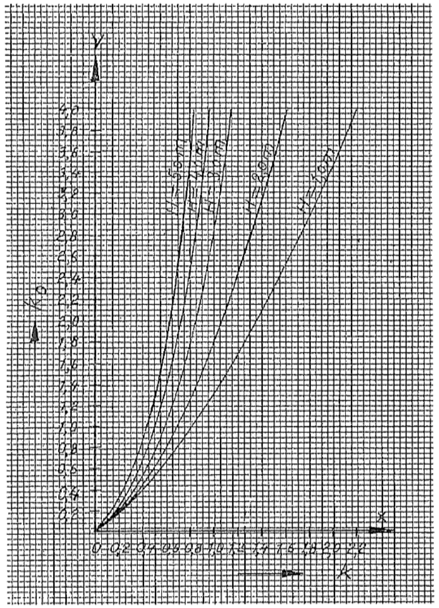
Example:

If you have 3-glass, normally and you calculate Q (Wh) from the table so is the right value Q x 0.72.

CALCULATION FACTORS FOR WINDOWS ACCORDING TO CLOUDY DAYS

MONTH	CALCULATION FACTOR
January	0.45
February	0.49
March	0.58
April	0.58
May	0.63
September	0.58
October	0.51
November	0.42
December	0.43


N
-180
-150
-120
E
-90
-60
-30
W
S
0
30
60
90
120
150



5. Diagrammet anger sambandet mellan värmegenomgångstalet k för en vägg med jord på ena sidan, väggens djup (H) under markytan och värmegenomgångstalet (k_0) för väggens övre del ovan markytan.

I tabell 5 visas sambandet mellan k_0, H och k. Sedan k_0 beräknats och höjden H mätts upp, kan man få det verkliga värmegenomgångstalet k ur tabellen. För fuktiga grundmurar bör dessa k-värden ökas med 15 %.

Diagrammet i fig. 5 ger grafiskt sambandet mellan nämnda storheter. När k_0 och H är kända, kan man avläsa verkliga k-värdet ur diagrammet.

Höjden H finns endast angiven i jämna meter både i tabellen och i diagrammet. Söker man k-värden vid andra höjder, kan man interpolera mellan närmaste övre och undre värden (gäller även för k_0).

Tabell 5. k-värden för grundmur under mark

Djup H i meter under markytan	Värmegenomgångstal k_0 (utan hänsyn till omgivande mark)										
	0,5	0,6	0,7	0,8	1,0	1,2	1,5	2,0	2,5	3,0	4,0
	Värmegenomgångstal k vid ovanstående k_0-värden										
1,0	0,43	0,50	0,57	0,67	0,80	0,93	1,11	1,37	1,60	1,81	2,19
2,0	0,38	0,43	0,48	0,58	0,69	0,78	0,90	1,06	1,22	1,36	1,62
3,0	0,34	0,38	0,43	0,51	0,60	0,67	0,76	0,87	0,96	1,04	1,18
4,0	0,31	0,35	0,38	0,45	0,53	0,60	0,68	0,74	0,81	0,88	0,98
5,0	0,29	0,32	0,35	0,42	0,48	0,53	0,58	0,64	0,70	0,75	0,84

Exempel 3. Beräkna värmegenomgångstalet för den under mark belägna delen av källarväggen i fig. 6.

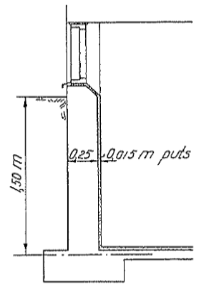
Lösning:

ytmotstånd $= 0,20$

motstånd hos betong $= \frac{0,25}{1,5} \approx 0,167$

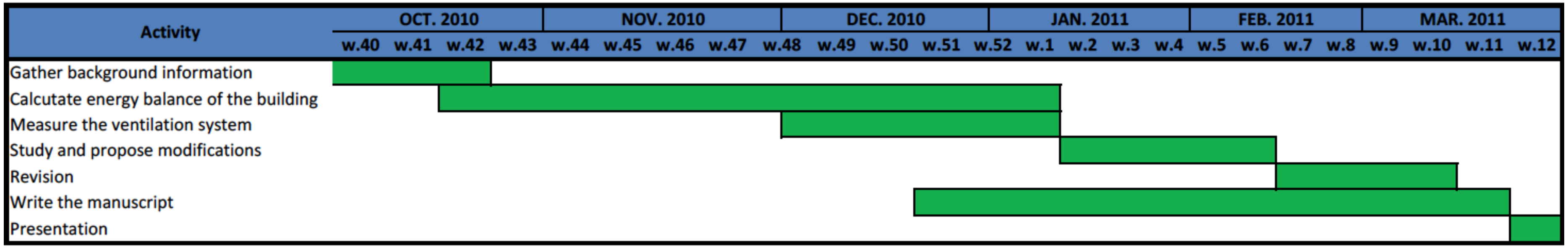
motstånd hos puts $= \frac{0,015}{0,9} \approx 0,017$

$\Sigma m \approx 0,39$



6. Tillhör exempel 3.

7.5 TIMING


Activity
OCT. 2010
NOV. 2010
DEC. 2010
JAN. 2011
FEB. 2011
MAR. 2011
w.40 w.41 w.42 w.43 w.44 w.45 w.46 w.47 w.48 w.49 w.50 w.51 w.52 w.1 w.2 w.3 w.4 w.5 w.6 w.7 w.8 w.9 w.10 w.11 w.12
Gather background information
Calcutate energy balance of the building
Measure the ventilation system
Study and propose modifications
Revision
Write the manuscript
Presentation

7.6 ECONOMIC STUDIES

7.6.1 VENTILATION INSTALLATION

Year	0	1	2	3	4	5	6	7	8	9	10	11	20
Outflow (SEK)	1.000.000	16.509	16.509	16.509	16.509	16.509	16.509	16.509	16.509	16.509	16.509	16.509	16.509
Inflow (SEK)	0	110.387	110.387	110.387	110.387	110.387	110.387	110.387	110.387	110.387	110.387	110.387	110.387
Cash flow (SEK)	-1.000.000	93.878	93.878	93.878	93.878	93.878	93.878	93.878	93.878	93.878	93.878	93.878	93.878
Accumulated Cash flow (SEK)	-1.000.000	-906.122	-812.243	-718.365	-624.486	-530.608	-436.729	-342.851	-248.972	-155.094	-61.215	32.663	877.569
NPVt	-1.000.000	89.408	85.151	81.096	77.234	73.556	70.054	66.718	63.541	60.515	57.633	54.889	35.382

7.6.2 HEATING PUMP

Year	0	1	2	3	4	5	6	7	8	9	10
Outflow (SEK)	200.000	47.153	47.153	47.153	47.153	47.153	47.153	47.153	47.153	47.153	47.153
Inflow (SEK)	0	75.055	75.055	75.055	75.055	75.055	75.055	75.055	75.055	75.055	75.055
Cash flow (SEK)	-200.000	27.901	27.901	27.901	27.901	27.901	27.901	27.901	27.901	27.901	27.901
Accumulated Cash flow (SEK)	-200.000	-172.099	-144.197	-116.296	-88.394	-60.493	-32.591	-4.690	23.212	51.113	79.015
NPVt	-200.000	26.573	25.307	24.102	22.955	21.862	20.821	19.829	18.885	17.986	17.129

7.6.3 DETECTORS

Year	0	1
Outflow (SEK)	20.000	0
Inflow (SEK)	0	84.555
Cash flow (SEK)	-20.000	84.555
Accumulated Cash flow (SEK)	-20.000	64.555
NPVt	-20.000	80.528

7.7 ROOMS CHECKLIST

7.7.1 BASEMENT

Number	Width (m)	Lenght (m)	Area (m2)	Windows	Supply air (m3/h)	Exhaust air (m3/h)	Outside air (l/s)	Min. outside air (l/s)	Difference (l/s)	SS oustside air (l/s)	Difference (l/s)	Activity	Fu
1			10,8	0,0	0,0	0,0	0,0	3,8	-3,8	3,8	-3,8	Stairs	1,00
2	1,0	1,5	1,5	0,0	0,0	30,0	8,3	0,5	7,8	0,5	7,8	Toilet	0,08
3	2,2	4,5	9,9	0,0	0,0	0,0	0,0	3,5	-3,5	3,5	-3,5	Dressing room	0,08
4	1,0	1,5	1,5	0,0	0,0	20,0	5,6	0,5	5,0	0,5	5,0	Toilet	0,08
5	1,0	2,0	2,0	0,0	0,0	10,0	2,8	0,7	2,1	0,7	2,1	Shower	0,08
6	1,0	1,0	1,0										
7			7,3	0,0	0,0	0,0	0,0	2,6	-2,6	2,6	-2,6	Dressing room	0,08
8	2,0	1,0	2,0	0,0	0,0	15,0	4,2	0,7	3,5	0,7	3,5	Shower	0,08
9	1,0	1,5	1,5	0,0	0,0	15,0	4,2	0,5	3,6	0,5	3,6	Toilet	0,08
10	3,2	5,0	16,0	0,0	0,0	40,0	11,1	5,6	5,5	5,6	5,5	Laundry	0,08
11	2,3	2,7	6,2	0,0	0,0	0,0	0,0	2,2	-2,2	2,2	-2,2	Bedroom	0,33
12	6,0	3,0	18,0	0,0	0,0	0,0	0,0	6,3	-6,3	6,3	-6,3	Stairs	1,00
13			66,3	0,0	129,6	284,4	79,0	23,2	55,8	23,2	55,8	Bar	0,04
14	1,2	3,2	3,8										
15	1,5	1,5	2,3										
16 17			19,4	0,0	0,0	0,0	0,0	6,8	-6,8	6,8	-6,8	Kitchen	0,08
18	1,8	1,8	3,2										
19	1,8	1,8	3,2	0,0	0,0	0,0	0,0	1,1	-1,1	1,1	-1,1	Elevator	1,00
20	0,8	2,0	1,6										
21	19,0	4,8	91,2	0,0	529,2	0,0	0,0	31,9	-31,9	331,9	-331,9	Bar	0,08
22	3,1	2,0	6,2	0,0	0,0	14,4	4,0	2,2	1,8	2,2	1,8	Toilet	0,08
23	1,5	1,0	1,5	0,0	0,0	7,0	1,9	0,5	1,4	0,5	1,4	Toilet	0,08
24	1,5	1,0	1,5	0,0	3,6	14,4	4,0	0,5	3,5	0,5	3,5	Toilet	0,08
25	10,3	3,2	33,0	0,0	210,0	0,0	0,0	11,5	-11,5	11,5	-11,5	Wardrobe	0,04
26	7,0	3,5	24,5	0,0	0,0	0,0	0,0	8,6	-8,6	8,6	-8,6	Junk room	0,04
27	1,7	1,7	2,9	0,0	0,0	15,0	4,2	1,0	3,2	1,0	3,2	Toilet	0,08
28	2,1	1,7	3,6	0,0	0,0	0,0	0,0	1,2	-1,2	1,2	-1,2	Toilet	0,08
29	2,5	1,2	3,0	0,0	0,0	7,0	1,9	1,1	0,9	1,1	0,9	Toilet	0,08
30	1,2	1,2	1,4	0,0	0,0	7,0	1,9	0,5	1,4	0,5	1,4	Toilet	0,08
31	21,5	10,5	225,8	0,0	1580,4	4284,0	1190,0	79,0	1111,0	829,0	361,0	Hall	0,04
32	6,0	9,0	54,0	0,0	0,0	0,0	0,0	18,9	-18,9	56,4	-56,4	Stage	0,04
33	3,8	1,5	5,7	0,0	0,0	0,0	0,0	2,0	-2,0	2,0	-2,0	Agreggate room	1,00
34	7,0	3,5	24,5	0,0	50,0	277,2	77,0	8,6	68,4	8,6	68,4	Junk room	0,04
35	7,0	3,8	26,6	0,0	0,0	0,0	0,0	9,3	-9,3	9,3	-9,3	Meeting room	0,08
36	2,1	10,2	21,4	0,0	0,0	0,0	0,0	7,5	-7,5	7,5	-7,5	Corridor	1,00
36a	8,1	3,5	28,4	0,0	108,0	0,0	0,0	9,9	-9,9	9,9	-9,9	Switch room	0,04
37	7,0	4,8	33,6	0,0	72,0	180,0	50,0	11,8	38,2	11,8	38,2	Meeting room	0,08
38	7,0	3,0	21,0	0,0	72,0	82,8	23,0	7,4	15,7	7,4	15,7	Meeting room	0,08
39			19,2	0,0	0,0	0,0	0,0	6,7	-6,7	6,7	-6,7	Stairs	0,08
39a	3,0	1,8	5,4	0,0	0,0	0,0	0,0	1,9	-1,9	1,9	-1,9	Corridor	1,00
39b	3,0	4,6	13,8	0,0	72,0	0,0	0,0	4,8	-4,8	4,8	-4,8	Server room	0,04
39c	12,2	6,4	78,1	0,0	72,0	0,0	0,0	27,3	-27,3	27,3	-27,3	Maitenance room	0,04
40	1,8	1,5	2,7										
41	1,2	2,0	2,4	0,0	0,0	0,0	0,0	0,8	-0,8	0,8	-0,8	Corridor	1,00
42	17,0	2,1	35,7	0,0	0,0	0,0	0,0	12,5	-12,5	12,5	-12,5	Corridor	1,00
43	2,0	2,0	4,0	0,0	0,0	0,0	0,0	1,4	-1,4	1,4	-1,4	Toilet	0,08
44	1,5	1,0	1,5	0,0	90,0	0,0	0,0	0,5	-0,5	0,5	-0,5	Toilet	0,08
45	1,5	1,0	1,5	0,0	54,0	0,0	0,0	0,5	-0,5	0,5	-0,5	Toilet	0,08
46	1,0	2,0	2,0	0,0	54,0	0,0	0,0	0,7	-0,7	0,7	-0,7	Toilet	0,08
47	2,0	2,0	4,0	0,0	0,0	0,0	0,0	1,4	-1,4	1,4	-1,4	Toilet	0,08
48	1,0	2,0	2,0	0,0	54,0	0,0	0,0	0,7	-0,7	0,7	-0,7	Toilet	0,08
49	1,5	1,0	1,5	0,0	32,4	0,0	0,0	0,5	-0,5	0,5	-0,5	Toilet	0,08
50	1,5	1,0	1,5	0,0	32,4	0,0	0,0	0,5	-0,5	0,5	-0,5	Toilet	0,08
51	2,6	2,0	5,2	0,0	32,4	0,0	0,0	1,8	-1,8	1,8	-1,8	Kitchen	0,08
52	5,3	2,0	10,6										
53	1,3	1,0	1,3										
54	6,7	5,5	36,9	0,0	468,0	108,0	30,0	12,9	17,1	27,9	2,1	Music room	0,08
55	3,2	5,5	17,6	0,0	468,0	108,0	30,0	6,2	23,8	6,2	23,8	Makeup room	0,04
56	3,5	5,5	19,3										
57	3,1	5,5	17,1	0,0	468,0	108,0	30,0	6,0	24,0	6,0	24,0	Makeup room	0,04

58	2,4	5,0	12,0										
59	13,0	6,2	80,6	0,0	0,0	0,0	0,0	28,2	-28,2	28,2	-28,2	Agreggate room	1,00
60			37,7	0,0	0,0	0,0	0,0	13,2	-13,2	13,2	-13,2	Heating eq.	1,00
61	2,7	4,5	12,2										
62	15,0	1,6	24,0	0,0	0,0	0,0	0,0	8,4	-8,4	8,4	-8,4	Stage basement	0,04
63	3,7	2,0	7,4	0,0	0,0	0,0	0,0	2,6	-2,6	2,6	-2,6	Switch room	0,04
64	10,0	2,0	20,0	0,0	0,0	0,0	0,0	7,0	-7,0	82,0	-82,0	Orchestra pit	0,04
65	1,3	1,5	2,0										
66	0,7	1,5	1,1										
SLUSS	2,6	3,3	8,6	0,0	0,0	0,0	0,0	3,0	-3,0	3,0	-3,0	Junk room	0,04
SKYDDSRUM 1			28,0	0,0	0,0	0,0	0,0	9,8	-9,8	9,8	-9,8	Junk room	0,04
SKYDDSRUM 2			28,0	0,0	0,0	10,8	3,0	9,8	-6,8	9,8	-6,8	Junk room	0,04
SKYDDSRUM 3			28,8	0,0	0,0	10,8	3,0	10,1	-7,1	10,1	-7,1	Junk room	0,04

Number	Users	Incandescent	Fluorescent	Focus	Computer	Speakers	Fax	Photocopier	Plotter	Microwave	Refrigerator	Oven	TV	Projector	Cash register	Fan	Hi-Fi eq.	Dishwasher	Coffee maker
1			2																
2		1																	
3		3	2																
4		1																	
5		1																	
6																			
7		2	2																
8		1																	
9		1																	
10																			
11			4																
12			3																
13		16				4					2				1		1		
14																			
15																			
16			3																
17																			
18																			
19																			
20																			
21	40	17									2								
22			4																
23			1																
24			1																
25		10																	
26			1																
27			1																
28			2																
29			2																
30			1																
31	100	62	23	2		4											1		
32	5	35																	
33			1																
34			1																
35		8	4																
36		3																	
36a			3																
37		5	4																
38			4																
39			1																
39a			1																
39b			3		1														
39c		1	13																
40																			
41		1																	
42			3																
43		1																	
44		1																	
45		1																	
46		1																	
47		1																	
48		1																	
49		1																	
50		1																	
51			1							3	2	1							2
52																			
53																			
54	2		4																
55		2	2																
56																			
57		2	2																

58																			
59			6																
60			2																
61																			
62			2																
63																			
64	10		1																
65																			
66																			
SLUSS			1																
SKYDDSRUM 1			1																
SKYDDSRUM 2			1																
SKYDDSRUM 3			1																

7.7.2 GROUNDFLOOR

Number	Width (m)	Lenght (m)	Area (m2)	Windows	Supply air (m3/h)	Exhaust air (m3/h)	Outside air (l/s)	Min. outside air (l/s)	Difference (l/s)	SS outside air (l/s)	Difference (l/s)	Activity	Fu
1	4,3	1,0	4,3	10,0	0,0	0,0	0,0	1,5	-1,5	1,5	-1,5	Main entrance	1,00
2			195,2	10,0	0,0	0,0	0,0	68,3	-68,3	68,3	-68,3	Entrance hall	1,00
3	13,0	2,5	32,5	0,0	0,0	0,0	0,0	11,4	-11,4	18,4	-18,4	Reception	0,33
4	2,0	2,5	5,0	0,0	0,0	40,0	11,1	1,8	9,4	1,8	9,4	Toilet	0,08
5	2,2	2,8	6,2	0,0	0,0	0,0	0,0	2,2	-2,2	2,2	-2,2	Toilet	0,08
6	2,0	1,0	2,0	0,0	0,0	55,0	15,3	0,7	14,6	0,7	14,6	Toilet	0,08
7	1,0	1,4	1,4	0,0	0,0	60,0	16,7	0,5	16,2	0,5	16,2	Toilet	0,08
8	1,0	1,4	1,4	0,0	0,0	50,0	13,9	0,5	13,4	0,5	13,4	Toilet	0,08
9			57,3	9,0	259,2	0,0	0,0	20,1	-20,1	76,1	-76,1	Dining room	0,33
9b	6,8	6,4	43,5	15,0	756,0	64,8	18,0	15,2	2,8	295,2	-277,2	Dining room	0,33
10	4,0	3,0	12,0	0,0	0,0	288,0	80,0	4,2	75,8	11,2	68,8	Rest's bar	0,33
11	2,0	1,5	3,0	0,0	0,0	0,0	0,0	1,1	-1,1	1,1	-1,1	Elevator	1,00
12			11,9	0,0	0,0	0,0	0,0	4,2	-4,2	4,2	-4,2	Corridor	1,00
13	1,0	1,2	1,2	0,0	0,0	0,0	0,0	0,4	-0,4	0,4	-0,4	Junk room	0,04
14	2,0	4,5	9,0	0,0	0,0	0,0	0,0	3,2	-3,2	3,2	-3,2	Corridor	1,00
15			61,3	6,0	180,0	0,0	0,0	21,4	-21,4	399,4	-399,4	Dining room	0,33
16			17,0	0,0	0,0	0,0	0,0	5,9	-5,9	5,9	-5,9	Corridor	1,00
17	6,5	7,0	45,5	4,5	504,0	1728,0	480,0	15,9	464,1	71,9	408,1	Rest's kitchen	0,33
18	3,4	4,5	15,3	0,0	0,0	216,0	60,0	5,4	54,6	5,4	54,6	Rest's kitchen	0,33
19	2,5	2,0	5,0	0,0									
20	2,0	1,5	3,0	0,0	0,0	0,0	0,0	1,1	-1,1	1,1	-1,1	Rest's Freezer	1,00
21	3,5	3,0	10,5	0,0	0,0	75,6	21,0	3,7	17,3	3,7	17,3	Corridor	0,33
22	2,0	2,0	4,0	1,5	0,0	43,2	12,0	1,4	10,6	1,4	10,6	Junk room	0,04
23	2,0	1,5	3,0	0,0	0,0	0,0	0,0	1,1	-1,1	1,1	-1,1	Rest's Freezer	1,00
24	2,0	1,4	2,8	0,0	0,0	0,0	0,0	1,0	-1,0	1,0	-1,0	Rest's Freezer	1,00
25	1,8	2,8	5,0	1,0	0,0	0,0	0,0	1,8	-1,8	1,8	-1,8	Stairs	0,08
26	1,0	1,5	1,5	0,0	0,0	21,6	6,0	0,5	5,5	0,5	5,5	Junk room	0,04
27	1,2	2,5	3,0	1,0	0,0	0,0	0,0	1,1	-1,1	1,1	-1,1	Office	0,33
28	2,0	1,3	2,6	0,0	0,0	0,0	0,0	0,9	-0,9	0,9	-0,9	Rest's Freezer	1,00
29	2,1	3,5	7,4	1,0	0,0	18,0	5,0	2,6	2,4	2,6	2,4	Junk room	0,04
30	1,5	1,4	2,1	1,0									
31	15,0	1,0	15,0	0,0									
32	1,7	8,5	14,5	0,0									
33	17,6	17,5	293,0	0,0	2592,0	2592,0	720,0	102,6	617,5	2902,6	-2182,6	Theater	0,04
33a	5,0	3,0	15,0	0,0	0,0	0,0	0,0	5,3	-5,3	12,3	-12,3	Projection room	0,04
34	19,0	8,0	152,0	0,0	720,0	0,0	0,0	53,2	-53,2	88,2	-88,2	Stage	0,04
35	2,1	1,9	4,0	0,0									
36	2,0	2,0	4,0	0,0									
37			36,0	0,0	0,0	133,2	37,0	12,6	24,4	12,6	24,4	Corridor	1,00
38	6,8	3,7	25,2	3,0	360,0	0,0	0,0	8,8	-8,8	8,8	-8,8	Kitchen	0,08
39	3,8	1,5	5,7	0,0	360,0	0,0	0,0	2,0	-2,0	2,0	-2,0		0,08
40	6,0	10,0	60,0	1,0	360,0	0,0	0,0	21,0	-21,0	21,0	-21,0	Room	0,08
41	1,0	1,5	1,5	0,0									
42	3,5	2,0	7,0	0,0	0,0	0,0	0,0	2,5	-2,5	2,5	-2,5	Room	0,08
43	3,5	4,0	14,0	0,0	0,0	0,0	0,0	4,9	-4,9	4,9	-4,9	Room	0,08
44	2,2	1,2	2,6	0,0	0,0	0,0	0,0	0,9	-0,9	0,9	-0,9	Room	0,08
45	2,0	2,2	4,4	0,0	0,0	0,0	0,0	1,5	-1,5	1,5	-1,5	Room	0,08
46	1,5	2,0	3,0	0,0	0,0	0,0	0,0	1,1	-1,1	1,1	-1,1	Room	0,08
47	1,5	2,2	3,3	0,0									
48	8,0	3,1	24,8	0,0									
49	9,3	3,0	27,9	0,0	0,0	28,8	8,0	9,8	-1,8	9,8	-1,8	Stairs	0,08
50	2,5	18,0	45,0	0,0	0,0	0,0	0,0	15,8	-15,8	15,8	-15,8	Corridor	1,00
51	6,7	7,8	52,3	4,5	576,0	288,0	80,0	18,3	61,7	18,3	61,7	Meeting room	0,08
52	6,7	7,0	46,9	4,5	576,0	288,0	80,0	16,4	63,6	16,4	63,6	Meeting room	0,08
53	6,7	11,8	79,1	8,6	1080,0	756,0	210,0	27,7	182,3	391,7	-181,7	Meeting room	0,08
54	2,5	1,5	3,8	0,0	0,0	0,0	0,0	1,3	-1,3	1,3	-1,3	Junk room	0,04
55	2,6	1,8	4,7	0,0	0,0	0,0	0,0	1,6	-1,6	1,6	-1,6	Toilet	0,08
56	3,0	4,0	12,0	1,0	0,0	40,0	11,1	4,2	6,9	4,2	6,9	Toilet	0,08
57	1,2	1,4	1,7	0,0	0,0	0,0	0,0	0,6	-0,6	0,6	-0,6	Toilet	0,08
58	1,2	1,4	1,7	0,0	0,0	0,0	0,0	0,6	-0,6	0,6	-0,6	Toilet	0,08
59	1,5	1,2	1,8	0,0	0,0	0,0	0,0	0,6	-0,6	0,6	-0,6	Toilet	0,08
60	1,5	1,2	1,8	0,0	0,0	0,0	0,0	0,6	-0,6	0,6	-0,6	Toilet	0,08
61	2,0	3,0	6,0	0,0									

Number	Users	Incandescent	Fluorescent	Focus	Computer	Speakers	Fax	Photocopier	Plotter	Microwave	Refrigerator	Oven	TV	Projector	Cash register	Fan	Hi-fi eq.	Dishwasher	Coffee maker	Griddle
1		4																		
2		21																		
3	1	26	5		1										1					
4		1	2																	
5		2																		
6			1																	
7			1																	
8			1																	
9	8	25		5																8
9b	40	20		4																
10	1	5									3				1					
11																				
12		2																		
13		1																		
14		3																	2	
15	54	24											1							
16			2																	
17	8		12							2	4	2					1			3
18			2																	
19																				
20																				
21			2																	
22			1																	
23																				
24																				
25		1																		
26		1																		
27			1																	
28																				
29			1																	
30																				
31																				
32																				
33	400	67		30		16								2						
33a	1	2												1						
34	5		3																	
35																				
36																				
37		3																		
38		5								1		1								
39																				
40			6																	
41																				
42			2																	
43			2																	
44			1																	
45			1																	
46			1																	
47																				
48																				
49			1																	
50		3	8																	
51		1	12											1		2				
52			8											1		2				
53	52		12			2								1		3				
54		1																		
55		3	1																	
56		3	3																	
57			1																	
58			1																	
59			1																	
60			1																	
61																				

Number	Users	Griddle	Fryer	Dishwasher	Freezer	Audio mixer	DVD player
1							
2							
3	1						
4							
5							
6							
7							
8							
9	8	8					
9b	40						
10	1						
11							
12							
13							
14							
15	54						
16							
17	8	3	2				
18				2			
19							
20					1		
21							
22							
23					1		
24					1		
25							
26							
27							
28					1		
29							
30							
31							
32							
33	400						
33a	1					1	1
34	5						
35							
36							
37							
38							
39							
40							
41							
42							
43							
44							
45							
46							
47							
48							
49							
50							
51							
52							
53	52					1	
54							
55							
56							
57							
58							
59							
60							
61							

7.7.3 FIRST FLOOR

Number	Width (m)	Lenght (m)	Area (m2)	Windows	Supply air (m3/h)	Exhaust air (m3/h)	Outside air (l/s)	Min. outside air (l/s)	Difference (l/s)	SS oustside air (l/s)	Difference (l/s)	Activity	Fu
1	4,7	4,5	21,2	2		20	5,6	7,4	-1,8	14,4	-8,8	Office	0,33
2	2,3	4,5	10,4	0,5									
3	2,0	4,5	9,0	0,5		20	5,6	3,2	2,4	3,2	2,4	Stairs	0,08
4	4,3	4,5	19,4	2		20	5,6	6,8	-1,2	13,8	-8,2	Office	0,33
5	3,5	4,5	15,8	0,5		15	4,2	5,5	-1,3	5,5	-1,3	Kitchen	0,08
6	2,0	4,5	9,0	1									
7	9,0	6,5	58,5	22,5	90	540	150,0	20,5	129,5	300,5	-150,5	Dining room	0,33
8			49,7	0		0	0,0	17,4	-17,4	17,4	-17,4	Corridor	1
9	4,7	4,5	21,2	2		20	5,6	7,4	-1,8	14,4	-8,8	Office	0,33
10	1,2	1,5	1,8	0									
11	1,0	1,2	1,2	0									
12	2,5	1,5	3,8	0		0	0,0	1,3	-1,3	1,3	-1,3	Toilet	0,08
13	4,5	4,2	18,9	2		20	5,6	6,6	-1,1	13,6	-8,1	Office	0,33
14	2,2	1,1	2,4	0									
15	2,5	1,5	3,8	0									
16	2,5	4,5	11,3	0		0	0,0	3,9	-3,9	3,9	-3,9	Corridor	1
17	4,2	2,0	8,4	0									
18	4,2	2,2	9,2	0									
19	4,5	4,7	21,2	2		0	0,0	7,4	-7,4	7,4	-7,4	Stairs	0,08
ABF café			300,0	24	1600	2050	569,4	105,0	464,4	154,0	415,4	Office	0,33
Rest of rooms estimation			300,0	24		520	144,4	105,0	39,4	154,0	-9,6	Office	0,33

Number	Users	Incandescent	Fluorescent	Focus	Computer	Speakers	Fax	Photocopier	Plotter	Microwave	Refrigerator	Oven	TV	Projector	Cash register	Fan	Hi-fi eq.	Dishwasher	Coffee maker
1	1		3		1														
2																			
3		1	2																
4	1		2		2														
5			2		1						1	1							
6																			
7	40	34																	
8			7					1											
9	1		4		1														
10																			
11																			
12			0,5																
13	1		3		1														
14																			
15																			
16			2																
17																			
18																			
19			1																
ABF café	7																		
Rest of rooms estimation	7	5	72		33		2	7	2	1	1	1	1						

7.7.4 SECOND FLOOR

Number	Width (m)	Lenght (m)	Area (m2)	Windows	Supply air (m3/h)	Exhaust air (m3/h)	Oustide air (l/s)	Min. outside air (l/s)	Difference (l/s)	SS oustside air (l/s)	Difference (l/s)	Activity	Fu
1			45,8	6,0	210,0	300,0	83,3	16,0	67,3	16,0	67,3	Meeting room	0,08
2													
3	4,5	3,5	15,8	1,0	45,0	60,0	16,7	5,5	11,2	5,5	11,2	Kitchen	0,08
4													
5													
6	1,5	0,7	1,1	0,0									
7	3,0	1,8	5,4	0,0									
8	4,4	3,3	14,5	1,0									
9	4,4	5,5	24,2	2,0		50,0	13,9	8,5	5,4	36,5	-22,6	Office	0,33
10	4,4	3,1	13,6	1,0		25,0	6,9	4,8	2,2	11,8	-4,8	Office	0,33
11	4,4	4,4	19,4	2,0		90,0	25,0	6,8	18,2	20,8	4,2	Office	0,33
12	4,4	2,1	9,2	1,0		25,0	6,9	3,2	3,7	10,2	-3,3	Office	0,33
13	4,4	2,4	10,6	1,0		50,0	13,9	3,7	10,2	17,7	-3,8	Office	0,33
14	4,4	7,6	33,4	3,0		85,0	23,6	11,7	11,9	11,7	11,9	Meeting room	0,08
15	4,4	2,0	8,8	1,0		50,0	13,9	3,1	10,8	17,1	-3,2	Office	0,33
16	4,4	4,4	19,4	2,0		30,0	8,3	6,8	1,6	13,8	-5,4	Office	0,33
17	6,5	3,0	19,5	1,0		0,0	0,0	6,8	-6,8	6,8	-6,8	Stairs	0,08
18			133,4	1,0		0,0	0,0	46,7	-46,7	46,7	-46,7	Corridor	1,00
19	4,4	2,1	9,2	1,0		20,0	5,6	3,2	2,3	10,2	-4,7	Office	0,33
20	4,4	2,6	11,4	1,0		20,0	5,6	4,0	1,6	11,0	-5,4	Office	0,33
21	2,0	4,2	8,4	0,0		60,0	16,7	2,9	13,7	2,9	13,7	Toilet	0,08
22	4,0	4,8	19,2	3,0		25,0	6,9	6,7	0,2	20,7	-13,8	Office	0,33
23	2,5	4,3	10,8	1,0		20,0	5,6	3,8	1,8	10,8	-5,2	Office	0,33
24	2,2	4,3	9,5	1,0		25,0	6,9	3,3	3,6	10,3	-3,4	Office	0,33
25	2,2	4,3	9,5	1,0		20,0	5,6	3,3	2,2	17,3	-11,8	Office	0,33
26	4,3	4,3	18,5	1,0		25,0	6,9	6,5	0,5	6,5	0,5	Kitchen	0,08
27	4,2	4,3	18,1	2,0		55,0	15,3	6,3	9,0	13,3	2,0	Office	0,33
28			54,4	5,0		145,0	40,3	19,0	21,3	19,0	21,3	Meeting room	0,08
29	9,0	4,3	38,7	4,0		50,0	13,9	13,5	0,3	27,5	-13,7	Office	0,33
30												Included in 28	
31	2,1	4,3	9,0										
32	4,5	8,7	39,2	6,0		60,0	16,7	13,7	3,0	13,7	3,0	Meeting room	0,08
33													
34	2,4	4,3	10,3	0,0		65,0	18,1	3,6	14,4	3,6	14,4	Toilet	0,08
35	3,8	1,2	4,6										
36	3,7	2,1	7,8										
37			16,1	2,0		0,0	0,0	5,6	-5,6	5,6	-5,6	Stairs	0,08
38	3,8	2,2	8,4	1,0		25,0	6,9	2,9	4,0	10,4	-3,5	Office	0,33
39	4,5	4,0	18,0	2,0		20,0	5,6	6,3	-0,7	13,8	-8,2	Office	0,33
40	4,5	4,3	19,4	2,0		30,0	8,3	6,8	1,6	36,8	-28,4	Meeting room	0,08
41	4,5	4,5	20,3	2,0		65,0	18,1	7,1	11,0	14,6	3,5	Office	0,33
42	4,5	4,1	18,5	2,0		35,0	9,7	6,5	3,3	14,0	-4,2	Office	0,33
43	4,5	2,2	9,9	1,0		35,0	9,7	3,5	6,3	11,0	-1,2	Office	0,33
44			112,9	8,0		165,0	45,8	39,5	6,3	69,5	-23,7	Office	0,33
45	4,5	4,5	20,3	2,0		75,0	20,8	7,1	13,7	7,1	13,7	Kitchen	0,08
46	2,7	2,4	6,5	0,0		20,0	5,6	2,3	3,3	2,3	3,3	Toilet	0,08
47	2,0	3,7	7,4	1,0		0,0	0,0	2,6	-2,6	2,6	-2,6	Stairs	0,08

Number	Users	Incandescent	Fluorescent	Focus	Computer	Speakers	Fax	Photocopier	Plotter	Microwave	Refrigerator	Oven	TV	Projector	Cash register	Fan	Hi-fi eq.	Dishwasher	Coffee maker
1			5																
2																			
3																			
4			2							1	1		1						
5																			
6																			
7																			
8																			
9	4		8		7		1												
10	1	1	1		1														
11	2	1	2		2														
12	1		2		2														
13	2		4		2			1											
14			8																
15	2	1	2		2														
16	1		1		1		1	1		1									
17			2																
18			15																
19	1		1		2														
20	1		2		1		1	1											
21		3																	
22	2	1	4		2														
23	1		2		1														
24	1		1		1			1											
25	2		2		2														
26										1	1	1							
27	1		2		1														
28			11		12									1					
29	2		6		2			1		1									
30																			
31																			
32			6		1														
33																			
34			5																
35																			
36																			
37																			
38	1		1		1														
39	1		4		1		2	2	2										
40	4		4		2			2											
41	1		4		1			1											
42	1		4		1														
43	1		2		1														
44	4		12		4														
45			2							1	1	1	1						
46		1																	
47																			

7.7.5 THIRD FLOOR

Number	Width (m)	Lenght (m)	Area (m2)	Windows	Supply air (m3/h)	Exhaust air (m3/h)	Oustide air (l/s)	Min. outside air (l/s)	Difference (l/s)	SS oustside air (l/s)	Difference (l/s)	Activity	Fu
1	4,4	4,5	19,8	4,0		50,0	13,9	6,9	7,0	6,9	7,0	Room	0,08
2	4,5	4,5	20,3	2,0		30,0	8,3	7,1	1,2	7,1	1,2	Meeting room	0,08
3	2,0	3,0	6,0	1,0		20,0	5,6	2,1	3,5	2,1	3,5	Room	0,08
4	4,5	2,4	10,8	0,0		0,0	0,0	3,8	-3,8	3,8	-3,8	Junk room	0,04
5	4,4	1,8	7,9	1,0		25,0	6,9	2,8	4,2	2,8	4,2	Room	0,08
6	4,4	3,4	15,0	1,0		35,0	9,7	5,2	4,5	5,2	4,5	Kitchen	0,08
7	4,5	3,0	13,5	1,0		20,0	5,6	4,7	0,8	11,7	-6,2	Office	0,33
8	2,0	6,8	13,6	0,0		0,0	0,0	4,8	-4,8	4,8	-4,8	Corridor	1,00
9	6,5	3,0	19,5	1,0		0,0	0,0	6,8	-6,8	6,8	-6,8	Stairs	0,08
10	4,5	2,0	9,0	1,0		20,0	5,6	3,2	2,4	3,2	2,4	Junk room	0,04
11	4,5	2,3	10,4	1,0		25,0	6,9	3,6	3,3	3,6	3,3	Photocopier room	0,33
12												Included in 9	
13	4,4	5,7	25,1	2,0		40,0	11,1	8,8	2,3	22,8	-11,7	Office	0,33
14	4,5	4,5	20,3	2,0		45,0	12,5	7,1	5,4	7,1	5,4	Meeting room	0,08
15	4,5	2,1	9,5	1,0		20,0	5,6	3,3	2,2	10,3	-4,8	Office	0,33
16	4,4	2,1	9,2	1,0		20,0	5,6	3,2	2,3	10,2	-4,7	Office	0,33
17	2,0	19,3	38,6	1,0		90,0	25,0	13,5	11,5	13,5	11,5	Corridor	1,00
18	4,4	2,1	9,2	1,0		30,0	8,3	3,2	5,1	10,2	-1,9	Office	0,33
19	4,5	2,1	9,5	0,0		15,0	4,2	3,3	0,9	10,3	-6,1	Office	0,33
20	4,5	2,3	10,4	1,0		25,0	6,9	3,6	3,3	10,6	-3,7	Office	0,33
21	4,4	4,5	19,8	1,0									
22	4,5	2,4	10,8	1,0		20,0	5,6	3,8	1,8	3,8	1,8	Kitchen	0,08
23	4,4	2,2	9,7	1,0		20,0	5,6	3,4	2,2	10,4	-4,8	Office	0,33
24	3,1	1,0	3,1	1,0									
25	4,5	2,5	11,3	0,0		60,0	16,7	3,9	12,7	3,9	12,7	Toilet	0,08
26	8,7	4,5	39,2	6,0		65,0	18,1	13,7	4,4	27,7	-9,6	Office	0,33
27	2,8	4,5	12,6	1,0		25,0	6,9	4,4	2,5	4,4	2,5	Photocopier room	0,33
28	3,8	4,5	17,1	2,0		35,0	9,7	6,0	3,7	13,0	-3,3	Office	0,33
29	2,8	4,5	12,6	1,0		20,0	5,6	4,4	1,1	11,4	-5,9	Office	0,33
30			20,2	0,0		0,0	0,0	7,1	-7,1	7,1	-7,1	Corridor	1,00
31	6,8	1,6	10,9	3,0		35,0	9,7	3,8	5,9	10,8	-1,1	Office	0,33
32	3,8	4,5	17,1	2,0		40,0	11,1	6,0	5,1	13,0	-1,9	Office	0,33
33	8,8	2,3	20,2	3,0		55,0	15,3	7,1	8,2	7,1	8,2	Kitchen	0,08
34	3,1	1,0	3,1	0,0									
35	2,8	4,5	12,6	1,0		20,0	5,6	4,4	1,1	11,4	-5,9	Office	0,33
36	3,7	4,5	16,7	2,0		30,0	8,3	5,8	2,5	12,8	-4,5	Office	0,33
37			6,4	0,0									
38	2,2	3,0	6,6	1,0									
39 40			24,3	5,0		80,0	22,2	8,5	13,7	15,5	6,7	Office	0,33
41	2,8	3,2	9,0	0,0									
42	4,5	2,3	10,4	1,0		20,0	5,6	3,6	1,9	10,6	-5,1	Office	0,33
43	4,3	2,2	9,5	0,0		0,0	0,0	3,3	-3,3	3,3	-3,3	Corridor	1,00
44	2,0	2,8	5,6	0,0									
45	1,7	2,5	4,3	1,0		25,0	6,9	1,5	5,5	1,5	5,5	Meeting room	0,08
46	3,9	2,5	9,8	1,0									
47	7,0	4,7	32,9	2,0		25,0	6,9	11,5	-4,6	11,5	-4,6	Stairs/corridor	1,00
48	4,0	4,0	16,0	1,0									
49	2,0	18,3	36,6	0,0		60,0	16,7	12,8	3,9	12,8	3,9	Corridor/Kitchen	0,08
50	4,1	2,5	10,3	0,0		20,0	5,6	3,6	2,0	3,6	2,0	Shower	0,08
51	4,7	13,7	64,4	5,0		120,0	33,3	22,5	10,8	43,5	-10,2	Office	0,33
52	4,1	2,3	9,4	1,0		20,0	5,6	3,3	2,3	17,3	-11,7	Acupunture room	0,08
53	4,1	4,3	17,6	2,0		40,0	11,1	6,2	4,9	20,2	-9,1	Acupunture room	0,08
54												Included in 51	
55												Included in 51	
56	4,1	2,2	9,0	1,0									
57												Included in 51	
58	4,1	2,1	8,6	1,0		20,0	5,6	3,0	2,5	17,0	-11,5	Acupunture room	0,08
59												Included in 51	
60	4,1	2,5	10,3	1,0		25,0	6,9	3,6	3,4	17,6	-10,6	Acupunture room	0,08
61	6,3	4,9	30,9	3,0		60,0	16,7	10,8	5,9	24,8	-8,1	Acupunture room	0,08
62	4,6	4,5	20,7	4,0		80,0	22,2	7,2	15,0	7,2	15,0	Room	0,08
63	4,6	1,6	7,4	1,0									

Number	Users	Incandescent	Fluorescent	Focus	Computer	Speakers	Fax	Photocopier	Plotter	Microwave	Refrigerator	Oven	TV	Projector	Cash register	Fan	Hi-fi eq.	Dishwasher	Coffee maker
1			4																
2			4																
3			1																
4			1																
5			2																
6			1							2	2	1						1	1
7	1		3		1														
8			2																
9		1	2																
10			2																
11			2				1	1											
12																			
13	2		5		2														
14			4					1					1						
15	1		2																
16	1		2		1														
17			6																
18	1		2		1														
19	1		2		1														
20	1		2		1														
21																			
22			1																
23	1		4		1														
24																			
25		2																	
26	2		8		2														
27			2				1	1											
28	1		3		1														
29	1		2		1														
30			3																
31	1				1														
32	1	1	3		1														
33		2	5							2	1	1						1	1
34																			
35	1		2		1														
36	1		1		1														
37																			
38																			
39	1		3		1														
40																			
41																			
42	1		3		1														
43			2					1											
44																			
45			4										1						
46																			
47			4																
48																			
49			8							1	1	1							
50		2																	
51	3	5	4		3														
52	2	6																	
53	2	6																	
54																			
55																			
56																			
57																			
58	2	6																	
59																			
60	2	3																	
61	2		5		1					1									
62			5		1								1						
63																			