UNIVERSITY OF GÄVLE

FACULTY OF ENGINEERING AND SUSTAINABLE DEVELOPMENT

Energy Audit of HiG Examination Building

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Preface

Here we chose to study the energy audit of examination building in University of Gävle. When carrying out our thesis, there are many people we must say thanks to.

At first, we would like to thank our supervisor Mr. Roland Forsberg. He guided us in our thesis and gave us many advices when we got in trouble with our thesis. He is also very patient with us and taught us when we met some problems in the calculation part.

We also would like to thank Mr.Maguns and Mr.Taghi. They gave all information about the examination building to us and explained to us the every aspect of this building.

At last, we could not forget to thank our friends and classmates. They taught us how to make a good team work.

Through the one year's studying, we not only learned the best knowledge of energy systems in Sweden, but also the responsible attitude to science.

Abstract

Nowadays, energy is becoming more and more important. With the development of society, the demand of energy is also increasing correspondingly. There is 22% of the total energy which is used in building part. A more effective and sustainable energy system becomes necessary due to increasing energy prices and demand. The aim of this thesis is to make an energy survey of this building, evaluating different sources of energy supply and losses in this building. By evaluating, a better thermal comfort is expectedly achieved when having examinations, and a possible saving method is also expected in order to reduce the cost of this system.

In this project, the building is located in University of Gävle which is surveyed. It has 2 floors. The first floor is underground as a basement. An examination room is included in the second floor. There are a space heating system and heating recovery system ventilation in this examination building.

At first step of analysis, the data of construction, ventilation, district heating and hot tap water were arranged by Mr. Magnus. Secondly, an energy balance had been done, and it helped to make energy input and output more clearly. In energy supply part, the solar radiation is 22.4MWh, the internal heat from people is 1.95MWh, the internal heat from equipment is 5.63MWh and district heating is 184MWh. In energy losses part, the transmission loss is 165MWh, the mechanical ventilation loss is 38.3MWh, the infiltration loss is 8.38MWh and the hot tap water is 2.09MWh. Thirdly, results of calculations were analyzed. At last, the optimization methods were given to save energy. The optimization methods were changing type of windows and

improving indoor temperature which influenced the transmission loss part. Another method was reducing operating time of the ventilation system.

Through these optimizing methods, the total energy use is reduced from 214MWh to 179MWh, and district heating is reduced from 184MWh to 149MWh. District heating of this building is supplied by Gävle Energi company, which is able to save 20% cost by these optimizing methods. According to the investment analysis, 19thousand SEK energy is saved per annum.

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1. Introduction

1.1 The Problem of Energy

With the development of society, energy is becoming more and more important to humans and the use of energy is increasing. Therefore, people cannot live without energy. But the overused of energy has exhausted traditional resources, with renewable energy becoming important in people's daily life.

Because of population increase and economic development, the use of primary energy of world has been increasing. In 1990, the used of primary energy of the world was just 102569TWh. However in 2008, the energy use had already increased to 143851TWh. The usage increased by 40%, and the growth rate of per annual was 2%. Nowadays, fossil fuel is still the primary energy source of the world, which includes coal, oil and natural gas, with coal obtaining 27%, oil 34% and natural gas 21%, which amounts to 81%. Other sources of energy are non-fossil energy and renewable energy. Although the demand of non-fossil energy and renewable energy is growing rapidly, it is still at a low percentage. Among all kinds of energy, only 19% is renewable energy and non-fossil energy[2]. Although fossil fuel is the main energy in the world, it is still facing energy exhaustion while at the same time destroying the environment. Therefore, developing new energy and saving energy is the currently problem to people.

1.2 Building Energy Use

According to University Administration, it can be known that the use of energy in buildings is 23% [1]. The main figures are shown in the following pie chart.

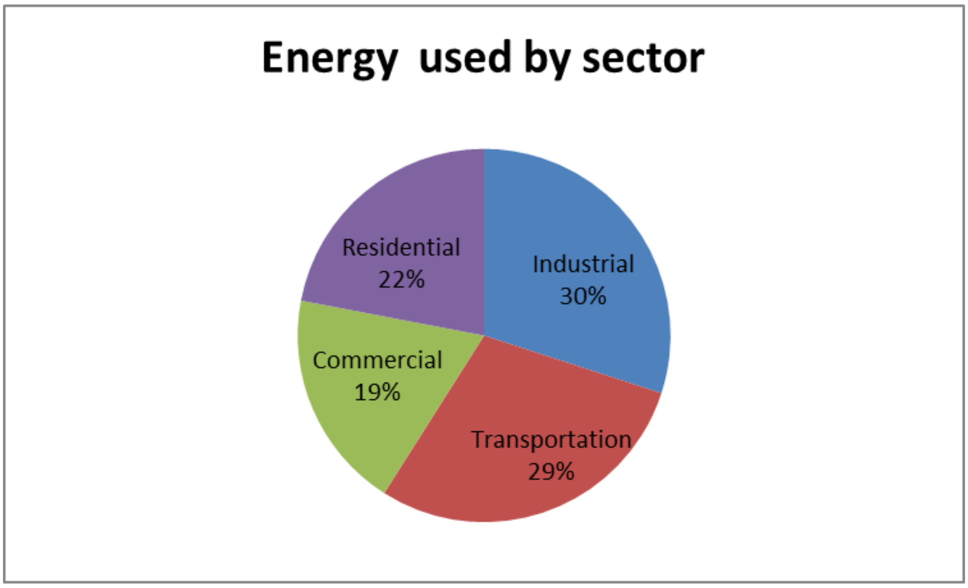


Figure 1.1 Energy used by sector [1]

From the pie chart, we can see that the energy use of buildings in Europe is almost from fossil fuels and electricity. The combustion of fossil fuels could lead to increase in CO_2 emission, thus worsening the global warming. As a result, the use of electricity is increasing. Under such circumstances, thinking of a way to improve energy efficiency in building becomes necessary. There are various measures to improve the energy efficiency. Among these measures, the best of which is to use less energy inside of a building while at the same time solving the environmental problems.

1.3 Literature Review

Before writing this thesis, some books are reviewed. The energy background and theory of energy can be provided by these books. The book Building and Energy-a systematic approach[29] helps us a lot. It includes introductions of basic theories of energy audit, the equations of energy audit, the knowledge of indoor climate. The energy balance of buildings is also introduced in this book. And in the book Energy: Management, Supply and Conservation[3], the effect of energy audit is introduced. It helps us to make a good analysis of the energy use, and let us understand energy balance more clearly.

R. Saidur analyzed the energy use, and possible savings of office buildings in tropical countries. In this paper, the energy use in office buildings and energy use of major equipment are estimated, and these results are compared with a number of selected countries[14]. Érika Mata made a survey of energy use in the Swedish residential build and analyzed CO_2 emissions of the Swedish residential building. Application of the energy saving measures(such as: using heat recovery in ventilation systems, reducing the indoor temperature, etc.) studied gives a maximum technical reduction potential in energy demand of 53%, corresponding to a 63% reduction in CO_2 emissions[15].

1.4 Aim of this Research

With a growing increasing of energy use, improving the energy efficiency becomes more and more important. The aim of this thesis is to make an energy survey of this building, evaluating different sources of energy supply and losses in this building. By evaluating, a better thermal comfort is expectedly achieved when having examinations, and a possible saving method is also expected in order to reduce the cost of this system. The content of this thesis is only suitable for the climate in North Europe. All the data in this thesis is from the year 2013.

1.5 General Information of HiG Examination Building

This building is used for the students' examination. There are two stories in this examination building. The first story is covered underground. It is a basement with an area of 1018m^2. There are four activity rooms, one sleeping room and seven storage rooms. On second floor, there are one examination room, six working rooms and several storage rooms. The two floors have the same structure. Three big toilets are also included in this building. This examination building is shown as follows.

Figure 1.2 HIG examination building

1.6 The Location of Gävle

Gävle is located 161 kilometers northwest of Stockholm, which is the capital of Sweden (with details shown in Figure 1.3). Gävle is the capital of Gävleborg and it is a seaside city lying in the east of Sweden, with the Baltic Sea on the east side of Gävle. Gävle is one of the oldest cities in Sweden. The average outdoor temperature in Gävle is 5℃ and the average indoor temperature of is 21℃.

Figure 1.3 The location of Gävle[25]

2. Theory

2.1 The Audit of Energy

The audit of energy is a survey of the total energy which is using in a building after a period of time[11]. From the energy audit, we can easy find the type of energy and how much to be used[3]. Through energy audit, auditors can find the existing problems of the building. After that, auditors can give advices to make energy distribution more reasonable. A large amount of money can be saved by energy auditing.

For normal buildings, the audit of energy includes the supply of energy, use of energy and energy losses.

For supply of energy, it includes district heating, solar radiation and internal heat from people and equipment.

For energy use, it includes demand of heat for hot tap water, lighting, etc.

For energy losses, it includes transmission through the building envelope, heat losses of air infiltration and heat losses of mechanical ventilation.

2.2 The Envelope of Building

The envelope of building is the external surface of building; it includes doors, walls, windows, roof and floors. We can divide the envelope of building into two parts: the first part is hyaline, such as windows, balconies, etc. The second part is non-transparent, such as walls, doors, roofs, etc. The most important function of envelope is making the climate different between indoor and outdoor. Through building envelope, the indoor environment can be protected and noise, pollution and other bad effects can be resisted from the outdoor environment. So a better envelope is very important to a building. And the airtight and thermal insulation of a building is also very important to improve energy efficiency. A good airtight building can make the air leakage less, and less heat to provide the indoor environment. The envelope of building cannot only provide a safe structure for human, but also control humidity, temperature and air pressure of indoor environment[5].

2.3 Indoor Climate of Building

Indoor climate is a very important part for human. A better indoor climate can make people feel comfortable[4]. It can improve the efficiency of working, and also health to people.

There are several factors could influence indoor climate[11]:

The building's ventilation

The building's envelope

People's activities

Outdoor climate

Heating systems

2.4 The Ventilation of Building

In building, the Heating Ventilation and Air Conditioning system is a better ventilation system. HAVC system is very important for controlling the indoor temperature and indoor humidity. It can improve indoor comfort level effectively[6]. Because Sweden is in high latitude,with low annual temperature, so the buildings in Sweden do not often use HAVC system to decrease indoor temperature.

2.5 The Energy Balance of Building

The energy balance of building means the amount of energy supply into the building equals to the amount of energy consumption. From the first law of thermodynamics, it could be known that energy cannot be generated or disappeared[11]. The main factors that influence energy balance include indoor and outdoor temperatures, human activities inside of rooms, heating that is produces by indoor facilities, indoor ventilations systems, and indoor materials, e.g., walls, floors as well as ceilings[11].

The energy balance is showing in the following picture.

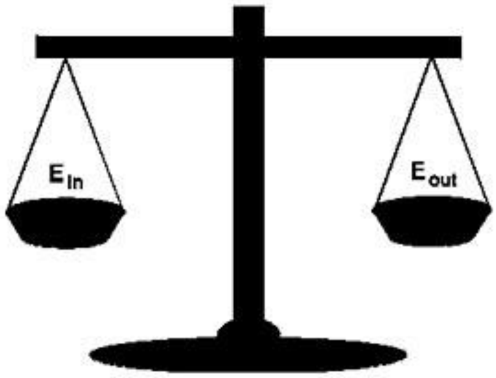


Figure 2.1 Energy Balance[19]

The first step of building energy balance is to figure out the volume of the whole system, i.e. building envelope. The second step is to determine all the parts of energy inputs and energy outputs. The third step is to write out energy balance equation according to the equal relationship between energy in and energy out.

The energy balance can be measured by following equation[11]:

$Energy_{in} = Energy_{out}$ (Eq.1)

$Energy_{in}$ is supply energy

$Energy_{out}$ is energy losses

The details of energy balance are shown in following equation[11]:

$Q_{transmission} + Q_{ventilation} + Q_{infiltration} + Q_{hot\ tap\ water} = Q_{internal\ heat} + Q_{solar\ radiation} + Q_{supply\ heat}$ (Eq.2)

Where,

$Q_{transmission}$: Transmission of heat losses through the building envelope [W]

$Q_{ventilation}$: Losses of mechanical ventilation [W]

$Q_{infiltration}$: Infiltration losses through air leakage [W]

$Q_{hot\ tap\ water}$: The demand of heating for hot tap water [W]

$Q_{internal\ heat}$: Internal heat from people's daily activities and equipment [W]

$Q_{solar\ radiation}$: Getting heat from solar radiation through windows [W]

$Q_{supply\ heat}$: Heat from district heating [W]

The details of building energy balance are shown in figure below

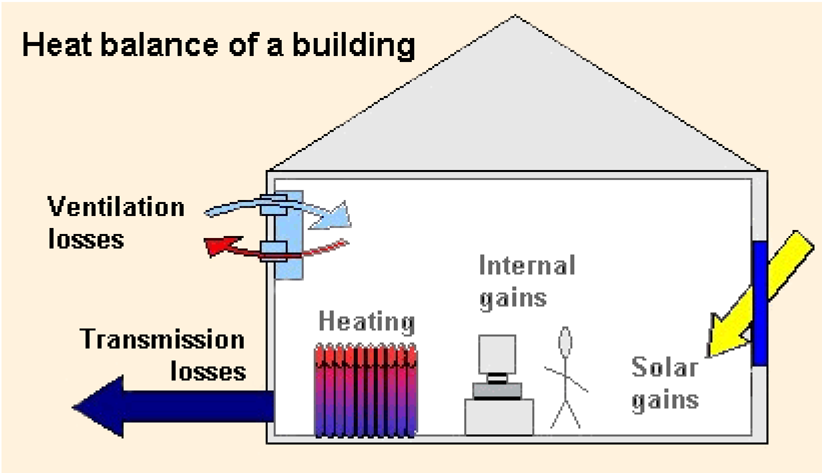


Figure 2.2 The Energy Balance of Building[20]

2.6 Heat Losses of Building

The heat losses of building include heat losses of mechanical ventilation, transmission through building, infiltration losses through air leakage and hot tap water. Every part of the heat losses would be introduced in following paragraphs.

2.6.1 Mechanical Ventilation Losses

Ventilation is a very important part of building. It can improve indoor environment. Ventilation system can provide the clean air to building, and remove the pollution. Moreover, it can control the indoor temperature to make human feel comfortable, and maintain the better air quality of the indoor environment. Although ventilation system is effective to improve indoor environment, it has the expensive cost of installation and running.

Using a heat recovery system in mechanical ventilation is effective to reduce energy loss. The heat exchanger uses waste exhaust heat to heat up incoming fresh air. The working principle of heat exchanger is shown in the following figure.

Figure 2.3. Heat exchanger[22]

The recovery efficiency is determined by the type of the heat exchanger, the size of the heat exchanging surfaces and the heat transferring properties of the surfaces. The counter flow exchanger is the most efficient in heat exchangers. The following figure shows a schema of a counter flow exchanger along with the temperature distribution of the hot and cold fluids. Once again, heat exchanger is treated as insulated around the outside so that the only heat transfer is between the two fluids. The cold fluid heats up and the hot fluid cools down[23].

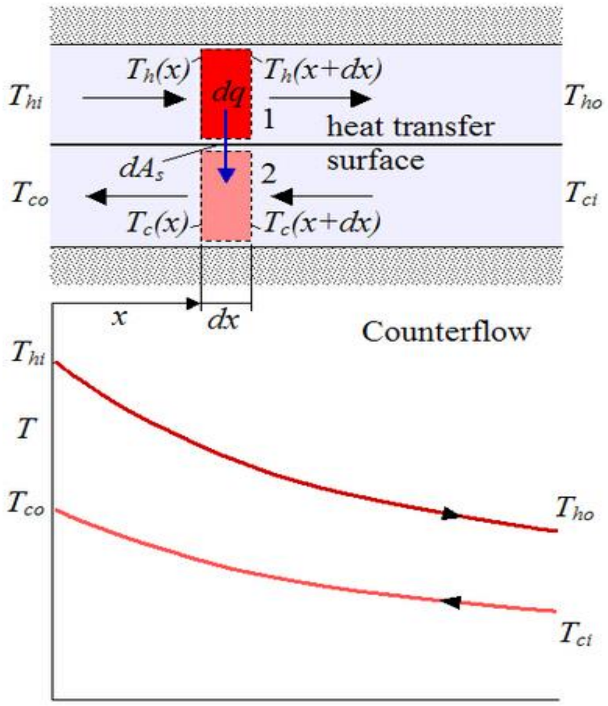


Figure 2.4. A schema of a counter flow exchanger[23]

The efficiency of exchanger can be calculated by following equation[11]:

$\eta=(T_{ho}-T_{hi})/(T_{ci}-T_{hi})$ (Eq.3)

Where,

T_{ho} : The temperature of supply air before the heat exchanger[℃]

T_{hi} : The temperature of supply air after the heat exchanger[℃]

T_{ci} : The temperature of exhaust air before the heat exchanger[℃]

T_{co} : The temperature of exhaust air after the heat exchanger[℃]

The mechanical ventilation losses can be calculated by following equation[11]:

$Q_{mechanical\ ventilation}=(1-\eta)*V*\rho*C_p*q_{degree}*(h/8760)$ (Eq.4)

Where,

V : Air flow [m^3/s]

ρ : The density of the air [kg/m^3]

C_p : The specific heat capacity of the air [J/kg°C]

q_{degree} : The degree-hours of one year [°Ch/year]

h : The operating hours of ventilation

η : The efficiency of the heat exchanger

2.6.2 The Heat Losses of Transmission

Because of the temperature difference and pressure difference between indoor environment and outdoor environment, there will be heat transmitting through walls, doors and windows from indoor to outdoor. When the gap of temperature and pressure is increasing, the transmission loss will increase. Meanwhile, transmission loss is also determined by the material and area of the walls, doors and windows.

The transmission losses can be calculated by following equation[11]:

$P_{transmission} = \sum U_i * A_i (T_{in} - T_{out}) = K_{tr} (T_{in} - T_{out})$ (Eq.5)

Where,

U_i : It means U value which means the transmission coefficient for different type of building materials [$W/m^{2}°C$]

A_i : the area of the building envelope [m^2]

T_{in} : the indoor temperature [°C]

T_{out} : the outdoor temperature [°C]

Transmission losses are through walls, doors, floors, windows and roof, among which the transmission losses through floors can be divided into two parts. The first part is the partial heating losses located at the one meter point adjacent to outside. The rest of the heat is lost under the ground. As is shown in the following:

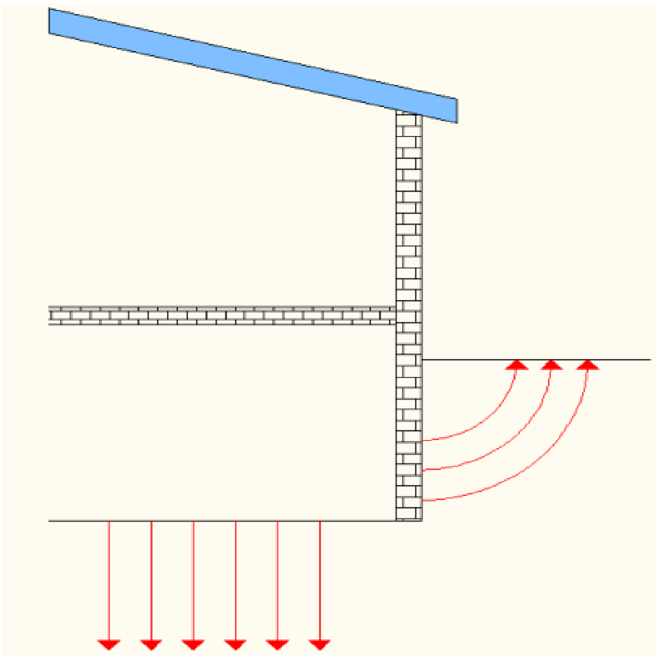


Figure 2.5 Different way of transmission through floor and wall[11]

The annual energy losses can be calculated by following equation[11]:

$Q_{transmission}=(U_i*A_i)(T_{in}-T_{out})*dt$ (Eq.6)

$Q_{transmission}=(\sum U_i*A_i)*q_{degree}$

Where,

U_i : It means U value which means the transmission coefficient for different type of building materials [W/m^2°C]

A_i : the area of the building envelope [m^2]

q_{degree} : the degree-hours [°Ch/year], it can be found in degree-hours table.

2.6.3 Infiltration Heat Losses

Infiltration heat losses are the air leakage through the windows, doors and cracks of envelope. They are also called natural ventilation heat losses. And these heat losses are caused by pressure gap between indoor and outdoor environment, and also the gap between supply air flow rate and exhaust air flow rate. Hence, the amount of the infiltration heat losses are determined by the airtight of the building envelope and the properties of the insulation[9]. As some parameters are unknown, it is impossible to figure out the accurate value. The only way to quantize these parameters is through long-term and complicated experimental measurement[11].

2.6.4 Hot Tap Water

The hot tap water is used in office and toilet within the examination building. It is supplied by the district heating system. The heat will be consumed when the hot water is used. So, we can say the hot tap water is the heat loss. The hot tap water is used for showers and kitchen duty.

The amount of hot tap water can be calculated by following equation[11]:

$$Q_{hot\ tap\ water} = m * Cp_{water} * (T_s - T_g) * (1/3600) \qquad (Eq.7)$$

Where,

m : The mass flow of hot water [kg/year]

Cp : The specific heat of the hot water [J/kg°C]

T_s : The temperature of supply water [°C]

T_g : The temperature of ground water [°C]

2.7 Heat supply of building

According to the energy balance, heat supply equals to heat losses. For human activities, it can be known that heat supply includes district heating, solar radiation and internal heat.

2.7.1 District Heating

District heating is the most significant part in energy supply. It is supplied by local district heating grid. The district heating system consists of thermal power plants, heat exchanger installation and pipe network and it distributes heat to residential buildings. The simple district heating grid is shown in the figure2.6. The heat is generated by a cogeneration plant burning fossil fuels with biomass is also used[24]. Because of greenhouse gas generation, the use of fossil fuels is reduced. Instead of fossil fuels, the biofuels are used more and more in thermal power plants.

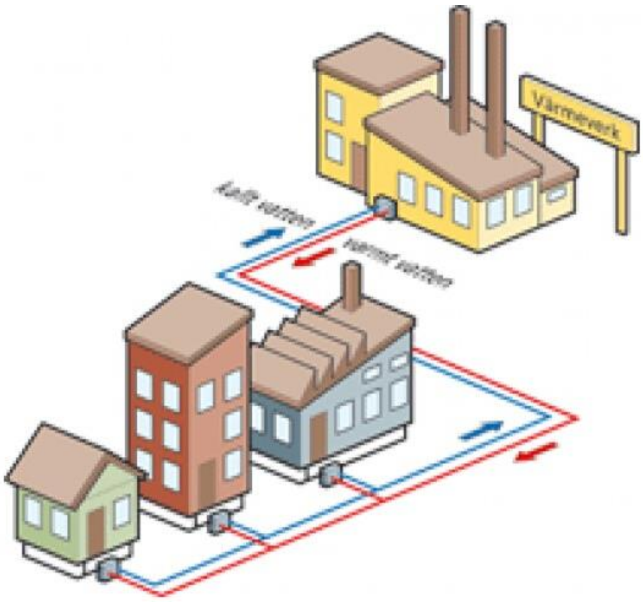


Figure 2.6 The district heating grid[24]

In figure2.7, the combined heat and power system is shown, which is also called CHP system. The CHP system is very popular in northern Europe. The district heating system with combined heat and power is the most economical way to reduce CO_2 emission.

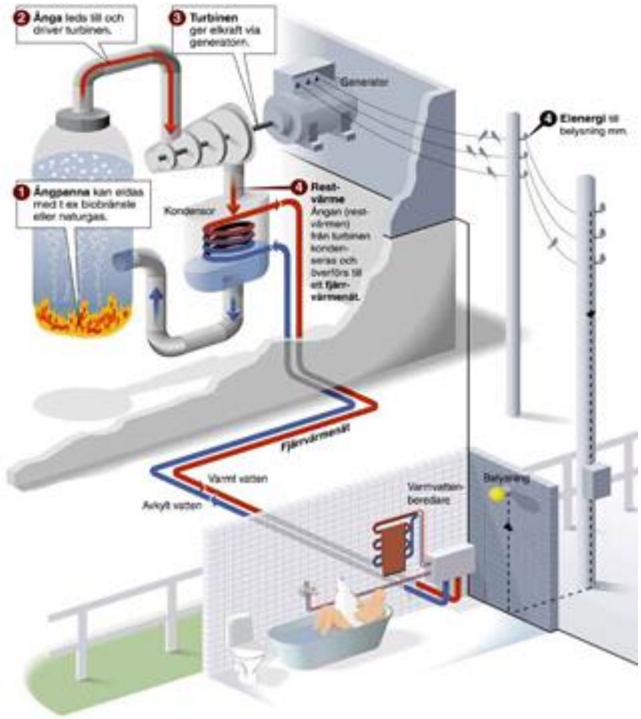


Figure 2.7. The CHP and district heating system[26]

For district heating is frequently used in residential building for radiators and hot tap water. District heating is way to improve the efficiency of energy and save fund.

2.7.2 Solar Radiation

Solar radiation is one of the main energy input, and it is coming from sun, and passing through windows. The first part of solar radiation is directly transmitted to inside of the rooms with the remaining part absorbed by the glass or reflected back[21]. The schema of solar radiation passing through windows is shown in figure2.8. Solar radiation also becomes heat when it falls on the solid surface of the building. This heat can increase the temperature of envelope surface, and then the surface releases the heat to increase the room’s temperature.

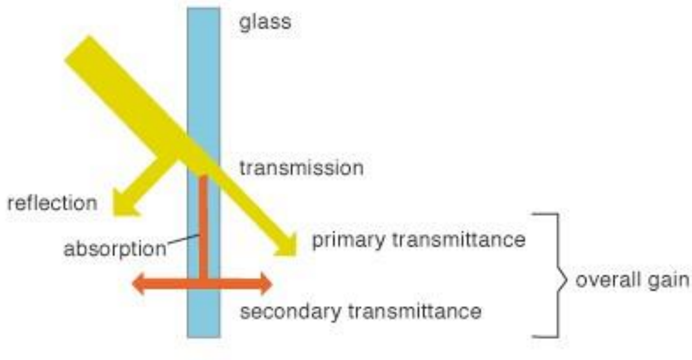


Figure 2.8 Solar radiation through the window[21]

In summer, there is increasing solar radiation entering the build to make large heat surplus. Solar radiation can influence energy balance effectively. So making a good use of solar radiation can improve the efficiency of energy. But for south-orienting windows, shadow is used to keep out the surplus radiation into the building. Hence, location of the building and weather factor could determine the energy of solar radiation into the building, due to the shading factor.

Solar radiation can be calculated by the following equation[11]:

$Q_{solar\ radiation}= Area_{window}* Calculation\ factor_{window\ type}* cloudy\ factor* orientation\ factor$ (Eq.8)

The orientation factor can be shown in following figure.

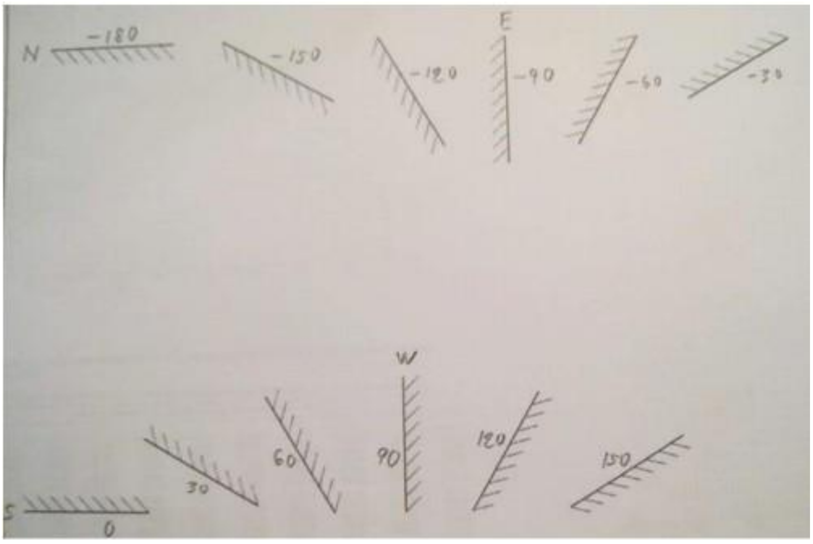


Figure 2.9 The orientation factor[7]

And the factor of different windows can be shown in following figure.

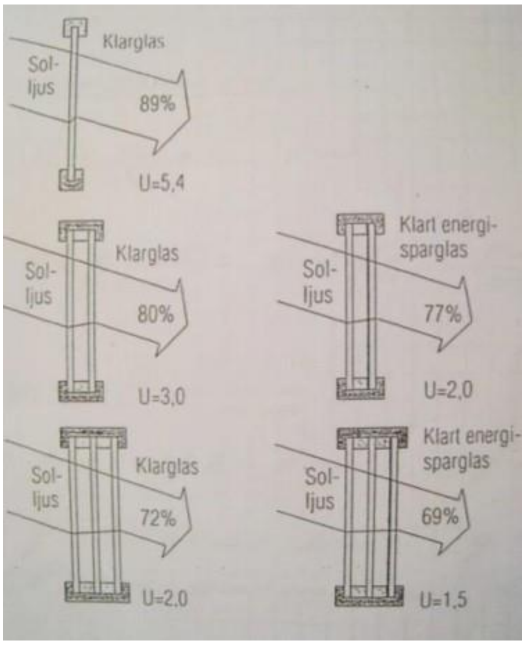


Figure 2.10 The U-value and factor of different windows[7]

2.7.3. Internal Heat

The internal heat of building includes internal heat from human activities and internal heat from equipment.

Internal Heat from Human Activities

To common people, his temperature is about 37 ℃, and the indoor temperature is about 21°C, so people emit heat through the skin, because of temperature gap. Human activity can also generate enormous amount of heat. The more people in the room, the more internal heat can be generated. Meanwhile, the time of people stay in the room also will influence internal heat.

The following equation can be calculated the internal heat from human[11]:

$Q_{human} = N_{human} * H_{working\ hours} * W_{activies}$ (Eq.9)

Where,

N_{human} : The number of people in room

$W_{activies}$: The power of huaman activies is about 100W/person

Internal Heat from Equipment

Within building, there are many electrical equipments. When they are working, the heat is produced, such as televisions, lamps, computers and printers. The more time they operate, the more heat they transfer to the room. Cooking can also generate large heat and transfer to the room.

The internal heat from equipment can be calculated by following equation[11]:

$Q_{equipment} = (\sum numbers * power * hours)$ (Eq.10)

2.8 Annuity investments

Before the implementation of an energy efficiency measure, the cost and expected return are the first things that need to be considered. When the annuity of this measure is lower than the expected annual savings, this measure is profitable. The following formula is needed when calculating annuity[7].

$$a = i/2 + 1/n \qquad \text{(Eq.11)}$$

Where, a : Annuity rate

i : interest rate

n : number of bank loan years

$$A = a*I \qquad \text{(Eq.12)}$$

Where, A : Annuity (SEK/year)

I : total investment (SEK)

3.Method

At first, all informations and data are provided by Mr. Magnus. Secondly, there are different specific methodologies used for calculating every parameter of the energy balance. Each part has its own calculation methods, which will later be presented in this chapter.

3.1 Solar radiation

From theory, the equation of solar radiation is shown in following formula:

$Q_{solar\ radiation}$= $Area_{window}$* Calculation $factor_{window\ type}$* cloudy factor* orientation factor

The direction of building is needed to be confirmed at first.

Figure 3.1 Orientation of the building

According to the figure3.1, the directions of windows in this building are N-120, W150, E-30 and S60 separately.

The window’s position of this examination building is “0” type and the value of solar radiation can be influenced by different window’s position. There are two different types of the window’s position shown in the following figure.

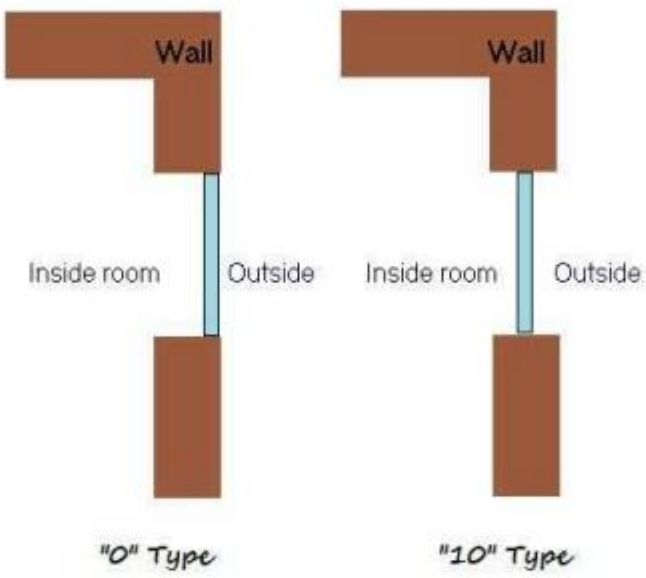


Figure 3.2 Two types of window’s position[7]

Then every month’s solar radiation value can be known from the following table.

Table 3.1 The solar radiation value(Wh/m^2)

Month	Window type	Calculation Value(Wh/m^2)			
Latitude 60° N		N -120	E -30	S 60	W 150
January	0	160	2360	1440	130
February	0	640	4280	2900	370
March	0	1720	5740	4520	900
April	0	3320	6370	5850	1990

May	0	4460	5980	6150	3050
June	0	5230	5820	6350	3870
July	0	4910	5820	6280	3510
August	0	3720	6070	5850	2380
September	0	2200	5760	4820	1230
October	0	1010	4960	3570	530
November	0	270	3340	1910	200
December	0	90	1770	1060	80

The type of window in this examination building is 2-glass, normally. So from the table below, it can be known that U-value is 2.9 and sun factor is 0.8.

Table 3.2 U-value and sun factor of different type window

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

The area of different direction of windows and cloudy factor can be seen from the table below.

Table 3.3 The area of windows

	N -120	E -30	S 60	W 150
Area	$86m^2$	$6m^2$	$20m^2$	$8m^2$

Table 3.4 Cloudy factor of Gävle

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

At last, calculate the free heat of each orientation windows in this building.

3.2 Internal heat

3.2.1 Internet heat from people

Because this building is used for students' examinations, it is too difficult to calculate the number of the people in this building and the time spending in this building. Here we assumed that there are 1/6 days in a year are used to examinations. One day's exam has 60 persons and the time spent on one day's exam is 8 hours. The power of human activities is about 100W/person. The summer time is from May 15th to September 15th. Therefore, the indoor heat is useless in these four months. The internal heat from people can be figured out by the following equation.

$Q_{human} = N_{human} * H_{working\ hours} * W_{activies}$

3.2.2 Internet heat from equipment

In this examination building, there are lamps, computers and printers. And we assumed that the power of each lamp is 60W, and the operating time of lamps is 5 hours per day. The power of each computer and printer is assumed 200W and 40W separately. And the operating time of each computer and printer is 4 hours per day. The summer is from May 15th to September 15th. Therefore, the indoor heat is useless for the four months.

(Lamps:8760h*$\frac{8}{12}*\frac{5}{24}$ = 1217h, Computer and Printer:8760h*$\frac{8}{12}*\frac{4}{24}$ = 973h)

Table 3.5Number of equipment

	Lamps	Computer	Printer
Floor 1	13	4	1
Floor 2	47	2	1

According to the equation: $Q_{equipment}$=(∑numbers* power* hours), the total internal heat from equipment can be calculated

3.3 District heating

District heating is one of the most important parts in building. In this audit, the consumption of district heating in 2013 is provided by Mr. Magnus[7]. The total consumption of district heating is 184.08MWh

The complete tables can be found in Appendix4.

3.4 Heat Losses from Transmission

According to theory, it can be known that the equation of the transmission losses is $Q_{transmission}=(\sum U_i*A_i)*q_{degree}$

The transmission losses are through building envelope, it includes losses through the window, losses through the roof, losses through the door, losses through walls and losses through the floor. According to the following tables, the U-value of different materials and area of building envelope can be known.

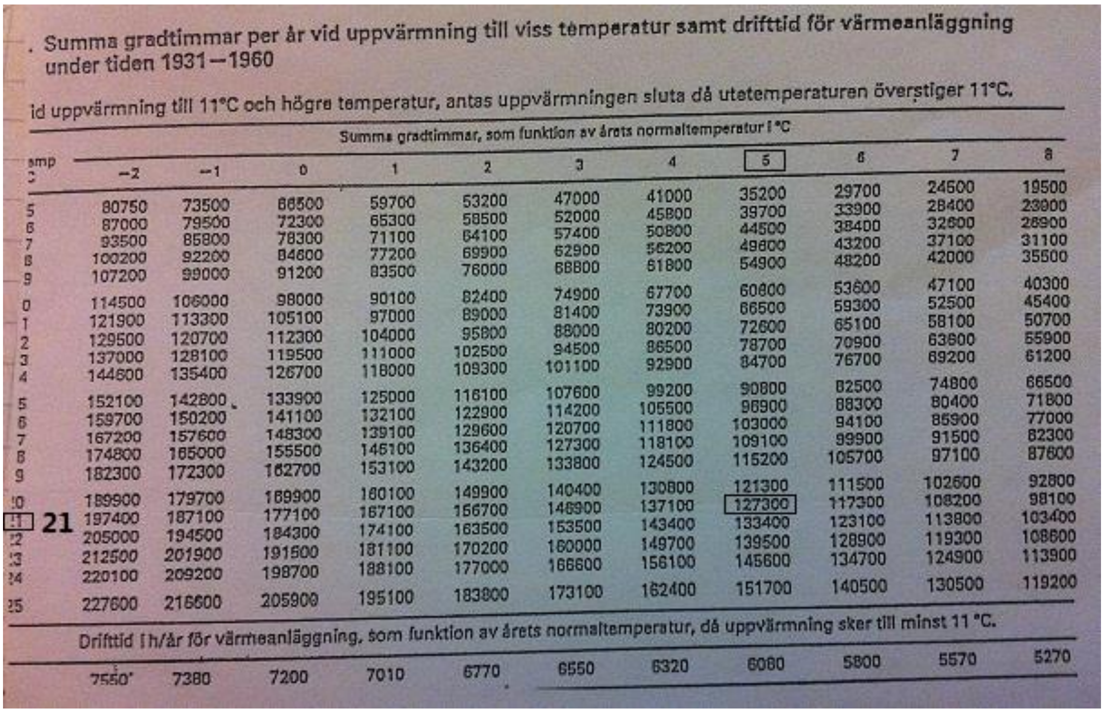
Table 3.6 U-value for different materials

	Window	Roof	Door	Wall	Floor
U-value	2.9	0.17	1	0.6	0.3

Table 3.7 Area of building envelope

	Window	Roof	Door	Wall	Floor
Area(m^2)	120	1198	24	696	1018

In Gavle, the average of outdoor temperature is 5 ℃. It assumed that the average of indoor temperature is 21℃. From the following figure, the q_{degree} can be known is 127300℃h.



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

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

amp 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	23900
7	93500	85800	78300	71100	64100	57400	50800	44500	38400	32600	28900
8	100200	92200	84600	77200	69900	62900	56200	49600	43200	37100	31100
9	107200	99000	91200	83500	76000	68800	61800	54900	48200	42000	35500
0	114500	106000	98000	90100	82400	74900	67700	60800	53600	47100	40300
1	121900	113300	105100	97000	89000	81400	73900	66500	59300	52500	45400
2	129500	120700	112300	104000	95800	88000	80200	72600	65100	58100	50700
3	137000	128100	119500	111000	102500	94500	86500	78700	70900	63600	55900
4	144600	135400	126700	118000	109300	101100	92900	84700	76700	69200	61200
5	152100	142800	133900	125000	116100	107600	99200	90800	82500	74800	66500
6	159700	150200	141100	132100	122900	114200	105500	96900	88300	80400	71800
7	167200	157600	148300	139100	129600	120700	111800	103000	94100	85900	77000
8	174800	165000	155500	146100	136400	127300	118100	109100	99900	91500	82300
9	182300	172300	162700	153100	143200	133800	124500	115200	105700	97100	87600
0	189900	179700	169900	160100	149900	140400	130800	121300	111500	102600	92800
1 21	197400	187100	177100	167100	156700	148900	137100	127300	117300	108200	98100
2	205000	194500	184300	174100	163500	153500	143400	133400	123100	113800	103400
3	212500	201900	191500	181100	170200	160000	149700	139500	128900	119300	108600
4	220100	209200	198700	188100	177000	166600	156100	145600	134700	124900	113900
5	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

Figure 3.3. Q_{degree} of Gavle

According to the table3.6 and figure3.3, we have gotten the U-value, area and q_{degree}. So the total transmission can be calculated by the following equation.

$Q_{transmission}=(\sum U_i*A_i)*q_{degree.}$

3.5 Mechanical ventilation losses

There are four machines to provide ventilation in different rooms of this examination building. The supply air and exhaust air of each floor is shown in following table, the total supply air and exhaust air of each floor can be found in the following table at the same time[7]. And the all details are shown in Appendix 2.

Table 3.8 Mechanical Ventilation

	Supply air(l/s)	Exhaust air(l/s)
First floor	783	612
Second floor	2188	2548

Total	2971	3160

It is assumed that the operating time of the ventilation system is from 8:00am to 5:00pm. Because of summer holiday and Christmas, the ventilation system works 9 months per year (8760h* $\frac{9}{12}$ * $\frac{9}{24}$ =2464h/year). The q_{degree} is 127300℃h which is same as the transmission losses part. And the efficiency of the ventilation system is 0.7.

At last, the mechanical ventilation losses can be calculated by the equation below.

$Q_{mechanical\ ventilation}=(1-\eta)*V*\rho*C_p*q_{degree}*(h/8760)$

3.6 Hot Tap Water

Because the use of this building is for student exams, so the cold tap water is just used in toilet, and the consumption of cold tap water is less than cold tap water consumption in residential buildings. And in 2013, the consumption of cold tap water in the examination building was just 107.9m^3[7]. The complete tables can be found in Appendix3.

In building, there is only 1/3 water for hot tap water, so the amount of hot tap water is 107.9* $\frac{1}{3}$ =35.97m^3. Assumed the average of water was 5℃ and it needed to be heated to 55℃, so the difference of temperature was 50℃, the consumption of hot tap water can be calculated by equation which is mentioned in theory.

$Q_{hot\ tap\ water}= m* Cp_{water}* (T_s-T_g)* (1/3600)$

The complete tables can be found in Appendix3.

3.2.4 Heat Loss from Infiltration

Infiltration is the air leakage through the windows, doors and cracks of envelope. So it is also called natural ventilation. Because infiltration heat losses is through the windows, doors and cracks of envelope, so the heat losses of infiltration is hard to be measured. But if the internal heat, solar radiation, district heating, transmission losses, mechanical ventilation losses and hot tap water can be known, the heat losses of infiltration can be calculated by the energy balance.

$$Q_{infiltration} = Q_{internal\ heat} + Q_{solar\ radiation} + Q_{supply\ heat} - Q_{transmission} - Q_{ventilation} - Q_{hot\ tap\ water}$$

4. Results

4.1 Heat Supply

4.1.1 Solar Radiation

The annual energy input coming from solar radiation through windows can be divided into the four different facade orientations.

Table 4.1 Heat from solar radiation (S60)

Orientation	Annual energy input (MWh)
S60	7.01MWh
W150	0.69MWh
E-30	2.26MWh
N-120	12.48MWh
Total	22.4MWh

According to the table 4.1, it can be inferred that the total energy input from solar radiation is 22.4MWh. This energy does not cost as it is a free heating. The energy almost comes from solar radiation, whose orientations are N-120 and S60, occupying 87% of the total energy. While the energy of other orientations just occupies 13% of the total energy. The details can be seen in the following figure.

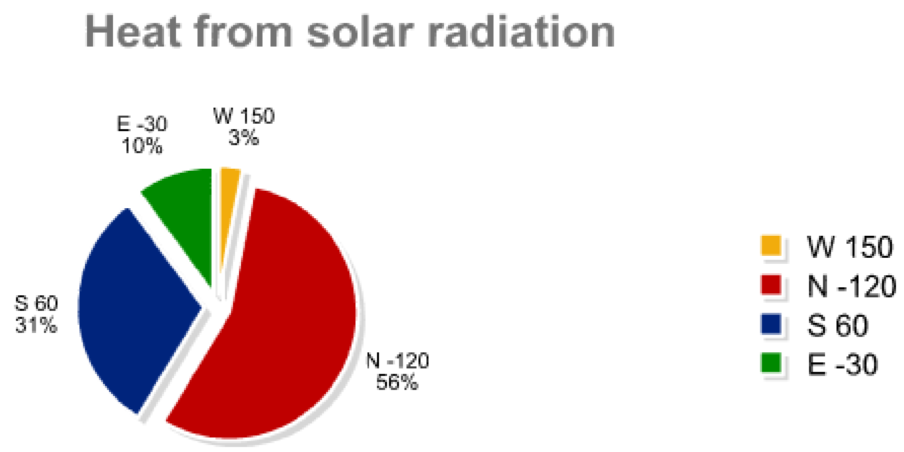


Figure 4.1 Heat from solar radiation

4.1.2 Internal heat from people and equipment

In this part, the results of internal heat from people and equipment are presented. At first, the table 4.2 shows the annual internal heat from people.

Table 4.2 Internal heat from people

	Numbers	Power	Working time	Heat(MWh)
people	60	100W	324h	1.95MWh

Secondly, the table 4.3 shows the annual internal heat from equipments.

Table 4.3 Internal heat from equipment

	Numbers	Power	Working time	Heat(MWh)
Lamps	60	60W	1217h	4.38MWh
Computer	6	200W	973h	1.17MWh
Printer	2	40W	973h	0.08MWh
Total				5.63MWh

At last, the table 4.4 shows the total internal heat from people and equipments.

Table 4.4 The total internal heat from people and equipment

	Internal heat(MWh)
People	1.95MWh
Equipments	5.63MWh
Total	7.58MWh

According to the table above, it can be inferred that 7.58MWh internal heat is generated by people and equipments. The internal heat coming from equipments occupies 74% of the total internal heat and the remaining part comes from people.

4.1.3 District heating

Table 4.5 shows the monthly consumption and annual consumption of district heating in 2013. The complete figures can be found in Appendix4.

Table 4.5 The consumption of district heating

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totle (MWh)
31.4	28.7	24.1	16.4	10.4	1.4	0.1	0.5	5.4	12.5	22.7	30.3	184.1

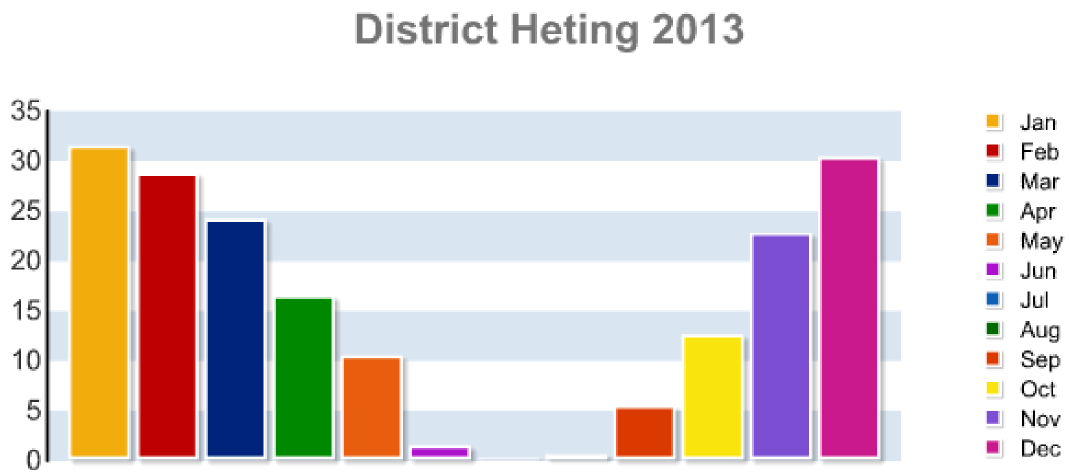


Figure 4.2 The consumption of district heating in 2013

From the figure 4.2, it is easy to find out that district heating consumption peaks take place during the winter months. The highest district heating consumption takes place in January where the consumption is 31.4MWh. While during the summer months, district heating is not overly seen to have been consumed.

According to the data of Svenskfjärrvärme[27], the average price of district heating in 2013 is 81öre/kWh. From this it can be figured out that the cost of district heating is 214.08 * 81öre/kWh*1000=17340480öre/year=173404.8 SEK/year.

4.2 Heat Losses

4.2.1 Heat Losses from Transmission

In this section, results of transmission losses are presented, and the overall look at the transmission losses is also shown in the following paragraph.

The table 4.6 shows the annual transmission losses through windows, doors, walls, floors and the ceiling. Figure 4.3 presents the percentage contribution of the transmission losses in each part.

Table 4.6 Transmission losses

	Window	Roof	Door	Wall	Floor
Area	120	1198	24	696	1018
U-value	2.9	0.17	1	0.6	0.3
q_{degree}	127300	127300	127300	127300	127300
Losses	44.3	25.9	3.06	53.16	38.9
Total					165.3MWh

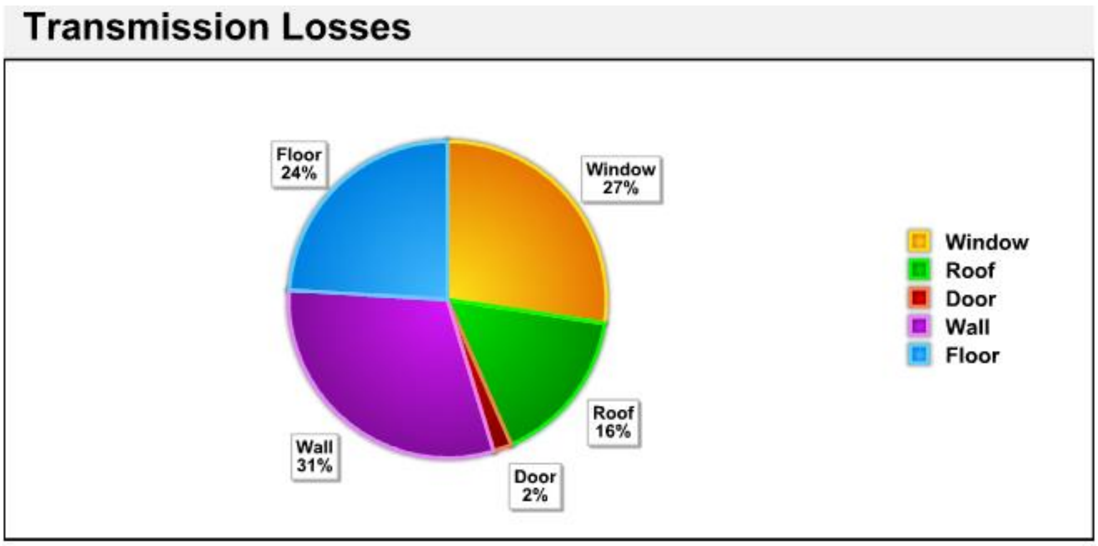


Figure 4.3Transmission losses

The total transmission losses are 165.3MWh. The transmission losses through walls are the biggest contributors in this flow, obtaining 31% of the total, which is followed by transmission losses through windows (27%).

4.2.2 Heat Losses from Mechanical Ventilation

As is mentioned in the method, the data of supply air flow and exhaust air flow are provided by Mr. Magnus[7] and shown in table 4.7. The annual mechanical ventilation losses are shown in table 4.8.

Table 4.7 Mechanical Ventilation

	Supply air(l/s)	Exhaust air(l/s)
First floor	783	612
Second floor	2188	2548
Total	2971	3160

Table 4.8 The Annual Mechanical Ventilation Losses

	efficiency	Air flow	$\rho*C_p$	q_{degree}	Working hour	Q_{mv}
Mechanical ventilation losses	0.7	2971	1200	127300	2464	38.29 MWh

The annual mechanical ventilation losses are 38.3MWh. More details are shown in Appendix2.

4.2.3 Hot Tap Water

Table 4.9 shows the consumption of cold tap water of each month. The figure 4.4 also shows the cold tap water consumption in 2013. The complete figures can be found in Appendix3.

Table 4.9 The consumption of cold tap water

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totle (m^3)
13.9	8.2	14.9	7.2	13.5	9.2	1.2	7.3	3.3	11.2	9.5	8.3	107.9

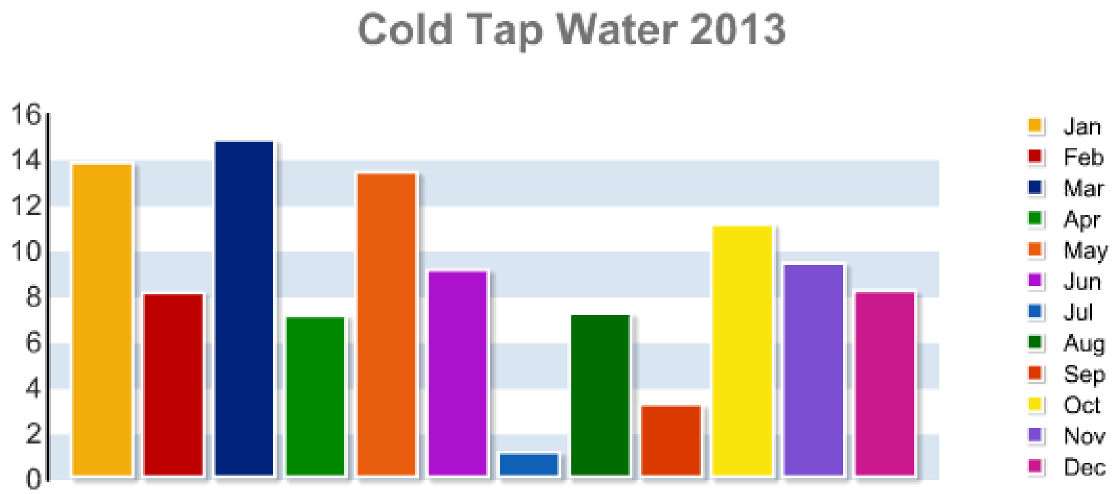


Figure 4.4 The consumption of cold tap water in 2013

The total cold tap water consumption is 107.9m^3. In March, the consumption of cold tap water is the highest. The minimum consumption of cold tap happens in July. In the other months, the consumption of cold tap water is almost the same. In the building, only 1/3 water is for hot tap water; therefore the consumption of hot tap water is $107.9*\frac{1}{3}=35.97m^3$. The hot tap water energy is calculated by the following equation.

$$Q_{hot\ tap\ water}= m* Cp_{water}* (T_s-T_g)* (1/3600)$$

$$= 35.97*1000*4.19*(55-5)*(1/3600)=2.09MWh$$

4.2.4 Heat Loss from Infiltration

The infiltration losses can be calculated by the following equation.

$Q_{infiltration} = Q_{internal\ heat} + Q_{solar\ radiation} + Q_{supply\ heat} - Q_{transmission} - Q_{ventilation} - Q_{hot\ tap\ water}$

$= 1.95+5.63+22.4+184.08-165.3-38.29-2.09 = 8.38\text{MWh}$

Although the infiltration losses are calculated by energy balance equation, the infiltration losses are also influenced by air density, air flow and temperature difference between indoor and outdoor[11] environment.

4.3 Energy Balance

In following table, the details of the energy balance are shown of the examination building. The consumption of each part of the heat losses and proportion of each part of heat losses is found in table. The proportion of each part of the heat supply also can be found in following table at same time.

Table 4.10 Energy balance

Energy supply		Energy losses	
Solar radiation	22.4(10%)	Transmission loss	165(77%)
Internal heat from people	1.95(1%)	Mechanical ventilation loss	38.3(18%)
Internal heat from equipment	5.63(3%)	Infiltration loss	8.38(4%)
District heating	184(86%)	Hot tap water	2.09(1%)
Total	214MWh		214MWh

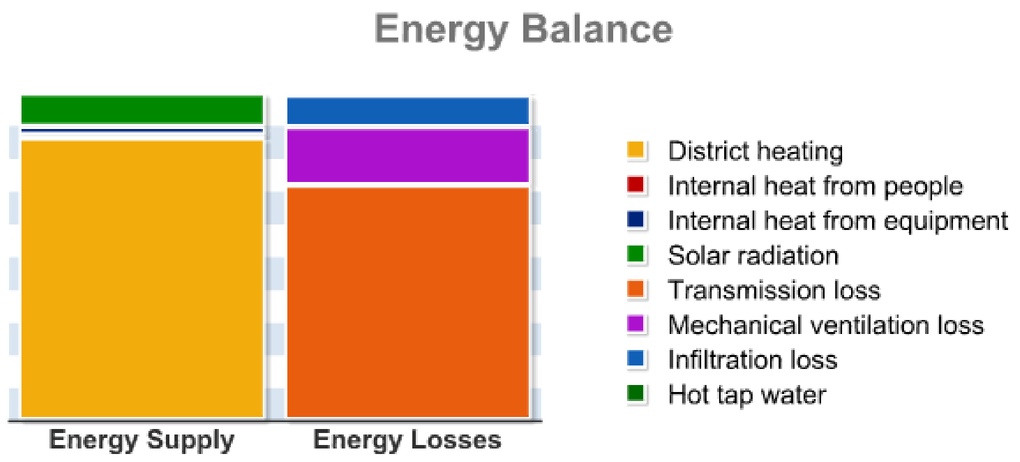


Figure 4.5 Energy balance

From the figure of energy balance, it is easily to find out the proportion of each part in energy supply and energy losses. In energy supply, the district heating occupies too much. And the internal heat from human activities is almost 0. And in energy losses, the transmission occupies much more than other part.

5.Discussion

For heat supply, district heating is the biggest part of the supply. The amount of the district heating is 184MWh, which occupied 86% of the total energy supply. Form the table 4.2 we could see that the consumption of district heating in winter increases distinctively, while it almost remains zero in summer. From this it can be inferred that there is a distinctive relationship between the demand of district heating and changes to outdoor temperature. When outdoor temperature increases, the demand for district heating becomes less correspondingly. Most of the district heating is used for space heating, with only a small part being used for the heating of hot tap water etc. Solar radiation is also an important part in heat supply, which occupies 10% of the energy supply, being 22.4MWh. From the table 4.1 we can see that the solar radiation provided by windows facing N-120 and S60 is the most, which is because walls facing north and south are much bigger than whose facing east and west. Therefore, even though the sun rises in the east and sets in the west, N-120 and S60 contribute the most solar radiation. Besides, internal heat from human and equipments obtains 4%, which is because this building is mainly used for students' examinations. The functioning of this building only occurs when there are human activities, like examination; therefore this part is much less compared with ordinary buildings.

Even though free heat only obtains 14% of the energy supply in this building, this is still an important part which cannot be ignored. In Sweden, it is cold most of the time during a year, so buildings need large amount of heat to tackle space heating. More free heat means less energy supply, and at the same time less wastes in terms of heat generation. Therefore, reasonably using free heat becomes very important.

For energy losses, it can be recognized that the transmission losses occupies the 77% of total heat losses, which is the biggest part of the energy losses. Reducing the transmission losses of the examination building is an effective way to save energy. From the table 4.3, it can be inferred that transmission losses from wall obtain the largest percentage, being 53.2MWh. But this doesn't mean that improving the insulation of wall is the best choice. As is shown in table 5.1, heat flow density of the window is 0.37, several times of the combination of walls, floors and ceiling. That is to say, given the same area, heat losses through the windows are several times than that through the walls, floors and the ceiling. Therefore, when considering the energy saving measures, optimizing the windows becomes the best choice.

Table 5.1 Heat flow density

Heat flow density (MWh/m^2)	Window	Wall	Roof	Floor	Door
	0.37	0.076	0.0216	0.038	0.128

Next, the mechanical ventilation loss occupies 18%, which is the second largest part of the energy losses. Last part of energy losses is hot tap water, which occupies only 1%. Consumption of cold tap water in the year 2013 is shown in table 4.4, among which 30% is hot tap water. In July, consumption of cold tap water hits the bottom line; while in other months, it remains relatively stable, being around $10m^{3.}$ This is because there are no examinations in July, which leaves the building empty. The same is true to other months as well. The uses are mainly for toilet.

From theory of the energy balance point of view, it can be known that energy losses impact the energy usage of the building. The energy use can be decreased by reducing energy losses. Hence, reducing energy losses is the way to save energy.

Transmission loss is the largest part of the energy losses. As mentioned above, windows have the highest heat flow density, with most heat lost through each 1 m^2. So windows optimization becomes the top priority. Besides, mechanical ventilation also obtains some proportion in energy loss, with optimizing the existing ventilation system being one of the most important things.

5.1 Changing the type of window

From the following figure, it can easy find out that the most of transmission losses are through wall and windows; meanwhile, the amount of the transmission losses through wall is almost same as the transmission loss through windows.

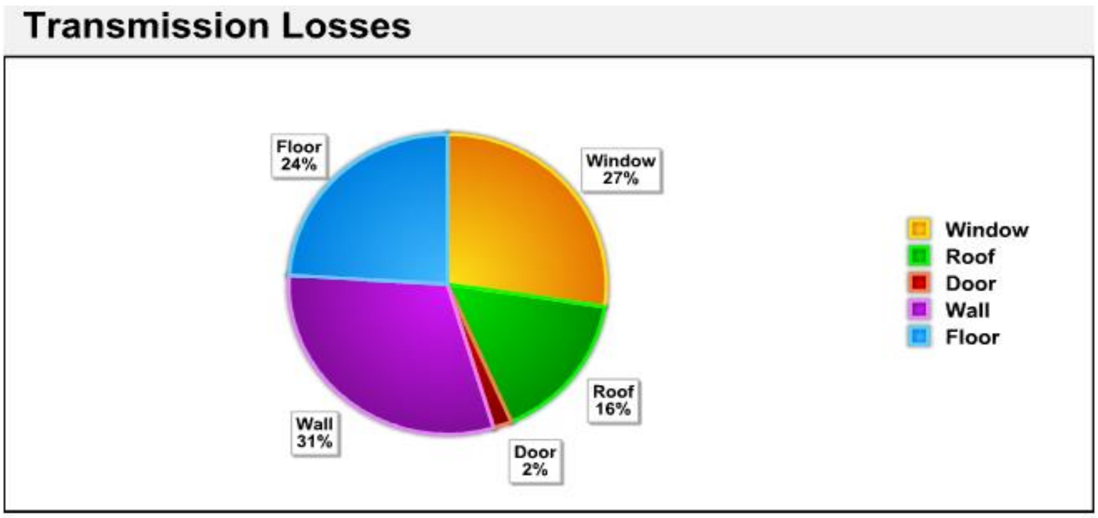


Figure 5.1 Transmission losses

As we know, increasing the insulation of the wall and roof is high cost, so, it is not worth. The first method is changing the type of windows to reduce the U-value.

The windows of the examination building are 2-glass, the method is using 3-glass windows to replace 2-glass windows, and the U-value can reduce from 2.9 to 1.9. The difference can be seen in the following table.

Table 5.2 The transmission losses from 2 type window

	U-value	Area	q_{degree}	Q
Window (before)	2.9	120	127300	44.3MWh
Window (after)	1.9	120	127300	29.02MWh

The transmission losses through 2-glass window are 44.3MWh, for the transmission losses through 3-glass window are only 29.02MWh. We can figure out the transmission losses through window are reduced 44.3-29.02=15.28MWh. It means that 34% energy can be saved.

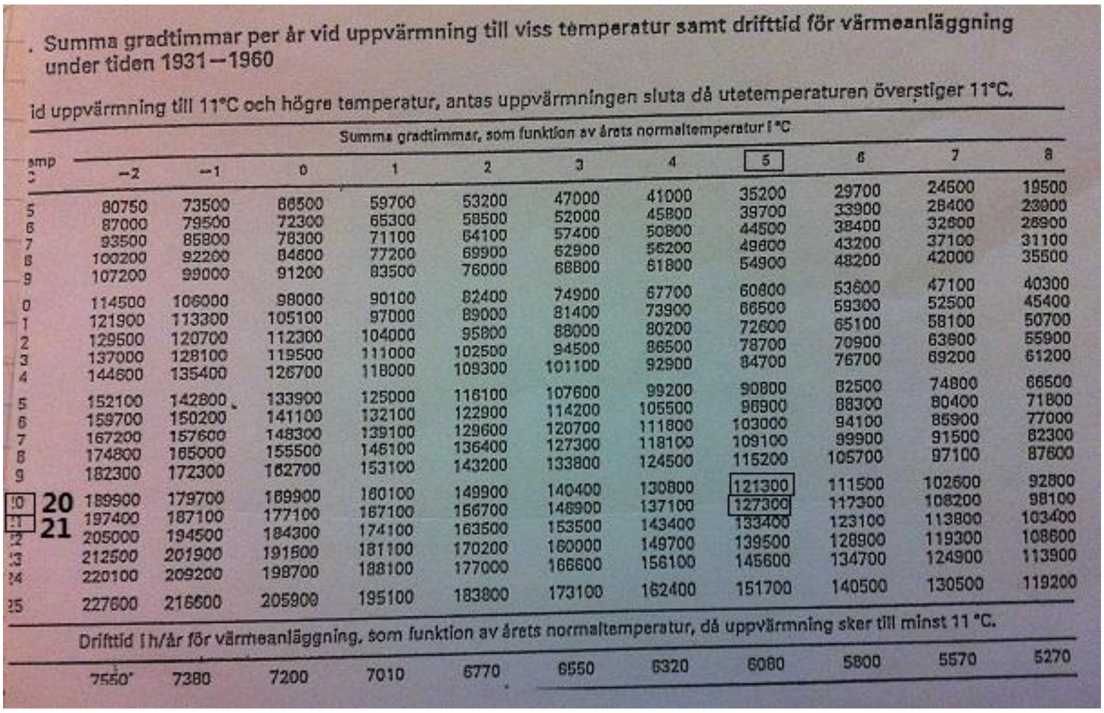
Changing the type of window can also change the sun factor. The sun factor is changed from 0.8 to 0.72. This change can impact the heat of solar radiation. Because of sun factor, the total heat of solar radiation is reduced from 22.4MWh to 20.16MWh. In other word, there is 22.4-20.16=2.24MWh reduced.

Hence, changing the type of window can save: 15.28-2.24=13.04MWh.

5.2 Reducing the indoor temperature

The second method is reducing the temperature of indoor environment, which means reducing the difference between indoor and outdoor temperature. When the gap decreased, the transmission losses of this building are reduced.

From the data below, we can find, the pervious temperature of indoor environment is 21℃. According to the figure 5.2, it can be known that the q_{degree} is 127300°Ch/year when the indoor temperature is 21℃, and q_{degree} is 121300°Ch/year when indoor temperature is 20°C. The indoor temperature is decreased from 21℃ to 20°C.


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

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

emp C	Summa gradtimmar, som funktion av årets normaltemperatur i °C										
	−2	−1	0	1	2	3	4	5	6	7	8
5	80750	73500	86500	59700	53200	47000	41000	35200	29700	24500	19500
6	87000	79500	72300	65300	58500	52000	45800	39700	33900	28400	23900
7	93500	85800	78300	71100	64100	57400	50800	44500	38400	32600	28900
8	100200	92200	84600	77200	69900	62900	56200	49800	43200	37100	31100
9	107200	99000	91200	83500	76000	68800	61800	54900	48200	42000	35500
0	114500	106000	98000	90100	82400	74900	67700	60800	53600	47100	40300
1	121900	113300	105100	97000	89000	81400	73900	66500	59300	52500	45400
2	129500	120700	112300	104000	95800	88000	80200	72600	65100	58100	50700
3	137000	128100	119500	111000	102500	94500	86500	78700	70900	63600	55900
4	144600	135400	126700	118000	109300	101100	92900	84700	76700	69200	61200
5	152100	142800	133900	125000	116100	107600	99200	90800	82500	74800	66500
6	159700	150200	141100	132100	122900	114200	105500	96900	88300	80400	71800
7	167200	157600	148300	139100	129600	120700	111800	103000	94100	85900	77000
8	174800	165000	155500	146100	136400	127300	118100	109100	99900	91500	82300
9	182300	172300	162700	153100	143200	133800	124500	115200	105700	97100	87600
0 20	189900	179700	169900	160100	149900	140400	130800	121300	111500	102600	92800
1 21	197400	187100	177100	167100	156700	146900	137100	127300	117300	108200	98100
2	205000	194500	184300	174100	163500	153500	143400	133400	123100	113800	103400
3	212500	201900	191500	181100	170200	160000	149700	139500	128900	119300	108600
4	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

Figure 5.2 Degree hours

At the beginning, the temperature of indoor environment is 21℃, the q_{degree} is 127300°Ch/year, the transmission of window, roof, door, wall and floor can be calculated by following equation:

$Q_{transmission}=(\sum U_i*A_i)*q_{degree}$

The details of every part can be found in the following table.

Table 5.3 The transmission losses when indoor temperature is 21℃

	Window	Roof	Door	Wall	Floor

Area	120	1198	24	696	1018
U-value	1.9	0.17	1	0.6	0.3
q_{degree}	127300	127300	127300	127300	127300
Losses	29.02	25.9	3.06	53.16	38.9
Total					150MWh

When indoor temperature is 20℃, the q_{degree} is 121300℃h/year. Calculate the transmission losses of window, roof, door, wall and floor in same equation. The results are shown in the following table.

Table 5.4 The transmission losses when indoor temperature is 20℃

	Window	Roof	Door	Wall	Floor
Area	120	1198	24	696	1018
U-value	1.9	0.17	1	0.6	0.3
q_{degree}	121300	121300	121300	121300	121300
Losses	27.66	24.7	2.91	50.65	37.05
Total					143MWh

The total transmission losses are decreased, due to decreasing temperature gap between indoor and outdoor temperature. There is 150-143=7MWh(4.7%) energy can be saved in this method.

5.3 Changing the operating time of ventilation

The third method is reducing the working time of ventilation system. For normal building, the ventilation system is always working for a long time to ensure a comfortable indoor environment. However, for the examination building, it not working frequently. It does not need to usualness turn on the ventilation. The operating time is change time from 2464h/year to 1642h/year, which means operating time is reduced from nine months per year to six months per year. The heat loss comparison between before and after is shown in the following table.

Table 5.5 The mechanical ventilation heat loss difference

	Operating Hours	Heat Loss
Ventilation before changing	2464	38.29MWh
Ventilation after changing	1642	25.53MWh

From the table, it can be known that reducing operating time can reduce the mechanical ventilation heat loss. The amount of the reduction is 38.29-25.53=12.76WMh. In other word, the 33% energy is saved.

5.4 Investment

As previously stated, there are three measures to save energy, namely, changing the type of window, reducing the indoor temperature and changing the operating time of ventilation. In these measures, changing the type of window needs extra investment.

According to the data provided by Elitfönster[28], the required investment is 99306 overall. As is shown below:

Table 5.6 Window cost

Type	Unit price(SEK)	Number of units	Total price(SEK)
Fast karm - 3-glas isolerruta EFK Storlek 6/10	2142	26	55692
Sidhängt - 3-glas isolerruta EFS Storlek 8/12	4413	6	26478
Fast karm - 3-glas isolerruta EFK Storlek 8/12	2142	8	17136

Assume a 20 years loan with an interest rate of 6%.

Annuity rate: a = 0.06/2 + 1/20 = 0.08

Table 5.7 Economic effect of changing the type of windows

Total investment	99306	Annual energy saved	13.04MWh
Annuity rate	0.08	District heating price	81öre/kWh
Annuity(SEK)	7944.5	Annual energy savings	10562.4

By changing the window type, it is estimated to reduce 10562.4-7944.5=2617.9SEK per year. Besides, reducing the indoor temperature and changing the operating time of ventilation do not need any extra investment. The details are shown as follows:

Table 5.8 Savings obtained with the other two measures

	Annual energy saved	Price	Savings(SEK/year)
Reducing the indoor temperature	7MWh	81öre/kWh	5670
Changing the operating time of ventilation	12.8MWh	81öre/kWh	10368

In conclusion, by using these three energy efficiency measures, it is estimated to save 2617.9+5670+10368=18655.9SEK every year.

5.5 New Energy Balance

Reducing the transmission losses is the main way to save the energy. Transmission losses include heat losses through window, wall, roof, floor etc. However, changing insulation of wall and roof is a hard work and high expense. As mentioned above, changing the U-value of window is more effective and economic. The transmission losses are also influenced by temperature gap between indoor and outdoor. The less heat transfer to outside due to lower temperature gap. Because of special role on building, changing the operating time of ventilation system is also an effective method to save energy. From these analyses, the new energy balance is figured out.

The details of new energy balance are shown in the following table.

Table 5.6 New energy balance

Energy supply		Energy losses	
Solar radiation	22.4(13%)	Transmission loss	143(80%)
Internal heat from people	1.95(1%)	Mechanical ventilation loss	25.5(14%)
Internal heat from equipment	5.63(3%)	Infiltration loss	8.38(5%)
District heating	149(83%)	Hot tap water	2.09(1%)
Total	179MWh		179MWh

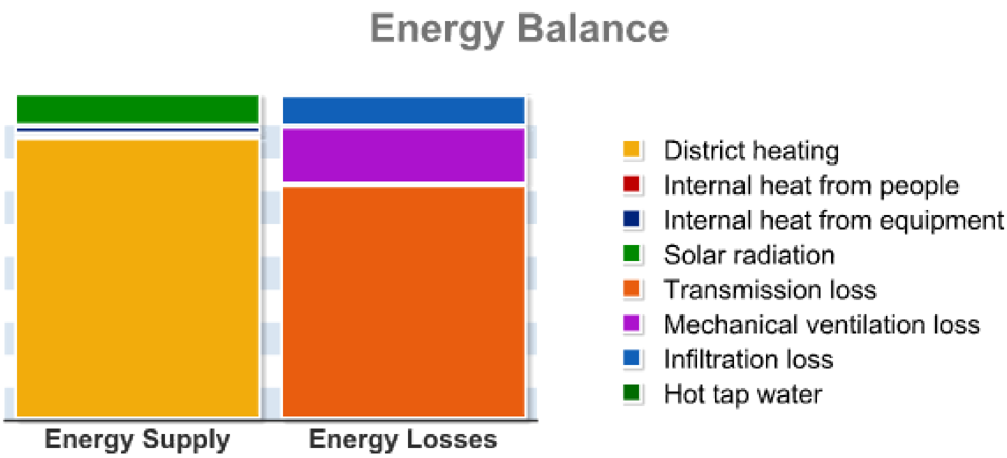


Figure 5.3 New energy balance

6. Conclusion

Through the energy audition of this examination building, it can be inferred that the total energy loss is 214MWh. According to calculation, it can be known that the transmission loss is the biggest part of the total energy loss. The amount of transmission loss is 165MWh, which obtains 77%. Mechanical ventilation ranks the second, which is 38.3MWh, meaning that the mechanical ventilation loss occupies 18% in total energy. Because this building is used for examination, the hot tap water is only used in toilet. The amount of hot tap water is 2.09MWh, obtaining only 1%.

It is known from theory that energy balance means that energy supply is equal to the energy losses. So the total energy supply is 214MWh. Through the energy audition, it can be known that the main source of energy supply is from solar radiation and district heating which is the biggest part. It occupies 86% of the total energy supply (184MWh). The solar radiation is 22.4MWh with a proportion of 10% in total energy supply. Because this is just an examination building, the internal heating is less than residential building, which is only 1.95MWh.

The transmission is the biggest source of the energy losses, so reducing the energy losses is the most effective way to save energy. The optimized method is to change the window type and lower the indoor temperature, while reducing the operating time of the ventilation system is also an optimized method. Through these optimized methods, 35.1MWh energy is saved, which means a 16% reduction in energy use. At the same time, 19thousand SEK is saved by these optimized methods.

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Appendix

Appendix 1. Solar Radiation

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
June	0,61
July	0,61
August	0,59
September	0.58
October	0.51
November	0.42
December	0.43

Figure 1.1 Cloudy factor

Table 1.1 Heat from solar radiation (S60)

Month	W (S60)	area	Sun factor	Cloudy factor	Days	Free heat (Wh)
1	1440	20	0.8	0.45	31	321408
2	2900	20	0.8	0.49	28	636608
3	4520	20	0.8	0.58	31	1300313.6
4	5850	20	0.8	0.58	30	1628640

5	6150	20	0.8	0.63	15	929880
6	6350	20	0.8	0	0	0
7	6280	20	0.8	0	0	0
8	5850	20	0.8	0	0	0
9	4820	20	0.8	0.58	15	670944
10	3570	20	0.8	0.51	31	903067.2
11	1910	20	0.8	0.42	30	385056
12	1060	20	0.8	0.43	31	226076.8
Total						7.01MWh

Table 1.2 Heat from solar radiation (W150)

Month	W (W150)	area	Sun factor	Cloudy factor	Days	Free heat (Wh)
1	130	8	0.8	0.45	31	11606.4
2	370	8	0.8	0.49	28	32489
3	900	8	0.8	0.58	31	100224
4	1990	8	0.8	0.58	30	221616
5	3050	8	0.8	0.63	15	184464
6	3870	8	0.8	0	0	0
7	3510	8	0.8	0	0	0
8	2380	8	0.8	0	0	0
9	1230	8	0.8	0.58	15	68486.4
10	530	8	0.8	0.51	31	53627.5
11	200	8	0.8	0.42	30	16128
12	80	8	0.8	0.43	31	6825
Total						0.69MWh

Table 1.3 Heat from solar radiation (E-30)

Month	W (E-30)	area	Sun factor	Cloudy factor	Days	Free heat (Wh)
1	2360	6	0.8	0.45	31	158018.4
2	4280	6	0.8	0.49	28	281863.7
3	5740	6	0.8	0.58	31	495385
4	6370	6	0.8	0.58	30	532022.4
5	5980	6	0.8	0.63	15	271252.8
6	5820	6	0.8	0	0	0
7	5820	6	0.8	0	0	0
8	6070	6	0.8	0	0	0
9	5760	6	0.8	0.58	15	240537.6
10	4960	6	0.8	0.51	31	376404.5
11	3040	6	0.8	0.42	30	183859.2
12	1770	6	0.8	0.43	31	113251.7
Total						2.26MWh

Table 1.4 Heat from solar radiation (N-120)

Month	W(N-120)	area	Sun factor	Cloudy factor	Days	Free heat (Wh)
1	160	86	0.8	0.45	31	153561.6
2	640	86	0.8	0.49	28	604119
3	1720	86	0.8	0.58	31	2127681.3
4	3320	86	0.8	0.58	30	3974438.4
5	4460	86	0.8	0.63	15	2899713.6

6	5230	86	0.8	0	0	0
7	4910	86	0.8	0	0	0
8	3720	86	0.8	0	0	0
9	2200	86	0.8	0.58	15	1316755.4
10	1010	86	0.8	0.51	31	1098541.4
11	270	86	0.8	0.42	30	234043
12	90	86	0.8	0.43	31	82534.6
Total						12.48MWh

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.

Figure 1.2 U-value of window and sun factor

II:2.1.2 Dygnssummor den 15:e i varje månad av strålning mot vertikala ytor, Wh/m²dygn 151

Månad	Horisont-avskärmning,°	Vertikala ytans orientering N −180	N −150	N −120	E −90	E −60	E −30	S 0	S 30	S 60	W 90	W 120	W 150
Latitud 60 °N													
Januari	0	130	130	160	550	1 440	2 960	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	4 290	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	3 670	5 230	6 180	6 350	5 820	5 460	5 820	6 350	6 180	5 230	3 670
	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	2 630	3 510	4 910	5 960	6 280	5 620	5 590	5 690	5 280	5 960	4 910	3 510
	10	2 270	3 020	4 410	5 540	6 060	5 870	5 560	5 870	6 060	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	5 780	6 130	5 780	4 820	3 520	2 200	1 230
	10	880	1 070	1 930	3 200	4 530	5 580	6 080	5 580	4 630	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	850	1 500	2 850	4 290	4 870	4 290	2 850	1 500	850	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	980	1 590	1 810	1 590	980	300	160	160
December	0	80	80	90	350	1 060	1 770	2 090	1 770	1 060	350	90	80
	10	40	40	50	60	90	120	130	120	90	60	50	40

Figure 1.3 The solar radiation value(Wh/m^2)

Appendix 2. Mechanical Ventilation

Eriks Ventilations Service AB

LUFTFLÖDESPROTOKOLL

Anläggning: Högskolan	Byggnad: Fd Markan	Ritn nr: V57:962
Fläktsystem: FT	Fläktbet: TA 1/FF 1	Betjänar: Skrivsal mm
Utfört av: E Bergefur	Datum: 951013	Enhet: l/s

Rums nr	Tilluft (in)		Mät met	Frånluft (out)		Mät met	Noteringar
	progr.	uppm.		progr.	uppm.		
962:39	30	30	6				
962:40				30	30	3	
962:41				30	31	3	
962:42	30	30	6				
962:43	1500	1420	1	1500	1470	6	
	what we want	what we have					

Övriga upplysningar:	1 Prandtlrör
	2 Påsmetoden
	3 Swema

Figure 2.1 The result of measure of TA1/FF1

Eriks Ventilations Service AB

LUFTFLÖDESPROTOKOLL

Anläggning: Högskolan	Byggnad: Fd Markan	Ritn nr: V57:962
Fläktsystem: FT	Fläktbet: TA2/FF3	Betjänar: Del
Utfört av: Erik Bergefur	Datum: 951013	Enhet: l/s

Rums nr	Tilluft		Mät met	Frånluft		Mät met	Noteringar
	progr.	uppm.		progr.	uppm.		
962:02	280	162	7	260	270	7	
962:03	120	72	7	110	75	7	
962:05	200	110	7	200	135	7	
962:08				30	21	3	
962:09	120	75	7	120	82	7	
962:10	100	62	7	100	73	7	
962:11	120	70	7	120	85	7	
962:12	80	80	7	60	45	3	
962:13					30	3	

Övriga upplysningar:	1 Prandtlrör
	2 Påsmetoden
	3 Swema

Figure 2.2 The result of measure of TA2/FF3

Eriks Ventilations Service AB

LUFTFLÖDESPROTOKOLL

Anläggning: Högskolan	Byggnad: Fd Markan	Ritn nr: DE 3
Fläktsystem: FF	Fläktbet: FF 4	Betjänar: Del
Utfört av: E Bergefur	Datum: 951013	Enhet: l/s

Rums nr	Tilluft		Mät met	Frånluft		Mät met	Noteringar
	progr.	uppm.		progr.	uppm.		
962:15				15	15	3	
962:16				20	21	3	
962:17				20	20	3	
962:18	20	20	7	20	20	3	
962:19		15	7				
962:20					10	6	
962:21					10	6	
962:22					10	6	
962:23		20					
962:24				5	5	3	
962:28	30	22	7	15	15	3	
962:29				15	15	3	
962:32				15	15	3	
962:34				15	15	3	
962:35				15	15	3	
962:36				15	15	3	

Övriga upplysningar:	1 Prandtlrör
	2 Påsmetoden
	3 Swema

Figure 2.3 The result of measure of FF4

Eriks Ventilations Service AB

LUFTFLÖDESPROTOKOLL

Anläggning: Högskolan	Byggnad: Fd markan	Ritn nr:
Fläktsystem: FT	Fläktbet: TA 2,3,4/FF 3,4	Betjänar:
Utfört av: E Bergefur	Datum: 951102	Enhet: l/s

Rums nr	Tilluft		Mät met	Frånluft		Mät met	Noteringar
	progr.	uppm.		progr.	uppm.		
961:02		200	3		45	3	TA 3/
961:05					0	3	/
961:08					11	3	/FF 4
961:09		25	3				TA 2
961:10					8	3	/FF 4
961:11		10	3		8	3	TA 2/FF 4
961:12					6	3	/FF 4
961:13		7	3		15	3	TA 2/FF 4
961:14					10	3	/FF 4
961:16					20	3	/FF 4
961:19		155	1		73	3	TA 2/FF 3
961:22					15	3	/FF 3
961:23					11	3	/FF 3
961:24					16	3	/FF 3
961:25		55	3				TA 2/
961:26					18	3	TA 4/FF 3
961:27					30	3	/FF 3
961:28					10	3	/FF 3
961:29		75	3		66	3	

Övriga upplysningar:	
	1 Prandtlrör
	2 Påsmetoden
	3 Swema

Figure 2.4 The result of measure of TA2,3,4/FF3,4

Eriks Ventilations
Service AB

LUFTFLÖDESPROTOKOLL

Anläggning: Högskolan	Byggnad: Fd Markan	Ritn nr:
Fläktsystem: FT	Fläktbet: TA4 /FF3	Betjänar:
Utfört av: Erik Bergefur	Datum: 951102	Enhet: 1/s

Rums nr	Tilluft		Mät met	Frånluft		Mät met	Noteringar
	progr.	uppm.		progr.	uppm.		
961:30		256	1				
961:31							
961:32					250	1	
961:33							

Övriga upplysningar:	1 Prandtlrör
	2 Påsmetoden
	3 Swema

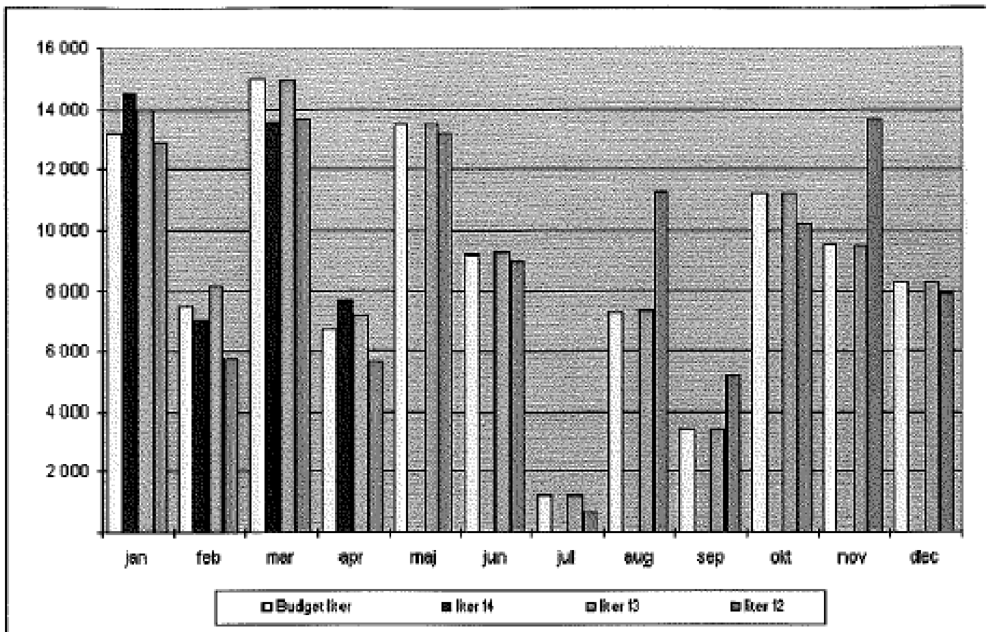
Figure 2.5 The result of measure of TA4/FF3

Appendix 3. Hot tap water

Driftrapport

Vatten

Objekt **X0038096** **Högskolan gävle, Balder hus 96**
Intervall120101-141231 Skapad 2014-04-30
BRA: 2035m²



Månad	Budget liter	liter 14	liter 13	liter 12	liter/m² 14	liter/m² 13	liter/m² 12
jan	13 200	14 526	13 962	12 906	7,1	6,9	6,3
feb	7 500	7 033	8 159	5 724	3,5	4,0	2,8
mar	15 000	13 536	14 948	13 648	6,7	7,3	6,7
apr	6 700	7 688	7 167	5 622	3,8	3,5	2,8
maj	13 500	0	13 525	13 159	0,0	6,6	6,5
jun	9 200	0	9 248	8 995	0,0	4,5	4,4
jul	1 200	0	1 234	615	0,0	0,6	0,3
aug	7 300	0	7 309	11 252	0,0	3,6	5,5
sep	3 400	0	3 392	5 186	0,0	1,7	2,5
okt	11 200	0	11 228	10 218	0,0	5,5	5,0
nov	9 500	0	9 483	13 643	0,0	4,7	6,7
dec	8 300	0	8 283	7 921	0,0	4,1	3,9
Summa	106 000	42 783	107 938	108 889	21,0	53,0	53,5

Figure 3.1 The consumption of hot tap water

Appendix 4. District heating

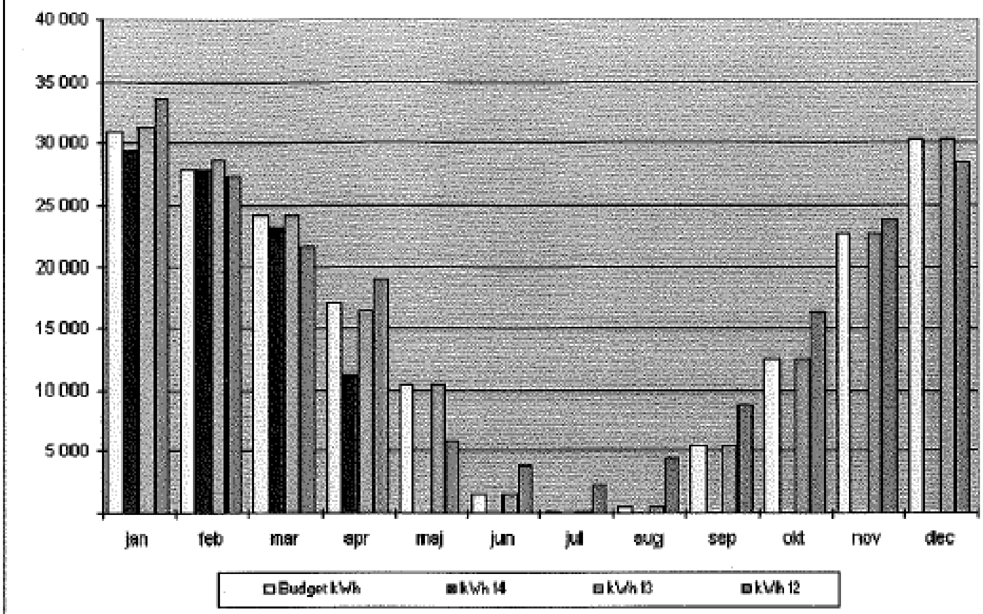
Driftrapport

Klimatkorrigerad värme

Objekt **X0038096** **Högskolan gävle, Balder hus 96**

Intervall120101-141231 Skapad 2014-04-30

BRA: 2035m²



Månad	Budget kWh	kWh 14	kWh 13	kWh 12	kWh/m² 14	kWh/m² 13	kWh/m² 12	Delta t °C 14	Flöde m³ 14
jan	30 920	29 356	31 363	33 559	14,4	15,4	16,5	7,2	3374
feb	27 841	27 951	28 676	27 368	13,7	14,1	13,4	6,2	2803
mar	24 130	23 165	24 148	21 682	11,4	11,9	10,7	5,2	2954
apr	16 984	11 200	16 440	19 040	5,5	8,1	9,4	3,5	2658
maj	10 418	0	10 418	5 818	0,0	5,1	2,9	0,0	0
jun	1 422	0	1 422	3 879	0,0	0,7	1,9	0,0	0
jul	100	0	100	2 200	0,0	0,0	1,1	0,0	0
aug	507	0	507	4 433	0,0	0,2	2,2	0,0	0
sep	5 447	0	5 447	8 753	0,0	2,7	4,3	0,0	0
okt	12 502	0	12 501	16 321	0,0	6,1	8,0	0,0	0
nov	22 723	0	22 723	23 773	0,0	11,2	11,7	0,0	0
dec	30 330	0	30 330	28 496	0,0	14,9	14,0	0,0	0
Summa	183 323	91 672	184 075	195 321	45,0	90,5	96,0		11789

Figure 4.1 The consumption of district heating

Appendix 5. Transmission losses

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	6,6	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

Figure 5.1 The outdoor temperature of Gävle