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Energy audit in Ockelbo healthcare center

Energy use analysis and cost-effective saving measures

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ABSTRACT

As the world is becoming aware of the impact of global warming reducing greenhouse gases emissions presents itself as a fundamental issue in order to avoid the environmental collapse and its negative consequences. One of the key points of this challenge it's to make a responsable use of the energy.

In European countries, buildings sector consumes around the 40% of the total energy use. Thus ensuring energy efficiency becomes a vital issue in order to reduce energy usage and its environmental impact.

This master thesis reports on the energy audit made in Din Hälsocentral. The energy use of the health center is studied through a heat energy balance from September to May (the months when the local district heating network works) with the aim of suggesting cost-effective energy saving measures.The study combines information provided by Din Hälsocentral, data estimated based on the characteristics of the installations and literature review.

The energy balance shows that Din Hälsocentral has a heat energy input 595 MWh. This heat is received by the health center through district heating, solar radiation and internal heat generation while it's lost through transmission losses, mechanical ventilation losses, infiltration heat losses and tap water heating.

To decrease the energy use five saving measures have been suggested: the substitution of the health center windows by more efficient ones, the reduction of the indoor temperature, the replacement of the heat exchangers from the mechanical ventilation system, the installation of an aerothermal heating system in order to replace the district heating supply and the improvement of the roof isolation.

The implementantion of those different measures would report heat energy savings between the 4% and the 63%, having payback periods between 0 and 7 years. However, the viability of application of aerothermal heating system in the health center installations as well as its maintenance costs must be studied more deeply.

Keywords: Energy audit, heat balance, energy use, greenhouse gases emissions, improvement measures, efficiency.

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Abbreviations

Qgained : Health center heat energy input (MWh)

Qlost : Health center heat energy ouput (MWh)

Qdh : Heat supplied by district heating network (MWh)

Qrad : Heat gained by solar radiation (MWh)

Qint : Heat gained by internal generation (MWh)

Qtrans : Transmissions losses trough walls, roof, floor, windows and doors. (MWh)

Qmv : Heat losses for mechanical ventilation. (MWh)

Qnv : Infiltration heat losses (MWh)

Qhtw : Heat supplied for hot tap water. (MWh)

I : Solar radiation per unit area and time for each window orientation (MWh/(m^2*day))

K : Absorption factor of each window time

A_w : Area of each window (m^2)

Cf : Cloudiness factor for each month

d_m : Days of each month (days/month)

U : Value of each kind surface (MWh/(m^2*ºC))

A_s : Total area of each surface (m^2)

q_{degree} : Measure of the temperature difference during the year ((ºC*h)/year)

s : Number of different surfaces of transmission

T_1 : Fresh air temperature (K)

T_2 : Pre heated fresh air temperature (K)

T_3 : Indoor air temperature (K)

$q_{supplyair}$: Volume flow of supply air (m^3/s)

d_a : Density of supply air (kg/m^3)

Cp_a : Specific heat of supply air (kJ/(kg*K))

η : Efficiency value of the heat exchanger

$q_{tap\ water}$: Volume flow of tap water being heated (m^3/s)

d_w : Density of the water heated (kg/m^3)

Cp_w : Specific heat of the water (kJ/(kg*K))

TWout : Temperature of the water going out of the heat exchanger (ºC)

TWin : Temperature of the water going in the heat exchanger (ºC)

w : Number of different windows

1 INTRODUCTION

1.1 Background

Nowadays humanity is facing a big challenge such as climate change. One of the main causes of this problem is the rapidly growth of the world energy use which doesn't only creates environmental problems but also supply difficulties and exhaustion of energy resources [1] .

This energy use is mostly based on fossil fuels which produce big amounts of polluting gases every year being the main cause of the global warming. Actually studies defend that their demand it's projected to increase in the upcoming years [2] due to the population growth and the increasing demand of energy and transport.

In order to improve this situation the EU has set many climate-related action such as EU 20-20-20 action plan which set the objective of reducing a 20% the greenhouse gas emissions, increasing the share of renewable energy to 20% and increasing the energy efficiency 20% [3].

This measures has increased the interest in energy audit over buildings and factories during the last years [4]. In the case of the building sector, it uses 40% of the world energy and emites over 33% of the global greenhouse gas emissions so it presents a perfect oportunity to reduce emissions. [5]

As part of the European Union, Sweden is one of the countries that are leading this change to a more sustainable energy use, making a significant reduction of CO_2 emissions, investing in renewable energies and improving energy management in industries and households.

As a country where the weather is cold and people spend 80% of their time indoors [6] the majority of the energy is used in space heating a sector where a good isolation must be ensured in order to enhance efficiency.

1.2 Object discerption

The place were the energy audit will be made it's called Ockelbo Din Hälsocentral (See Figure 1), it's a healthcare center located in Ockelbo, a little village from the Gävleborg county. The center have an area of 3282 m^2 and it's part of the Sjöängsgården building where there's also a nursing home, the adress of the health center is Sjöängsvägen 26.

Figure 1 – Din Hälsocentral [7]

Ockelbo is located in the east of Sweden, 49 km away from Gävle, the main city of the county and it's 25 km away from the sea, the coordinates of the village are 60°53′N 16°43′E (See Figure 2). Temperatures in Ockelbo are extremely cold in winter and moderated in summer as in the whole county. The average temperature is 5ºC so the heating demand in the buildings of the zone is high.

Figure 2 – Location Ockelbo [8]

1.3 Aims of the thesis

As it's explained before energy efficiency in buildings it's something crucial in order to reduce the energy use, its costs and the damage it causes to the environment. Even though some changes have been made since its contruction, the building where the health center is located was built in the seventies so a lot of room for improvement should be found.

The aims of the study will be to make a heat energy balance of the installations understanding clearly where the health center is losing and gaining heat, providing to the owner information about how the energy is being used. Then several improvement measures for the health center will be proposed in order to improve the energy efficiency with costs effective measures.

1.4 Limitations

During the development of the work some limitations have been found. Due to the coronavirus crisis this work has been entirely made online, specifically from Spain, so it has been impossible to visit the building in Ockelbo and making specifical measurements. In order to solve that problem some values have been estimated according to the characteristics of the building.

In addition, this energy audit focuses only on the use of thermal energy in Din Hälsocentral. This is because most of the energy demanded is used for heating. The use of electricity hasn't been taken into account since its demand is low and it presents few possibilities for improvement.

2 THEORY

2.1 Energy Audit

An energy audit is the study of the energy flow of a system, in this case, the energy flow of a building. As it can be seen in the Figure 3, the energy audit is divided in three main parts: energy survey, analysis and suggested measures. During the energy survey it's recovered as useful data as it's possible about the installations studied such as energy use data, energy invoices etc.

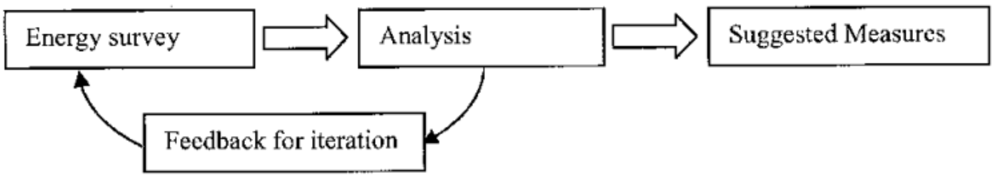

Figure 3 - Steps Energy Audit [9]

Then this data will be analyzed in order to obtain values of the system's energy flow. The stages of analysis and energy survey will be normally related during their achievement as during the work of analysis more information will be required to allocate the energy use of the relevant processes.

By last some improvement measures will be suggested along with information about the investment required, the annual savings obtained in terms of energy use, economical costs and reduction of greenhouse gas emissions.

2.2 Energy Balance

During the analysis process a heat energy balance have been made in order to understand the energy use of the health center. As it's said in the statement of energy conservation: energy can't be created or destroyed, it only can be transformed to another type. Thus, the same energy that go into the health center will go out in order to maintaine the balance in the comfort values required.

In the balance made during the analysis the next factors have been studied. District heating, solar radiation and internal heat generation are processes where the health center gains energy while it will have losses through transmission, hot tap water heating, mechanical ventilation and heat infiltrations.

$$Q_{gained} = Q_{lost} \quad \text{(Equation 1)}$$

Where, *Qgained* : Health center heat energy input (MWh)

Qlost: Health center heat energy ouput (MWh)

$$Q_{int} + Q_{rad} + Q_{dh} = Q_{trans} + Q_{mv} + Q_{nv} + Q_{htw} \quad \text{(Equation 2)}$$

Where, *Qdh* : Heat supplied by district heating network (MWh)

Qrad : Heat gained by solar radiation (MWh)

Qint : Heat gained by internal generation (MWh)

Qtrans : Transmissions losses trough walls, roof, floor, windows and doors. (MWh)

Qmv : Heat losses for mechanical ventilation. (MWh)

Qnv : Infiltration heat losses (MWh)

Qhtw : Heat supplied for hot tap water. (MWh)

2.3 Definition of processes in the energy balance

The explanation of the processes involved in the energy balance and the equations and theories used to calculate their values are shown below.

2.3.1 District Heating

In order to guarantee the thermal comfort in the building during the cold season, for maintaining the balance in a reasonable temperature (around 21ºC) an important amount of heat is supplied.

Depending on the building needs different types of heat supply can be found. In this case of study the heat is supplied by a local district heating network. An example of district heating network can be seen in Figure 4, heat is produced in a central boiler and distributed to the different consumption points using a heated fluid.

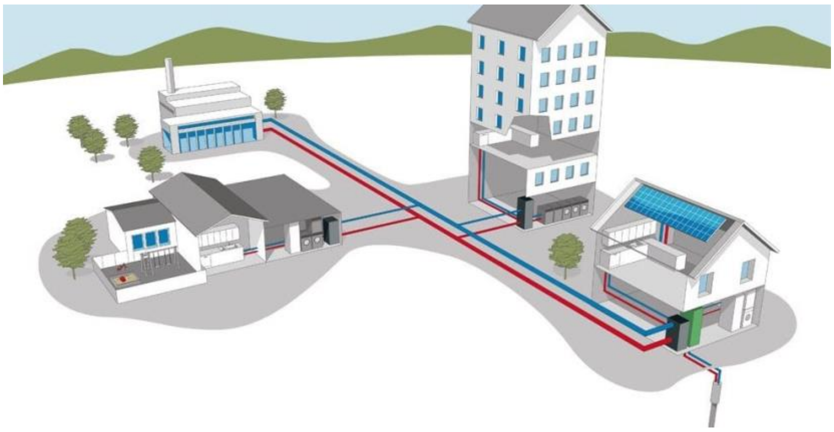

Figure 4 – District Heating Network [10]

Then the heated fluid will arrive to the radiators of the building and part of the heat contained by the fluid will be transferred to the air through the convection process. By last the fluid return through a return pipe to repeat the cycle.

District heating is very common in the nordic countries [11] as it is the main heat supply source. It presents a lot of advantages as it can use a big variety of fuels and can take advantage of the waste heat from industry and power plants, increasing efficiency. It reduces the need of electricity but especially the peaks in demand. As the electricity demand is peaking at the coldest winter days, the district heat networks allow for heat storage. Therefore, district heating has an important role for the electricity system as well.

Even though district heating presents big advantages it also presents some limitations, pipe grid is costly to distribute in rural area with low population density. There must be a reasonable heating demand so that building a heating central is economically profitable.

If we wanted to calculate the district heating supplied to a building we must use the following equation:

2.3.2 Solar Radiation

In adittion to district heating solar radiation will strongly contribute to the heating of the building, this process is developed naturally. The windows of the building are heated by the solar radiation, as the window's surface temperature increase and surpass the air temperature heat is emited inside the building through the convection effect (See Figure 5).

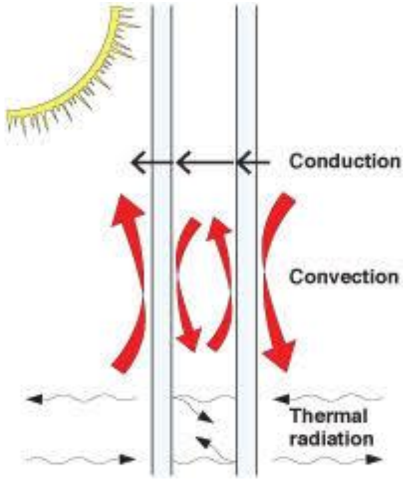

Figure 5 – Convection Effect [12]

This heat also will be kept in the building, in the walls, floor and roof and will be release during a period of time which will depend on the kind of structure that the building is made of. In buildings where the structure is heavy the heat will be kept longer than in buildings with light materials.

This solar radiation will vary with the change of the seasons, the weather and the orientation and location of each window. For example, the solar radiation will have the lowest value during the Winter Solstice while it will have its highest value during the Summer Solstice. The clouds will reduce the solar radiation and the windows will receive more radiation the more south-facing they are. By last the absorption factor of the windows also will be taken into account remaining the following equation.

$$\boldsymbol{Q_{rad}} = \sum_{n=1}^{n=w}(\boldsymbol{I} * \boldsymbol{K} * \boldsymbol{A_w} * \boldsymbol{C_f} * \boldsymbol{d_m}) \quad \text{(Equation 3.)}$$

Where, *Qrad* : Heat gained by solar radiation (MWh)

I : Solar radiation per unit area and time for each window orientation (MWh/(m2*day))

K : Absorption factor of each window time

A_w : Area of each window (m2)

Cf : Cloudiness factor for each month

d_m : Days of each month

w : Number of different windows

2.3.3 Internal Heating Generation

The last source of heat emission considered in this study will be the internal heating generation. Even though its weight in heating the building it's normally much smaller than district heating and solar radiation it's value must be considered.

As solar radiation internal heating generation doesn't have costs, as it's produced naturally by the humans and the electrical equipment. In this case, the impact of the internal generation will be positive as the building studied normally needs to be heated up. In the case of buildings that normally need to be cool down this process will have a negative impact, increasing the cooling demand, the energy use and its costs.

This heat is emitted by the humans through a physiological characteristic named metabolism. Part of the energy that human bodies produce to stay alive is dissipated in form of heat to the environment, this quantity of heat flow varies depending on each person features and what the person is doing. For example a person will dissipate more heat when is doing exercise than when is resting.

As the humans, all the electrical machines tranfer heat to the air during operation even though if it's not the goal of their operation. Depending on their efficiency the machines will emite more or less heat, for example a LED light bulb will emite less heat than an halogen light bulb, thus LED light bulbs have less heat losses and higher efficiency as it can be seen in the Figure 6.

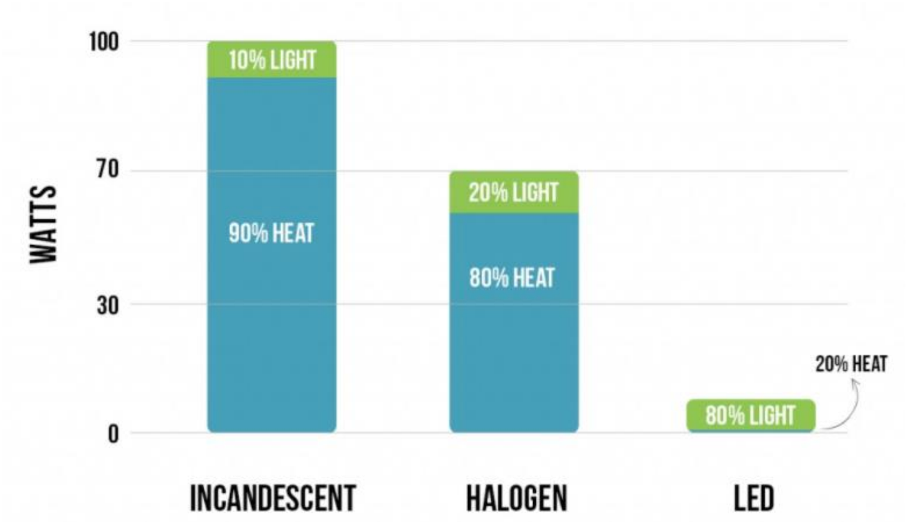

Figure 6 – Heat emited by different kinds of light bulbs [13]

2.3.4 Transmissions Losses

The heat trasnmissions losses are due to the difference of temperatures between indoors and outdoors. This difference enables the heat flow through roof, walls, floor, windows and doors. As it happens with solar radiation, heat is transferred more easily through light surfaces such as windows and doors where we will see that there are more transmission losses per unit of area.

In order to obtain the value of the transmission losses we must know the area and the U-value of each kind of surface in the building, the total amount of heat lost by transmission will be the summation of the product of the area, U-value and degree-hours of each kind of surface found in the health center. The degree-hours only depends on the temperature difference so it will be the same for all the surfaces.

$$Q_{trans} = \sum_{n=1}^{n=s} U * A_s * q_{degree}$$ (Equation 4.)

Where, *Qtrans* : Heat lost by transmission (MWh)

U : Value of each kind surface (MWh/(m^2*ºC))

A_s : Total area of each surface (m^2)

q_{degree} : Measure of the temperature difference during the year ((ºC*h)/year)

s : Number of different surfaces

2.3.5 Mechanical Ventilation Losses

Air quality it's very important in every building design as it's something fundamental for people's health. Research results have demonstrated that air pollution increases mortality and reduces human life expectancy. [14]

In close spaces the air quality decreases constantly due to different factors, in order to solve this problem mechanical ventilation systems are installed to ensure the quality of the environment inside the buildings.

The mechanical ventilation system provides to the building fresh air and extracts the old air using a fan, this process needs energy supply and entails energy losses, as heated air is removed from the building and replaced by fresh air that must be heated again.

In order to improve the energy efficiency heat exchangers are located in strategic points heating up the incoming fresh air with the low-quality air that is being removed from the building as we can see in the Figure 7.

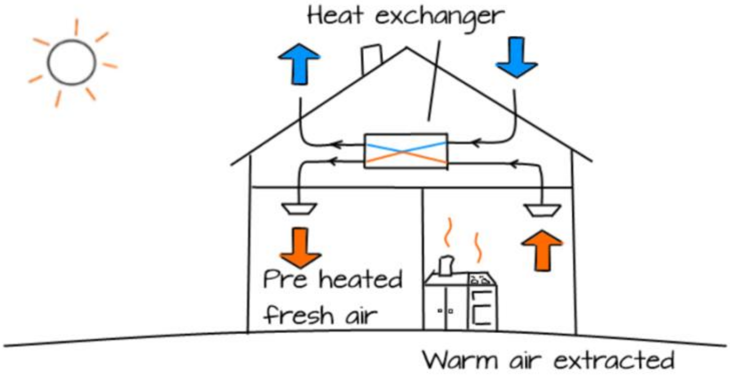

Figure 7 – Heat recovery in mechanical ventilation [15]

The efficiency of the heat exchanger will be defined by the equation that can be seen below, heat exchanger efficiency it's an important fact in order to ensure the efficiency of the system as they avoid the waste of part of the heat removed. In fact, improving heat recovery in mechanical ventilation is one of the most common measures used around the world to reduce energy use in buildings. [16]

$$\eta = \frac{T_2 - T_1}{T_3 - T_1} \quad \text{(Equation 5.)}$$

Where, η : Efficiency value of the heat exchanger

T_1 : Fresh air temperature (K)

T_2 : Pre heated fresh air temperature (K)

T_3 : Indoor air temperature (K)

The energy lost by mechanical ventilation can be calculated with the next equation:

$$Q_{mv} = q_{supplyair} * d_a * Cp_a * (1 - \eta) * (T_3 - T_1) \quad \text{(Equation 6.)}$$

Where, Qmv : Heat lost by mechanical ventilation (MWh)

$q_{supplyair}$: Volume flow of supply air (m^3/s)

d_a : Density of supply air (kg/m^3)

Cp_a : Specific heat of supply air (kJ/(kg*K))

η : Efficiency value of the heat exchanger

T_1 : Fresh air temperature (K)

T_3 : Indoor air temperature (K)

2.3.6 Infiltration Heat Losses

The energy lost through infiltrations is lost in the same way than mechanical ventilation, the heated air goes out of the building and it's replaced by the new fresh air. The difference between this kind of ventilation and the mechanical ventilation is that this process happens without control in a spontaneous way.

This phenomenon is due to the infiltration and exfiltration of air through walls, roofs, windows and doors caused principally because of the natural air currents created by the pressure difference between indoor and outdoor the building. [17]

If we could measure all the air that leaves the building through infiltration we could calculate the losses using the same equation than with the mechanical ventilation losses, assuming than the exchanger efficiency is void.

As making that measurement is impossible we must estimate that the infiltration heat losses as the value that equales the heat supplied to the building with the heat lost in the building through the processes described, remaining the equation below.

$$Q_{nv} = Q_{dh} + Q_{rad} + Q_{int} - Q_{trans} - Q_{mv} - Q_{htw} \quad \text{(Equation 7.)}$$

Where,

Qdh : Heat supplied by district heating network (MWh)

Qrad : Heat gained by solar radiation (MWh)

Qint : Heat gained by internal generation (MWh)

Qtrans : Transmissions losses trough walls, roof, floor, windows and doors (MWh)

Qmv : Heat losses for mechanical ventilation (MWh)

Qnv : Infiltration heat losses (MWh)

Qhtw : Heat supplied for hot tap water. (MWh)

2.3.7 Hot Tap Water Demand

In the health center tap water is heated up by the district heating network. In the energy balance we have put this value on the side of the energy losses as we spend the energy gained with the district heating in heating up the water that then will leave the building through the pipes. The next equation shows how to calculate the amount of energy needed to heat up the tap water:

$$Q_{htw} = q_{tap\ water} * d_w * Cp_w * (TW_{out} - TW_{in}) \quad \text{(Equation 8.)}$$

Where, Q_{htw} : Energy demand for hot tap water (MWh)

$q_{tap\ water}$: Volume flow of tap water being heated (m3/s)

d_w : Density of the water heated (kg/m3)

Cp_w : Specific heat of the water (kJ/(kg*K))

TW_{out} : Temperature of the water going out of the heat exchanger (ºC)

TW_{in} : Temperature of the water going in the heat exchanger (ºC)

3 METHODS

3.1 Energy survey

In order to make the analysis of the energy use in the health center some data have been required during the development of the work. The health center has provided its construction plans and consumption data from the building where is located. The rest of the data required have been provided by the technical supervisor and estimated by the student.

3.2 Analysis of support processes

During the development of the analysis the energy balance have been made. The district heating in the health center is supplied from September to May. Thus the energy input and output from the health center have been calculated for these nine months.

3.2.1 District Heating

The heat energy is supplied to Din Hälsocentral by district heating. No data of the health center district heating demand has been given so an estimation of the district heating demand has been done based on the center features.

3.2.2 Solar Radiation

The next value calculated have been the heat gained by solar radiation, this value depends on the windows area, the type of window, the cloudy factor and the solar intensity. The solar radiation has been calculated for windows of each orientation each month of the year from September to May.

First of all the solar intensity receive by the windows has been calculated. Solar intensity received depends on the orientation of the wall [18] where the windows are located. Using the map, the angles of the health center can be found as Figure 8 shows. In Din Hälsocentral there are four different orientations for the walls, 19 º, 109 º, -71º and -161º. [19]

Then all the windows of the health center have been accounted , using the information from the construction plans found in the appendices 7-10. Some changings have been made since the construction of the building, Google Maps have been used to identify the number of the different types of windows in the health center, more information about these windows is shown in the appendix 12.

Figure 8 – Orientation of Din hälsocentral [19]

In the health center there are 96 windows that have a total area of 195,5 m_2. Table 1 shows the number of windows of each type, their area, their U-value and the material they are made of. To simplify the calculations it has been calcualted an average K factor for all the windows of the building, the K value is 0,8.

Table 1 – Number of windows

WINDOWS INFORMATION					
WINDOWS TYPE	Number	Area (m²)	material	U (W/(m²*K))	TOTAL AREA (m²)
F16A	15	2,09	2-glass normally	3	31,35
F15A	34	2,25	2-glass normally	3	76,5
F10Av	4	1,39	2-glass normally	3	5,56
FP16	1	3,21	3-glass normally	2	3,21
F16B	28	2,09	2-glass normally	3	58,52
F13	2	1,14	2-glass normally	3	2,28
F10Bh	10	1,39	2-glass normally	3	13,9
F16C	2	2,09	2-glass normally	3	4,18
TOTAL	**96**				**195,5**

Then windows have been classified according to their orientation and if they are in the sun or in the shade during the day. The health center plans from appendices 7-10 and Google Maps have been used, the position of the windows (sun/shade) have been estimated according to their orientation and their position with respect to other walls. The table 2 shows the windows found por each orientation and position and their total area.

Table 2 – Windows area for each orientation

WINDOWS ORIENTATION			
Degrees (°)	SUN/SHADE	WINDOWS OF EACH KIND	A (m²)
-71	sun	1-F16A, 14-F15A, 2-F10Bh	36,37
	shade	3-F15A, 3-F16B	13,02
-161	sun		
	shade	6-F15A, 5-F16B, 5-F16A, 4F10Av	39,96
109	sun		
	shade	6-F15A, 1-FP16, 5-F16A, 2-F16C, 12-F16B, 2-F10Bh	59,20
19	sun	4-F16A, 5-F15A, 6-F10Bh, 5-F16B	38,40
	shade	2-F13, 3-F16B	8,55
TOTAL			**195,5**

The cloudy factor indicated varies every month, it has been given by the technical supervisor, the document can be found in the Appendix 3, it indicates the cloudy factor values for each month in Gävle. In the table 3 are shown the values for the months studied in the energy audit.

Table 3 – Cloudy factors

CLOUDY DAYS FACTOR	
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

The solar intensity values have been provided by the technical supervisor, the document shown in the Appendix 2 indicates the solar radiation values for a Latitude of 60ºN. These values are indicated for 16 different orientation angles, each month of the year and if the window are in the sun or in the shade.

As the angles of the document given don't match with the orientation angles of the Din Hälsocentral's windows interpolation method has been applied using Excel. Table 4 shows part of the solar radiation values, in the white cells it's shown the values given in the document (see Appendix 2) and in the blue cells the values interpolated.

Table 4 – Solar Radiation Values

SOLAR RADIATION VALUES						
			VERTICAL SURFACE ORIENTATION (°)			
			150	-180	-161	-150
January	sun	RADIATION (Wh/m²/day)	130	130	130	130
	shade		70	70	70	70
February	sun		370	370	370	370
	shade		340	340	340	340
March	sun		900	730	838	900
	shade		730	710	723	730
April	sun		1990	1350	1755	1990
	shade		1640	1170	1468	1640

3.2.3 Internal Heating Generation

Internal heating generation is the energy emitted by electricity equipment and people that are in the health center. Annual heating is calculated as the sum of heat generated by peopole and electricity equipment.

-Heat emited by people:

The heat emited by people depends on each person characteristics and the kind of activity that are doing. For example, people emite more heat when they are doing intense activities than when they are resting. Thus different activities made in Din Hälsocentral have been classified according to the amount of heat that people emite when they do them.

The table 5 shows thre degrees of activity, the AMR values have been taken form ASHRAE. [20] It's considered that when they are in the health center the pacients are resting, the reception and office workers are considered to make office work and the doctors and nurses are considered to make moderate work. The number of workers have been estimated by the student as no interviews could have been done. The table values are the average amount of people that there are in the health center 9 hours per day, five days per week during the 39 weeks contained from September to May.

Table 5 – Internal generation values [20]

Internal generation values from ASHRAE			
Degree of activity	State of people	AMR(W/person)	Number
Seated at rest	Pacients	100	30
Office work	Reception, office…	130	5
Moderate work	Doctors, nurses…	160	20

-Heat emited by electrical equipment:

Electrical equipment it's something very important in our lives, specially in a health center where people's lifes sometimes depend on electrical machines. These machines and lights emite a considerable amount of heat every year, contributing to the heating of the health center. As Din Hälsocentral couldn't have been visited by the student, no accountments of electrical equipment have been made. Thus an estimated value has been given by the technical supervisor of the annual heat emited by the electrical equipment per square meter annually. The value estimated is 10 kWh/m_2/year.

3.2.4 Transmissions Losses

Transmission losses represent the biggest amount of heat lost by the health center every year. This heat is lost because of the difference of temperatures inside and outside the center. This heat is lost through transmission effect and its values depends on the U-values of the different surfaces that delimit the building, the area of the surface and the q_{degree} value.

In Din Hälsocentral there are 5 different surfaces: floor, walls, roof, windows and doors. Each surface has a different area and a different U-value, the U-value is the transmission factor of each surface. The average U-value of doors and windows has been calculated using the information from the construction plans found in the appendices 12 and 13 and in the table 1. The value from roof, floor and walls have been estimated based in the installation characteristics. The table 6 shows the values obtained.

Table 6 – U-values for the different surfaces

SURFACES U-VALUES	
TYPE	U(W/(m²*K))
Floor	0,47
Walls	0,7
Windows	3
Doors	2,6
Roof	0,47

The qdegree is obtained from the table found in the Appendix 1 and depends on the average annual temperature inside and outside the health center. For the outside temperature it's been used the annual average temperature in Gävle which is 5ºC. It has been obtained from the Appendix 4. Applying a temperature inside the building of 21 ºC the q_{degree} obtained for the whole year is value is 127300 (ºC*h).

3.2.5 Mechanical Ventilation Losses

Mechanical ventilation ensures the air quality of the health center, a basic need for people's health. Mechanical ventilation losses depend on the volume flow of the air extracted and supplied to Din Hälsocentral and on the heat recovery efficiency.

The supplied air couldn't have been measured as there was no enough information in the construction plans and no measurements could have been made by the student. To calculate the mechanical ventilation losses a value of 1,3 L/(s*m2) has been given by the technical supervisor. The heat recovery it's found in the construction plans and have a value of 70%. (See Appendix 14)

The fresh air supplied has an average temperature of 2 ºC (Appendix 4), this fresh air is pre-heated in a heat exchanger where the outcoming air is cooled down. The ventilation system has been estimated to work 12 hours per day during the working days and during the vacations to be shuttle down. That means a total amount of 2340 hours as we arer takeng into account the heat lost during 39 weeks of the year. It has been used a specific heat value for air of 1 kJ/(kg*K) and an air density of 1,2 kg/m3. The table 7 shows the values used for the calculations.

Table 7 – Mechanical ventilation working hours in Din Hälsocentral

MV (L/(s*m²))	1,3
n heat exch (%)	70
time (hours/day)	12
days/week	5
density air (kg/m³)	1,2
Cp air (kJ/(kg*K))	1
HC area (m²)	3282
Tin (℃)	2
Tout (℃)	21
weeks no summer	39
days with vent	195
ventilation hours	2340

3.2.6 Infiltration Heat Losses

The value of air replaced by infiltration can't be measured as this phenomenom happens uncontrollably. Thus this value will be calculated as the differences between all the heat gained by the healthcare center trough the differents processes described before and all the heat lost trough transmission losses, mechanical ventilation and hot tap water demand.

In an energy audit normally this value represents between the 5% and the 15% of the energy lost by the installation, so the result obatained must be between these values if the data recovered and the calculations made are correct.

3.2.7 Hot Tap Water Demand

Other of the basic needs from the health center is the hot tap water demand, in Din Hälsocentral tap water is heated up by district heating, this heat energy is lost then when the hot water leaves the health center through the pipes so hot tap water demand it's considered as a part of the energy losses.

The monthly tap water demand from the Sjöängsgarden building between 2016 to 2018 has been provided by the health center (Appendix 6). Unfortunately other installations apart from the healthcenter are found in this building so the tap water demand has been calculated according to the area of the health center with respect to the total area of the building obtaining a total value for tap water demand of 1229 m^3/s as it can bee seen in the Table 8.

Table 8 – Tap water demand in Din Hälsocentral

Building area (m^2)	10577
Health center area (m^2)	3282
Building-Water Demand (m^3/year)	3.960
HC-Water Demand (m^3/year)	**1229**

This tap water demand includes cold and hot water, so it's been considered that one third of the tap water demanded is heated from 5ºC to 55ºC. With the values of water density of 1000 kg/m^3 and specific heat of water of 4,18 kJ/(kg*K) used we can calculate the hot tap water demand.

4 RESULTS

In this chapter the results obtained in the energy balance are shown.

4.1 District heating

As it has been said before the district heating demand has been estimated based on the age of the building. The value applied has been given by the technical supervisor and as it shows Table 9, it has a value of 150 kWh per square meter per year. As the health center has an area of 3282 m_2 the total amount of district heating demand is 492 MWh.

Table 9 – District Heating demand

DISTRICT HEATING DEMAND	
Estimated demand (kWh/(m²*year))	150
Building area (m²)	3282
TOTAL DISTRICT HEATING DEMAND (MWh)	**492**

4.2 Solar Radiation

Heat gained by solar radiation has been calculated for the windows of each orientation in the shade and in the sun. The next tables indicate the differents amount of heat received through solar radiation.

Table 10 – Heat supply from solar radiation for an orientation of 19º in the sun

19 SUN						
Month	Solar radiation (Wh/m²*day)	Cloudy factor	Window area(m²)	Calc factor	days	Energy (Wh)
January	2488	0,45	38,40	0,8	31	1066360
February	4500	0,49	38,40	0,8	28	1896653
March	5953	0,58	38,40	0,8	31	3287929
April	6385	0,58	38,40	0,8	30	3412783
May	5888	0,63	38,40	0,8	31	3532774
September	5896	0,58	38,40	0,8	30	3151399
October	5202	0,51	38,40	0,8	31	2526524
November	3201	0,42	38,40	0,8	30	1239146
December	1865	0,43	38,40	0,8	31	763850
TOTAL						**20877418**

Table 11 – Heat supply from solar radiation for an orientation of 19º in the shade

19 SHADE						
Month	Solar radiation (Wh/m²*day)	Cloudy factor	Window area (m²)	Calc factor	days	Energy (Wh)
January	187	0,45	8,55	0,78	31	17398
February	3710	0,49	8,55	0,78	28	338849
March	5539	0,58	8,55	0,78	31	663078
April	6244	0,58	8,55	0,78	30	723358
May	5843	0,63	8,55	0,78	31	759724
September	5763	0,58	8,55	0,78	30	667637
October	4503	0,51	8,55	0,78	31	473936
November	1671	0,42	8,55	0,78	30	140145
December	124	0,43	8,55	0,78	31	10975
TOTAL						**3795101**

Table 12 – Heat supply from solar radiation for an orientation of (-71º) in the sun

(-71) SUN						
Month	Solar radiation (Wh/m²*day)	Cloudy factor	Window area (m²)	Calc factor	days	Energy (Wh)
January	1114	0,45	36,37	0,8	31	452025
February	2405	0,49	36,37	0,8	28	960069
March	3981	0,58	36,37	0,8	31	2082645
April	5447	0,58	36,37	0,8	30	2757486
May	5959	0,63	36,37	0,8	31	3386361
September	4343	0,58	36,37	0,8	30	2198901
October	3035	0,51	36,37	0,8	31	1395970
November	1518	0,42	36,37	0,8	30	556391
December	800	0,43	36,37	0,8	31	310150
TOTAL						**14099999**

Table 13 – Heat supply from solar radiation for an orientation of (-71º) in the shade

(-71)SHADE						
Month	Solar radiation (Wh/m²*day)	Cloudy factor	Window area (m²)	Calc factor	days	Energy (Wh)
January	122	0,45	13,02	0,8	31	17679
February	1796	0,49	13,02	0,8	28	256710
March	3385	0,58	13,02	0,8	31	633879
April	4980	0,58	13,02	0,8	30	902567
May	5580	0,63	13,02	0,8	31	1135041
September	4042	0,58	13,02	0,8	30	732626
October	2355	0,51	13,02	0,8	31	387814
November	737	0,42	13,02	0,8	30	96725
December	79	0,43	13,02	0,8	31	10969
TOTAL						**4174010**

Table 14 – Heat supply from solar radiation for an orientation of 109º in the shade

(-161) SHADE						
Month	Solar radiation (Wh/m²*day)	Cloudy factor	Window area (m²)	Calc factor	days	Energy (Wh)
January	70	0,45	39,96	0,8	31	31217
February	340	0,49	39,96	0,8	28	149124
March	730	0,58	39,96	0,8	31	419593
April	1640	0,58	39,96	0,8	30	912239
May	2570	0,63	39,96	0,8	31	1604541
September	1070	0,58	39,96	0,8	30	595180
October	480	0,51	39,96	0,8	31	242599
November	160	0,42	39,96	0,8	30	64447
December	40	0,43	39,96	0,8	31	17045
TOTAL						**4035986**

Table 15 – Heat supply from solar radiation for an orientation of (-161º) in the shade

109 SHADE						
Month	Solar radiation (Wh/m²*day)	Cloudy factor	Window area (m²)	Calc factor	days	Energy (Wh)
January	77	0,45	59,20	0,8	31	51092
February	631	0,49	59,20	0,8	28	410011
March	1719	0,58	59,20	0,8	31	1463785
April	3327	0,58	59,20	0,8	30	2741661
August	3720	0,59	59,20	0,8	31	3222606
September	2396	0,58	59,20	0,8	30	1974183
October	962	0,51	59,20	0,8	31	720059
November	211	0,42	59,20	0,8	30	126110
December	54	0,43	59,20	0,8	31	33880
TOTAL						**10743387**

The table 16 shows the results of the heat input through solar radiation in the different walls of the health center. The total amount of heat gained is 58 MWh, as it can be seen most of the heat is gained by the windows orientated in an angle of 19º and (-71º) located in the sun, these windows receive the 60% of the solar radiation heat.

Table 16 – Heat gained by solar radiation

HEAT GAINED		
ORIENTATION (°)	HEAT (MWh)	%
19-SUN	21	36
19-SHADE	4	7
(-71)-SUN	14	24
(-71)-SHADE	4	7
(-161)-SHADE	4	7
109-SHADE	11	19
TOTAL	**58**	**100**

4.3 Internal heat generation

As it's explained in the methos internal heating generation is calculated in two parts: Heat emitted by people and heat emitted by electrical equipment, this last part includes the heat emitted by lightning.

-Heat emitted by people:

The total amount of heat emitted by people it's calculated with the data shown in Table 17:

Table 17 – Heat emitted by people

Internal generation values from ASHRAE					
Degree of activity	State of people	AMR(W/person)	Number	Working (hours/year)	Heat generated (MWh)
Seated at rest	Pacients	100	30	1755	5
Office work	Reception, office...	130	5		1
Moderate work	Doctors, nurses...	160	20		6
TOTAL					12

The total amount of heat generated by people is 12 MWh of which 5 MWh are emitted by the pacients while 1 MWh and 6 MWh are emitted by the office workers and health personnel respectively.

-Heat emitted by electrical equipment:

About the electricity equipment it has been estimated a value of 10 kWh of heat emitted per square meter per year, that means a total amount of heat of 33 MWh emitted annually.

Table 18 – Electrical equipment heating generation in Din Hälsocentral

Building area (m^2)	3282
L&M (kWh/m^2)	10
E (MWh/year)	33

The sum of these two values gives us a total value of 45 MWh of internal heating generation per year.

Table 19 – Internal heating generation in Din Hälsocentral

INTERNAL HEATING GENERATION		
PEOPLE HEATING (MWh/year)	12	27
MACHINERY HEATING (MWh/year)	33	73
TOTAL HEATING (MWh/year)	**45**	100

4.4 Hot tap water

According to the estimation explained in the methods chapter the health center has a tap water demand of 1229 m^3 per year. One third of this water is heated up from 5ºC to 55ºC. Applying the data found in the table 20 and using the Equation 9 it's obtained a total value for heat losses of 24 MWh per year.

Table 20 – Energy lost through tap water heating in Din Hälsocentral

TAP WATER HEATING DEMAND (MWh)	
Cp water (kJ/(kg*K))	4,18
Vt water (m^3/year)	1.229
V warmwater (m^3/year)	410
Tin (℃)	5
Tout (℃)	55
density water (kg/m^3)	1000
Qwarm water(MWh/year)	**24**

4.5 Mechanical ventilation losses

Using the data seen in the Table 21 and applying the Equation 6 it's been obtained that every second a mass flow of air of 5 kg/s leaves the health center, 30% of the heat contained in this air is losed. That means a power lose of 29 kW while the mechanical ventilation is working, that suppose a total energy losses of 68 MWh per year.

Table 21 – Energy lost through mechanical ventilation in Din Hälsocentral

MV (L/(s*m^2))	1,3
n heat exch (%)	70
density air (kg/m^3)	1,2
Cp air (kJ/(kg*K))	1
HC area (m^2)	3282
Tin (℃)	2
Tout (℃)	21
ventilation (hours/year)	2340
MV volume flow (L/s)	4267
MV mass flow (kg/s)	5
Plossed (kW)	29
Energy lost (MWh/year)	**68**

4.6 Transmission losses

Table 22 shows the annual heat energy losses from walls, doors, roof, floor and windows through transmission. The values shown in the table have been applied to the Equation 4 obtaining the next results.

Table 22 – Transmission losses in Din Hälsocentral

TANSMISSION LOSSES					
TYPE	AREA (m^2)	U ($W/(m^2*K)$)	q_{degree} (℃*h)	Qtrans (MWh)	%
Floor	2223	0,47	127300	133	29
Walls	1166	0,7		104	23
Windows	196	3		75	16
Doors	48	2,6		16	3
Roof	2223	0,47		133	29
TOTAL				**461**	**100**

The total amount of heat energy lost through trasmission is 461 MWh, as it shows figure 9, the biggest part of heat is lost by the floor and roof followed by walls, windows and doors.

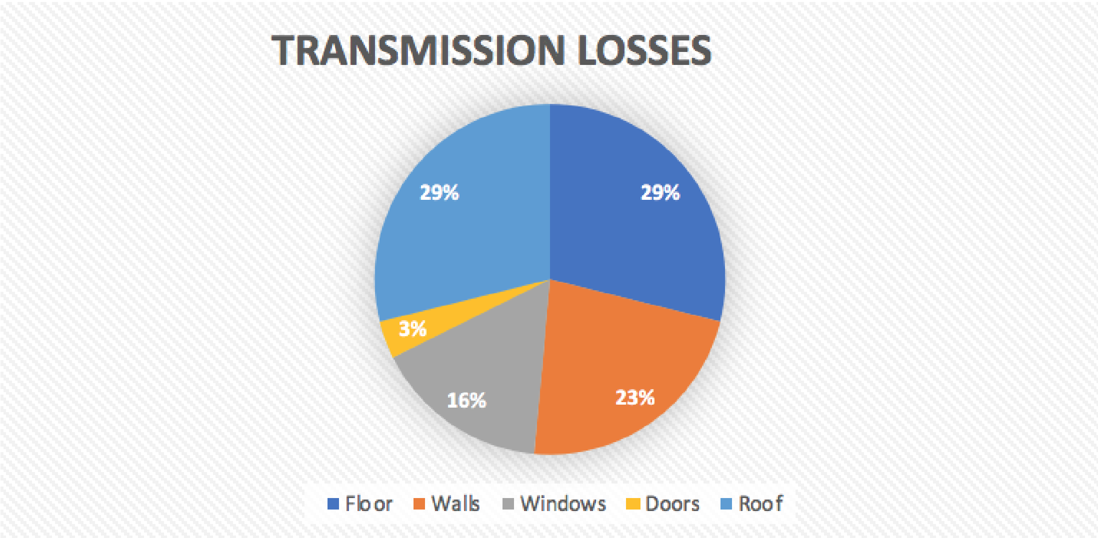

Figure 9 – Transmission losses in each part of the building

4.7 Infiltration heat losses

The heat lost through infiltration is calculated using the Equation 7. After introducing the values from the rest of the processes is obtained that the amount of heat lost through heat infiltration is 42 MWh/year. This represents the 7% of the annual heat energy losses in the health center so the heat infiltration losses fit with the predicted range of values between 5% and 15%.

4.8 Energy balance

In the picture below the results of the energy balance can be seen, the heat energy input and output from September to May is of 595 MWh.

Table 23 – Energy Balance of Din Hälsocentral

ENERGY BALANCE					
Qgained(MWh)		%	Qlost(MWh)		%
District heating	492	83	Transmission losses	461	78
Solar radiation	58	10	Infiltration heat losses	42	7
Internal gener	45	7	Mechanical ventilation losses	68	11
			Hot tap water	24	4
TOTAL	**595**	100	**TOTAL**	**595**	100

The biggest amount of heat energy input is supplied through district heating which represents the 83% of all the heat gained by the health center. The center receives the 10% of the heat by solar radiation and the 7% by internal heat generation.

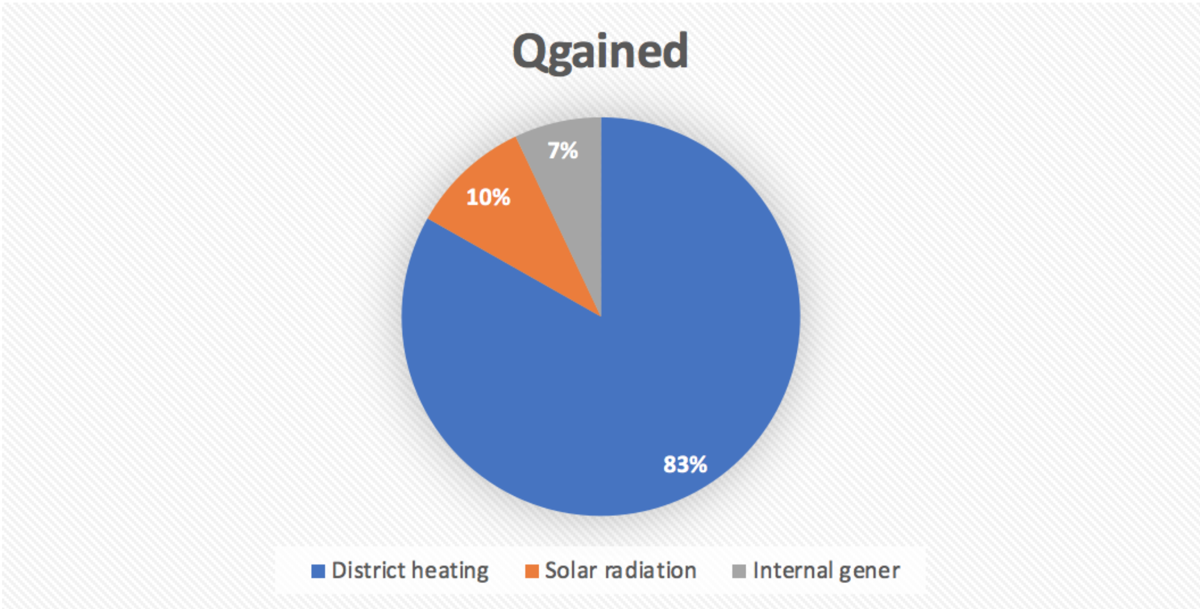

Figure 10 – Heat energy input in Din hälsocentral

The main part of the energy losses are due to the transmission factor which represents the 78% of the heat lost while mechanical ventilation, infiltration heat losses and hot tap water cause the 11%, 7% and 4% of the energy losses respectively.

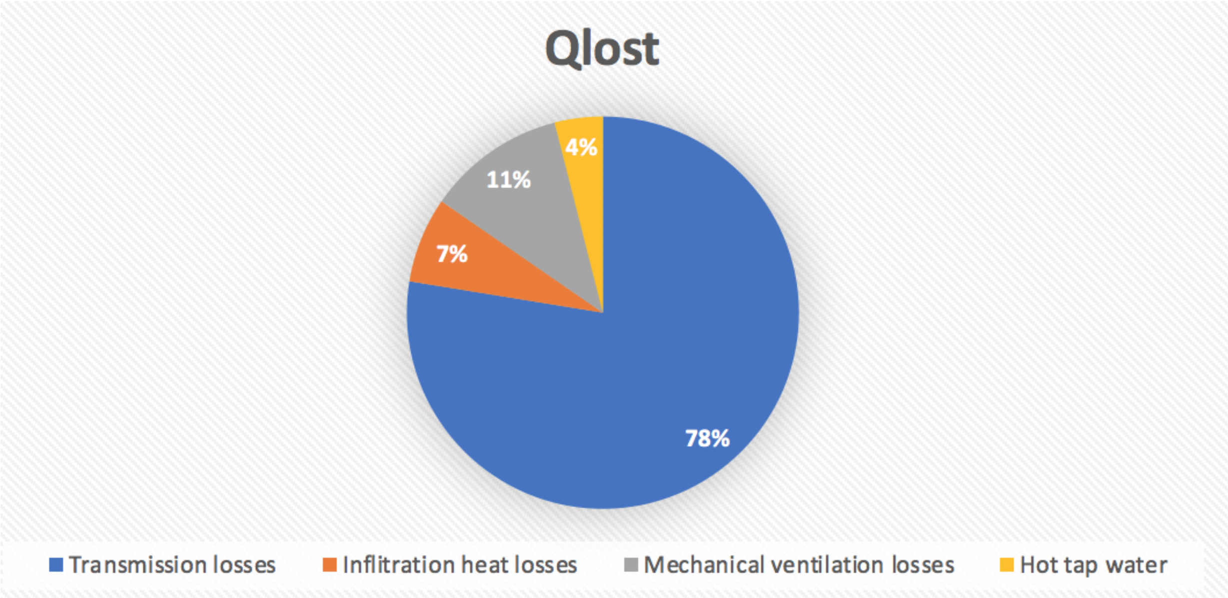

Figure 11 – Heat energy output in Din hälsocentral

5 SUGGESTED MEASURES

The energy use characteristics of the health center are described in the energy balance. In this chapter different improvement measures are suggested. The investment needed for their application along with their impact in the energy consumption, energy costs and CO_2 emissions are detailed.

The impact of the measures described have been calculated taking into account that:

→ The price of the local district heating network energy is 1 SEK/kWh.

→ The price of the electricity is 1,776 SEK/kWh.

→ The CO_2 emissions are 14,7 grams/kWh.

5.1 Window substitution

The first measure proposed is to replace all the windows of the health center by more efficient ones. Most of the heat losses in the building are due to transmission, windows represent an importante percentage of these losses (16%) and their replacement doesn't require major reforms in the building as it would happen with the replacement, or isolation improvement of walls, floor or roof.

In addition to reducing transmission losses, replacing windows will also reduce heat received by solar radiation. Therefore, the energy savings obtained will be calculated as the difference between the reduction of transmission losses and the reduction of the heat received by solar radiation.

The windows selected for the replacement are sold by the Swedish company Toolbockx (See Appendix 11). Two kind of PVC windows are proposed for the substitution, the first type of windows have 3 glass panels each and present a U-value of 1 W/(m^2*K). The second type of windows have 2 glass panels and a U-value of 1,3 W/(m^2*K). Changing the windows type also affects to the K factor that will be reduced in both types of windows to the value of 0,7 something which influences in the heat gained by the building trough solar radiation.

The investment required for this measure is of 314000 SEK for the 3 glass panel windows and 254000 SEK for the 2 glass panel windows for replacing all the windows of the health center. This price have been calculated choosing an standard window, with an average area of 2,04 m^2. Then the price for all the windows has been calculated. Also it's been added the cost of the window installation, estimating a work price of 1000 SEK for each window.

As it can be seen in the Table 24 the window substitution will supose annual savings of 43 MWh for the windows of 3 glass panels and savings of 35 MWh for the window of 2 glass panels. The installation of 3 glass panels windows will reduce the annual heating costs in 42600 SEK and would have a payback period of 7 years while the installation of 2 glass panels windows will reduce the costs in 35200 SEK and would have a payback period of 7 years.

Table 24 – Substitution of windows in Din Hälsocentral

WINDOW SUBSTITUTION 3-GLASS		WINDOW SUBSTITUTION-2GLASS	
SR BEFORE (MWh/year)	58	SR BEFORE (MWh/year)	58
SR AFTER (MWh/year)	51	SR AFTER (MWh/year)	50
TRLOS BEFORE (MWh/year)	461	TRLOS BEFORE (MWh/year)	461
TRLOSAFTER (MWh/year)	411	TRLOSAFTER (MWh/year)	418
TOTAL SAVINGS (MWh/year)	43	TOTAL SAVINGS (MWh/year)	35
MONEY SAVINGS (kSEK/year)	42,6	MONEY SAVINGS (kSEK/year)	35,2
REDUCTION OF EMISSIONS (kgCO_2/year)	627	REDUCTION OF EMISSIONS (kgCO_2/year)	517

5.2 Reducing indoors temperature

The next measure proposes to reduce the temperature inside the building. The temperature of the center is 21ºC, reducing it doesn't need any investment and it would decrease mechanical ventilation and transmission losses, reducing the energy use of the health center.

In the case of mecanical ventilation, the reduction of energy is due to the fact that the difference between indoors and outdoors temperatures is lower so the energy lost through the air replacement will be lower. The transmission losses decrease because of the new q_{degree} factor which will be lower as as the temperature is reduced.

To calculate the energy savings produced by this measure, the reduction of energy losses through mechanical ventilation and transmission are added. Loss reduction is obtained by calculating the difference in energy lost with the current temperature and with the temperature of the proposed saving measure.

Table 25 – Reduction of temperature in Din Hälsocentral

CHANGING TEMPERATURE	
TR LO BEFORE (MWh/year)	461
TR LO AFTER 20℃ (MWh/year)	439
TR LO AFTER 19℃ (MWh/year)	417
MV BEFORE (MWh/year)	68
MV AFTER 20℃ (MWh/year)	65
MV AFTER 19℃ (MWh/year)	61
SAVINGS 20℃ (MWh/year)	25
SAVINGS 19℃ (MWh/year)	51
MONEY SAVINGS 20℃ (kSEK/year)	25,3
MONEY SAVINGS 19℃ (kSEK/year)	51,0
EMIS REDUC 20℃ (kgCO_2/year)	372
EMIS REDUC 19℃ (kgCO_2/year)	749

Thus, reducing the temperature setting to 20ºC, the energy consumption reduction will be of 25 MWh with annual savings of 25300 SEK and the CO_2 emissions reduction will be of 372 kg per year while reducing the temperature to 19ºC will decrease the energy consumption in 51 MWh, the energy costs to 51000 SEK and the CO_2 emissions in 749 kg each year.

As the measure doesn't require investments the payback period will be zero. As a disadvantage the thermal comfort demand could not be satisfied with the new temperature so after the implementation of the measure is recommendable to prove that people from the health center is comfortable with it.

5.3 Exchanger substitution

The third measure proposed it's to renovate the heat exchangers used for the mechanical ventilation. The current heat exchanger is a rotative exchanger that recovers the 70% of the heat that would be lost with the air renovation.

The two heat exchangers chosen for the replacement are counterflow exchangers with a efficiency of 84%, that means losing only the 16% of the air heat that would be lost by ventilation in place of the current 30%.

Table 26 – Heat recovery substitution in Din Hälsocentral

EXCHANGER SUBSTITUTION	
EFFICIENCY BEFORE (%)	70
EFFICIENCY AFTER (%)	84
MV BEFORE (MWh/year)	68
MV AFTER (MWh/year)	36
TOTAL SAVINGS (MWh/year)	32
MONEY SAVINGS (kSEK/year)	32,1
EMIS REDUCT (kgCO_2/year)	472

With this substitution the mechanical ventilation heat losses will change from 68 MWh to 36 MWh which means a total reduction of 32 MWh per year in the heat energy demand producing money savings of 32100 SEK and an CO_2 emissions reduction of 472 kg each year.

Figure 12 – Heat exchanger model [21]

The heat exchangers are sold by the Spanish company Bikat [21], the model chosen is RCE-18N-AE (See Figure 12). Each heat exchanger has a power of 16,5 kW and a price of 7600 €. The price of both heat exchanger along with the workforce it's been estimated in 173000 SEK so that the investment would be recovered in 5 years.

Table 27 – Exchanger substitution costs

INVESTMENT	
PRICE/UNIT (k€)	7,6
UNITS	2
WORK PRICE (k€)	1
TOTAL (kSEK)	16,3
€ to SEK	10,6
TOTAL (kSEK)	173

5.4 Aerothermal heat pump

Aerothermal heat pump extracts the energy contained in the air for different processes such as space heating, air conditioning or water heating. Even though it consumes electricity it's considered a renewable energy in Europe, where is playing an imporant role in the EU climate-related action plans. [22]

This energy extracted from the air trough an evaporator it's transferred inside the building by a heat pump. This system can be reversible, that means that the heat from the building can also be transferred outside in order to cool down the building.

Using the air energy allows this system to work with a high coefficient of performance, which depends on the climatic zone and is normally higher than 3 [23]. That means that in the case that the system has a COP value of 3, the system will need 1 kWh of electricity in order to transfer 3 kWh of heat to the space heated up. This performance decreases when the temperatures are too low or too high.

Table 28 – Aerothermal heating pump installation in Din Hälsocentral

AEROTHERMAL HEATING SYSTEM	
INVESTMENT COSTS (kSEK)	581
DISTRICT HEATING DEMAND (MWh/year)	492
DISTRICT HEATING COSTS (kSEK/year)	492,3
ELECTRICITY DEMAND HEAT PUMPS (MWh/year)	120
ELECTRICITY COSTS (kSEK/year)	213,2
ENERGY SAVINGS (MWh/year)	372
SAVINGS (kSEK/year)	279,1
EMISIONS REDUCTION (kgCO_2/year)	5472

This improvement measure propose to use an aerothermal heat pump to heat up the health center and the tap water. In this case, district heating would be replaced by the aerothermal heating system. The new system selected must supply a heat energy amount of 492 MWh every year.

The aerothermal heat pumps selected are produced by Toshiba , a Japanese manufacture. The system would have 4 heating pumps of 23 kW each and a COP of 4,1. The annual heating demand is of 492 MWh that costs 492300 SEK every year as district heating local price is 1 SEK/kWh. With the aerothermal heat pump the electrical consumption would be of 120 MWh/year that will cost 213200 SEK every year as the Swedish electricity price is 1,776 SEK/kWh.

Table 29 – Heat pump installation costs

INVESTMENT COSTS	
HEATING POWER (kW)	22,6
COP	4,1
ELECTRICITY DEMAND (kW)	5,5
PRICE/UNIT (k€)	11,2
UNITS	4
EXTRA (k€)	10
TOTAL (k€)	54,7
€ TO SEK	10,6
TOTAL (kSEK)	581

For the installation four heat pumps with model *Estía Alfa Heat Pump* [24] are installed, each pump has a cost of 11200 €, and an extra price of 10000 € has been estimated for workforce and other devices required for the installation of the system. That means that the total price of the measure is 581000 SEK, and the payback period would be of 2 years.

5.5 Improvement of the roof isolation

The last measure proposes to improve the isolation of the roof, reducing its U-value from 0,47 W/(m_2*K) to 0,28 W/(m_2*K) which would reduce the tranmission losses through this surface. For it, a new cover for the roof has been chosen. The model selected is named *Alphatoit* and it is manufactured by the Spanish company Isover [25]. As it shows the Table 30 the investment costs required for this measure are 377000 SEK.

Table 30 – Roof isolation improvement costs

INVESTMENT COSTS	
Area roof (m^2)	2223
Area (m^2/pallet)	1,2
Number of pallets	1853
Price pallets (€/unit)	19,2
Workforce (k€)	5
TOTAL (k€)	35,6
€ to SEK	10,6
TOTAL (kSEK)	377

In order to obtain the annual energy savings the difference between the transmission losses before and after the improvement of the roof have been calculated. In the table 31 shows the results obtained. The improvement of the insulation would decrease the annual energy use in 54 MWh, reducing the annual energy costs in 53800 SEK and the annual CO_2 emissions in 791 kg year so the investment would recover in 7 years.

Table 31 – Savings from improving roof isolation

ROOF IMPROVEMENT	
INVESTMENT COSTS (kSEK)	377
TL BEFORE (MWh/year)	461
TL AFTER (MWh/year)	407
ENERGY SAVINGS (MWh/year)	54
MONEY SAVINGS (kSEK/year)	53,8
EMISIONS REDUCTION (kgCO_2/year)	791

6 DISCUSSION

6.1 Implementation of measures

In the table below it’s seen the impact of the different measures proposed. They are ordered according to their payback periods which shows how fast the investment made it’s going to be recovered. It’s recommended to implement first the measures with the lowest payback period unless the investment required it’s too high for the owner.

Table 32 – Payback periods of the measures

Suggested measures	Investment (SEK)	Payback period (years)
CHANGE TEMP TO 20℃	0	0
CHANGE TEMP TO 19℃	0	0
AEROTHERMIA	581000	2
HEAT EXCHANGER	173000	5
ROOF ISOLATION	377000	7
WINDOW SUBS 2 GLASS	254000	7
WINDOW SUBS 3 GLASS	314000	7

The measure with the lowest payback period is the reduction of the air temperature which doesn’t require any investment even though this measure must be applied taking into account that it doesn’t affect to the health center pacients and workers needs.

Aerothermal heat pump presents the highest saving potential of all the suggested measures and a very low payback period of 2 years which makes its application totally recomendable even though its high investment costs can make this measure impementation less affordable.

In case the investment required it’s unaffordable, it could be an option to apply this measure partially, intalling less aerothermal heating power, that would mean mixing aerothermal and district heating supply, reducing the savings but also the investment costs.

If the measure is wanted to be fully implemented, a professional should verify the viability of completely replacing the district heating supply with an aerothermal heating system in the health center. Of course, this measure could only be applied when the contract with the district heating network ends.

Heat exchanger and windows substitution require investments of similar amounts but heat exchanger substitution must be made first as its payback period is of 5 years versus the 7 years required to recovered the investment made by window substitution. On the other hand the window substitution presents the advantage that can be applied by stages very easily.

By last the roof isolation presents a payback period of 7 years, the same period than the windows substituion measure but it requires higher investment costs.

6.2 Restriction

An energy balance and improvement measures are presented in this study. During the development of this investigation some limitations have been found.

As it's said before, due to external facts this energy audit has been held totally online so no measures could have been done by the student in the health center.In order to solve this problem the next estimation have been done.

The district heating demand of the health center has been estimated at 150 kWh/m^2/year. The values of the tap water demand are for the Sjöängsgården building, so the tap demand for the health center has been calculated based on the area of the center with respect to the entire building.

The mechanical ventilation demand has been estimated with a value of 1,3 L/s/m^2, the indoors temperature as 21ºC and the floor, roof, walls and doors isolation have been estimated according to the time when the building was constructed. Also the electrical equipment heat generation in the health center has been provided by the technical supervisor, with a value of 10 kWh/m^2/year.

About the improvement measures, the prices used for the heat exchangers, aerothermal heat pumps and roof isolation are prices from the Spanish market. As this prices are from large companys with sells in Sweden the prices shouldn't vary excessively. Workforce it's also estimated, it's been used high values in ordere to obtain as realistic values as possible.

7 CONCLUSIONS

7.1 Study results

This master thesis reports on the energy balance made in the health center Din Hälsocentral and concludes on four measures to reduce energy use and improve efficiency in a cost-effective manner. Those different measures would reduce annual heat energy demand between 4% and 63% with and investment that could be recovered between 0 and 7 years as it can be seen in Table 33.

Table 33 – Energy saving measures

Suggested measures	Investment (kSEK)	Energy savings (MWh/year)	Payback period (years)	Heat energy use reduction (%)
CHANGE TEMP TO 20℃	0	25	0	4
CHANGE TEMP TO 19℃	0	51	0	9
AEROTHERMIA	581	372	2	63
HEAT EXCHANGER	173	32	5	5
ROOF ISOLATION	377	54	7	9
WINDOW SUBS 2 GLASS	254	35	7	6
WINDOW SUBS 3 GLASS	314	43	7	7

In the heat energy balance made the energy input and ouput of the health center has been obtained. Every year, from September to May, this health center receives 595 MWh, out of which 83% is district heating supply, 10% is solar radiation and 7% is internal heating generation. This heat received is lost through transmission losses(78%), mechanical ventilation(11%), infiltration heat losses(7%), and hot tap water demand(4%).

These results define a health center with a high energy use rate of 181 kWh/m2/year which presents big margin of improvement as in new residential building in Europe, heating load is 60-100 kWh/m2/year and 15 kWh/m2/year for the passive hose. [26]

First of all, lowering the temperature inside the health center would reduce the energy use at no cost and with little impact on pacient comfort. In case the health center sets a target temperature one degree below the current 21ºC, energy use would be reduce by 25 MWh. (4%). This reduction would account to 9% if the temperature was lowered by 2ºC.

A second measures consists on installing a aerothermal heating pump and cutting off the dependence on the district heating supply. Purchasing and setting this new equipment would cost 581000 SEKs with expected energy savings of 372 MWh/year, the 63 % of the annual heat energy demand.

The third measure suggests to replace heat exchangers used to reduce the energy losses produced by mechanical ventilation. The new heat exchangers and their installations require an investment of 173000 SEK and would reduce the thermal energy use by 5%.

Replacing the current health center windows with more efficient ones would produce energy savings of 35 MWh (6%) if the windows selected have 2 glass panels and 43 MWh (7%) if the windows selected have 3 glass panels. The investment required is 254000 SEK for the 2 glass panels windows and 314000 SEK for the 3 glass panels windows.

By last, improving the roof isolation would lower the annual transmision losses in 54 MWh (9%). To apply this measure an investment of 377000 SEK is required.

7.2 Outlook

In case the measures suggested in this report are wanted to be applied some recommendations must be taken into account by the health center.

The reduction of Din Hälsocentral temperature must be made taking into account the thermal comfort of the workers and pacients, specially the most vulnerable pacients as temperature lowering could put their health at risk.

The viability of application of aerothermal heating system in the health center installations as well as its maintenance costs must be studied more deeply. Enough information has been lacking to study these two topics in the thesis.

7.3 Perspectives

The measures suggested in this study enable the health center to reduce the energy use and to increase its energy efficiency.

However, in a broader perspective, it also empowers workers of Din Hälsocentral as they are being resposable of their own actions making a responable use of the energy, having a positive impact on the climate change without depending on the actions of governments and companies.

This positive impact on the climate change doesn’t affect only to the health center workers and pacients but also to the planet and their population, helping to recover the balance between the nature and the human action.

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APPENDIX

Appendix 1 – q_{degree} value based on outside and inside temperatures

Temperature		Out door average temperature										
		-2°C	-1 °C	0 °C	1 °C	2 °C	3 °C	4 °C	5 °C	6 °C	7 °C	8 °C
In door average temperature	5 °C	80750	73500	66500	59700	53200	47000	41000	35200	29700	24500	19500
	6 °C	87000	79500	72300	65300	58500	52000	45800	39700	33900	28400	23000
	7 °C	93500	85800	78300	71100	64100	57400	50800	44500	38400	32600	26900
	8 °C	100200	92200	84600	77200	69900	62900	56200	49600	43200	37100	31100
	9 °C	107200	99000	91200	83500	76000	68800	61800	54900	48200	42000	35500
	10 °C	114500	106000	98000	90100	82400	74900	67700	60600	53600	47100	40300
	11 °C	121900	113300	105100	97000	89000	81400	73900	66500	59300	52500	45400
	12 °C	129500	120700	112300	104000	95800	88000	80200	72600	65100	58100	50700
	13 °C	137000	128100	119500	111000	102500	94500	86500	78700	70900	63600	55900
	14 °C	144600	135400	126700	118000	109300	101100	92900	84700	76700	69200	61200
	15 °C	152100	142800	133900	125000	116100	107600	99200	90800	82500	74800	66500
	16 °C	159700	150200	141100	132100	122900	114200	105500	96900	88300	80400	71800
	17 °C	167200	157600	148300	139100	129600	120700	111800	103000	94100	85900	77000
	18 °C	174800	155000	155500	146100	136400	127300	118100	109100	99900	91500	82300
	19 °C	182300	172300	162700	153100	143200	133800	124500	115200	105700	97100	87600
	20 °C	189900	179700	169900	160100	149900	140400	130800	121300	111500	102600	92800
	21 °C	197400	187100	177100	167100	156700	146900	137100	127300	117300	108200	98100
	22 °C	205000	194500	184300	174100	163500	153500	143400	133400	123100	113800	103400
	23 °C	212500	201900	191500	181100	170200	160000	149700	139500	128900	119300	108600
	24 °C	220100	209200	198700	188100	177000	166600	156100	145600	134700	124900	113900
	25 °C	227600	216600	205900	195100	183800	173100	16400	151700	140500	130500	119200

Appendix 2 – Solar Radiation values in a latitude of 60ºN

Månad	Horisont-avskärm-ning,°	Vertikala ytans orientering N			E			S			W		
		−180	−150	−120	−90	−60	−30	0	30	60	90	120	150
Latitud 60 ° N													
Januari	0	130	130	160	550	1440	2360	2710.	2360	1440	550	160	130
	10	70	70	70	90	140	180	200	180	140	90	70	70
Februari	0	370	370	640	1550	2900	4280	4880	4280	2900	1550	640	370
	10	340	340	400	1030	2240	3530	4020	3530	2240	1030	400	340
Mars	0	730	900	1720	3050	4520	5740	6320	5740	4520	3050	1720	900
	10	710	730	1290	2460	3920	5290	5970	5290	3920	2460	1290	730
April	0	1350	1990	3320	4750	5850	6370	6410	6370	5850	4750	3320	1990
	10	1170	1640	2810	4220	5420	6160	6390	6160	5420	4220	2810	1640
Maj	0	2350	3050	4460	5630	6150	5980	5730	5980	6150	5630	4460	3050
	10	1840	2570	3910	5130	5840	5920	5710	5920	5840	5130	3910	2570
Juni	0	3210	3870	5230	6190	6350	5820	5460	5820	6350	6190	5230	3870
	10	2420	3180	4570	5650	6070	5790	5430	5790	6070	5650	4570	3180
Juli	0	2830	3510	4910	5960	6280	5820	5580	5890	6280	5960	4910	3510
	10	2270	3020	4410	5540	6050	5870	5560	5870	6050	5540	4410	3020
Augusti	0	1700	2380	3720	5020	5850	6070	5970	6070	5850	5020	3720	2380
	10	1400	2020	3240	4550	5520	5950	5940	5950	5520	4550	3240	2020
September	0	900	1230	2200	3520	4820	5760	6130	5760	4820	3520	2200	1230
	10	880	1070	1930	3200	4530	5580	6080	5580	4530	3200	1930	1070
Oktober	0	510	530	1010	2110	3570	4960	5620	4960	3570	2110	1010	530
	10	470	480	650	1500	2850	4290	4870	4290	2850	1500	650	480
November	0	200	200	270	840	1910	3040	3480	3040	1910	840	270	200
	10	160	160	160	300	990	1590	1810	1590	990	300	160	160
December	0	80	80	90	350	1060	1770	2030	1770	1060	350	90	80
	10	40	40	50	60	90	120	130	120	90	60	50	40

Appendix 3 – Cloudy factor Gävle

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

Appendix 4 – Monthly average temperatures in Swedish cities

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
[illegible]ffer	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
Eksjö	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

Appendix 5 – Windows calculation factors

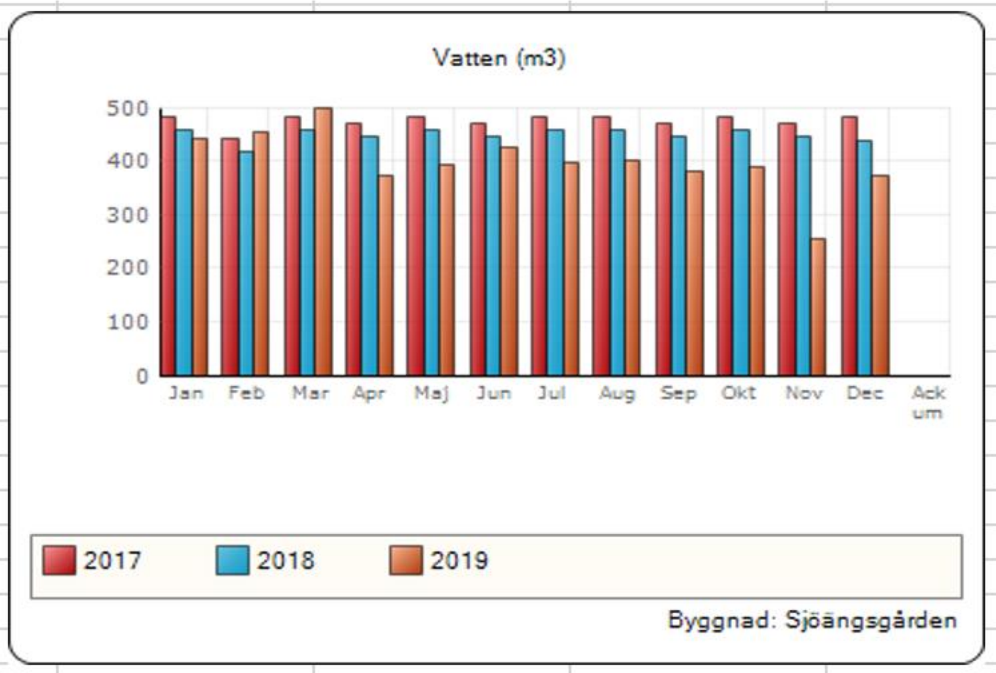
CALCULATION FACTORS FOR WINDOWS ACCORDING TO SUN RADIATION

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

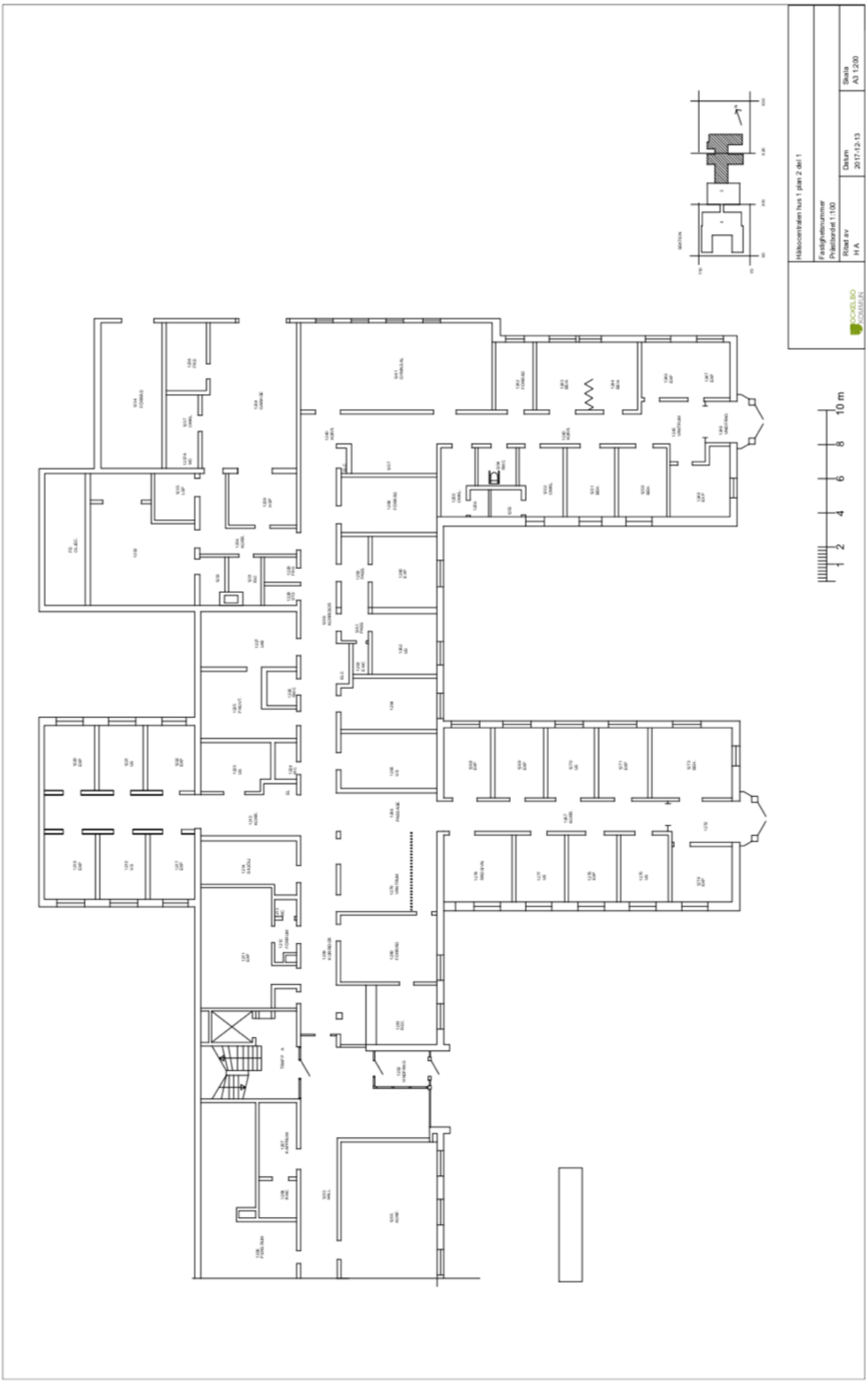
Example:

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

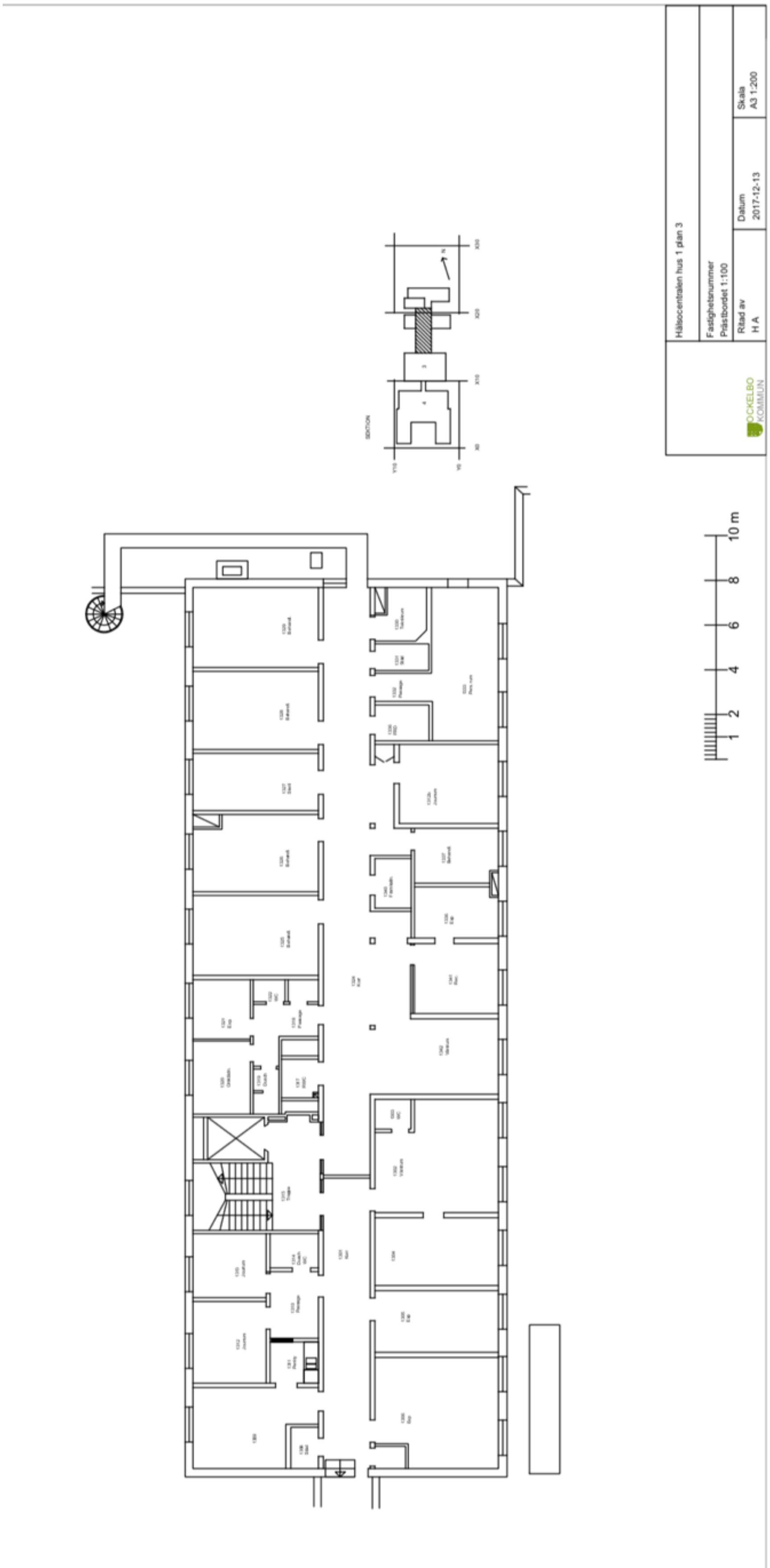
Appendix 6 – Tap water demand in Sjöängsgarden building



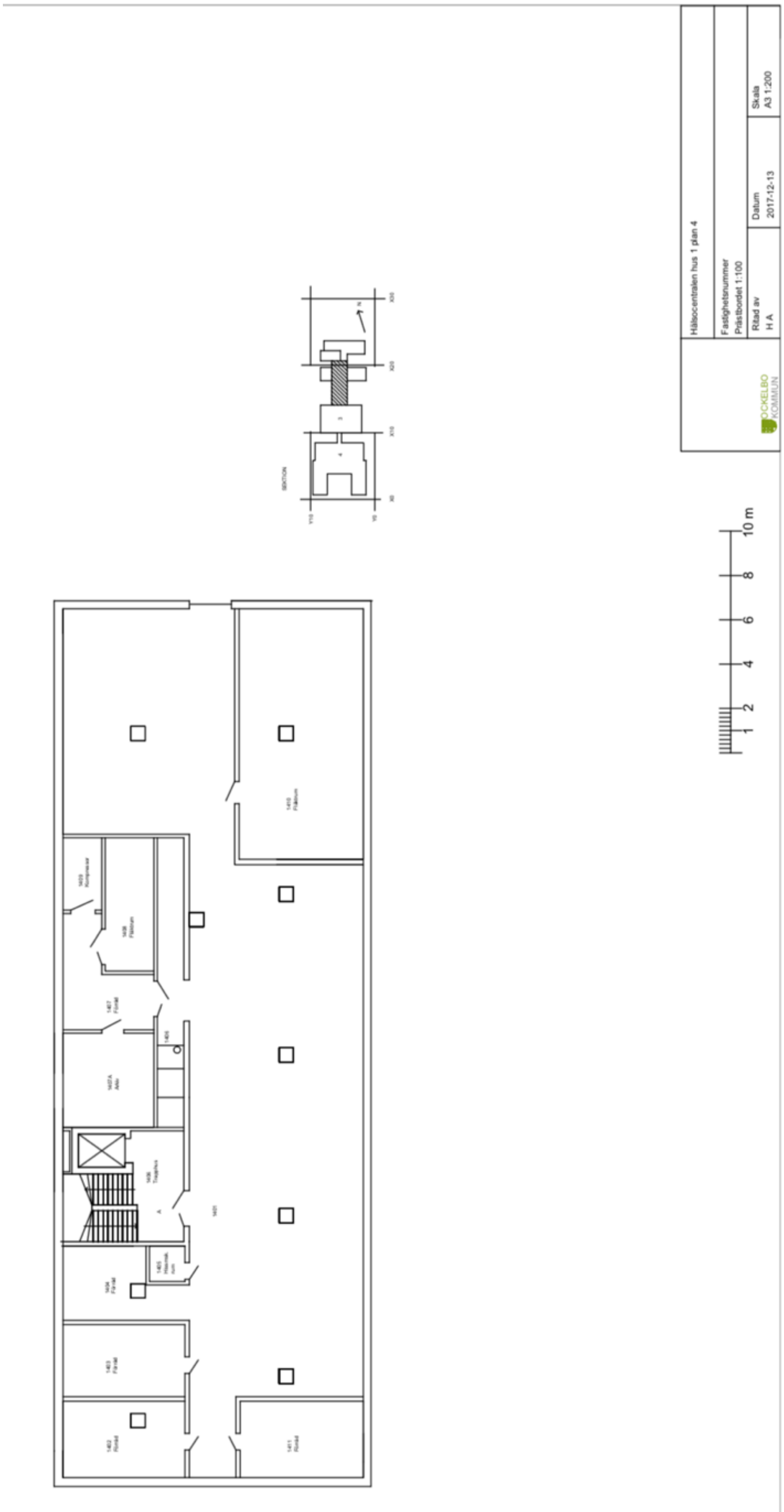
Appendix 7 – Construction plan Din Hälsocentral 1



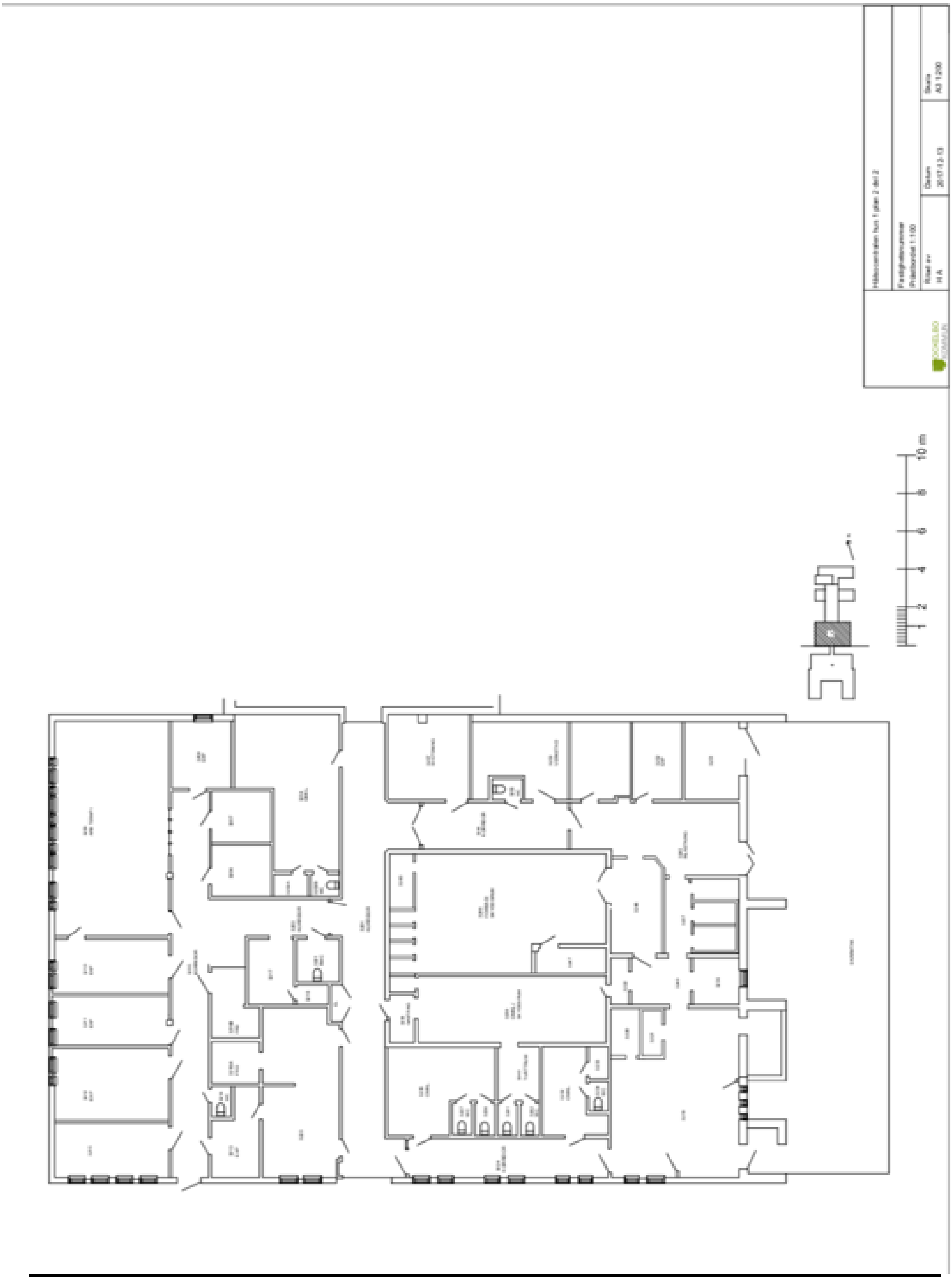
Appendix 8 – Construction plan Din Hälsocentral 2



Appendix 9 – Construction plan Din Hälsocentral 3



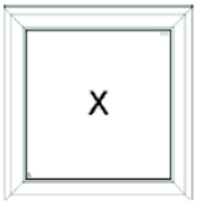
Appendix 10 – Construction plan Din Hälsocentral 4



Appendix 11 – Toolbocks windows prices

dobroplast

Toolbockx
Fönster för framtiden



Fast fönster med båge(FMB)

2glas PVC-fönster U-värde 1,3W/m2K (-32db) OBS! Pris 2-glas

3glas PVC-fönster U-värde 1,0W/m2K (-34db) OBS! Pris 3-glas Alla

- Karmdjup 70mm, 5-kammars PVC-profil med förstärkning i stål
- Argongasfyllning mellan glas

PVC-fönster är måttbeställda – karmyttermått i mm! Alla priser är inkl moms och gäller i Sverige!

Höjd ↓	Bred→	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800
500	2-glas	354	425	462	498	560	622	684	746	808	846	870	928	986	1002
	3-glas	438	526	580	633	712	791	870	949	1027	1082	1123	1198	1273	1306
600	2-glas	425	510	555	597	642	687	732	777	822	864	909	954	999	1044
	3-glas	526	632	697	759	824	890	955	1020	1085	1114	1179	1278	1343	1409
700	2-glas	462	555	603	651	699	747	798	846	894	942	990	1041	1089	1137
	3-glas	580	697	768	840	912	983	1058	1130	1201	1273	1344	1419	1491	1562
800	2-glas	498	597	651	705	756	810	861	915	966	1020	1071	1125	1179	1230
	3-glas	633	759	840	921	999	1080	1158	1239	1317	1398	1476	1557	1638	1716
900	2-glas	560	642	699	756	813	870	927	984	1041	1098	1152	1209	1266	1323
	3-glas	712	824	912	999	1086	1174	1261	1349	1436	1523	1608	1695	1782	1870
1000	2-glas	622	687	747	810	870	930	990	1053	1113	1173	1233	1296	1356	1416
	3-glas	791	890	983	1080	1174	1268	1361	1458	1552	1646	1739	1836	1930	2024
1100	2-glas	684	732	798	861	927	990	1056	1122	1185	1251	1314	1380	1446	1515
	3-glas	870	955	1058	1158	1261	1361	1464	1568	1668	1771	1871	1974	2077	2183
1200	2-glas	746	777	846	915	984	1053	1122	1191	1257	1326	1395	1464	1539	1608
	3-glas	949	1020	1130	1239	1349	1458	1568	1677	1784	1893	2003	2112	2228	2337
1300	2-glas	808	822	894	966	1041	1113	1185	1257	1332	1404	1476	1554	1626	1701
	3-glas	1027	1085	1201	1317	1436	1552	1668	1784	1946	2018	2134	2256	2372	2491
1400	2-glas	846	864	942	1020	1098	1173	1251	1326	1404	1482	1563	1638	1716	1794
	3-glas	1082	1148	1273	1398	1523	1646	1771	1893	2018	2144	2272	2394	2519	2645
1500	2-glas	870	909	990	1071	1152	1233	1314	1395	1476	1563	1644	1722	1806	1887
	3-glas	1123	1213	1321	1476	1608	1739	1871	2003	2134	2272	2403	2532	2667	2798
1600	2-glas	928	954	1041	1125	1209	1296	1380	1464	1554	1638	1722	1809	1893	1980
	3-glas	1198	1278	1419	1557	1695	1836	1974	2112	2256	2394	2532	2673	2811	2952
1700	2-glas	986	999	1089	1179	1266	1356	1446	1539	1626	1716	1806	1893	1983	2073
	3-glas	1273	1343	1491	1638	1782	1930	2077	2228	2372	2519	2667	2811	2958	3106
1800	2-glas	1002	1044	1137	1230	1323	1416	1515	1608	1701	1794	1887	1980	2073	2166
	3-glas	1306	1409	1562	1716	1870	2024	2183	2337	2491	2645	2798	2952	3106	3260
1900	2-glas	1058	1089	1185	1284	1380	1482	1578	1674	1773	1806	1965	2063	2160	
	3-glas	1379	1474	1634	1797	1957	2123	2283	2444	2607	2704	2927	3089	3250	
2000	2-glas	1114	1134	1236	1335	1440	1542	1644	1743	1845	1947	2046	2148		
	3-glas	1452	1539	1709	1875	2048	2217	2387	2553	2723	2892	3059	3228		
2100	2-glas	1134	1176	1284	1392	1497	1602	1707	1812	1917	2022	2127	2232		
	3-glas	1488	1601	1780	1851	2135	2206	2487	2558	2838	2909	3190	3261		
2200	2-glas	1176	1221	1335	1446	1554	1671	1773	1881	1992	2100	2208			
	3-glas	1547	1667	1855	2040	2222	2414	2590	2772	2957	3140	3322			

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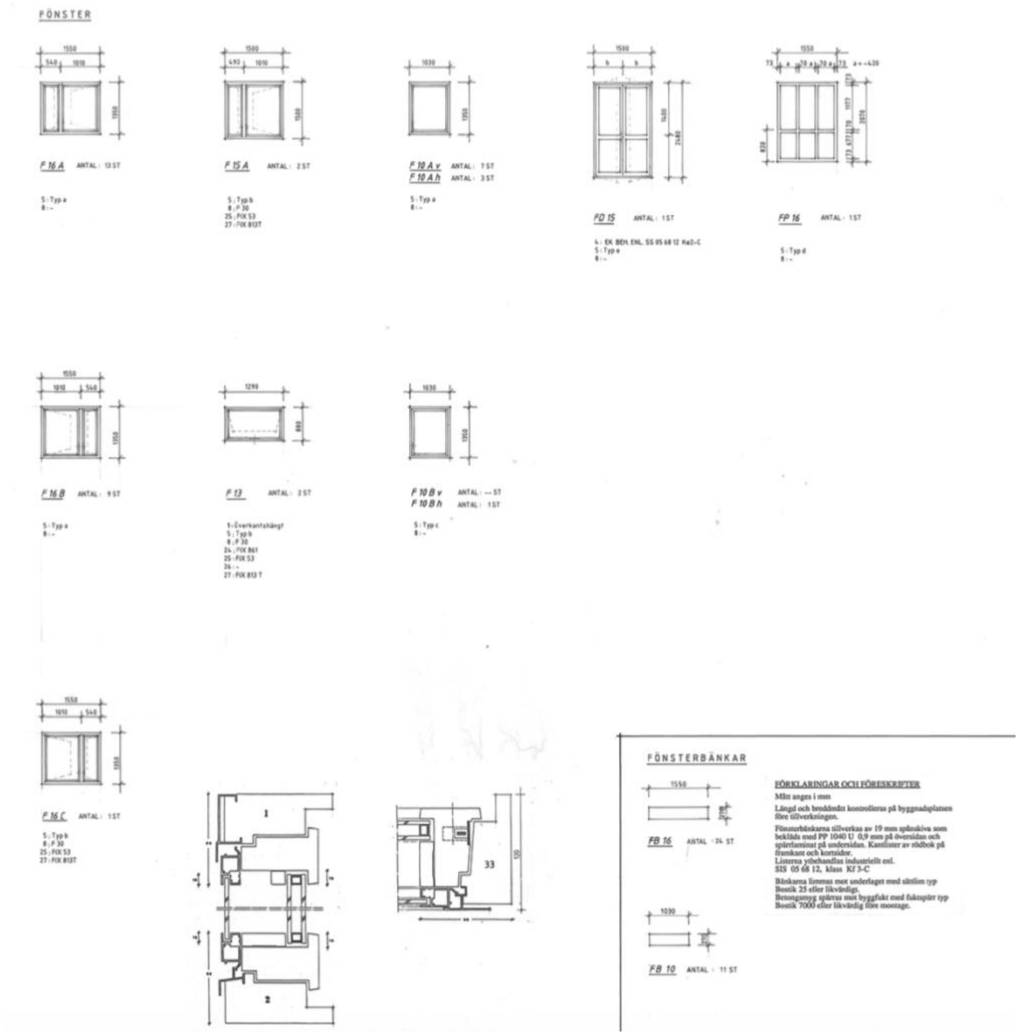
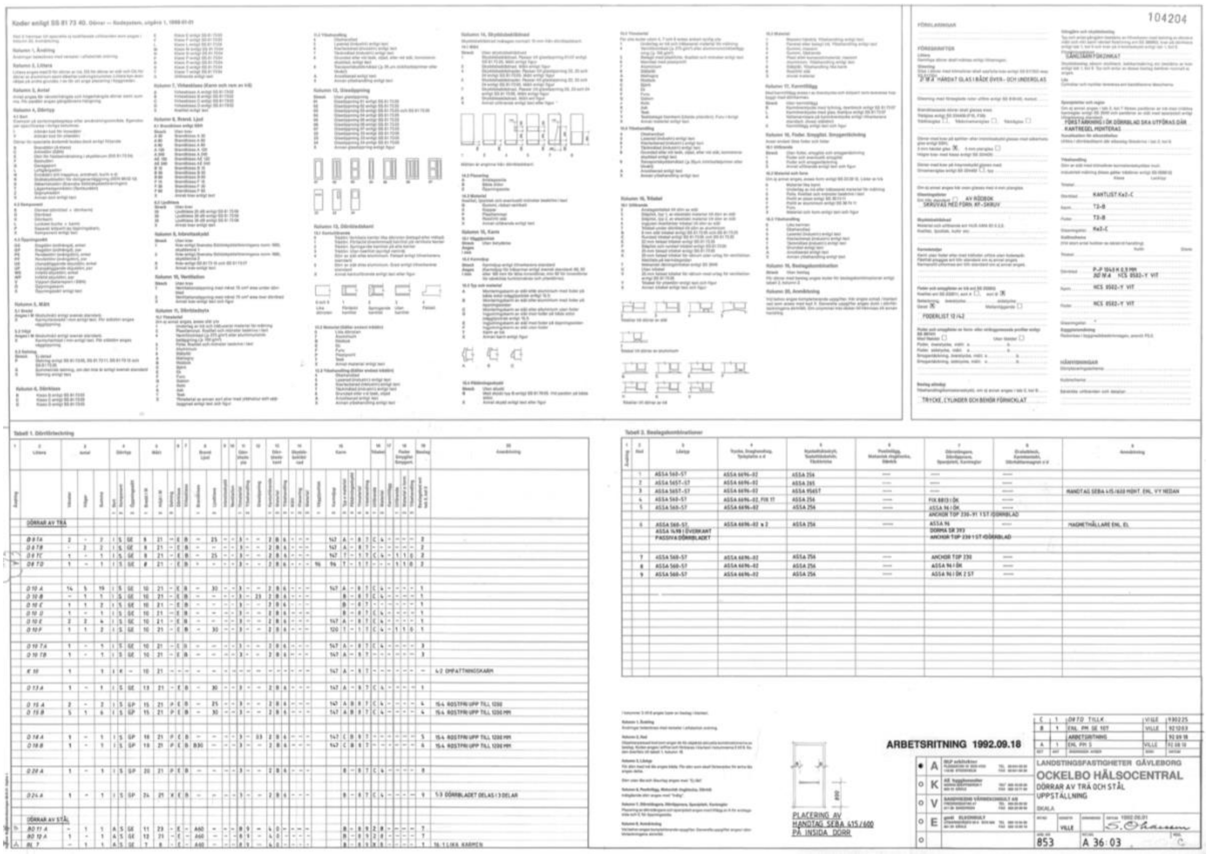
sida 5

Appendix 12 – Din Hälsocentral windows information



Appendix 13 – Din Hälsocentral garageports and ambulance doors information

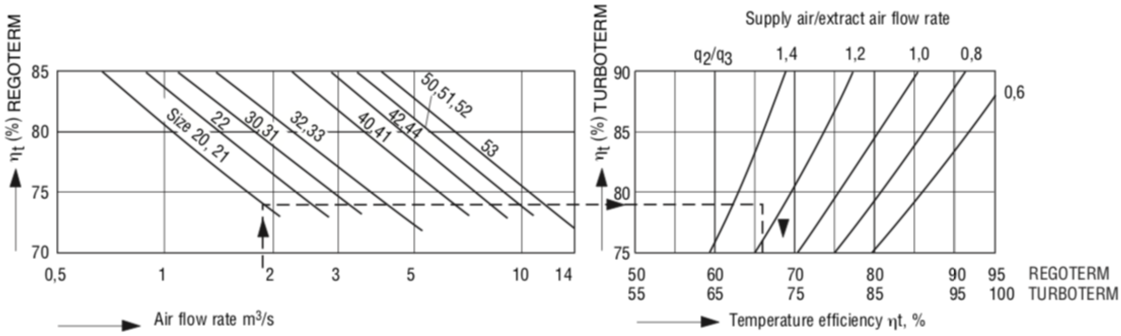


Appendix 14 – Current heat exchanger for mechanical ventilation in Din Hälsocentral (Model- Regoterm 31)

Rotary heat exchanger - REGOTERM - TURBOTERM - EURA

Temperature efficiency

Chart 1



Temperature- and moisture efficiency

Chart 2